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Energy Conservation Measures in Heavy Trucks Freight Transport

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Abstract

Since the independence of South Sudan, Sudan lost 75% of its oil reserves, this led to major fuel shortages country wide, the fuel shortage raised the fuel prices and the overall transport prices. Scarcity led to black market trade of fuel specially in states away from the Capital City (Khartoum).

Managing the available stock comes first before increasing the supply amount in order to solve the problem, one of the major fuel consumers to be managed is the transport sector specially the long haulage freight transport. Moving freight in Sudan is constrained by inadequate infrastructure and high costs. This paper covers specifically the long haulage freight transport between Khartoum State and Western side of the country (Darfur Region), Contributing to manage fuel consumption for trucks, taking into account trucks types used, roads, environmental impacts and mitigation measures applicable to save fuel .

The results showed that the primary reason for the excessive fuel consumption is the usage of the rigid trucks (lorries) for transport specially the Hino700 series, this truck type, overload and absence of weight stations and control policies contributed significantly to deterioration of roads and transport efficiency decreasing.

First step towards the solution would be in upgrading roads infrastructure assuring high quality along with enforced weight regulations and weight stations to protect roads from damages. High quality roads shall ease the usage of different truck types with different configurations. Then stablish a policy to force replacement of the low efficiency lorry truck types with high quality tractor semi-trailer combinations.

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1. Introduction

This paper covers "demand-side management" or DSM, as applied to energy efficiency measures that modify or reduce end-user's energy demand. This has traditionally been applied to electricity loads, but is also used for changes that can be made to demands for all types of energy. The benefits for the energy user are reduced energy costs for a given output. For the energy provider, the benefit is a better use of its supply capacity.

Long distance freight transport plays today a central role for any Country economy and its plans for growth. Indeed, long-distance road transport system is an irreplaceable cornerstone of Sudan mobility and transportation.

It's clear that Sudan has major infrastructure problems and shortage in energy supply, energy such as electricity, cooking gas and mostly fuels (Benzene, Diesel). Looking ahead, Sudan's most pressing infrastructure challenges lie in the water and transport sectors. The core of the problem could be traced back to June 2011 when South Sudan become an independent country, the separation costs Sudan 75% of its oil reserve to South Sudan [1].

One of the causes of deficit in fuel is its competitiveness. Gasoil is used by power generation, transportation, and agriculture sectors. Qarri Power station uses 9 Tons of Diesel per hour to produce 30 MW of power [6]. 9 tons of diesel is equivalent to 12,474 Liters, this is enough fuel to drive a 30 tons of freight truck almost 23 trips between Khartoum and Nyala (assume standard fuel consumption)

As energy conservation measure fuel shift of gasoil is recommended for power generation and agricultural sector, gasoil is to be redirected to transportation sector, heavy fuel oil is recommended for thermal power generation as in Qarri 4 power station, which uses Coal. Total electrification of agricultural sector via using solar water pumping system rather than Internal Combustion motors .

1.1 Transport Sector

Sudan has 4,725 kilometers of narrow-gauge, single-track railways Serving mainly the northern and central portions of the country. West side of the country, is an old line from Khartoum to Nyala in Southern Darfur, no rail connection exists to Al-Fasher or further west to Al-Junayna. With no Plans to extend the rail in the near future, trucks are the preferable transport method, also trucks have the advantage of shorter delivery time and the ease cargo load criteria .

The cost of moving freight in Sudan is almost twice what it is on other continents, though it compares with the average for Africa. The average freight tariff between Khartoum and Port Sudan is about $0.10 per ton-km [1]. These prices are comparable to that of East Africa but much higher than the global standard of around $0.04 per ton-km.

In the transport sector, even though the road network almost doubled in length to 6,200 kilometers (km) between 2000 and 2008 [1], a sizable share of the country lacks roads. There are a few well-developed internal corridors, but rural connectivity is weak. Road density is exceedingly low and traffic along most roads is sparse. Poor-quality roads drastically undermine the efficiency of transport services. Further, the large volumes of unpaved roads make movement impossible during the rainy season .

