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Discovery the most effective roads of the main network of the Sfax City in Tunisia to fit for the tramway insertion.

Auteur 1 : Hana ELLEUCH,
Auteur 2 : Kamel HELALI,

Hana ELLEUCH, Assistant Professor in planning and environment engineering
National School of Engineering, University of Sfax, 3038, Tunisia.

Kamel HELALI, Associate professor in Quantitative Methods
Department of Applied Quantitative Methods.
Faculty of Economics and Management of Sfax. University of Sfax.

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Abstract

The continuous expansion witnessed in the city of Sfax has culminated in a significant extension of the distances separating the dwelling areas from work places, rendering the extension of its transport network an urgent priority. In effect, ever since the 1980s, the trips split model has veered towards the generalization of the private car. Today, the city's urban transport network has reached its maximum capacity limits. As a remedy to this saturation state, the authorities have been pondering on setting up a mass transport system similar to the tram. As result, an effective geometric study would enable to draw a feasibility geometric map viable to integrate a tramway across the city's transport network (Sfax). Hence, three road sections: red, green and yellow labels, have been identified, in accordance with the two major factors accounted for on designing the tram line layout, specifically, the road width as well as the existing buildings' distribution. The present road has a heterogenous distribution of exiting building. The tramway inserting could have a many problem: land acquisition differs according to the property nature and ownership structure, ranging from roadside buildings (long-term land acquisition), villas (medium-term land acquisition), bare land (short-term land acquisition), and buildings with a four to five-meter setback for private parking lots (land acquisition completed). Noteworthy, however, is that riverside access turns out to pose a major problem as it could well affect the tram commercial speed. The score length methodology would help us establish a distinctive categorization of the existing roads from the least to the most appropriate for setting up the tramway. For the Lafran road : the red section length score is 33 along the right road sides, yellow sections length score is 20, green section length score is 6. Accordingly, our conducted study is focused on classifying the routes, making up the city's road network, in terms of effective disposition to accommodate the tram. Indeed, the least effective roads identified for the installation are Lafran, El Ain and Gremda, registering total scores exceeding forty, while the most effective ring road identified to fit for the installation turns out to be the Majida Boulila Avenue, recording a total score of eleven.

Keywords: Congestion; Tramway; Sections; Length; Total score; Classification.

1. Introduction

The city of Sfax is characterized with a radio-concentric view, with a predominantly central semicircular seaside sited municipal area, and six suburban municipalities located in the outskirts, lying along radial axes stretching from north to south (Bennasr, 2013). However, the major transportation problem relates mainly to the functional asymmetry between a hyper-centric concentrated and increasingly tertiary-sector based center (with nearly 55,000 service-sector related jobs), and an under-equipped and increasingly urbanized residential periphery (Hamza, 2019), characterized with a low share of structuring jobs. On the other hand, the estimated 0.81% growth rate marking the area of Greater Sfax reflects well a significant population growth, which increased from 475649 in 2004 to 515725 in 2014, to 536952 in 2019 (INS, 2004a, INS, 2014a). In addition, car ownership per household recorded a significant growth rate of 3.91%, rising from 54009 in 2004 to 61356 in 2014, to 74290 in 2019 (INS, 2004b, INS, 2014b). Hence, the number of cars circulating in the Greater Sfax area increased from 1134279, in 2009, to 1719810, in 2019, registering an average annual growth rate (AAGR) of 4.25% (Hagui and Tlili, 2014).

In effect, the expansion witnessed in the city of Sfax has been accompanied with a significant spread of its urban surface and a noticeable extension of its urbanized limits. A remarkable spatial indicator of urban sprawl is the change noticeable in the private car use for travel purposes, which registered a yearly rate of 9.8% between 1986 and 2003, compared to 0.9% per year for public transport (Hagui and Tlili, 2014). Accordingly, the number of passengers transported via the urban network by the public Sfax Regional Transport Company (SORETRAS) fell from 61 million in 2008 to 45 million in 2013 (Daoud, 2013). As a result, the quality of public transport service on most of the SORETRAS busing lines has continued to deteriorate owing to traffic problems and difficulties. Commercial speed, for instance, is very low, especially in the city center. Similarly, the registered bus travel frequencies have significantly decreased from one scheduled bus every 15 minutes to a one-bus schedule every 60 minutes (Hagui and Tlili, 2014).

As a result, the authorities must act face to an overall increase in the demand for traveling relative to a very slow improvement in supply. Faced with such a situation, the authorities might well consider establishing a mass transport system that breaks away with the traditional transportation modes (Prasetijo, et al, 2017), by setting up the tramway system already operating in France, so far succeeding in connecting 24 of large French cities. Actually, the light rail mode turns out to be a highly profitable option given the ecological, modern, silent, comfortable, safe and economical advantages it offers (Fouchard, 2012).

The objective of implementing a structured transport system project is normally to meet user demand by establishing a public transport network with fast, frequent, and comfortable lines (Munafo et al., 2012). **dedicated public transport**, **exclusive right-of-way public transit** systems emerged with the revival of the tramway in the late 1970s (Fouchard, 2012). This term refers to a transport system that uses a dedicated lane exclusively reserved for public transport, isolating it from other traffic. The advantages of dedicated lanes are numerous: visibility of the dedicated lane (no conflicts with motorists), system reliability, improved operating speed, and safety in pedestrian zones. Moreover, if dedicated public transport is guided transport, its benefit is even greater (Balay, 2009): the ground footprint is reduced, alignment with the platform is safer, accessibility is increased for users and ride comfort is enhanced.

Our study is primarily based on the design assumptions of the feasibility studies for the first tramway network installed in Sfax, with Montreal and Brussels cited as examples (***Calvert and Snelder, 2017).***. To obtain a comprehensive overview of tramway design practices in urban environments (Systra, 2009), various standards and references were identified and consulted. To define the geometric design parameters used, the city's existing practices regarding road and pedestrian infrastructure must be considered (Fatteh et al, 2017). Regarding the tramway's components, the design principle for the track layout was first defined in plan and profile, specifying certain particular provisions applicable to the infrastructure associated with the tramway platform. The width of the tramway platform must be calculated based on the Obstacle Limit Gauge (Mc Gettrick, 2020). The concept of Obstacle Limit Gauge (OLG) is an essential element which is involved in both the design of guided transport systems and in the operation of these systems.

Still, the installation of the tramway platform requires a reflection on the users' distribution over the public space. Indeed, the width of the platform is necessarily gained from the space already devoted to other modes of transport (Lammoglia, 2013). On the other hand, the layout of the tramway line need be designed by accounting mainly for the roadway width as well as the distribution of the existing buildings. For this purpose, a geometrical study must be conducted so that a feasibility map based on a minimum value of the tramway insertion, relevant to the insertion of the first tramway network in Sfax.

