NEW SOLUTIONS TO REDUCE THE ENVIRONMENTAL IMPACT OF ROAD TRAffiC EMISSIONS, USING SUMO.

Ali GOUNNI
Laboratory Computer and Modeling, University, Fez, Morocco
Tél : 0641890046
Email: ali.gounni@yahoo.fr

Noureddine RAIS
Laboratory Computer and Modeling, University, Fez, Morocco
Tél:0661483201
Email: raisn@gmail.com

Mostafa AZZOUZI IDRISSI
Laboratory Computer and Modeling, University, Fez, Morocco
Tél:0661481281
Email: m_azzouzi@yahoo.fr

ABSTRACT

The impact of road traffic on the environment is a key factor in traffic management and the design of smart cities today. Alternative fuel technologies aim to reduce emissions and provide environmentally sustainable solutions. Thus, the potential of alternative fuel technologies needs to be taken into account in future environmental policy. This paper examines the possibility of reducing greenhouse gas emissions by using liquefied natural gas (LNG) as an alternative fuel technology for light-duty vehicles. The survey uses a scenario-based traffic simulation approach by applying a simulation of microscopic traffic emissions. We have considered two scenarios: optimistic, in the case of a total intervention of the State, which supposes 100% of LNG and 0% of conventional fuel (diesel and gasoline). Pessimistic in the absence of state intervention, assumes 0% LNG and 100% of conventional fuels. SUMO includes two emission assessment models. Both models implement different classes of vehicle emissions. The first model is based on HBEFA v2.1 (a continuous reformulation of the HBEFA v2.1 emissions database), the second is PHEMLIGHT, a derivation of the original PHEM emission model. The results presented in this article are generated by using PHEMLIGHT.

Keywords: Sumo Structure; Liquified Natural Gas (LNG); Greenhouse Gas Emissions; Passenger Car.

Gounni Ali, Rais Noureddine and Azzouzi Idrissi Mostafa.2019. NEW SOLUTIONS TO REDUCE THE ENVIRONMENTAL IMPACT OF ROAD TRAFFIC EMISSIONS, USING SUMO. *In Proceedings of NISS19, March 27–29, 2019, Rabat, Morocco © 2019 Association for Computing Machinery. ACM ISBN 978-1-4503-6645-8/19/03…$15.00 https://doi.org/10.1145/3320326.3320365*

1. INTRODUCTION

According to the World Bank, the transport sector causes nearly 30% of the total greenhouse gases emissions in Morocco [1]. And is therefore a major obstacle to compliance with environmental commitments cited by Morocco. In fact, measures have been taken to reduce the negative impact of transport but remain insufficient and very expensive. Morocco is committed to reduce 13% of its emissions (planned) by 2030 (according to the Minister Delegate in Charge of the Environment for the Kingdom of Morocco from 2013 - 2017). The financial support within “10 billion dollars” will be offered by the kingdom. It is ready to carry out an "additional reduction of 19%", estimated at 35 billion dollars, if the international community can support this goal. This would result in a 32% reduction by 2030.

Given this very high financial effort, the adoption of cheaper and more efficient alternative solutions is a possible and necessary strategy to improve the environmental performance of transport at a lower cost. Natural gas is the most appropriate alternative to conventional fuels because it is readily available and accessible and has a minimal negative impact on the environment [2]. In addition, the price difference between natural gas and conventional fuels has often been cited as the most important factor in encouraging users to switch to CNG (compressed natural gas) vehicles [3]. Natural gas can be used either in the liquid state, called LNG (liquefied natural gas), or in the compressed state, called CNG (compressed natural gas). The great advantage of LNG is that its combustion causes about 80% less nitrogen oxides (NO_x), about 20% less carbon dioxide and about 99% less particle (PM) and sulfur oxide (SO_x) emissions, compared to diesel [4].

The introduction of alternative fuels into the fleet of passenger cars has become a necessity to fight against global warming. Studies show that market introduction depends on the actions of many stakeholders, such as the automotive industry, oil companies and consumers. The process requires timely action and investment, while economic opportunities and risks are spread very unevenly. Decision-makers define framework conditions, although the influence of the magnitude and timing of subsidies, tax cuts and other stimulus measures are not yet well understood [5].

