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Striving for smart mobility in Morocco: a case of lanes designated to heavy goods vehicles in Casablanca

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ABSTRACT

This article highlights the need to rethink how to manage mobility in Morocco more intelligently, given that it is a major pillar of economic competitiveness. Smart mobility based on Intelligent Transport Systems (ITS) allows to improve and ensure the optimal use of existing infrastructure before embarking on heavy and irreversible infrastructure projects. The case regarding the separation of the urban traffic and the Heavy Goods Vehicles (HGV) traffic circulating between Casablanca Port and Zenata Dry Port is a relevant example where smart mobility could provide efficient solutions without building costly tunnels. A dynamic simulation was made using the Aimsun software to quantify the relevance of the proposed lane designated to HGV in the existing road. This simulation allows to visualise congestion sections and quantify the circulation of vehicles and pedestrians. The article presents defined functions and characteristics of the Advanced Traffic Management (ATM) to ensure the optimal operation and efficient setting of the simulation. All appliances, hardware, and sensors that will be set up on-site will help to improve traffic safety, traffic flow, traffic information, and reduce congestion and pollution. This case study illustrates the complexity of managing the flow of goods in cities and suggests how to solve this type of problems using smart mobility. This research proposes reserving a special lane for HGV. ITS will help this cost-optimal alternative, will promote the urban framework of the coastal road, and contribute to sustainable mobility in Casablanca.

KEY WORDS

sustainable mobility, smart mobility, intelligent transport systems, advanced traffic management, heavy goods vehicles

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Introduction

Managing mobility of people and goods in large cities is a thorny issue. The growing demand for travel of urban populations put pressure on transport infrastructure. Major Moroccan cities are no exception to the struggle, aiming to respond to the challenges of accelerating urbanisation and increased mobility demands. This will inevitably prevent them from turning into smart cities.

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Smart cities can be identified by six closely-linked levers: smart economy, smart mobility, a smart environment, smart residents, a smart lifestyle and smart administration (Giffinger et al., 2007).

Therefore, a “smart city” (Bashynska & Dyskina, 2018; Winkowska et al., 2019) is inseparable from “smart mobility”. The Fourth Industrial Revolution and the digital transition impelled to rethink mobility management: the design and construction of road infrastructures, new services for “connected mobility” without excessive waiting or congestion at interconnections, and functional and economical solutions for operation and maintenance (intelligent sensors, user information solutions, intelligent transport infrastructure, and systems).

The term “smart” certainly alludes to better use of technologies, but “smart mobility” is also defined as “a set of coordinated actions intended to improve the efficiency, effectiveness and environmental sustainability of cities” (Benevolo et al., 2016). The term “mobility” highlights the preponderance of humans over infrastructure and vehicles.

Current solutions for traffic congestion consist of fitting and widening infrastructure, which only encourages more trips and results in even more critical consequences. Even intelligent transport systems are helpless beyond certain traffic density.

The concept of dynamic lane management opens up new perspectives. Its objective is to manage and optimise road traffic in a variable manner, in space and time. Generally speaking, it is “Advanced Traffic Management”, “Active Traffic Management” (ATM), or “Managed Lanes” (ML).

In Casablanca, the traffic problem is one of the major challenges, which must be addressed irrespective of the choice by decision-makers to implement a “smart city” solution. An efficiency gain in terms of circulation and mobility could lead to significant savings. However, it appears that conventional traffic management would not sustainably absorb the consequences of congestion during peak hours. Traffic congestion inevitably leads to the deterioration of the urban framework and road safety conditions and harms the city’s competitiveness.

Growing HGV flows from or to the Casablanca Port intensify congestion, result in roadway degradation and other negative impacts, such as pollution (noise, air, visual). Moreover, they contribute to the consumption of public spaces and the mortality of alternative mode users. At the same time, industrial and commercial blocks in the city centre with storage facilities generate a high demand for transport and parking.

Consequently, the effort to divert HGV flows from the city centre becomes a major urban challenge. The optimisation of logistics for the delivery of goods is vitally important for the competitiveness and attractiveness of the city, the improvement of the quality of life, accessibility, and road safety.

The mega-project “Wessal Casablanca Port” includes the development of a 17 km seaway connecting the port of Casablanca with Zenata Multi-Flow Logistics Zone (MFLZ). This project aims to enhance and develop the historic area of the Casablanca Port for tourism, with a view to relieve the main urban axes, improve traffic conditions, and streamline the flow of goods.

The strategic position of the dry port of Zenata MFLZ will be reinforced upon the completion of an efficient connection road with the Casablanca Port, which is the main traffic generator in the city. Zenata MFLZ will take over a large part of the cargo from the current port, which handled 30 million tonnes in 2019 and concentrates almost 20% of the import/export traffic of Morocco (METLE, 2018).

This case study concerns the connection of the Casablanca Port and Zenata MFLZ by 5 km long coastal road (Fig. 1).

The development of this project must meet the following requirements:

- an optimised impact on the expropriation and the networks;
- design compatible with the adjacent cornice Ain Sebaa project from an urban and functional point of view;
- flow and protection of pedestrians heading towards the beach;
- separation of port traffic and urban traffic;
- sufficient capacity on the current section of lanes reserved for HGV;
- maintained operation in the event of accidents in the lanes reserved for HGV;
- secure traffic at intersections;
- travel time promoting the competitiveness of the logistics area;
- flow of vehicles and improvement of capacity on highways;
- flow and unrestricted management of traffic during development works;
- limited equipment maintenance;
- remaining within the project budget.

This article reflects on the development of the road dedicated to HGV, the first of its kind in Morocco. The project aims to alleviate the discomfort caused by trucks in the urban road network of Casa-