After identification the geometric map of the tramway insertion in the road network in Sfax City: Hence, three road sections: red, green and yellow labels are identified. Land acquisition differs according to the property nature and ownership structure: ranging from roadside buildings (long-term land acquisition), villas (medium-term land acquisition), bare land (short-term land acquisition), and buildings with a four to five-meter setback for private parking lots (land acquisition completed). Noteworthy, however, is that riverside access turns out to pose a major problem as it could well affect the tram commercial speed.

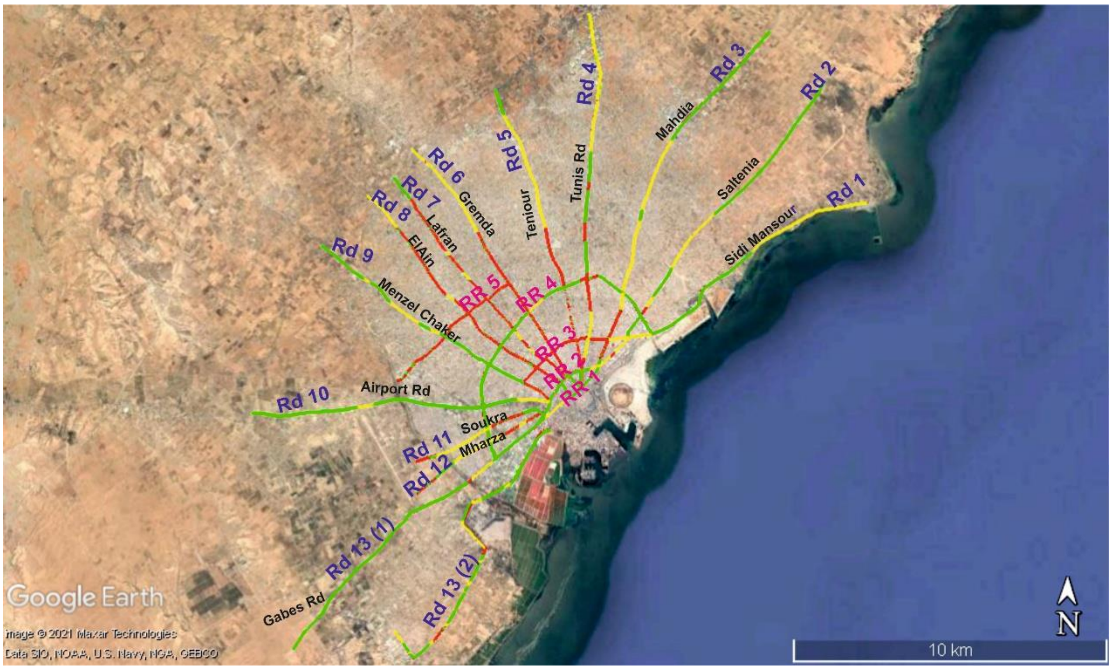
Moreover, a number of questions seem worth posing, for instance: could the road infrastructure of Sfax accommodate the tramway platform? What might the outcomes of this 'implantation' be? Could the tramway offer a regular operating circuit (punctuality, frequency etc.)? Could it make faster trips compared to other modes of transport? Moreover, the tramway line alignment should be set up while accounting for the roads actual conditions and status-quo situations, the roadway should satisfy a recommended width to meet the set standards (Tian et al., 2016). In fact, an effective tramway insertion should maintain a restructured transit system that guarantees and offers the community a high-level service, thereby, enhancing modal shift, by transferring a proportion of the trips already secured by a particular mode (private vehicles) to another (tramway) (Labbouz, 2008).

For a thorough analysis of the above-discussed points, our article will be elaborated in terms of the following plan. The second section is devoted to describing the road network characteristics already available in Sfax. Concerning the third section, it involves our advanced conception of the geometrical design parameters of the road network. As to the last section, it is dedicated to presenting a detailed classification of the radial lines and bypasses in terms of their aptitude order to accommodate the tramway.

2. Characteristics of the Sfax road network

The city's road network involves mainly thirteen radial lines, six among them are regional and seven are local (the Sidi Mansour, El Ain, Lafran, Saltenia, Mharza, Soukra and Teniour roads) (Ayadi and Hammemi, 2015). These roads, all converging towards the city center, are laid out as 2x2 lanes up to km 11, on a entirely bi-directional carriage way. The road network also encloses six bypasses, or intersection routes, commonly dubbed 'rings' or 'ring roads' (ensuring lateral traffic exchanges. However, in the current study, these radial roads will be labeled as Rd1,….Rdn and Ring Roads as RR1, …… RRn (Figure 1).

Fig. 1. Geometrical feasibility map of the tramway installation network in Sfax



Satellite Image (Google earth)

Section fit for tramway installation

Section fit for tramway installation with modification

Section unfit for tramway installation

As detailed by (Zouari, 2005), the road network of Sfax is characterized with the prevalence of recently constructed buildings with a setback of 4 to 5 m away, providing space for private parking lots. The congestion becomes increasingly noticeable the closer you approach to the focal center. Numerous crossings are encountered along the road axes intersecting the main road (secondary roads, streets, etc.).

Traffic congestion is usually persistent, mainly across the central and periphery-central areas, mainly at peak hours (morning, noon and evening), generated mainly by the spatial concentration of economic activities and administrative services. It is further intensified by the noticeably significant lack of parking lots, resulting in a rather anarchic parking of vehicles throughout the city.

3. Parameters of the city’s geometric road design

Regarding the tramway's components, the design principle for the track layout was first defined in plan and longitudinal profile, specifying certain particular provisions applicable to the infrastructure associated with the tramway platform. The width of the tramway platform must be calculated based on the Obstacle Limit Clearance Gauge (Fatteh et al,2017). The Obstacle Limit Clearance Gauge (OLCG) is an essential element that is relevant to both the design and operation of guided transport systems (Elleuch and Rouis, 2017). The tramway insertion site is a dedicated road space for tram traffic, separated from roadways by a continuous white stripe 20 cm wide (Labbouz, 2008), generally with a physical boundary (a raised platform with beveled edges, most often with a minimum recommended height of 8 cm). It is passable by other vehicles to bypass an obstacle on the roadway or to allow access for residents.