This paper examines the possibility of reducing greenhouse gas emissions by using liquefied natural gas (LNG) as an alternative fuel technology for light-duty vehicles. The survey uses a scenario-based on traffic simulation approach by applying a simulation of microscopic traffic emissions. The rest of this article is structured as follows: First, a general view of the SUMO simulation tool. Second, the generic steps taken in this study and the results are detailed for each step. Finally, the results are discussed and future work illustrated.

2. METHOD AND TOOLS

2.1. SUMO STRUCTURE

"Simulation of Urban Mobility (SUMO) is an open source, highly portable, microscopic and continuous road traffic simulation package designed to handle large road networks and allows to simulate how a given traffic demand which consists of single vehicles moves through a given road network. SUMO is licensed under the Eclipse Public License V2". [6]

Being open source, SUMO is ready to implement new behavioural models or to control the simulation remotely using various programming environments. It's a free tool into which own algorithms can be implemented and evaluated. These and other features make SUMO one of the most often used open source traffic simulations with a large and international user community.

SUMO is split into several features. Each of them has a certain purpose and must be run individually. This is something that makes SUMO different to other simulation packages.

Since 2001, with the first running version, SUMO has been used within a large number of projects done within the DLR. The main application was to implement and evaluate traffic management methods, such as new traffic light systems or new traffic guidance approaches. Additionally, SUMO was used for short-term (30min) traffic forecast during large events with many participants, and was used for evaluating traffic surveillance using GSM networks.

Since 2002, SUMO is in use at many institutions. It's also of immense importance for researchers as well as practitioners in the field of transportation.

The researches which cite or use SUMO come from all over the world, albeit European countries and the USA dominate. Research on vehicular communication is the major application topic to be found within the papers and, even if extrapolating the numbers, one should assume that it states at this position for the next time.

SUMO's possible areas of interest include (but are not limited to):

- **Intermodal Transport**: The conceptual center of intermodal traffic is the individual person. This person needs to undertake a series of trips where each may be taken with a different mode of transport such as personal car, public bus or walking.

- **Autonomous Driving**: It is a multi-agent setting where users do not have to drive at all. So, the host vehicle must apply sophisticated negotiation skills with other road users when overtaking, giving way, merging, taking left and right turns and while pushing ahead in unstructured urban roadways.

- **Logistics Simulation:** It's an interdisciplinary research field, covering aspects of operations research, mathematics, statistics, computer science, and engineering. Most of these disciplines consider to some extent questions of verification and validation of their applications, techniques, and models. It's implemented in sumo by containers and container stops.

- **Mobility Modelling:**

It is one of the important aspects in Vehicular Network. It can be commonly classified into the following categories: Macroscopic models, Mesoscopic models and Microscopic models.

- **Microscopic traffic simulation:** It is used to estimate the movement of vehicles on roads, in the case that available information is limited or a large amount of factors are involved, such as intersections with traffic lights and accidents.

- **Traffic Applications examples** (but not limited to):

    - Traffic safety applications are those that are primarily applied to decrease the probability of Traffic accidents and loss of life.

    - Traffic efficiency & management applications are focusing on improving the vehicle traffic flow, traffic coordination, and driver assistance.

    - Infotainment applications are, for instance, media downloading, instant messaging etc.

- **Traffic Management Solutions:** they are increasingly called for to address problems of transport and mobility. In particular, introducing and enforcing variable speed limits, installing local-express lanes and coordinated traffic lights, imposing differentiated road pricing or optimizing traffic signal timing.

- **Vehicular Communication:** The probably most popular application for the SUMO suite is modeling traffic within research on V2X (vehicle-to-vehicle and vehicle-to-infrastructure) communication.

- **Open Tools and Open Data:** The use of open tools (such as SUMO and Python) and open data for transport modeling in general has attracted considerable research interests in recent years.

- **E-Mobility:** since 2009 e-mobility has become very much in vogue. The central idea is that the electric car will contribute to sustainable transport development.

So far, most of the references or documentation available concern the use of sumo. The documentation of Structure is weak or non-existent, hence the need to carry out a basic study illustrating the static side and offering new users a general view of sumo(Figure1). “The development of SUMO started in the year 2000” [7], but the implementation started in 2001, with a first open source released in 2002.