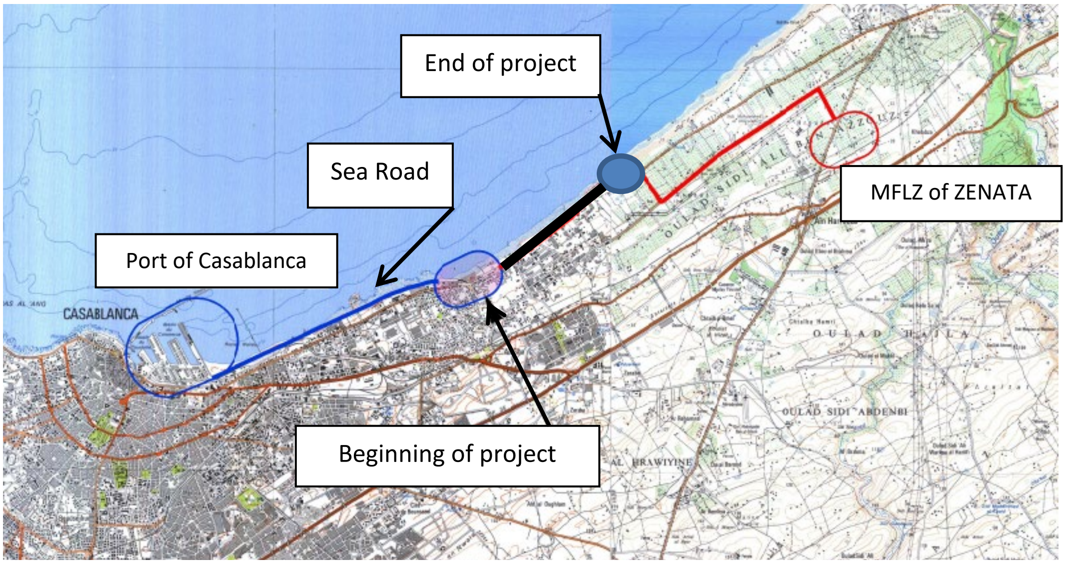

Fig. 1. Location of the project connecting the Casablanca Port and Zenata MFLZ
Source: Map of Morocco – topographic map of Casablanca 1/50000.

blanca. This research is an ideal opportunity to reflect on the introduction of ITS to ensure the optimal use, especially at intersections and pedestrian crossings of urban roads in Morocco.

1. Literature review

Next, the article reviews the international experience concerning designated HGV roads, then initiatives and strategies concerning HGV in Morocco, and finally, presents an analysis of the current situation of mobility in Casablanca.

1.1. Republic of Mauritius

To streamline port traffic between the Red Sea and the Jin Fei industrial area and increase the existing motorway capacity, a third lane dedicated to trucks was built in July 2019, extending 3.1 km and having the width of 4 m on each side. The traffic saturation in the North region and the separation of traffic from container ships will allow the birth of a smart city (Maurice Actu, 2019).

Several innovations have been included in the project, such as demarcated lanes, traffic signs conforming to the Vienna Convention to improve road safety, and Light-Emitting Diode (LED) lighting to offer better brightness and visibility and improve energy efficiency (Maurice Actu, 2019).

However, the buy-in of various stakeholders was not ensured during the design phase, which resulted in the change to the initial route. The third lane had to be built using red asphalt, and 200 trees were felled without replanting (Maurice Actu, 2019).

1.2. State of Georgia in the USA

The State of Georgia has decided to deploy major means to ease traffic on its motorways, which are particularly heavily loaded with HGV. Georgia has decided on the record investment of more than USD 2 billion and a construction site planned for at least four years to create one or two additional lanes on certain portions of motorways (Masquelier, 2018).

These new lanes will be exclusive for HGV and will be separated from the rest of the traffic by a theoretically insurmountable barrier. They will link Atlanta suburbs to the rapidly developing Macon City, about 40 miles away. This project is interesting from multiple points of view.

The new lanes will solve the congestion problem, allow to transport goods more quickly and easily, and make transport safer in general. The routes will be fitted with sensors to inform truck drivers in real-time regarding possible traffic jams and slowdowns so that they can modify their routes if possible (Masquelier, 2018).

1.3. Germany

In 2019, Germany started a three-year project that equipped 10 km of motorways with energy supply by overhead catenary in a lane dedicated to hybrid trucks, i.e., the e-highway. The section between Weiterstadt and the Langen / Mörfelden exit is called the ELISA Project. This motorway segment receives

135000 vehicles daily, 10% of which are HGV (Taberlet, 2019).

This infrastructure is one of the neutral goods transport solutions developed in the country. According to Siemens, EUR 20 000 in fuel savings can be achieved for a 40-tonne truck travelling at 80 km/h using this system over 100 000 km (Taberlet, 2019).

1.4. France

In France, the road haulage industry accounts for more than EUR 53 billion with an annual turnover of about 280 billion tkm. The French authorities, favouring the transport of people above all, seem cautious to invest in the transport of goods, in particular, semi-autonomous vehicles and reserved traffic lanes. France is currently constructing dedicated lanes, but they will firstly be reserved for buses and taxis before carpool (Masquelier, 2018).

Since 2016, several manufacturers of trucks, such as DAF, IVECO, and SCANIA, have joined forces to think about new solutions for the transport of goods to optimise overall costs, improve the safety of truck drivers and motorists, and reduce CO2 emissions (Masquelier, 2018).

The companies created a truck platooning project (a convoy of semi-autonomous trucks) TOGETHER, which should be operational from 2021. Once real road traffic needs are established for each participant, equipment manufacturers will quantify and budget this new system for transporting goods. From 2021, concrete tests are planned, probably in the Netherlands. They can already rely on Germany's encouraging results in terms of platooning. For several months now, DB SCHENKER and MAN TRUCK & BUS have been testing the solution in Bavaria (Masquelier, 2018).

1.5. Morocco

In 2014, the National Sustainable Development Strategy 2030 (SNDD 2030) identified the transport sector as the third energy consumer in Morocco. It accounts for 16% of total emissions and 28% of emissions from energy. Sustainable mobility is defined as "a transport policy which seeks to reconcile accessibility, economic progress, and the reduction of the environmental impacts of the selected transport systems" (SEDD, 2017). The transport of goods is also concerned with ambitions to optimise existing networks and improve nearby exchange platforms and New Technologies of Information and Communication (NTIC), allowing efficient transfers between different modes of transport.

Morocco is the first country to have initiated an adaptation of the global macro-roadmap for the transformation of transport based on the Paris Process on Mobility and Climate (PPMC). The 2018 Moroccan Roadmap, which aims to support national strategies and, more particularly, the SNDD 2030, recommends the creation of vertically and horizontally integrated, sustainable industrial zones close to consumption and connected to mass transportation modes. Defragmented and shortened supply chains reduce the need for transport and eliminate unnecessary trips.

Over the past decade, Morocco has seen significant progress and reforms in the areas of the environment, sustainable development, and the fight against climate change. Several sectoral strategies, including transport and logistics, integrate these environmental dimensions. The economic stakes are high as the cost of air pollution in Morocco accounts for more than 10 Md DH (1% of GDP) (METLE, 2018).

Morocco is implementing an integrated national strategy for the development of the logistics sector by 2030 with clear and quantified macro-economic, urban, and environmental objectives. Since sustainable development is at the heart of this strategy, its objectives contribute to a reduction of around 35% in CO2 emissions resulting from the transport of goods by road (METL, 2017).

To achieve these objectives, pooling flows of goods has been considered as a primary solution. The creation of 3000 ha of logistics platforms by 2030 is among the main levers for reducing delivery costs and the carbon footprint of the import/export supply chain, thereby improving the quality of life, accessibility, and competitiveness of urban communities (AMDL, 2016).