The lanes allow for pedestrian and bicycle traffic in a shared space, most often crossing built-up or semi-built-up areas. In the city of Sfax, built-up areas are very prevalent. In urbanized areas, land constraints lead to the construction of narrower roadways. In this case, the width of traffic lanes is reduced to 3.25 meters in each direction to ensure proper passing and safety for all modes and users (cars, standard buses, trucks, household waste collection vehicles, street sweepers, fire trucks, etc.) (Landry, 2015). For a one-way lane, the width must be at least 3.25 m to allow for comfortable turning maneuvers. The radial lines of Sfax constitute an important traffic artery with 2x2 lanes. They traverse a heterogeneous urban fabric composed of individual and multi-family housing, as well as numerous public facilities such as schools and colleges (Elleuch and Rouis, 2026). The integration of the tramway right-of-way with its stations along the central axis results in two traffic lanes: one to the right of the tram station and another to the left. These traffic lanes must be suitable for vehicles and at least 3.25 m wide. To meet this requirement, the road must be at least 21 m wide. A 2 m wide parking area along the entire length of the tram stations (35 m) is not feasible due to space constraints. When the tramway is in a straight line (tram in operation), the platform width for a single track is 2.8 m.

The installation of a double-track tramway in a central location results in two traffic lanes: one to the right of the tramway right-of-way and another to the left. These traffic lanes must be suitable for vehicles and at least 3.25 meters wide. To meet this requirement, the road must be at least 20 meters wide, taking into account a 2-meter-wide parking area on each side of the roadway. Tram traffic within the protected right-of-way must run in the same direction as the adjacent tramway traffic lane to avoid physical separation (island, barrier, curb, parking strip, planted shoulder, etc.) and thus reduce the road width. A 20-centimeter-wide white line must be maintained.

4. Classification of radial lines and bypasses in order of suitability for a tramway installation

The geometrical study helps in providing a geometrical feasibility map for the introduction of a tramway network, fit for installation on an axial and crossable site, in Sfax. In this context, the entirety of the city roads are going to be divided into various sections, wherein, three colors are selected to identify the suitability rate of each section to host a tramway site according to the set criteria (Fig.1). Accordingly, the green-color section should designate the section wherein a tramway installation is possible, displaying a road width equal to or exceeding 21m. As to the red section, it denotes the section's impossibility to accommodate a tramway, reflecting a width of less than 20m, while the yellow section refers to the section wherein a tramway is possible to install, with a road width greater than or equal to 20m.

The length score is computed in accordance with the following formula:

$$\text{Lenght Score} = 100 \times \begin{bmatrix} 0.6 \times (\text{Red Section}) + 0.3 \times (\text{Yellow Section}) \\ + 0.1 \times (\text{Green Section}) \end{bmatrix} \tag{1}$$

The formulation of equation (1) is based on the following weighting: 0.6 for the Red Sections; 0.3 for the Yellow Sections; and 0.1 for the Green Sections. This choice serves to identify the roads from the least fit to the best fit. Accordingly, it follows that the red sections appear to pose a major problem as to the tramway introduction. In effect, they turn out to display a width separating opposed buildings that is too inferior to the recommended roadway width (<20 m) (Elleuch and Rouis, 2017). Regarding the yellow sections, they exhibit a width separating two opposite buildings exceeding the recommended roadway width (>20m). As for the green sections, they display a width range separating opposite buildings that exceeds the recommended roadway width at the station's levels (>21m) (Elleuch and Rouis, 2017). These sections are more clearly illustrated on the Figure 1.

4.1. The red sections associated problems

The layout of the tramway line is conceived based on the roadway width and distribution of the existing buildings. However, is that solutions, such as expropriation measures, remain imposed as necessary means to enlarge the available track, through gaining land rights (Bourbonnais, 2007). This is an extreme solution because it can have a relatively high political cost. Actually, the procedures for installing the tramway take too long, and the ensuing dissatisfaction of the local population remains difficult to manage.

$$\text{Red Length Score} = 100 \times \begin{bmatrix} 0.55 \times (\text{Roadside Located Buildings}) + 0.15 \times (\text{Bare Land}) \\ + 0.25 \times (\text{Roadside Located Villas}) \\ + 0.05 \times (\text{Buildings With a New Setback}) \end{bmatrix}$$

(2)

Consequently, the formulation of equation (2) turns out to depend on the following weighting: 0.55 for the roadside located buildings (RSB); 0.25 for the roadside located villas (V); 0.15 for bare land (BL), and 0.05 for buildings with a new setback (BNS). This option would help us establish a distinctive categorization of the existing roads from the least to the most appropriate for setting up the tramway. Such a rating classification rests on the fact that land acquisition differs according to the property nature and ownership structure, ranging from roadside buildings (long-term land acquisition), villas (medium-term land acquisition), bare land (short-term land acquisition), and buildings with a four to five-meter setback for private parking lots (land acquisition completed) (Figure 2).

Fig. 2. Simplified plan composition of the sfax road network

Source: Satellite Image (Google earth)

$$\underset{\text{(Red Sections)}}{\text{Road Crossings Score}} = 100 \times \left(\frac{\text{Number of Road Crossings}}{\text{Max (Number of Road Crossings at the sections level)}} \right) \tag{3}$$

The choice of equation 3 rests on the fact that riverside access should constitute a major problem in case the tramway would be installed on an axial and traversable site (Figure 2). The exploitation of a tramway line also depends highly on the visual driving principle or dimension. On a passable site, the tramway is mixed with the other users generated traffic, requiring the driver to be particularly and skilfully vigilant. Actually, commercial speed could be noticeably reduced, and time lost might be further amplified by vehicles stored on the platform, waiting to turn left towards a street or riverside access.

4.2. The yellow sections related problems

A major road classification relevant issue is that of uncontrolled parking. For instance, in case the road width appears to range between 20 and 23 m, traffic congestion would be aggravated and intensified by the uncontrolled parking of vehicles, whether at the level of buildings (Figure 3), villas (Figure 4), or even buildings with a new setback (Figure 5). At the bare land level, however, there would be no parking at all.

In the case where the road width proves to exceed 23 m, the pavement profile should include vehicle parking with bicycle/cycling lanes on both sides, thereby, minimizing vehicular use, and therefrom, congestion (Figure 6).

$$\text{Yellow Length Score} = 100 \times \begin{bmatrix} 0.5 \times \left(\underset{\text{(Road Width Between 20 and 23m)}}{\text{Roadside Located Buildings}} \right) + 0.05 \times (\text{Bare Land}) \\ + 0.2 \times \left(\underset{\text{(Road Width Between 20 and 23m)}}{\text{Roadside Located Villas}} \right) + 0.075 \times \left(\underset{\text{(Road Width Greater than 23 m)}}{\text{Roadside Located Villas}} \right) \\ + 0.1 \times (\text{Buildings with a New Setback}) \\ + 0.075 \times \left(\underset{\text{(Road Width Greater than 23m)}}{\text{Roadside Located Building}} \right) \end{bmatrix} \tag{4}$$