After this date, SUMO has evolved into a full featured suite of traffic modelling utilities including a road network importer capable of reading different source formats, demand generation and routing utilities, which use a high variety of input sources (origin destination matrices, traffic counts, etc.). “The major part of the development is undertaken by the Institute of Transportation Systems at the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt, DLR)” [6]

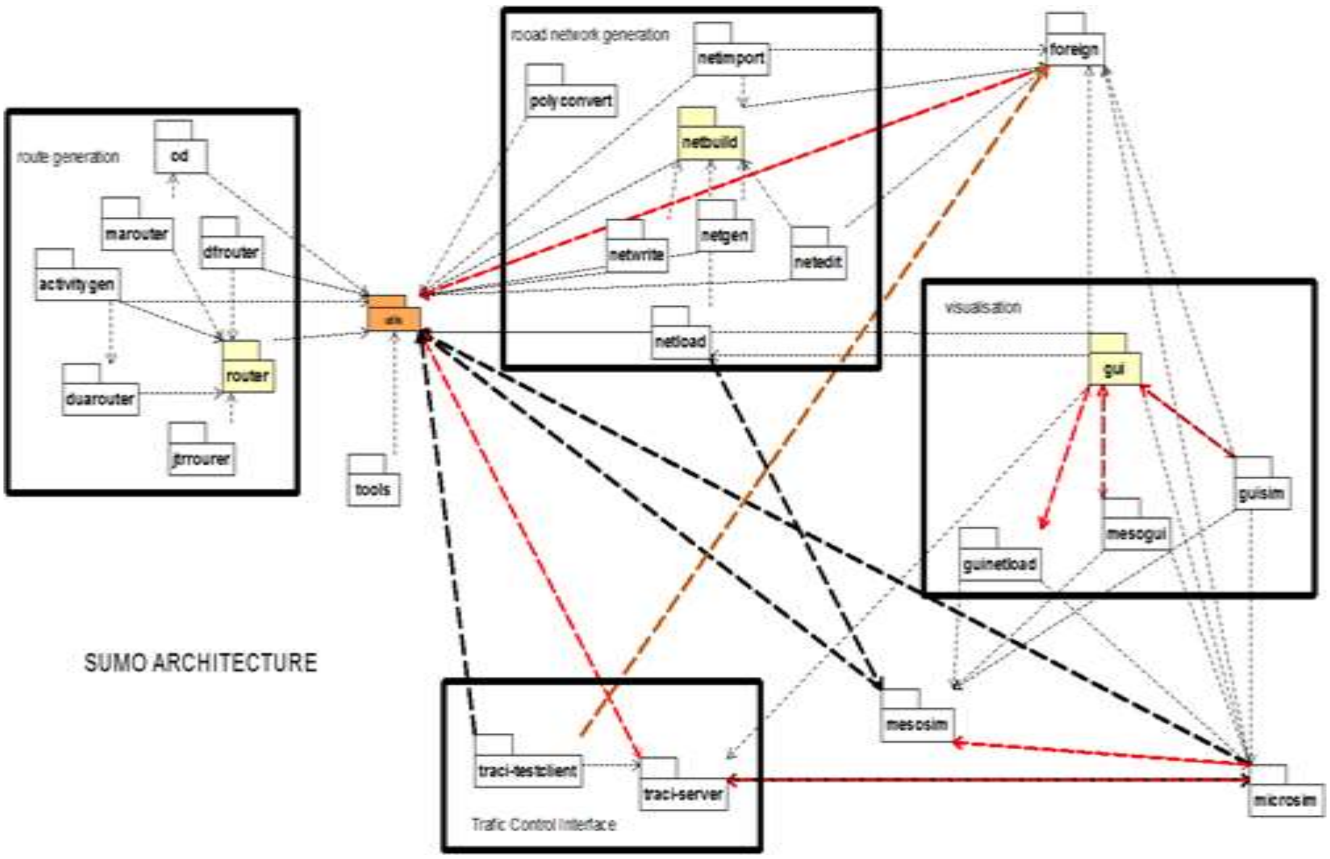

Figure 1 : The diagram shows the architectural components and the relationships between them.

2.2. PHEM (Passenger Car and Heavy Duty Emission Model):

PHEM (Passenger Car and Heavy Duty Emission Model) is an instantaneous vehicle emission model developed by the TU Graz since 1999. PHEM is based on an extensive European set of vehicle measurements and covers passenger cars, light duty vehicles and heavy duty vehicles from city buses up to 40 ton semi-trailers [8].

