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CO₂ EMISSION'S STUDY OF THE HYDROCARBON SUPPLY CHAIN AIMING FOR RESOURCES POOLING STRATEGY

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ABSTRACT: *Transport is an activity at the heart of logistics, it plays an essential role in economic and social development. Its contribution to the gross domestic product, to the employment and its share in energy consumption. However, the road transport, especially for petroleum industry sector is not without consequences on social welfare, the depletion of resources, pollution to the eco-system, etc.*

In this paper, We present the current supply chain petroleum products model in Morocco (diesel gasoil and gasoline products as a case study), and we propose the "transport means pooling" as a new organization strategies for sustainable logistics using a simulation approach (ARENA software) based on a real data during 78 months to estimate the parameters variation needed to calculate the CO₂ emissions in order to improve logistics chains performance in sustainable development context.

KEYWORDS: *Logistics chain, simulation, resources pooling, sustainable development, environment, CO₂ emissions.*

1 INTRODUCTION

Transport has become a key of success for most companies facing structural changes in the supply chain, its importance is assessed by a consumer market characterized by a strong demand for raw, semi-finished and finished products; a very high level of customer requirements and strong competition between all the players along the logistics chain.

A situation forces the different players in the supply chain to respond to different market demands and to develop their activities in the face of many constraints: social, economic, environmental, etc.

In terms of sustainable development (SD), transport plays an important economic and social role. However, its negative impact on the environment and the degree of safety make it necessary to reconfigure the system.

The laws and regulations currently in force in Morocco remain insufficient to reduce the transport impact, particularly in terms of regulating the flow of goods.

Therefore, transport efficiency becomes an important indicator for improving logistics, and a new organization of the transport sector will be a necessity to be provided by companies in the current limited situation, in order to ensure a more efficient transport system and to reduce the

greenhouse gas emissions (GHG) for a sustainable development. In this context our paper focuses on Moroccan hydrocarbon supply chains and propose the pooling of transport resources as a possible solution between the two largest Moroccan petroleum importers, through a simulation approach, an analysis of the current supply chain and an improvement of performance indicators such as loading rate, resource availability, average stock and the rate of greenhouse gas emissions, especially CO₂ emission.

2 STUDY CONTEXT

After the shutdown of the only Moroccan refinery in August 2015, the Moroccan energy security is absolutely depended on imports for all fossil fuels, which account for almost 90% of total primary energy supply (TPES) and Oil constituted 62% of TPES in 2017, followed by coal (22%) and natural gas (5%). The country's energy import bill rose to MAD 69.5 billion in 2017 (USD 7.3 billion, EUR 6.3 billion). (International Energy Agency IEA report, Morocco 2019)

In 2016, the total Moroccan's storage capacity was around 1.8 million m³, which its concentrated about 65% in northern Morocco between Mohammedia and Mohammedia (excluding the storage capacity of SAMIR). (Moroccan Agency for Development of Logistics AMDL, 2016).

Furthermore, in the same year, the consumption of the petroleum products achieved 13 million tons, with 3% annual increase rate from 2010 to 2016 and it continued to grow, as shown Figure 1.

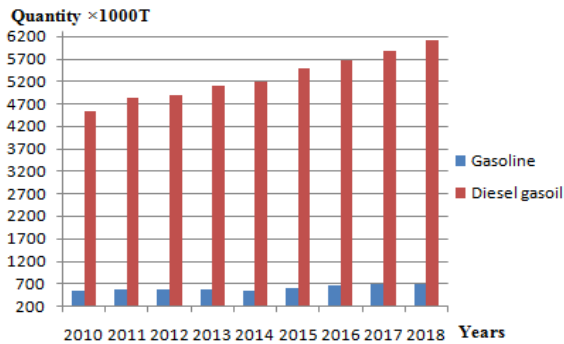


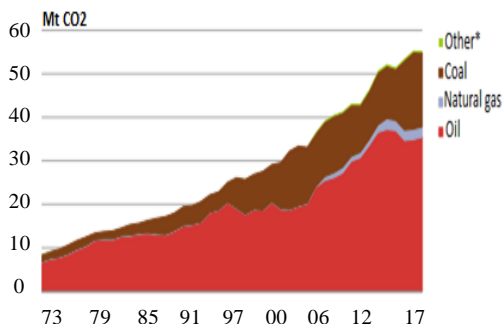
Figure 1: Consumption evolution of petroleum products (Report of the Moroccan parliamentary committee on the hydrocarbons sector, 2018)

Moreover, Morocco's energy security related concerning the global supply chain risks is increasing, and its strategic stock is less than the legal requirements for all products.