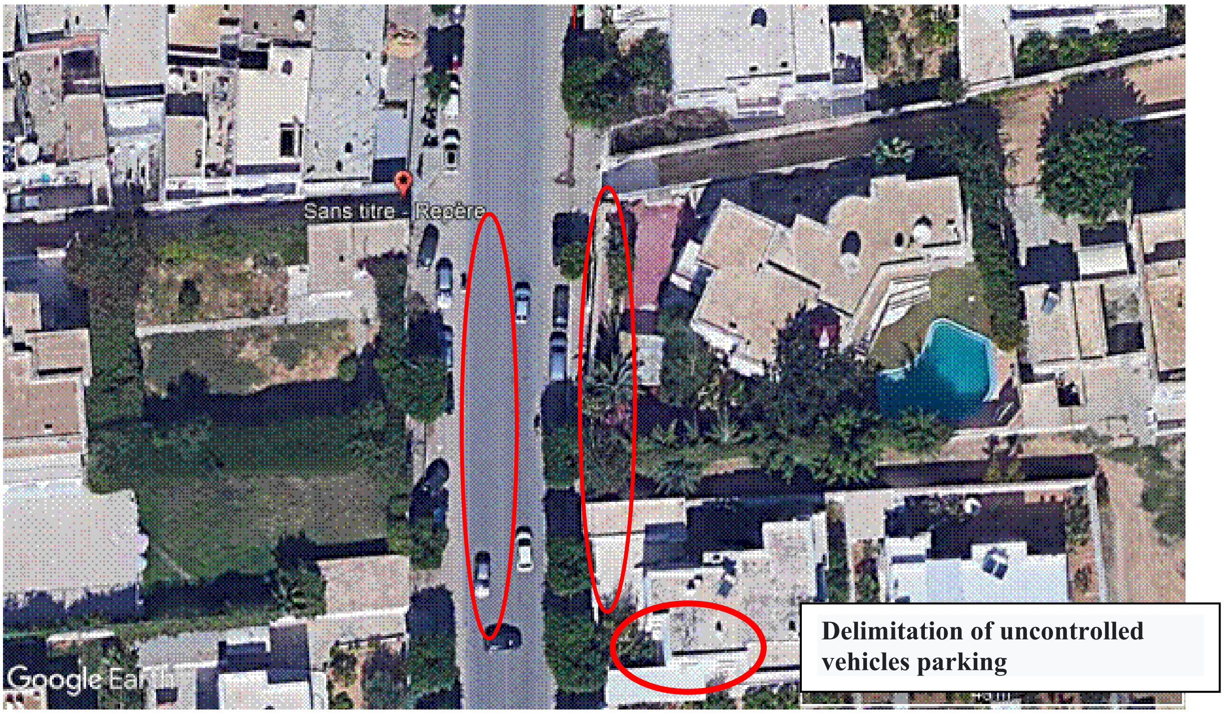
The formulation of equation (4) relates to the following weighting: 0.5 for buildings located at the roadside with a width ranging between 20 and 23m (RSBL); 0.2 for villas located at the roadside with a width between 20 and 23m (VL); 0.1 for buildings with new setback (BNS); 0.075 for roadside buildings with a width greater than 23m; 0.075 for roadside villas with a width greater than 23m, and 0.05 for bare land (BL). This choice relates well to the roads' distinction and categorization, in terms of tramway installation appropriateness, from the least effective to the most effective. This proceeding stems from the fact that buildings and villas located a roadside with a width ranging between 20 and 23 m result in further worsening the traffic congestion. In fact, buildings and villas sited on the side of a road with a width exceeding 23m reflect the optimally required road profile (Figure 6).

The score number of crossings (Yellow Section) is computed in relation to equation (3).

Fig.3. Parking of vehicles at roadside buildings level

Source: Satellite Image (Google earth)

Fig. 4. Vehicles parking at the villas level

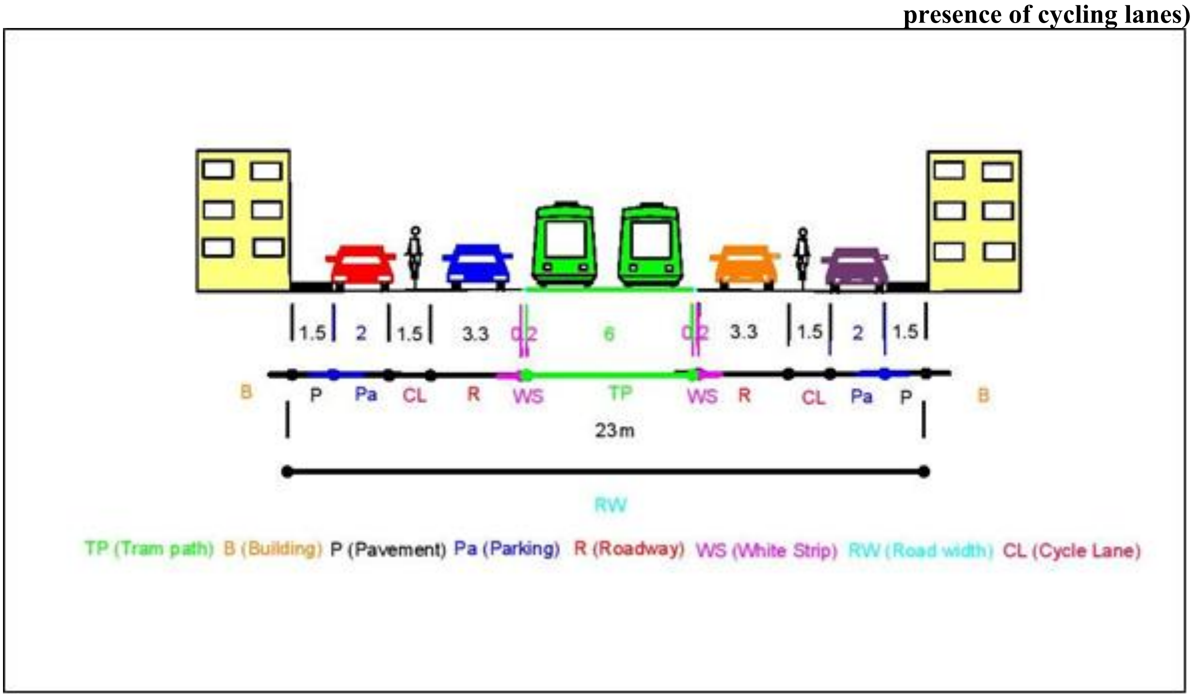


Source: Satellite Image (Google earth)

Fig. 5. Vehicles parking at the new-setback buildings level

Source: Satellite Image (Google earth)

Fig. 6. Roadway design following the tramway installation in axial site and straight alignment (in presence of cycling lanes)



4.3. The green sections associated problems

Computation of the green sections' length score applies the same principle as that associated with computing the yellow sections' length score (see equation 5).