The chosen approach, presented in the following, uses a simplified model of PHEM named “PHEMLIGHT” that is directly included into SUMO’s simulation core. PHEMLIGHT integrates most emission classes for different categories of vehicles (light vehicles, heavy vehicles, motorcycles) and for different technologies (conventional fuel and alternative fuel), but only two classes of emission are included in the public version: passenger cars with gasoline engine (PC_G_EU4) and passenger cars with diesel engine (PC_D_EU4). Any other vehicle class must be approved by TU Graz [9].

3. STUDY APPROACH and configuration

3.1. Study approach

In 2009, and during COP15, MOROCCO launched a strategy to combat global warming; named PNRC (the National Plan for Combating Global Warming).This strategy is based on two axes:

- ✓ An adaptation strategy containing projects such as: green Morocco plan, AZUR plan, water strategy …
- ✓ A mitigation strategy includes projects such as: Renewable Energy Program, Building Energy Efficiency Program, Reforestation Master Plan (RDP) and Transportation.

The mitigation measures taken by the PNRC should reduce greenhouse gas emissions estimated at 53 million t-eq CO_2 / year, or 13% by 2030(Figure 2). They mainly concern the sectors of energy, transport, industry, waste, agriculture, forestry and construction.

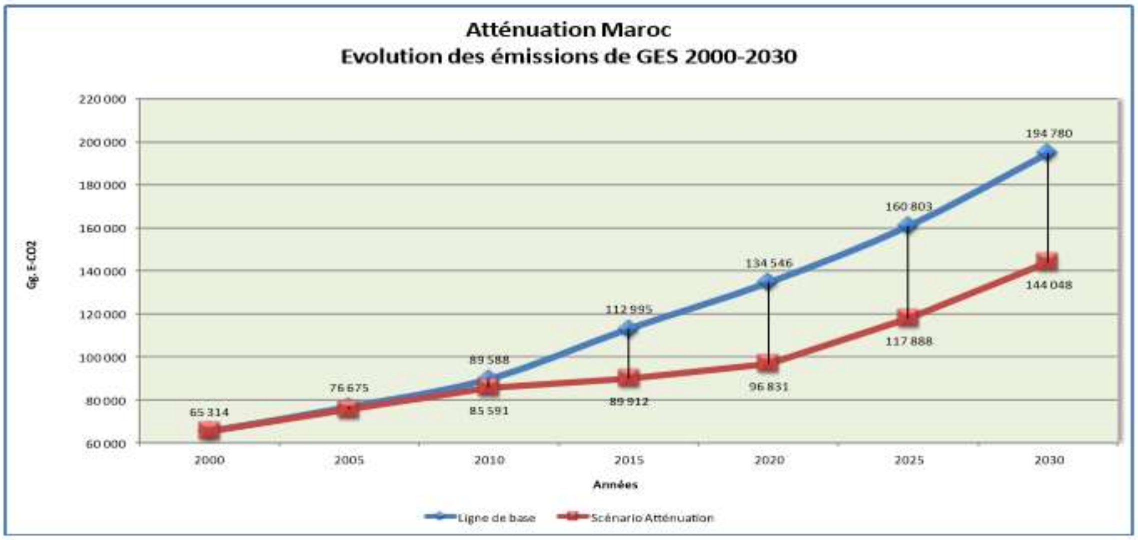

Figure 2 : evolution of emissions of greenhouse gases in Morocco between 2000 and 2030.

According to the World Bank, CO_2 emissions attributable to transport for MOROCCO in 2014 is about 30%, hence the importance of this sector to fight against global warming (Figure 3).