Thus, the dry port of Zenata will divert more than 13000 HGV per day by 2025 from the city centre of Casablanca (ANP, 2019). This solution will:

- relieve the key axes of the city and improve road safety by diverting the port traffic, which currently uses the main roads of Casablanca, particularly the coastal road;
- shorten HGV journeys and travel time;
- improve working conditions and transport of goods and, consequently, the competitiveness of transport companies.

1.6. Mobilise Your City

One hundred metropolises are committed to "Mobilise Your City (MYC)" — an initiative aimed at a proactive transition and a deep cultural and organisational transformation of mobility and logistic activities to make cities more inclusive and reduce greenhouse gas (GHG) emissions. This initiative builds on collective intelligence networks and existing planning practices based on principles of integration, participation, and evaluation (MYC, 2019).

Made of a coalition of international partners (development agencies, urban transportation planning agencies, non-governmental organisations and development banks), MYC offers a methodological framework, capacity building, technical assistance and facilitates access to financing at the local and national levels. The initiative will develop an international benchmark platform for sharing best practices and technical and academic expertise in planning sustainable urban mobility.

Morocco was among the first countries to have embarked on the MYC initiative during the COP22 in Marrakech in 2016. Efforts to implement mobility planning in 26 municipalities and the sustainable development approach, stemming from the MYC project, had the following objectives:

- improve the quality of life and the economic attractiveness of the city;
- improve transport systems and propose alternative solutions to individual vehicles;
- adopt solutions that are more capable of saving space and reducing carbon footprint, and are affordable and adapted to the needs of the inhabitants;
- set up a Sustainable Urban Mobility Plan (SUMP).

In 2019, Casablanca was selected by IEEE, a prestigious American scientific organisation, to be part of the IEEE Smart Cities Initiative. The city was recognised for innovative projects aimed at the transformation to a smart city and intentions to invest in the human and financial capital of the city.

1.7. Casablanca's Urban Mobility Plan

Casablanca's Urban Mobility Plan (UMP), drawn up between 2004 and 2008, is a planning document that defines a coherent organisation scheme for the mobility of people and goods within the Perimeter of Urban Transport for 15 years. It includes the definition of a frame of reference and objectives broken down into 25 actions that guide elected officials in their decisions.

Aiming to tackle economic, urban, and environmental challenges the Casablanca's UMP considered the following trend scenario (Ministry of the Interior, 2004):

- the energy consumption: MAD 4.2 billion in 2004 compared to MAD 9 billion in 2019;
- the cost of congestion: MAD 114 million in 2004 against MAD 3.4 billion in 2019;
- the cost of pollution: MAD 319 million in 2004 against MAD 1 billion in 2019.

To address these challenges, the priority actions recommended in the Casablanca's UMP include the creation of logistics lanes for HGV on a regional scale. But this approach, which aimed to resolve the problems by a mode of transport, has its limits. Mobility demands must be the primary focus rather than transport infrastructure as an input.

2. Research methods

Based on automatic counting results established by a permanent post, the average annual daily traffic on the coastal road is 21 000 vehicles (DR, 2018). A metering campaign quantitatively and qualitatively determined a load of directional traffic at crossroads and in the section during the rush hour. The maximum peak hourly traffic at the section is around 3300 vehicles in both directions, 10% of which are 13-m-long HGV.

The strongest hypothesis of the National Ports Agency (ANP) considers that 100% of container HGV (3200 HGV) and 100% of non-container HGV from port activity (5600 HGV) will pass through the northern service in both directions daily. The peak hourly traffic is 1100 HGV (36% of 13-m-long HGV and 64% of 17-m-long HGV).

To quantify the impact of the proposed lane dedicated to HGV, a dynamic simulation was carried out using the Aimsun software. This simulation allows visualising the circulation of vehicles and pedestrians at crossings. The above-described traffic data was used to generate vehicle traffic on the main road and secondary roads.

Several replications were launched to obtain an average per hour. Each replication generates traffic randomly over time while respecting the origin/destination matrix.

Thus, each replication has variations in traffic, making it possible to observe different traffic conditions (local congestion, repetitive calls on secondary axes, absence of pedestrian calls).

3. Research results

3.1. Analysis and proposal for the development of a lane reserved for HGV

Possible options

Six variants can be considered:

- Variant 1: a road in 2x3 lanes for mixed HGV and urban traffic (Fig. 2).
- Variant 2: dedicated corridor for HGV, partial separation of traffic
  - Sub-Variant 2.1: dedicated central corridor for HGV in 2x2 lanes (Fig. 3).
  - Sub-Variant 2.2: dedicated central corridor for HGV in 2x1 lanes (Fig. 4).
  - Sub-Variant 2.3: dedicated corridor for HGV in 2x1 lanes (Fig. 5).
  - Sub-Variant 2.4: two dedicated bilateral ways for HGV (Fig. 6).
- Variant 3: dedicated corridor for HGV in 2x2 lanes and uneven junctions, total separation of traffic (Fig. 7).