As regards the number of crossings relevant score (green section), it is calculated according to equation (3).

$$\text{Green Length Score} = 100 \times \left[\begin{array}{l} 0.5 \times \left(\underset{\text{(Road Width Between 20 and 23m)}}{\text{Roadside Located Buildings}} \right) + 0.05 \times (\text{Bare Land}) \\ + 0.2 \times \left(\underset{\text{(Road Width Between 20 and 23m)}}{\text{Roadside Located Villas}} \right) \\ + 0.075 \times \left(\underset{\text{(Road Width Greater than 23 m)}}{\text{Roadside Located Villas}} \right) \\ + 0.1 \times (\text{Buildings with a New Setback}) \\ + 0.075 \times \left(\underset{\text{(Road Width Greater than 23m)}}{\text{Roadside Located Building}} \right) \end{array} \right]$$

(5)

5. Data analysis and interpretation

In this work, a special methodology is advanced, whereby, a feasible process to facilitate the tracing of a tramway line is developed (Elleuch and Rouis, 2017). The steps to follow include the sampling of satellite images by Google Earth, achieved in conformity with a scale setting of (1 cm→4000 cm (1/4000)). Then, the buildings as well as the sidewalks' boundary lines are identified. In a next step, the different elements constituting the road (buildings, sidewalks etc.) are traced via Autocad. Subsequently, the roads are classified in terms of their relevant characteristics, by considering the distances respectively separating the roadside from the buildings, from the buildings with a new setback, from the free land parcels and from the villas.

Table 1. The different sections relevant length-range score results (in kilometers)

	L	GS	RS	YS	length-range score
Rd 1	9,0	4,5	0,0	4,5	**20**
Rd 2	12,6	8,1	0,6	4,0	**19**
Rd 3	13,5	6,0	1,7	5,8	**25**
Rd 4	13,0	3,9	2,5	6,6	**30**
Rd 5	9,9	0,9	4,7	4,3	**42**
Rd 6	10,0	0,6	5,6	3,8	**46**
Rd 7	9,0	0,9	6,9	1,1	**51**
Rd 8	9,8	0,9	7,0	1,9	**50**

Rd 9	9,3	6,4	1,0	1,9	**20**
Rd 10	9,9	8,3	0,0	1,6	**13**
Rd 11	4,6	0,7	2,0	2,0	**40**
Rd 12	4,8	0,8	2,0	1,9	**39**
Rd 13 (1)	11,0	10,0	0,2	0,9	**12**
Rd 13 (2)	10,9	6,2	1,7	3,1	**23**
RR 1	2,3	1,3	0,1	0,9	**20**
RR 2	2,6	2,4	0,0	0,2	**12**
RR 3	4,8	0,0	3,4	1,4	**51**
RR 4	10,7	9,5	0,6	0,6	**14**
RR 5	4,7	0,0	4,7	0,0	**60**

Notes: L: road length; GS: green section; RS: red section; YS: yellow section, Rd: Road.

According to table 1, both of the Rd 1 and Rd 10, along with the RR2 do not display any red sections, whereas the Rd 8, Rd 7, Rd 6, Rd 5, Rd 11, Rd 12 and RR 3 appear to include red sections of more than 40% of the total lenght. On the other hand, the Rd 3, Rd 4, Rd 9 and Rd 13 (2) turn out to display red sections of length rates ranging between 10 and 20 %. The RR5 have a red sections in full.

Table 2, below, highlights the red sections appearing along the right roadsides. For instance, the Rd 2, Rd 3, Rd 6, Rd 7 and Rd 8, Rd 9, RR1, RR3 and RR5 display roadside buildings extending over distances more than 40%. Noteworthy, also, is that the Rd 3, Rd 4, Rd 5, Rd 7, Rd 8 and Rd 11, Rd 13 (1) as well as the RR 3 and RR 5 appear to display a predominance of villas at road edge levels, extending over distances more than 40% of the total lenght.

Table 2. Results relevant to the red sections' length score concerning the right roadsides (in kilometers)

Roads	RSB	V	BL	BNS	red sections' length score
Rd 1	0,0	0,0	0,0	0,0	**0**
Rd 2	0,4	0,2	0,0	0,0	**45**
Rd 3	0,9	0,7	0,0	0,2	**38**
Rd 4	0,4	2,1	0,0	0,1	**29**
Rd 5	1,3	2,6	0,1	0,7	**30**
Rd 6	3,4	1,0	0,1	1,0	**40**
Rd 7	2,7	2,8	0,2	1,1	**33**
Rd 8	2,9	2,8	0,3	1,1	**34**
Rd 9	0,4	0,2	0,0	0,4	**30**
Rd 10	0,0	0,0	0,0	0,0	**0**
Rd 11	0,2	1,2	0,3	0,2	**25**
Rd 12	0,6	0,7	0,4	0,3	**29**
Rd 13 (1)	0,0	0,1	0,0	0,0	**23**
Rd 13 (2)	0,5	0,6	0,6	0,0	**30**
RR 1	0,1	0,0	0,0	0,0	**50**
RR 2	0,0	0,0	0,0	0,0	**0**

RR 3	1,7	1,4	0,1	0,2	**38**
RR 4	0,0	0,0	0,0	0,0	**0**
RR 5	2,1	1,9	0,4	0,3	**36**

Notes: RSB: Road-Side Buildings; V: Villas; BL: Bare Lands; BNS: Buildings with New Setback.

Table 3 illustrates the yellow sections extending over the roads' right side. Accordingly, roads with width ranging between 20 and 23m, namely, the Rd 5, Rd 9, Rd 10, RR 1 and RR 2 appear to display roadside buildings extending over sections of more than 40% of the total lenght. As for the roads displaying widths ranging between 20 and 23 m, the Rd 1 and Rd 9 display roadside villas extensions of more than 40%, while the Rd 7, Rd 10, Rd 11 and RR 1 demonstrate the existence of villas prevailing along roadside sections of 20 %.