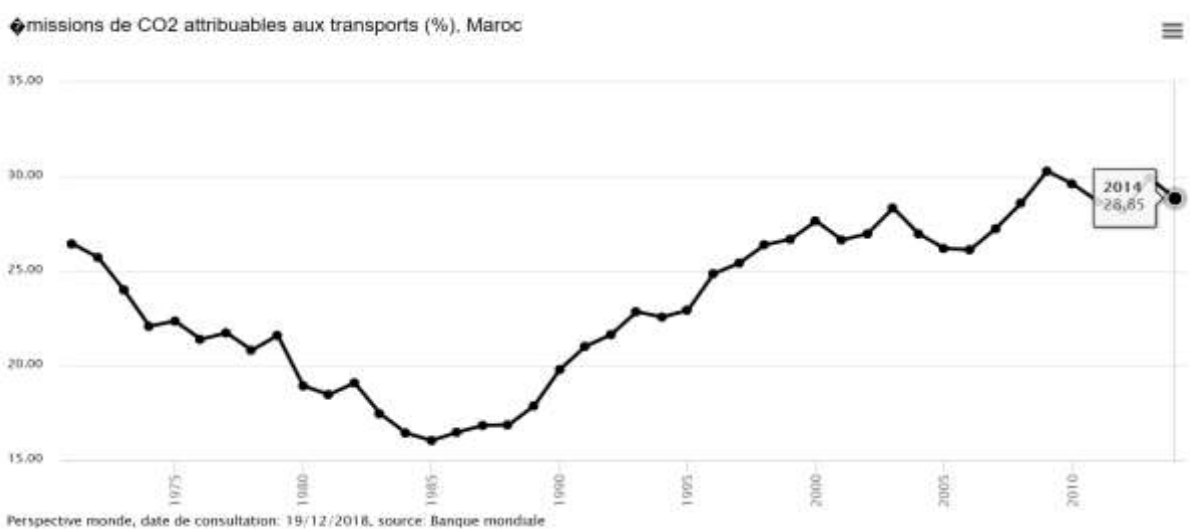

Figure 3 : Evolution of CO2 emissions related to transport according to the World Bank (%)

.

Today, MOROCCO has launched mitigation measures according to 3 levels:

- ✓ Modes of transport: Rabat-Salé tramway, Casablanca tramway, Tanger-Casablanca TGV and Fez-Oujda electrification.
- ✓ Transport management: Introduction of EURO standards on pollutant emissions from new vehicles, Reinforcement of technical control of vehicles in circulation by Technical Visit Centers, implementation of Urban and Interurban Travel Plans, ensuring coherence with plans communal facilities...
- ✓ Fuel used: Generalization in 2009 of the use of diesel 50 ppm and unleaded gasoline.

However all these measures remain insufficient, hence the need for a new less expensive and more efficient strategy: alternative fuel technology.

3.2. Traffic Model Development and Configuration

The traffic model is based on openStreetMap (OSM). OSM is a valuable source for real-world map data that provides a digital map. However, data in OSM is often not completely ready for traffic simulation. For a good simulation, the map must generally be improved. The defined scenarios concern exclusively routes in central fez. For this reason, the map for fez was imported into SUMO to simulate the simulations of concrete scenarios [10]. While the OSM format is a widely used format for describing a map, SUMO has its own format for this: the SUMO network format. Therefore, one must first convert the OSM file into an SUMO network file (Figure 4), using the SUMO NETCONVERT module. NETCONVERT extracts the simulation-related information from the OSM file and puts it out in the SUMO network file. During this process, it adds some assumptions about the traffic lights and the connections between lanes at junctions [10].

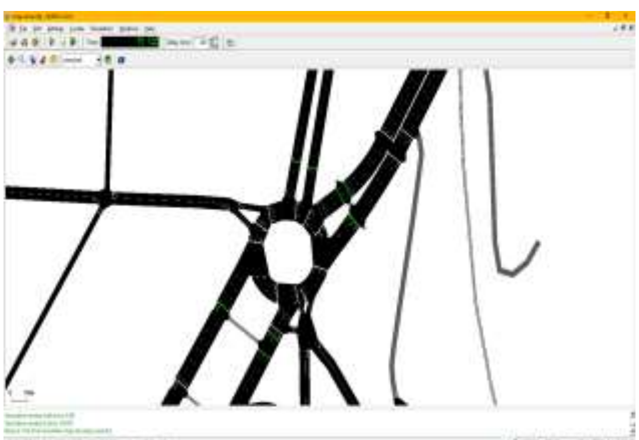

Figure 4 : Network implemented in the traffic simulation model

The tool NETCONVERT generates the network that can be read by SUMO, but does not generate vehicles traffic. This is made by the tool DUAROUTER (by specifying only the source and destination edges, and optionally, some intermediate edges). the tool DUAROUTER receives as input the file "trip.xml" (Figure 5) and the network file "net.xml" and generates as output the file "rou.xml"(Figure 6). during this process DUAROUTER searches for the shortest path between source and target edges using a particular routing algorithm (by default "dijkstra"). As SUMO is a microscopic traffic simulator, each vehicle follows its own path (list of edges). The traffic demand (mobility of all vehicles) is written into a routes file (.rou.xml). The routes file contains several physical parameters (e.g. color, length, maximum speed, acceleration, deceleration, etc.), the model used for changing lanes, the model used for the car following, the emission class, etc.

```
<trips>
<trip to="145129815#0" from="136901456#19"
depart="10"/>
</trips>
```