In addition, the importation and distribution process of petroleum products (gasoline, diesel gasoil, fuel,...) are dominated by road transport for almost all the flows between the storage facilities and the 2477 petrol stations in the country. (Business Economics, 2018)

This flows tension state generates infrastructures saturation, road networks congestion, transport variation cost according to the barrel price in world market also it creates significant CO₂ emissions.

In 2017, oil was responsible for 64% of total CO₂ emissions and the transport sector created 30% of the global emissions from 2006 to 2017 with an increasing about 63% which runs counter the country's overall strategy for reducing the Greenhouse Gas emissions (GHG). Figure 2 & 3



* Other includes biomass and waste.

Figure 2: Moroccan emissions by fuel, 1973-2017 (International Energy Agency IEA report, CO₂ Emission from Fuel Combustion, Morocco 2018)

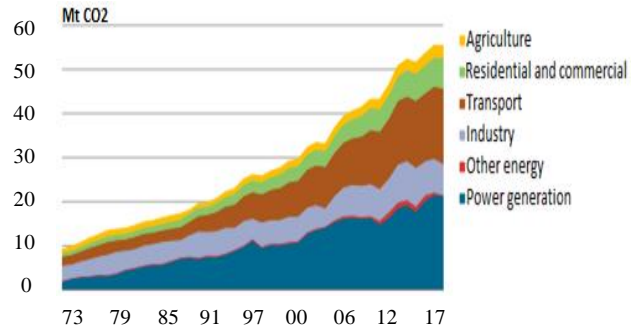


Figure 3: Moroccan emissions by sector, 1973-2017 (International Energy Agency IEA report, CO₂ Emissions from Fuel Combustion, Morocco 2018)

Indeed, the government is worked to increase oil products storage capacities also for its efficient monitoring mechanism of all oil products supplies and it has defined an integrated national development strategy of logistics sector in the horizon 2030. One of the strategy objectives is to reduce of CO₂ emissions by 35% of the road goods transport. (Moroccan Agency for Development of Logistics AMDL, 2016)

The transport resources pooling is therefore an interesting way to explore, particularly in the case of transporting petroleum products. Before proceeding to the complete Moroccan hydrocarbons logistics chain diagnosis, we will present a summary of main works dealing with the transport pooling.

3 LITERATURE REVIEW

According to authors (Pan et al., 2013), Logistic pooling corresponds to partners logistics network co-design (suppliers, customers, carriers, etc.) with a common objective, to share logistic networks (warehouses, platforms, means of transport, etc.) and to provide management needed data. In seeking common goal and close to facilities, pooling is appropriate for logistic chains operating in the same sectors.

Pooling implies a flows massification; that consists in concentrating certain flows on the same site in order to optimize the supply and distribution circuits. (OITC, 2005)

Logistics chain pooling resources issue has been treated in several studies. The majority of works suggest that pooling resources is a solution of various logistics problems in order to improve logistics chain performance.

The next table provides a work summary according to the sector activity and the pooling purpose, the authors highlight in their work the benefits expected from resources pooling in terms of economic, environmental and political performance.