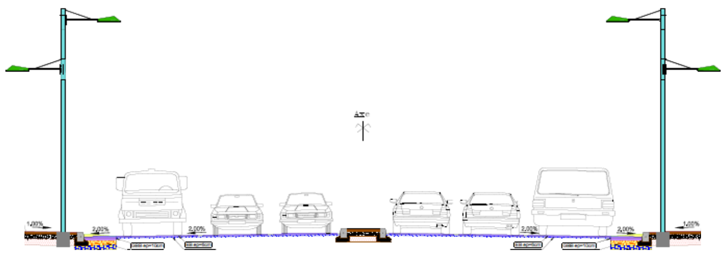

Fig. 2. Cross-type profile of Variant 1

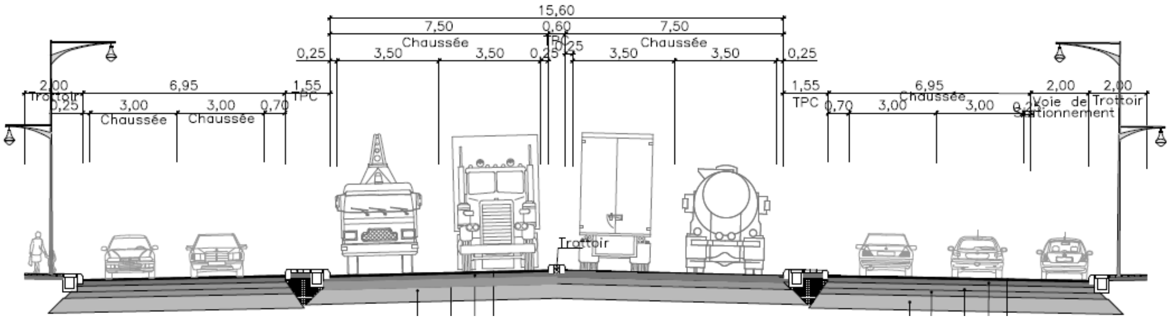

Fig. 3. Cross-type profile of Sub-Variant 2.1

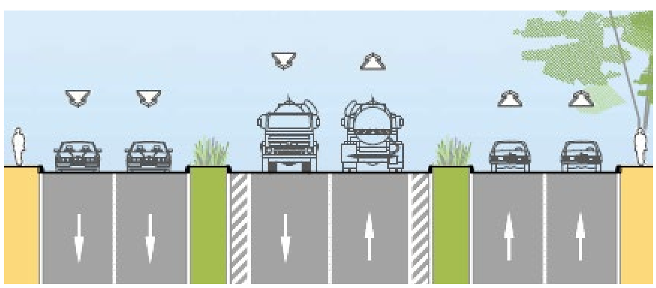

Fig. 4. Cross-type profile of Sub-Variant 2.2

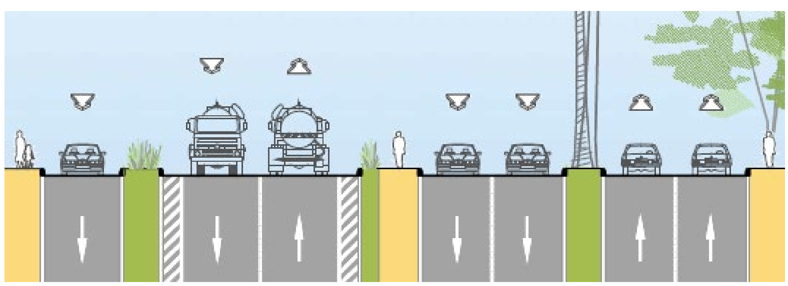

Fig. 5. Cross-type profile of Sub-Variant 2.3

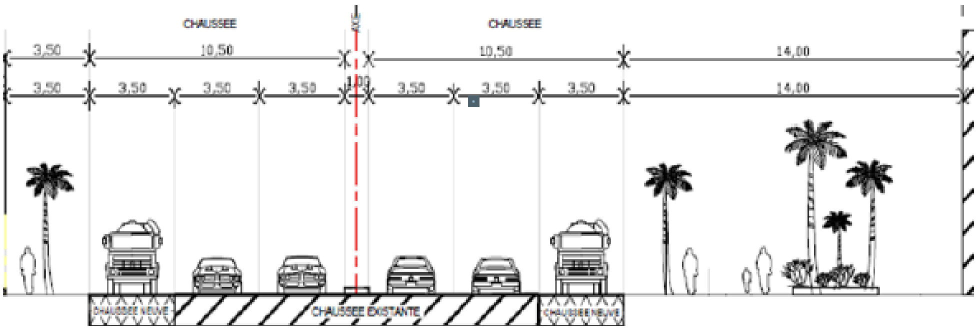

Fig. 6. Cross-type profile of Sub-Variant 2.4

Fig. 7. Cross-type profile of Variant 3

Tab. 1. Multi-criteria analysis

Variants / Analysis criteria	Variant 1	Sub-Variant 2.1	Sub-Variant 2.2	Sub-Variant 2.3	Sub-Variant 2.4	Variant 3
Land impact	++	-	+	+	+	--
Network's impact	++	-	+	+	+	--
Compatibility with the Corniche	++	-	+	--	-	--
Landscaping	++	--	+	-	-	--
Pedestrian flow	+	--	++	+	-	--
Pedestrian safety	-	--	+	--	-	-
Separation of HGV traffic from urban traffic	--	+	+	+	+	++
Reduction of conflict points	--	+	+	--	-	++
HGV exit/entry possibility via intermediate intersections	++	+	+	-	+	--
Travel time	--	+	+	+	+	++
Traffic during works	+	-	+	+	-	--
Cost/completion time	++	-	+	+	-	--

Legend: (--) Very negative / (-) Medium to negative / (+) Positive / (++) Very positive

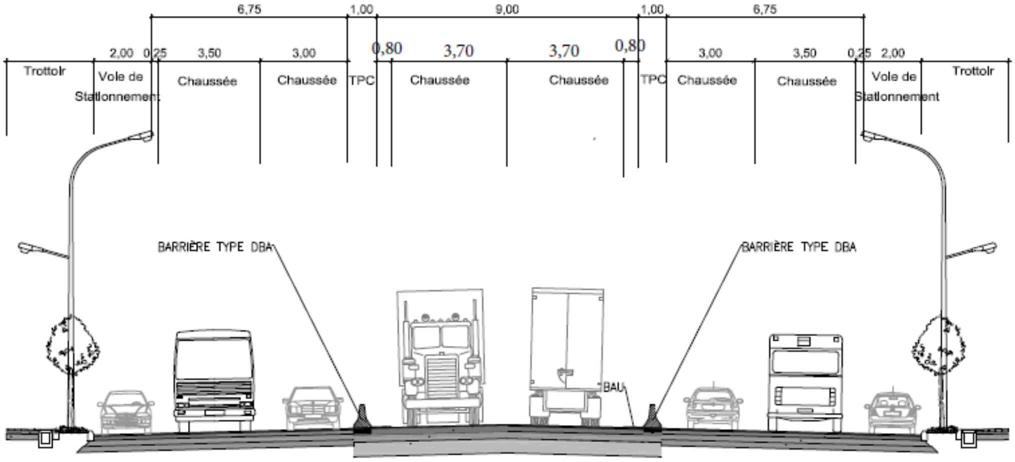

Fig. 8. Cross-type profile recommended of Sub-Variant 2.2

Multi-criteria analysis

Based on the defined requirements in the introduction, six proposed variants were evaluated to find the best alternative (Tab. 1).

Recommended alternative

Considering the multi-criteria analysis, Sub-Variant 2.2 can be recommended. Its feasibility was subsequently studied. The cross-type profile (Fig. 1) of this variant is as follows:

- 2x2 lanes of urban traffic at the lateral level and the 3rd turn left lane at the crossroads;
- central corridor dedicated to HGV in 2x1 lanes, 9 m wide:
- a separation between the two corridors by movable double concrete partitions in the event of an accident;
- support measures in terms of detection and traffic management.