1.2 Policies

The reason for the high price tag is the policy of the country and corruption. From Khartoum to Nyala Every trucks pays 1200 SDG named asphalt fees, then along the road and in every state truck pays a crossing tariff, totaling a payment of 8000 SDG. Road payments forced truck owners to raise the transport per ton tariff to a relatively high values.

Already existing policy is that the trucks maximum weight should not exceed 35 tons [2], Weight stations are not implementing the weight regulatory, overweight trucks destroying the roads and asphalt layer, decreasing transport efficiency and presenting a danger factor on other road users.

This paper covers specifically the Long-haul Freight transport between Khartoum and The Western side of the country; Darfur Region, looking into energy consumption, environmental impacts and energy conservation opportunities applicable .

2. Case Study

Due to the rough route and road condition between Khartoum and Darfur the rigid truck type (lorries) are the most preferred truck type for usage.

The valleys and the unpaved roads specially between Al-Fasher and Al-Junayna make it almost impossible for a semi-tractor trailer to go further west of Al-Fasher specially in rainy season. (Figure 1)

2.1 Case I

Iveco Euro Trakker 2004 (lorry)

(Figure 2)

Specifications

Engine:12.8 Liter displacement, 6 in-line Cylinders

Payload: 30 tons of bean

6*4 drive configuration (six axles, four driven by powertrain)

Fuel Type: Diesel Fuel

Fuel Consumption Rate: 0.015 liter/ton-km (at average speed of 85km/h) [4]

Trip Route: (as shown in figure 3)

Table 1

2.2 Case II

Hino 700series 4041 (lorry)

(Figure 4)

Specifications

Engine: 12.9Liter Displacement, 6 Cylinder

6*4 Drive configuration

Payload: 30 tons of different goods

Fuel Type: Diesel Fuel

Fuel consumption Rate: 0.015 liter/ton-km

Trip Route: (as shown in Figure 5)

Table 2

2.3 Road Description

Both Trucks in both cases use the same route to Nyala City. The road is only two lanes with low quality asphalt, this leads to road facing high traffic density due to large numbers of trucks passing upon it, increases danger factor and lead to traffic congestion. (Table 3)

In the two cases, there is a big gap in fuel consumption between the standard consumption and the actual fuel consumption.

Estimations indicate there are a minimum of 600 trucks travelling daily form Khartoum towards Darfur Region, on the existing poor roads this leads to traffic congestions, consequently to millions of liters of fuel being wasted. Fuel consumption in road traffic is directly affected by insufficient traffic infrastructure, absent traffic flow instruction, wrong vehicle configurations, vehicle efficiency and driving behavior. (Figure 6)

Thus the fuel consumption of a 40-ton truck can treble if the truck has to stop twice per kilometer instead of driving with an average speed of 50km/hr. Truck drivers in the mentioned cases are confronted daily by such situations as a result of capacity bottlenecks on traffic routes, e.g. security checks and state borders. The development of a modern traffic guidance system and expanding roads infrastructure can make a substantial contribution to fluent traffic flow.

3. Mitigation Measures

3.1 Source of Energy Losses

The IC engines have two thirds of its energy wasted and only one third is used (as illustrated in Figure 7). There is a potential savings to be achieved in the aerodynamics of the vehicles in the study case. It is easy to understand that optimizing aerodynamics specially in respect of long haulage on highways can achieve considerable savings in consumption. A heavy tractor with semi-trailer requires 160hp at 80km/hr. to overcome the resistance of tires (45%), aerodynamics (40%) and accessories [10]. Under inflated tires can add an increase of 8% in consumption [12], the savings potential of fixing the overweight and regular tire pressure check becomes obvious.

Fuel consumption can be positively affected by choosing the correct vehicle configuration, introducing a wind deflector with the right adjustment on the roof of the cabin alone can reduce consumption by up to 4% [7].

Not to dive into technical details further, but over the years there has been a clear reduction in fuel consumption. Today a van emits only one third CO2 than was the case in 1980. Trucks manufacturers are working to develop a smarter and more fuel economic trucks every day.