Works	Sectors	Objectives	Results
How fairness perceptions, embeddedness, and knowledge sharing drive green innovation in sustainable supply chains: an equity theory and network perspective to achieve sustainable development goals (Zhou et al., 2020)	Green innovation	Examination of embeddedness, knowledge sharing, and green innovation in the sustainable supply chain.	-Embeddedness and knowledge sharing have a partial impact on green innovation in the sustainable supply chain; -Company size as a control variable is a positive effect on green innovation.
Throughput optimization in a coal export system with multiple terminals and shared resources (Rocha et al., 2019)	Exportation	-Optimization of the Hunter Valley coal export system in Newcastle, Australia with sharing a rail network on their inbound/outbound operations; -Maximizing of flow at a single coal terminal with sharing resources simultaneously.	The solutions are on average 17% better than those obtained with the current method.
Information Sharing in Logistics Firms: An Exploratory Study of the Vietnamese Logistics Sector (Pham et al., 2019)	Logistics firm	-Examination the role of information logistics and methods shared with the firms and their partners; -Influencing factors of the sharing practice on supply chain logistics.	Influencing factors practices are: • Technical capability; • Security risks; • Organization rules and policies; • Mutual trust.
Benefit analysis of shared depot resources for multi-depot vehicle routing problem with fuel consumption (Li et al., 2018)	Transport/ Storage	Quantifying the benefit of shared depot resources.	The benefit of shared depot resources depends on instance characteristics (depot–customer geographic distribution, maximum route distance, and number of depots).
A multi-agent system for sharing distributed manufacturing resources (Li et al., 2018)	Distribution	Proposition a multi-agent system based approach to promote competition and cooperation among multi-agents and to achieve global optimal scheduling.	Enterprise alliance multi-agent system (EA-MAS) which integrates a sharing resource information, provides shared scheduling scheme for distributed manufacturing with a good performance.
Green supply chain game model and analysis under revenue-sharing contract (Song et al., 2017)	Green supply chain	Quantitative analysis of contact impact on decision variables and supply chain performance.	Manufacturer and retailer get an important profit by using a sharing contract.
Allocation of Transportation Cost & CO ₂ Emission in Pooled Supply Chains Using Cooperative Game Theory (Xu et al., 2012)	Transport	Implementation of the horizontal supply chain pooling for reducing transportation cost and CO ₂ emission.	Pooling scheme reduced the transportation cost and the carbon tax (cost-reduction rate of 25.98%).

Table 1: Published works on the pooling of resources in different sectors

In general, the hydrocarbon's transport in Morocco under land and sea routes constitutes nearly 14% of the global costs of the logistics chain, with a fleet of more than 1200 tanker trucks rolling over the national territory. In 2014, the distance traveled by all the tankers of the same company from Mohammedia to all the warehouses (Casablanca, El Jadida, Jorf lasfar, Larache, Mdiq, Tangier, Marrakech, Nador and Meknes) was estimated at 3 813 000 km, with an empty transport estimated at 50% over the whole of this distance, and a total quantity

of diesel and unleaded lead transported on the order of 352 000 tons. (SAMIR, 2019)

In view of these distances traveled, and these empty tours, naturally raises the question of the transport resources' pooling for these main importers. To what extent would the pooling of distribution means (trucks), allow a reduction of CO₂ emissions? Before answering this question in the simulation part, we present below the methodologies for calculating CO₂ emissions.

4 METHODOLOGY FOR CALCULATING CO₂ EMISSIONS

The quantity of CO₂ emitted by trucks comes from the combustion of fuels producing the energy needed to transport goods. These emissions have a direct relationship with the quantities transported and the distances traveled.

Several references are available in the literature, using different methodologies and units for the calculation of gas emissions, making comparisons difficult of all the results produced. For this purpose, three units are widely used for the measurement of Greenhouse Gases (GHG) or CO₂ alone: (Pan, S., 2010)

- Carbon equivalent (kg eq C)
- CO₂ equivalent (kg CO₂ eq)
- Emission of CO₂ alone (kg CO₂).

In this article, we will present all results only in CO₂ emission; it is the amount of CO₂ emitted directly.

The global fleet studied in this paper composed of a Heavy Duty Vehicle HDV tanker truck for transporting petroleum products, which its capacity limited on 32-40 tons.

The project report of Methodologies for estimating air pollutant emissions from transport (MEET) defines the global pollutant emissions emitted of a vehicle in circulation as the sum of emissions when the vehicle is warm after the start (E_{hot}); emissions when starting the vehicle ($E_{start-up}$) and emissions due to fuel evaporation ($E_{evaporation}$). The function is of the form: (Hickman et al., 1999)

$$E_{total} = E_{hot} + E_{start-up} + E_{evaporation} \quad (1)$$

According to The deliverable report of MEET (Hickman et al., 1999), CO₂ emission is not concerned by this emission type $E_{evaporation}$. In our study, transport is always over a long distance (365km), which allows us to neglect the vehicle's starting emissions that only exist when the engine is cold.

$$E_{total} = E_{hot} \quad (2)$$

Therefore, we can calculate the rate of emission for an unloaded vehicle, on a road with a 0% gradient by the following function in form: (Hickman et al., 1999)

$$E_{hot} = K + av + bv^2 + cv^3 + \frac{d}{v} + \frac{e}{v^2} + \frac{f}{v^3} \quad (3)$$

Where: ε is the rate of emission (g/km) for an unloaded vehicle on a road with a 0% gradient; K is a constant; a-f are coefficients; v is the mean velocity of the vehicle (km/h).