Figure 5 : Trip file

```
<routes>
   <vType
            id="type1"
            length="5"
            maxSpeed="70"
            carFollowModel="Krauss"
            accel="2.6"
            decel="4.5"
            sigma="0.5"
            emissionClass = "PC_G_EU4"
      />
</routes>
```

Figure 6 : Route file

4. RESULTS

The introduction of alternative fuels on the market does not depend solely on the state, but generally on the actions of many stakeholders such as the automotive industry, fuel distribution companies and consumers [5]. For this reason, we have considered two scenarios: optimistic, in the case of the total intervention of the state and it assumes 100% of LNG and 0% of diesel and gasoline. Pessimistic in case of the absence of the state intervention and it assumes 0% of LNG and 100% of diesel and gasoline. In both scenarios, the 2030 date was chosen since it is the date determined by the state to reduce the percentage of greenhouse gas emissions by 13%. And in each scenario we generate results for a vehicle and for n vehicles. n is a positive integer means the number of vehicles in 2030 in the selected geographical area. The two scenarios have the same duration "25.50 second", and the same distance traveled "139 meters", however The XML output data generated includes different amounts of the standard CO_2, NO_x and PM_x emissions in [g / km / h] by vehicle type :

First scenario 2030: 0% de LNG

- ✓ One vehicle:

Table 1 : First scenario (one vehicle)

	CO_2	PM_x	NO_x
PC_D_EUR4	66201.01	7.24	178.12
PC_G_EUR4	69642.26	0.32	16.15

- ✓ n vehicles :

Table 2 : First scenario (n vehicles)

	CO_2	PM_x	NO_x
PC_D_EUR4	66201.01n	7.24n	178.12n
PC_G_EUR4	69642.26n	0.32n	16.15n

From this table, we observe that CO_2 emissions remain significant and almost the same for gasoline or for diesel, which shows the poor performance of the measures taken by the Moroccan authorities in terms of transport by limiting these measures to the widespread use of 50 ppm diesel and unleaded gasoline, hence the need to think differently and look for less expensive and more efficient solutions.

Second scenario 2030 : 100% de LNG

- ✓ One vehicle
- Quantity of CO_2: 66201.01-20% = 52960.81
- Quantity of PM_x: 7.24-99% = 0.0724
- Quantity of NO_x: 178.12-80% = 35.624

Table 3 : second scenario (one vehicle)

	CO_2	PM_x	NO_x
PC_D_EUR4	66201.01	7.24	178.12
LNG	52960.81	0.0724	35.624

- ✓ n vehicles :

Table 4 : second scenario (n vehicles)

	CO_2	PM_x	NO_x
PC_D_EUR4	66201.01n	7.24n	178.12n
LNG	52960.81n	0.0724n	35.624n

5. DISCUSSION

Liquefied natural gas, LNG, is known to be an innovative alternative fuel technology. In Europe, studies show that the introduction of LNG becomes a real interest. However, the potential pioneer users have several requirements such as profitability, availability of infrastructure and harmonization of rules [11]. In Morocco, studies in this field are weak or non-existent. So this study can be considered as one of the first studies dealing with this subject in the Kingdom. Even if the European requirements (profitability, availability of infrastructure, harmonization of rules), remain almost identical for Morocco, the main advantage lies in the existence of a political will to fight against GHG. In this study, the emissions (CO_2, NO_x, PM_x) were chosen because these emissions, cause cancer (PM_x), are responsible for the increase of the tropospheric ozone layer and the formation of smog (NO_x) or are greenhouse gases (CO_2) [12]. Generally, in the second scenario of 2030, the use of alternative fuels has a significant impact on total NO_x and PM_x emissions. The results of the simulation show that the increase in the quantity of LNG vehicles proportionately decreases the emissions produced. Knowing have not taken into account other criteria, such as (driving behavior, fleet evolution, etc.), which may affect the proportional relationship between the increase in the quantity of vehicles and the amount of emissions produced. This can be considered one of the limitations of this study. Another known limitation is the use of the LDV only and not to take into account the HDV because of the public version of the emission model used, PHEMLIGHT, integrated in SUMO and which implements only two classes of emission (PC_G_EU4) and (PC_D_EU4). For this reason, future work could integrate HDV.