3.2. Checking the Feasibility of the Planned HGV Lane

Verification of the proposed lane width

Figs. 9 & 10 show that the proposition of the 9 m width for the two bidirectional lanes dedicated to HGV means the operation in a degraded mode in the event of a truck failure on the lane. Measures can be used in the event of a truck breakdown, such as mov-

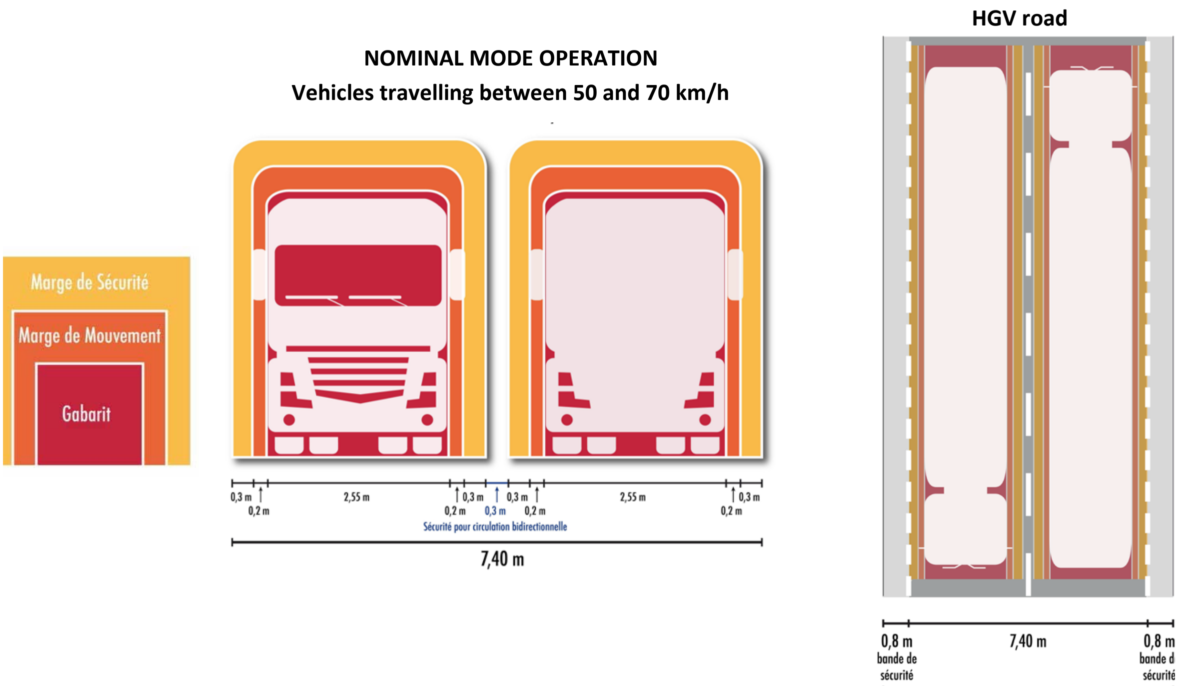

Fig. 9. Checking the gauge of dedicated traffic lanes for HGV in nominal mode operation

DEGRADED MODE OPERATION

Vehicles travelling between 0 and 20 km/h

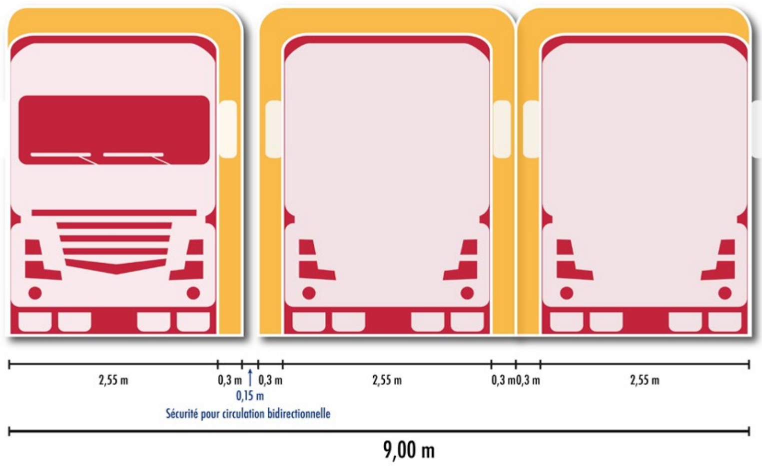

Fig. 10. Checking the gauge of dedicated traffic lanes for HGV in degraded mode operation

able double concrete partitions used to clear HGV through side lanes in the event of a serious accident in the HGV lane.

Implementation of the simulation

Intersections regulated by traffic lights are programmed in the Aimsun software as follows:

- cycle time of 80 seconds;
- keeping the main axis green (at least 45 seconds of green to clear the 550 HGV/h per direction);
- turn left and secondary axes phases on-call (8 seconds of green for each phase).

Sensors are placed on the turn-left lane and secondary axes to detect the presence of a car and leave the rest to the main phase.

The Aimsun software has a "yellow box" function for traffic intersections. When this function is activated on the crossroads, vehicles do not enter in the case of a risk of lifts and blocking. Vehicles wait at the light until the intersection empties. To reproduce the effect of the "yellow box", the saturation loop system and early closing of lanes at stop lines are to be expected (Fig. 11 and Fig. 13).

Pedestrians at the crossroads can cross during turn-left phases and the operation of secondary axes. Pedestrians on secondary axes can cross during the main phase. Pedestrian detection devices will be used for these crossings to reduce the waiting time for pedestrians if no vehicles are approaching the crossroads.

To manage pedestrian crossings on call, a dedicated facility will be created for pedestrian traffic. When a pedestrian is detected, a call is made, and the car/HGV phase turns red after 29 seconds so as not to