According to the same report, vehicle load and road gradient both are two correction factors the most important proposed to calculate the total emissions emitted by a vehicle.

4.1 Gradient correction factor :

The gradient factor can be calculated as a polynomial function in the following: (Hickman et al., 1999)

$$as = A6.v^6 + A5.v^5 + A4.v^4 + A3.v^3 + A2.v^2 + A1.v^1 + A0 \quad (4)$$

Where: as is the correction factor ; v is the mean speed in km/h; A0-A6 are constants for each pollutant, vehicle and gradient class.

Furthermore, we can calculate the emission factor due to gradient road factor as the following:(Hickman et al., 1999)

$$E_{Chot} = as \times E_{hot} \quad (5)$$

where: E_{Chot} is the corrected emission by the gradient factor of the CO₂ pollutant (g/km); E_{hot} is the emission factor (g/km) with 0% gradient.

4.2 Vehicle loading factor:

Scientifically, a big mass requires a great energy during a trip to move it, in the next function we calculate the emission factor for a vehicle in loading state: (Hickman et al., 1999)

$$\varepsilon = E_{hot} \times \Phi(\gamma, v) \quad (6)$$

Where: ε is the emission factor when loaded in g/km; E_{hot} is the emission factor when unloaded (g/km); $\Phi(\gamma, v)$ is the load correction factor function; γ is the gradient (%); v is the mean velocity of the vehicle (km/h).

Load correction factor functions $\Phi(\gamma, v)$ are of the form: (Hickman et al., 1999)

$$\Phi(\gamma, v) = k + n\gamma + p\gamma^2 + q\gamma^3 + rv + sv^2 + tv^3 + u/v \quad (7)$$

Where: k is a constant; n-u are coefficients.

According to the above factors, which are the vehicle load and road gradient, the total emission can be presented in following function form: $E_{g/km} = E_{hot} \times as \times \Phi(\gamma, v)$ (8)

Moreover, we calculate the CO₂ emission in two levels: Firstly, we consider the quantity emitted is totally dependent on the vehicle loading rate, the distance traveled and the truck average speed. The following simplified formula allows us to calculate the CO₂ emission in function only to the loading rate by ignoring the gradient factor, so the formula (8) will be by integrating the equations (4) and (7) as following: (Pan, S., 2010)

$$\varepsilon = E_{hot} \times \Phi(\gamma, v) \quad (9)$$

$$\varepsilon = (1576 - 17,6v + 0,00117v^3 + 36067/v^2) \times [1 + \alpha(0,43 - 0,916/v)] \quad (10)$$

$$\varepsilon = 0,417\alpha + 0,753 \quad (11)$$

Where: α is the rate loading of truck; v is the mean velocity of the vehicle in km/h. With: $\alpha=1$ for a full load regime and $\alpha=0$ for an empty load regime. All coefficients and constants for the calculation of the gradient correction factor and

loading vehicle factor are presented in tables A27, A40 and A46 on the project report MEET. (Hickman et al., 1999)

Secondly, we calculate the CO₂ emission by adding the road gradient as a parameter for analyzing the influence of this last on the total quantity emitted by the fleet used in our study. (Equation 8)

5 SIMULATION

We build a simulation model using the software Arena simulation to assess gas emissions emitted by a fleet of tanker trucks during transportation of petroleum products. We start our simulation model by creating an entity for company A, for a regular period of a demand, then we assign the declared entity with its mathematical function presented the company needs.

The simulation is done on two possible cases:

Case 1: The loading carries out with the regional stock using the bloc "Decide", if the demand validates the following condition:

$$\text{Tank capacity(Tangier)} - \text{Demand} > 0.5 \times \text{Tank capacity(Tangier)}$$

So the loading will do successfully and the process will be finished by the "Dispose" block.