Table 3. Results regarding the yellow sections' length ranges along the right roadsides (in kilometers)

Roads	RSBL >23 m	RSBL between 20 and 23m	VL between 20 and 23m	VL > 23 m	BL	BNS	yellow sections' length Score
Rd 1	0,2	0,3	2,5	1,0	0,5	0,0	**17**
Rd 2	1,9	0,7	0,5	0,4	0,4	0,0	**16**
Rd 3	2,2	1,6	0,9	0,5	0,4	0,2	**21**
Rd 4	2,5	0,2	0,2	1,1	1,8	0,8	**9**
Rd 5	0,9	1,8	0,3	0,3	0,8	0,2	**25**
Rd 6	2,1	0,0	0,0	0,6	0,7	0,3	**7**
Rd 7	0,0	0,3	0,3	0,3	0,1	0,2	**20**
Rd 8	0,5	0,0	0,0	0,6	0,6	0,2	**7**
Rd 9	0,0	0,9	0,8	0,0	0,1	0,2	**32**
Rd 10	0,0	0,7	0,3	0,0	0,1	0,5	**28**
Rd 11	0,2	0,1	0,6	0,7	0,2	0,2	**12**
Rd 12	0,3	0,5	0,2	0,3	0,2	0,4	**19**
Rd 13 (1)	0,2	0,0	0,0	0,4	0,1	0,2	**8**
Rd 13 (2)	1,2	0,7	0,0	1,0	0,1	0,0	**17**
RR 1	0,0	0,6	0,2	0,0	0,0	0,0	**41**
RR 2	0,1	0,1	0,0	0,0	0,0	0,0	**32**
RR 3	1,3	0,0	0,0	0,1	0,0	0,0	**8**
RR 4	0,2	0,0	0,0	0,1	0,1	0,3	**9**
RR 5	0,0	0,0	0,0	0,0	0,0	0,0	**0**

Notes: **RSBL:** road-side buildings Length, VL: roadside located villas Length, BL: Bare Lands, BNS: Buildings with new setback.

Table 4, below, depicts the green sections recorded for the roads' right side edges. In fact, for roads with a width ranging between 21 and 23m, such as Rd 3, the Rd 10 and Rd 13 (1) roads, they reveal buildings sites located between 1 and 5% of the total length.

Table 4. Results concerning the green sections' length ranges along the right roadsides (in kilometers)

Roads	RSBL >23 m	RSBL between 20 and 23m	VL between 20 and 23m	VL > 23 m	BL	BNS	green sections' length Score
Rd 1	1,1	0,0	0,0	0,6	2,7	0,1	**6**
Rd 2	3,1	0,0	0,0	0,7	4,2	0,0	**6**
Rd 3	2,5	0,3	0,0	0,1	3,0	0,1	**9**
Rd 4	0,1	0,0	3,4	0,0	0,0	0,4	**19**
Rd 5	0,0	0,0	0,0	0,0	0,9	0,0	**5**
Rd 6	0,3	0,0	0,0	0,1	0,0	0,2	**8**
Rd 7	0,0	0,0	0,0	0,2	0,7	0,0	**6**
Rd 8	0,0	0,0	0,0	0,2	0,0	0,6	**9**
Rd 9	2,5	0,0	0,0	1,5	1,8	0,5	**7**
Rd 10	3,6	0,1	0,1	0,9	2,6	1,1	**8**
Rd 11	0,4	0,0	0,0	0,0	0,2	0,0	**7**
Rd 12	0,3	0,0	0,0	0,3	0,2	0,0	**7**
Rd 13 (1)	0,7	0,2	0,0	1,2	7,6	0,3	**6**
Rd 13 (2)	2,4	0,0	0,0	1,7	1,9	0,2	**7**
RR 1	0,2	0,0	0,0	0,7	0,1	0,3	**8**
RR 2	1,6	0,0	0,0	0,0	0,0	0,8	**8**
RR 3	0,0	0,0	0,0	0,0	0,0	0,0	**0**
RR 4	3,9	0,0	0,0	3,2	1,3	1,1	**7**
RR 5	0,0	0,0	0,0	0,0	0,0	0,0	**0**

Table 5, below, depicts the left roadsides registered red sections. Accordingly, the Rd 2, Rd 3, Rd 4, Rd 6, Rd 7,Rd 8, Rd 9, Rd 12, Rd 13 (2), RR 1 and RR 3 appear to display the predominance of buildings along the north section, extending a long distance more than 40% of the total lenght. As regards the RR 5 and the Rd 5, they turn out to demonstrate buildings located along segments with 35 % of the total lenght, extending over the left roadsides. Concerning Rd 2, Rd 3, Rd 4, Rd 5, Rd 7, Rd 11, RR1 and RR 3 they appear to reveal villas extending along roadside section lengths more than 40%.

Table 5. Results relevant to the red sections' length concerning the left roadside (in kilometers)

Routes	RSB	V	BL	BNS	red sections' length score
Rd 1	0,0	0,0	0,0	0,0	**0**
Rd 2	0,2	0,3	0,0	0,0	**37**
Rd 3	0,7	0,7	0,2	0,1	**35**
Rd 4	1,1	1,0	0,2	0,2	**36**
Rd 5	1,6	2,3	0,1	0,7	**32**
Rd 6	3,2	1,2	0,4	0,9	**38**
Rd 7	2,7	2,9	0,5	0,8	**34**
Rd 8	3,6	1,1	0,7	1,6	**35**
Rd 9	0,5	0,1	0,0	0,4	**34**

Rd 10	0,0	0,0	0,0	0,0	**0**
Rd 11	0,7	1,0	0,3	0,1	**32**
Rd 12	1,1	0,4	0,4	0,2	**38**
Rd 13 (1)	0,0	0,1	0,0	0,0	**23**
Rd 13 (2)	1,0	0,5	0,1	0,0	**42**
RR 1	0,1	0,1	0,0	0,0	**43**
RR 2	0,0	0,0	0,0	0,0	**0**
RR 3	1,7	1,3	0,0	0,4	**38**
RR 4	0,0	0,0	0,0	0,0	**0**
RR 5	1,7	2,1	0,5	0,3	**33**

Table 6, below, illustrates the yellow sections depicted with regard to the left roadside areas. In this respect, the roads displaying a width ranging between 20 and 23m, specifically, the Rd 10, RR1, RR 2 appear to exhibit buildings intensity over sections of more than 40% across the left roadside. As regards the Rd 1, exhibiting width ranges varying from 20 to 23m, it displays villas extending over section more than 40%, across the left roadside. As for the Rd 2, Rd 3, Rd 9 and Rd 11, they demonstrate a predominance of villas persisting over sections of 20% along the left roadside.