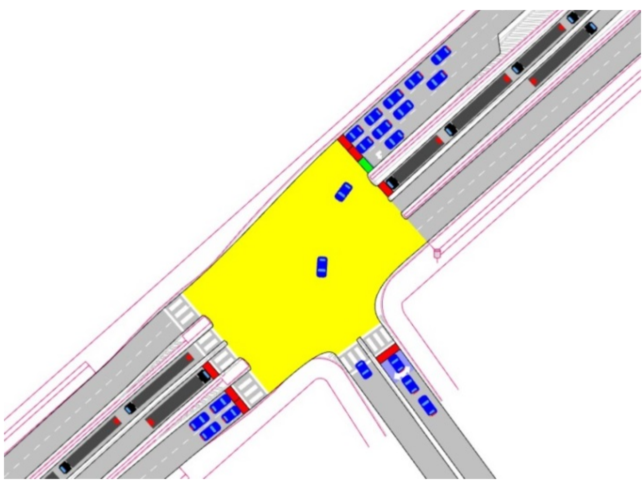

Fig. 11. Crossroad operation with "Don't block the box" mode

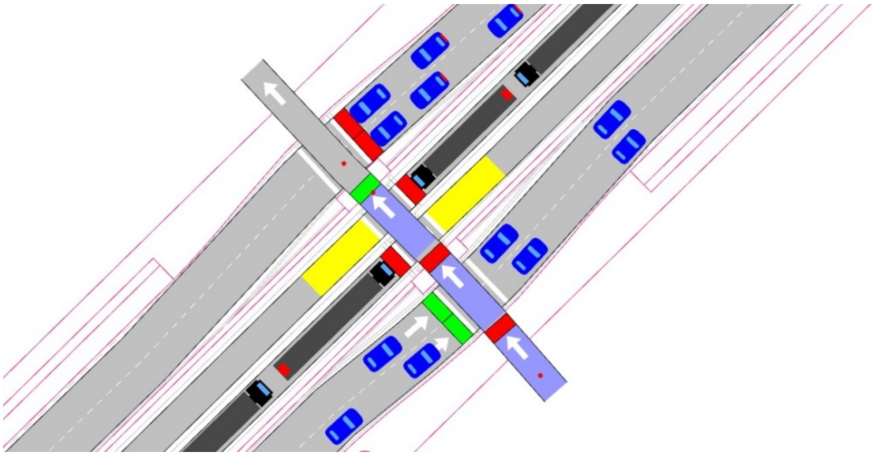

Fig. 12. Pedestrian crossings with "don't block the box" mode

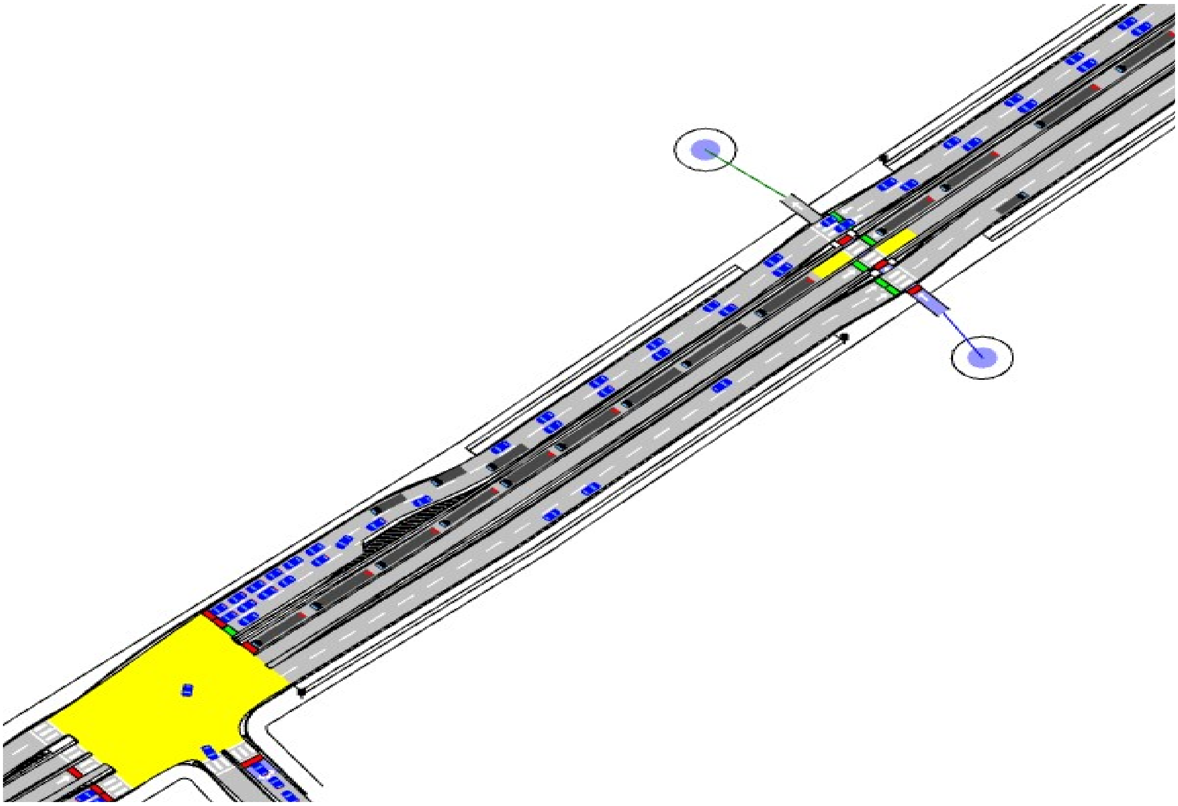

Fig. 13. Simultaneous operation of crossroads and pedestrian crossings with "don't block the box" mode

constrain the flow of vehicles. The operation of pedestrian crossings on call impedes the creation of a green wave on the entire road.

To optimise the operation of pedestrian crossings transversely, each pedestrian signal opens in the offset to limit the times of red car/HGV (pedestrian green wave principle).

A "yellow box" is placed downstream of the pedestrian crossing (Fig. 12). This function is activated in order not to have a car/HGV blocking the pedestrian crossing. Trucks do not cross the pedestrian crossing if there is insufficient space for it to stop. The blue areas on the pedestrian path are detectors that activate the pedestrian green when a presence is detected.

4. Discussion of the results

4.1. Simulation Analysis

HGV traffic on a dedicated central site

In the simulation, all HGV arrive at their destination without too much waiting due to congestion. The average journey time is 12 min over the entire section. Their total downtime is 3 min and 40 sec. The average speed is 25 km/h (Fig. 14).

Vehicle traffic on the sideways

Vehicles (825 vehicle/lane/direction/hour) benefit from the same green time as HGV (1475 vehicle/lane/direction/hour) although their number is less. Therefore, no problem arises with the queue.

Cars travel 5 km in 9 min, which means the average speed of 32 km/h (Fig. 15).

Vehicles coming from the secondary axis of an intersection regularly pass to the second cycle. This intersection as a resting point on the main one operates cyclically due to the permanent calls from the secondary axis. Vehicles wait an average of 75 seconds to pass the lights (green time amounting to 10 seconds).

Pedestrian flow

Fifteen pedestrian crossings in the section are managed with a pedestrian pushbutton and the thermal detection system. A detected pedestrian is given 29 seconds after the detection to leave a minimum of green time for HGV in the dedicated site. On average, a pedestrian takes 54 seconds to cross the entire road (including detection time) with an average speed of 5 km/h (Fig. 16).