6. CONCLUSION

The purpose of this paper was to examine the possibility of reducing greenhouse gas emissions by using liquefied natural gas (LNG) as an alternative fuel technology for light-duty vehicles. The survey uses a scenario-based traffic simulation approach by applying a simulation of microscopic traffic emissions. But the main objective was to expose the Moroccan authorities to a new, cheaper and more effective strategy to reduce transport-related greenhouse gas emissions and to subsequently convince them to support the implementation of LNG. To our knowledge, this is the first study on the effects of LNG in Morocco. This study showed that the amount of CO_2, NO_x and PM_x emissions decreases with the increase in the number of vehicles running on LNG. The results are useful to the extent that particulate reduction is a primary goal of the National Plan to Combat Global Warming (PNRC) and one of Morocco's commitments to COP22. Future work could include the study of other roads and points of interest for the management of the network. In addition, this work should focus on other calibrations of the traffic simulation model, especially for heavy vehicles.

7. REFERENCES

[1] u. d. sherbrooke, «Perspective monde,» université de sherbrooke, [En ligne]. Available: http://perspective.usherbrooke.ca/bilan/servlet/BMTendanceStatPays?langue=fr&codePays=MAR&codeStat=EN.ATM.CO2E.KT&codeStat2=x. [Accès le 22 12 2018].

[2] S. Yeh, «An empirical analysis on the adoption of alternative fuel vehicles: the case of natural gas vehicles,» *Energy Policy 35,* p. 5865–5875, 27 August 2007.

[3] L. Dondero et J. Goldemberg, «Environmental implications of converting light gas vehicles: the Brazilian experience,» *Energy Policy 33,* pp. 1703-1708, 2005.

[4] S. Kumar, H.-T. Kwon, K.-H. Choi, W. Lim, J. H. Cho, K. Tak et I. Moon, «LNG: An eco-friendly cryogenic fuel for sustainable development,» vol. 88, n° %112, p. 4264 – 4273, 2011.

[5] A. Janssen, S. F. Lienin, F. Gassmann et A. Wokaun, «Model aided policy development for the market penetration of natural gas vehicles in Switzerland,» *Transportation Research Part A,* vol. 40, n° %14, p. 316–333, 2006.

[6] D. K. a. J. E. a. M. B. a. L. Bieker, «Recent Development and Applications of {SUMO - Simulation of Urban MObility},» *International Journal On Advances in Systems and Measurements,* vol. 5, n° %13, 2012.

[7] Dkrajzew, «Sumo at a Glance,» DLR, [En ligne]. Available: http://sumo.dlr.de/wiki/Sumo_at_a_Glance. [Accès le 14 12 2017].

[8] Behrisch, «Information for "Models/Emissions/PHEMlight",» DLR, 2017. [En ligne]. Available: http://sumo.dlr.de/wiki/Models/Emissions/PHEMlight. [Accès le 2018].

[9] S. Hausberger et D. Krajzewicz, «Deliverable 4.2 - Extended Simulation Tool PHEM coupled to SUMO with User Guide,» 2014.

[10] Namdre, «Tutorials/Import from OpenStreetMap,» DLR, 2018. [En ligne]. Available: http://sumo.dlr.de/wiki/Tutorials/Import_from_OpenStreetMap. [Accès le 2018].

[11] P. Sarah, A. Gerald, S. Laura et S. Oliver, «Facilitating the implementation of LNG as an alternative fuel technology in landlocked Europe: A study from Austria,» *Research in Transportation Business & Management,* vol. 18, pp. 77-84, March 2016.

[12] K. Daniel, B. Michael, W. Peter, H. Stefan et K. Mario, «Second Generation of Pollutant Emission Models for SUMO,» chez *2nd SUMO Conference 2014,* Berlin, 2014.