Table 6. Results obtained for the left roadside yellow sections' length score (in kilometers)

Roads	RSBL >23 m	RSBL between 20 and 23m	VL between 20 and 23m	VL > 23 m	BL	BNS	yellow sections' length Score
Rd 1	0,2	0,1	1,8	0,8	1,5	0,1	**12**
Rd 2	1,7	0,7	1,0	0,3	0,3	0,0	**18**
Rd 3	1,9	1,3	1,1	0,8	0,4	0,3	**20**
Rd 4	2,3	0,1	0,3	1,1	1,4	1,4	**9**
Rd 5	1,0	1,3	0,7	0,3	0,9	0,2	**22**
Rd 6	2,8	0,0	0,0	0,6	0,4	0,1	**7**
Rd 7	0,0	0,2	0,2	0,5	0,0	0,1	**19**
Rd 8	0,5	0,0	0,0	0,6	0,6	0,2	**7**
Rd 9	0,0	0,7	0,8	0,0	0,2	0,2	**29**
Rd 10	0,0	0,7	0,4	0,0	0,5	0,0	**29**
Rd 11	0,2	0,1	0,6	0,3	0,4	0,3	**13**
Rd 12	0,3	0,7	0,3	0,0	0,1	0,5	**25**
Rd 13 (1)	0,3	0,0	0,0	0,1	0,4	0,1	**7**
Rd 13 (2)	1,3	0,5	0,3	0,4	0,6	0,0	**15**
RR 1	0,0	0,7	0,2	0,0	0,0	0,0	**44**
RR 2	0,0	0,1	0,0	0,0	0,0	0,1	**29**
RR 3	0,7	0,0	0,0	0,4	0,3	0,1	**7**
RR 4	0,1	0,0	0,0	0,1	0,1	0,3	**8**

Table 7 highlights the left roadsides detected green sections. Regarding the roads displaying a width ranging between 21 and 23 m, the Rd 3 appears to involve buildings stretches extending along segments of 40%. As to the roadside located villas, this road turns out to display segments of 30 %.

Table 7. Results obtained for the length score of the left roadside lying green sections (in kilometers)

Routes	RSBL >23 m	RSBL between 20 and 23m	VL between 20 and 23m	VL > 23 m	BL	BNS	green sections' length Score
Rd 1	1,6	0,0	0,0	1,3	1,4	0,1	**7**
Rd 2	2,7	0,0	0,0	1,1	4,3	0,0	**6**
Rd 3	2,9	0,3	0,1	0,4	2,4	0,0	**9**
Rd 4	0,3	1,7	1,2	0,0	0,2	0,5	**30**
Rd 5	0,1	0,0	0,0	0,0	0,8	0,0	**5**
Rd 6	0,0	0,0	0,0	0,1	0,1	0,5	**9**
Rd 7	0,1	0,0	0,0	0,2	0,6	0,1	**6**
Rd 8	0,3	0,0	0,0	0,0	0,0	0,6	**9**
Rd 9	2,9	0,0	0,0	1,8	1,1	0,5	**7**
Rd 10	2,0	0,1	0,1	1,2	3,1	1,8	**8**
Rd 11	0,1	0,0	0,0	0,4	0,0	0,1	**8**
Rd 12	0,3	0,0	0,0	0,0	0,5	0,0	**6**
Rd 13 (1)	1,9	0,2	0,1	1,4	6,3	0,1	**7**
Rd 13 (2)	1,2	0,0	0,0	2,4	2,5	0,1	**7**
RR 1	0,6	0,0	0,0	0,2	0,0	0,5	**8**
RR 2	1,5	0,0	0,0	0,2	0,1	0,5	**8**
RR 3	0,0	0,0	0,0	0,0	0,0	0,0	**0**
RR 4	3,2	0,0	0,0	2,9	1,3	2,0	**8**
RR 5	0,0	0,0	0,0	0,0	0,0	0,0	**0**

Table 8, below, depicts the crossings recorded scores relevant to the right roadsides. Concerning the red sections, the Rd 7, Rd 8, and Rd 6 roads turn out to register the highest number of crossings, with scores exceeding sixty crossings. With respect to the yellow sections, the Rd 2, Rd 3, Rd 4, Rd 5, and Rd 6 roads appear to display the highest number of crossings, with scores exceeding sixty. As regards the green sections, the Rd 9, Rd 10 and RR 4 appear to record the greatest number of crossings, exceeding sixty.

Table 8. Crossings recorded scores relevant to the right roadsides

Roads	Score: Number of Crossings (Red sections)	Score: Number of Crossings (Yellow sections)	Score: Number of Crossings (Green sections)
Rd 1	0	10	36
Rd 2	1	87	46
Rd 3	17	100	32
Rd 4	3	67	11
Rd 5	62	85	3

Rd 6	69	87	1
Rd 7	100	33	8
Rd 8	93	36	3
Rd 9	13	36	64
Rd 10	0	21	68
Rd 11	23	49	4
Rd 12	31	46	4
Rd 13 (1)	1	28	39
Rd 13 (2)	6	49	38
RR 1	1	15	7
RR 2	0	3	8
RR 3	39	8	0
RR 4	0	5	100
RR 5	51	0	0

Table 9. Crossings recorded scores relevant to left roadside

Roads	**Score: Number of Crossings (Red sections)**	**Score: Number of Crossings (Yellow sections)**	**Score: Number of Crossings (Green sections)**
Rd 1	0	62	73
Rd 2	6	73	90
Rd 3	26	100	48
Rd 4	14	90	52
Rd 5	49	69	4
Rd 6	77	58	8
Rd 7	92	17	13
Rd 8	100	33	4
Rd 9	11	23	100
Rd 10	0	10	96
Rd 11	34	27	8
Rd 12	26	40	6
Rd 13 (1)	2	10	46
Rd 13 (2)	6	21	23
RR 1	0	10	15
RR 2	0	2	27
RR 3	40	4	0
RR 4	0	2	98
RR 5	55	0	0

Table 9 depicts the Crossings recorded scores regarding the left roadsides. Concerning the red sections, Rd 7, Rd 8, and Rd 6 turn out to score the highest number of crossings, exceeding seventy. Regarding the yellow sections, the Rd 1, Rd 2, Rd 3, Rd 4, Rd 5, and Rd 6 seem to register the highest number of crossings, recording scores beyond fifty crossings. With respect to the green sections, the Rd 1, Rd 2, Rd 9 and Rd 10, along with the RR 4 tend to score the highest number of crossings that exceed seventy.

Based on table 10, the least effective roads in terms of tramway installation turn out to be the Rd 7, Rd 8 and Rd 6, recording total scores that exceed forty, with red sections occupying 50% of the total road length. Additionally, the roadside existing buildings appear to stretch along more than 40% of the road total length, while the number of crossings recorded scores tend to exceed seventy.

Table 10. Total scores final results

Roads	Total Score	Order
Rd 7	41	**1**
Rd 8	40	**2**
Rd 6	40	**3**
RR 5	37	**4**
Rd 5	35	**5**
RR 3	33	**6**
Rd 3	31	**7**
Rd 12	31	**8**
Rd 4	30	**9**
Rd 11	30	**10**
Rd 2	27	**11**
Rd 9	26	**12**
Rd 13 (2)	22	**13**
RR 1	20	**14**
Rd 1	19	**15**
Rd 10	18	**16**
RR 4	17	**17**
Rd 13 (1)	14	**18**
RR 2	11	**19**

It is worth noting that Rd 5, RR 3 and RR 5 appear to display total scores ranging between 33 and 37, while the red sections turn out to occupy 50% or more of the Rd 5 and RR 3. Furthermore, the roadside existing buildings prove to score rates ranging between 30% and 50%. In addition, the recorded number of crossings scored turns out to vary between 39 and 62.