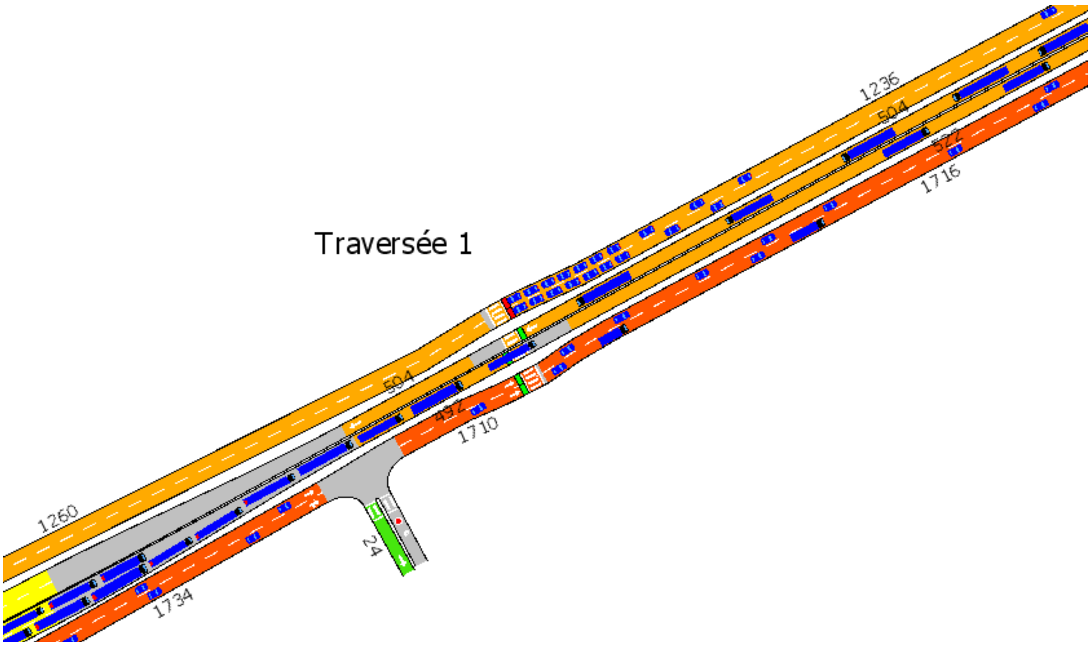

Fig. 14. Calculation and verification of hourly flow rates in lateral lanes and dedicated lanes

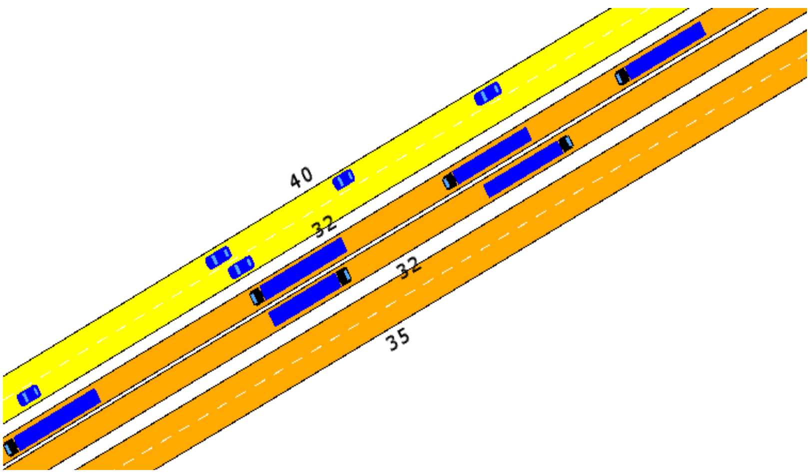

Fig. 15. Average speed in the lateral road and HGV lanes

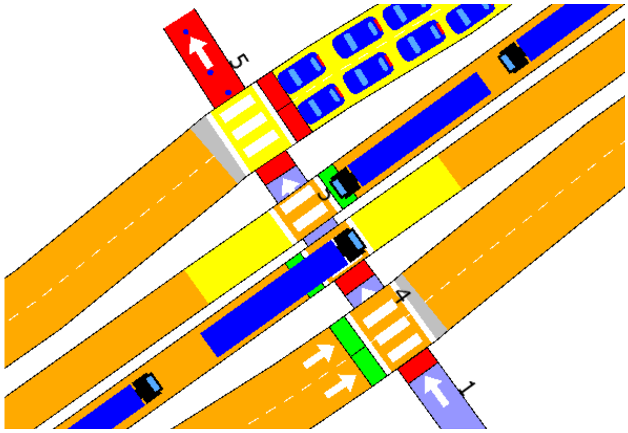

Fig. 16. Average speed at pedestrian crossings

4.2. ITS Criteria

To ensure the optimal simulated operation at the Aimsun software level, the equipment of the vehicle and pedestrian detection system and ATM must constitute an ITS and have the following functions:

Diagram of the overall functioning of the ATM system

The diagram below summarises the overall operation of the integrated traffic operating system allowing ATM with prioritisation of HGV flow, detection and securing of pedestrian crossings, intelligent management of traffic lights, information for users through Variable Message Panels (VMP) and data acquisition and monitoring using the Internet (Fig. 17).

The adaptive and intelligent traffic light controller

It is an automated system dedicated to adaptive management and intelligent regulation of road traffic without a central control having the following specific characteristics:

- history of traffic data, analysis, optimisation and evaluation of the effectiveness of the dynamic control system;
- recognition of the absence of a vehicle at the intersection to avoid unnecessary priority-giving;
- processing of information from various traffic detectors;
- compatibility with DIASER and OCIT 2.0 communication protocols;