Case 2: The demand is treated by a national storage (Mohammedia) by creating a "process" block. After the trucks are loading, and they returned to Tangier city, we create a "Record" block to calculate the number of trucks used in this operation, also the quantity of CO₂ emitted during the transportation process.

The objective of our simulation will be to obtain the distance traveled by the carriers and their load factors in order to measure the CO₂ emission for different fuel distribution companies. In this part, we propose studying the hydrocarbon transport's ecological impact. For this reason, we will extract from the simulation the total distance traveled by all the means of transport in order to measure the CO₂ emission. To measure this distance, we will have as input data for our model:

- The demand of different stations;
- The capacity of each carrier;
- The distance to be traveled between the different places of interest and The means of transport used.

5.1 Modeling the hydrocarbon transport process

The hydrocarbons' import is mainly from the various ports of the country and the supply is based on need. The provisioning model is represented in the following diagram:



Figure 4: Supply model

The condition on order initiation will be dependent on the stock level of the company's tanks.

5.2 Modeling the distribution process

From the demand forecast, we can generate the different CO₂ emission from the different distances that will be traveled to satisfy the needs of the company's customers. The hydrocarbon distribution model is as follows:

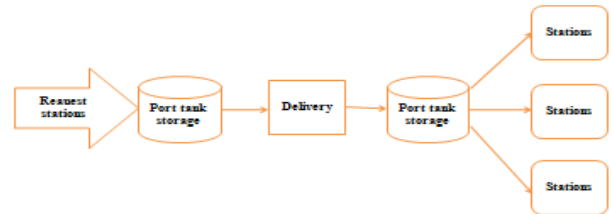


Figure 5: Fuel distribution models

The generated demand will be based on previous requests for different regions of the country for each company.

6 RESULTS AND DISCUSSIONS

The results presented on the following table showed a filling rate α varying around the 0,5 which is consistent with empty trucks returns. However, the two transporters' total emission factor E_{hot} with zero road gradient exceeded 49 million kg and there filling rates approaching 50%.

Consequently, an increase of the filling rate would reduce the total distance traveled, so reducing the CO₂ emissions. Furthermore, if the road gradient factor is taken into account, the simulation results show that the total corrected emission $E_{C_{hot}}$ is higher about 41% than the total emission E_{hot} with 0% road gradient.

Input parameters	Importer A	Importer T
Tank capacity (ton×10 ³)	71	34
Fleet	200	67
Distance (km)	365	
Average velocity (km/h)	70	
Slope (%)	0,52	
Emission rate ϵ (kg/km) (Unloaded vehicle,0% gradient)	0,7527	
Gradient correction factor α	2,1980	
Load correction factor Φ	1,4193	
Emission factor E_{hot} (kg/km) (0% road gradient)	0,9613	0,9610
Corrected emission $E_{C_{hot}}$ (kg/km) (gradient factor)	1,3556	1,3556
Emission factor ϵ_l (kg/km) (Loaded vehicle)	1,0683	

Table 2: Simulation inputs (from January 2013 to May 2019)

Output parameters	Importer A	Importer T
Average stock (ton)	448	212
Filling rate α	0,4995	0,4989
Total E_{hot} (kg/km)	33 062 202	16 020 139
Total $E_{c_{hot}}$ (kg/km)	46 623 449	22 598 231
Total ε_l (kg/km)	36 742 277	17 808 860

Table 3: Simulation outputs

7 CONCLUSION

The modeling approach discussed in the paper for hydrocarbons logistics chain in Morocco to allow doing simulations regarding to the means of transport's organization.

The simulation allowed us to estimate the parameters variation needed to calculate the CO₂ emissions, which are the total distance traveled, the filling rate α and the road gradient. Moreover, the road gradient factor represents the one of the main parameters to calculate the CO₂ emissions. Moreover, the simulation results show that the total corrected emission $E_{c_{hot}}$ is higher about 41% than the total emission E_{hot} with zero road gradient.

In perspective, pooling transport resources between two or more operators could be considered as an approach to increase filling rates, so reducing the environmental impact. Therefore, the next work will propose a mathematical model of petroleum supply chain to minimize the CO₂ emission generated by the global fleet.

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