It is also important to highlight that the Rd 3, Rd 11, Rd 12 and Rd 4 turn out to record total scores of thirty and thirty-one, with the Rd 3 and Rd 4 displaying red sections ranging between 13% and 20%. At the yellow sections' level of the roads displaying width ranging between 20 and 23 m, the Rd 3 appears to exhibit roadside buildings erected along 25% of the road total length. At the level of the green sections of roads displaying width ranges of 21 and 23 m, the Rd 4 is discovered to display roadside constructed buildings prevailing along 40% of the road total length, while the crossings associated scores turns out to reach 67.

Concerning the Rd 2 and Rd 9, they appear to record a total score of 26, with red sections registering less than 15% of the road total length. With regard to the yellow sections, both roads display roadside building segments ranging between 20% and 45%. As regards the Rd 13 (2), Rd 1 and RR1, they turn out to register a total score of 20, wherein, the red sections cover 15% of the total road length for the Rd 13 (2), and 5% concerning the RR1.

Regarding the yellow sections of roads exhibiting width ranges between 20 and 23 m, the RR1 turns out to display roadside building segments exceeding 70% of the total length. As for the Rd 1, it displays roadside villas stretching along 45% of the entire road) at the left roadside level, while the yellow and green sections related crossings turn out to exceed 60.

With respect to the Rd 10 and RR 4, they appear to record a total score of 18, whereas the Rd 10 does not seem to involve any red sections. With regard to the yellow sections of roads displaying width ranges between 21 and 23 m, the Airport road turns out to involve buildings segments stretching along 40% of the total roadside length, while the RR 4 encloses only 6% of red sections.

In sum, the two roads that prove to be most suitably fit for accommodating the tramway installation turn out to be the Rd 13 (1) as well as the RR 2, which appear to record total scores inferior to 14. Indeed, the red sections perceived along the Rd 13 (1) appear to score just 1.4% of the total road length, while the RR 1 does not seem to display any red sections. Similarly, concerning the yellow and green sections, the number of crossings recorded scores turn out to vary between 10 and 46 for the Rd 13 (1) and between 2 and 27 regarding the RR 2.

Noteworthy, however, is that the most inconvenient roads, unfit for installing the tramway, are those displaying buildings segments stretching along most of the roadside, with red sections extending along more than 40% of the total road length, and crossings score figures exceeding seventy. More favorable for the installation are those roads displaying yellow sections and roadside buildings of a rate exceeding 20%. As for the most appropriate roads, they turn out to be exhibiting red sections and roadside buildings within a rate inferior to l6% and a crossings' score that does not exceed 46.

It is also important to note that regarding the most inappropriate roads, the existing widths need be necessarily extended, mainly at to the red sections levels, otherwise congestion would certainly be further aggravated. Consequently, some necessary, though often undesirable, solutions seem imposed, particularly expropriation, to help expand the available road lines status-quo, by gaining more land on a rights-of-way basis (Collet, 2009). It constitutes an extreme solution owing to the relatively high political costs it might well incur.

With respect to both of the yellow as well as the green sections, displaying width scores ranging between 20 and 23m, anarchic parking stands as a major issue. Hence, sharing the traffic space among the tramway, other modes of transport and pedestrians could well affect the tramway performance criteria (Fatteh et al, 2017). Indeed, commercial speed might well be influenced by the surrounding traffic, thereby, further increasing the risk of vehicle-train pile-up and congestion. Actually, for a system void of fully exclusive lanes, commercial speed would depend heavily on crossings with regard to surface networks (Fouchard, 2012).

Additionally, the most suitably selected roads should certainly help in boosting a public transit system that contributes in efficiently structuring and rehabilitating its environment. To this end, the light rail tramway system should be effectively designed in such a way as to meet such performance criteria as regularity, frequency, speed, comfort and accessibility (Tian et al., 2016). On the other hand, managing the priorities and optimizing the tramway traveling time is a lengthy task that requires the availability of special equipment, as well as a harmonious intervention, installation and coordination of controllers and light signals at each junction level (Odoni, 2016). However, the impact of effective infrastructure coupled with an efficient system management are essential conditions necessary for a highly effective and smooth traffic flow to take place, more specifically, exclusive lane, inter-station, regular frequencies, good management and elimination, or reduction, of junctions as minimally as possible.

6. Conclusion

The objective of a transit system project lies mainly in meeting the ridership demand, through the setting up an of an effective transport system, incorporating a fast, frequent, and comfortable road network (Munafo et al., 2012). The urban integration of the tramway system is defined according to a set of relevant criteria that need be fulfilled (Sharma, 2016), designed with the rolling-stock recommendations and communal rehabilitation planning provided technical data. Accordingly, the transport line layout and platform location (whether axial or lateral), along with the distribution of the public space different users must meet public expectations as much as possible (Labbouz, 2008), complying with the relevant technical and economic standards. The public transit does not constitute the exclusive user of public space, other users of this space must be accounted for determining the minimum roadway width requirements (Courtois and Dobruszkes, 2008). In this context, a thorough geometrical study, based on international standards applicable to tramway sites, would help provide a geometrical feasibility map for the insertion of the tramway network in Sfax. Accordingly, our study turns out primarily on a proper classification references, whereby, roads are specifically categorized in terms of suitability to accommodate a tramway site. For instance, the most appropriate lines fit for the tramway installation, namely, the Sidi Mansour and Airport roads. They appear that setting up a restructured public transport scheme would contribute significantly the economic development of the already existing districts, along with enhancing territorial rehabilitation.

In fact, heavy transport systems, and the relevant selection criteria, need be assessed at the level of the entire city and country context they are expected to develop (Collet, 2009). In this context, and on taking the example of the least convenient lines for the installation, the underground metro could still provide rather enhanced effective services in terms of frequency, speed and regularity (Fattah et al., 2017). It is worth highlighting, that this particular mode of transport in not without high implementation costs. Indeed, its cost would amount roughly to five times higher than the light rail. On the other hand, the infrastructure of a monorail (an elevated, single-rail guided mode of transport) turns out to be less space consuming. Moreover, the nuisance brought about by the monorail installation work would certainly be milder and less intense than that associated with a tramway installation, due mainly to the relatively quick installation of the piles.

Author contributions

Conceptualization: [H E] and [K H] ; Methodology: [K H]; Formal analysis and investigation: [H E] and [K H], Writing - original draft preparation: [H E] and [K H]; Writing - review and editing: [H E]; Funding acquisition: [H E] and [K H]; Resources: [H E] ; Supervision: [K H].

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