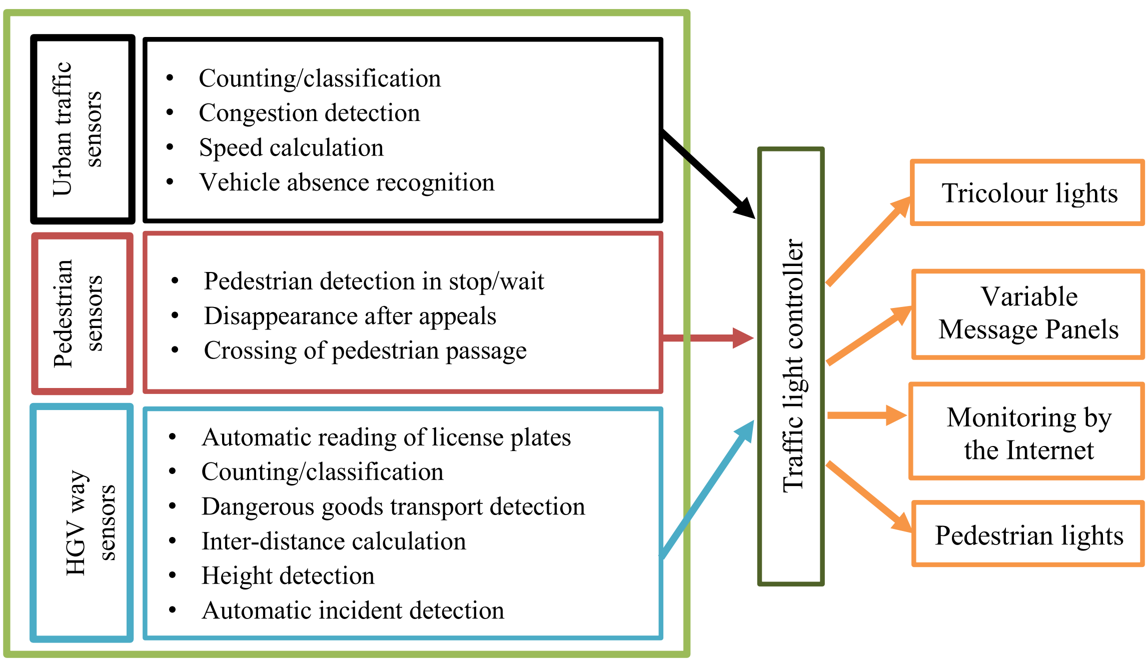

Fig. 17. Overall functioning of the ATM system

- equipped with SIL3 (Safety Integrity Level): redundancy of controls;
- complies with the requirements of EN12675 and EN50556 standards;
- programmable with third-party software LISA + and VS-PLUS;
- capable of controlling traffic lights in different voltages (230VAC / 110VAC) with bulbs or LEDs, 40VAC for LEDs, 24VDC (compatible with LEDs 1W, 10VAC);
- possibility of attenuation mode at nightfall with 42VAC dimming module;
- the possibility of manual control;
- priority configuration for firefighters/police/emergencies;
- equipped with programming and maintenance software;
- visualisation module system by the website.

Thermal detection system

It is a thermal imaging camera for vehicles and pedestrians with the following characteristics:

- detection of the lane saturation;
- Automatic Incident Detection (AID) on the HGV lane for traffic diversion through cross-arrow aspects;
- detection of pedestrians waiting and crossing;
- dynamic micro regulation of tricolour lights cycle times;
- "don't block the box" flow and saturation control;
- vehicle counting and classification;
- access height detection;
- reading Dangerous Goods Transport (DGT) plates;
- calculation of HGV speed through virtual loops (If V> Vmax: the light turns red);
- automatic Reading of License Plates (ARLP) by day and by night;
- all-in-one sensor (infrared and Complementary Metal Oxide Semiconductor (CMOS) "very high sensitivity");
- 24/7 detection in various weather conditions, without the need for additional lighting;
- low maintenance;
- IP connectivity and configuration via secure Wi-Fi / 3G connection;
- eight vehicles or pedestrian presence zones;
- video stream visible in Haut Definition Protocol (HD) and Real-Time Streaming Protocol (RTSP);
- countdown of the waiting time before going green;
- management of Variable Message Panels (VMP) and cross-arrow aspects.

Polycarbonate signal lanterns

The polycarbonate signal lanterns must have the following characteristics:

- led technology;
- optically attractive modern design;
- slim design, appropriate for historic urban areas;
- available in different colours and colour combinations;
- can be mounted vertically or horizontally;
- available in ø 100/210/300 mm;
- anti-vandalism.

LED modules

LED modules must have the following characteristics:

- no visible LED point — the central light source;
- higher anti-ghost performance (class 5);
- lower energy consumption and brilliant light output;
- products traceable by serial number;
- custom masks that can display any symbol;
- life cycle > 5 years;
- optimised thermal concept, reducing degradation to a minimum;
- automatic light compensation in case of diode failure;
- degraded mode functions available in 42V;
- compliant with DIN VDE 0832 standard.

Pedestrian pushbutton

Pedestrian pushbuttons must have the following characteristics:

- modular design allowing the adaptation to all types of intersections;
- no moving parts which could be deactivated with toothpicks, gum;
- anti-vandalism (solid body and integrated metal-core); laterally tactile symbols appeal to describe the passage for the visually impaired;
- location of the pushbutton, thanks to the acoustic and optical position signal (LED ring);
- integrated acoustic units;
- meet all the requirements of the current directives and regulations (RILSA, DIN 32981, DIN VDE 0832, EN 50293).

Environmental sensor

Environmental sensors should allow for the following:

- measurement of gases (NO2, O3, CO, CO2, VOC);
- measurement of polluting fine particles (PM1, PM2.5, PM10);
- measurement of humidity, temperature, and pressure;
- noise measurement.

Weighing at the current speed

Weighing-in-motion systems with dynamic weighing sensors help to quickly detect vehicles and axle weights for safer roads and better traffic management.

Conclusions

The installation of 15 secure pedestrian crossings throughout the 5 km of the project, in addition to a pedestrian crossing on each of the five main intersections, has made it possible to reduce HGV speed to manage traffic and ensure the maximum protection of pedestrians. Besides, with the help of ITS, several issues related to traffic regulation and flow have been resolved. The dynamic and adaptive management of traffic lights has, therefore, made it possible to reduce ways dedicated to HGV while minimising journey time.

The use of ITS will allow the registration of traffic data, the collection of information about special events, and the management of system efficiency for real-time. The innovations and intelligent systems made it possible for HGV to bypass the downtown of Casablanca with a significant gain in terms of business competitiveness and a substantial positive impact on the quality of life of citizens and the urban environment.

Future research will focus on the national level in Morocco, establishing a barometer to draw up an inventory of the dynamics of Moroccan cities and their existing and future smart city strategies. This research will allow tracing the roadmap for accelerating the sustainable transition and the transformation of Moroccan cities into smart cities. The barometer will provide an analysis of the data collected from a pre-established sample. Three conceptual models will be considered: the three components of the smart city by Nam and Pardo (2011); the six dimensions of the smart city by Giffinger et al. (2007); and ISO 37120: 2014.

The barometer will have to deal with four essential components:

- The first part will concern the understanding and apprehension of the concept of the smart city by various city stakeholders. It will identify the main perceptions associated with the emergence of the smart city and measures the importance given to technological, human and institutional factors. Finally, it will present a self-assessment established by the cities themselves to monitor the progress in the implementation of a smart city approach.
- The second part will explore the strategic axes developed within cities. It will present the prerequisites essential for strengthening a local strategy oriented towards a smart city approach. It will then highlight the main themes under development, the values conveyed, and the formalisation actions carried out to support smart city projects.
- The third part will deal with the implementation and monitoring of smart city projects. It will focus on the level of involvement of various actors and current or planned means of financing, and initiatives to strengthen the dynamics of the various stakeholders (public and private actors as well as citizens). Finally, it will identify the benefits generated as well as the obstacles encountered in the implementation of smart city projects.
- Finally, the last section will indicate the monitoring and control procedures as well as the obstacles that cities may encounter in the implementation and development of smart and sustainable city projects and the recommendations to overcome them.

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