3.2 Mileage

Due to the bad condition of the road, drivers are compelled to use the routes described above, with relatively low speed and low gear ratios resulting in high fuel consumption, while there are better routes can provide a shorter trip time and a more fuel economy if maintained and paved .

3.2.1 Case I

The truck is using the route Through Bara-Al-Fasher. Instead, the road through Ghubaysh-El Daein is shorter in distance and can save time and fuel, also relieving flow density on Al-Fasher road and leaving it for trucks heading only to Al-Fasher city. (Figure 8)

Some parts of this route are not paved and sandy, sand slows down driving speed and truck produce more power to overcome resistance, so sand obliterate the benefit of the shorter route, route must be upgraded and paved to make full benefit of it. Road upgrading costs and benefits are discussed later. (Table 4, Table 5)

3.2.2 Case II

The truck is heading south through Nyala instead of heading directly west to Al-Junayna, a road between Al-Fasher-Al-Junayna through Kabkabya does exist but it is unpaved with rough terrains, it needs an experienced driver who knows the area well. If the road is maintained and paved accompanied by proper driving instructions it can save the time going through Nyala city, decreasing traffic density on Nyala road. (Figure 9, Table 6)

3.2.3 Annual Savings Using the Alternative Routes

Driver's questionnaire showed that a truck from the under study type is making two trips per month depending on truck performance, driver ability and market activity. Along the year, the truck may stop one month for maintenance, thus the truck makes a minimum of 22 trip per year.

Assuming the alternative routes are paved and upgraded, with the massive number of 600 trucks daily, the alternative routes can have significant footprint on fuel savings. (Table 7)

Beside fuel savings, alternative roads can contribute to lesser traffic congestion on roads since trucks travelling to Al-Fasher will not be using the same route for trucks travelling to Nyala, consequently much safer roads and less stops for truck.

3.3 Eco Driving

3.3.1 Over Idle

Over idle is one of the most common bad habits among the truckers, where the driver leaves the engine on idle for a long period of time while he is taking a rest along the road or while the truck is being loaded/ Unloaded. Idling a heavy-duty truck consumes about 0.8 gallon (3 liters) of fuel per hour [3]. All the new trucks models come with technology that turns off the engine after certain amount of idling time.

3.3.2 Driving Speed

Due to the heavy load and the bad condition of the roads the drivers are obliged to drive on relatively low speeds and low gear ratios leading to high fuel consumption and consequently high carbon footprint, and also puts pressure on the engine and drivetrain. Optimum economic speed for fully loaded 40-ton truck is 60-75 km/hr. [7].

3.3.3 Accelerating

Gentle accelerating and higher gear ratios when possible contribute markedly to fuel efficiency. Natural potential fuel saving exists in the appropriate training of drivers which can be achieved with the aid of additional qualification for driving school instructors, in this way anticipatory driving and the correct choice of gear can have a decisive influence on consumption. License for driving long haulage trucks should be separated from the general driving license Sudan has now.

3.4 Payload Distribution on Truck

Maximum weight may not exceed 35 tons, yet how the cargo is organized and put on the payload area matters, all the piled up cargo above the truck's cabin height (as shown in Figure 10, Figure 15) affects the stability and aerodynamic drag significantly, Truck may become unstable in windy conditions, on turns and diagonal roads, the engine produces more energy to overcome the aerodynamic drag thus consuming more fuel and emitting more pollutants. Charging truck's crate above its original height should be avoided.

Fuel consumption can be positively affected by introducing a wind deflector with the right adjustment on the roof of the cabin alone can reduce consumption by up to 4% [7].

3.5 Overload

When it comes to road deterioration the blame is always put towards the material quality of the asphalt, but the loads on the road is never considered. Every road has a maximum weight to endure (so as trucks have maximum load per axle), beyond that weight the road starts to deteriorate and asphalt layer crumbles. A massive number of trucks malfunction on the road every day, due to exceeding the maximum load per axle, truck cracks suddenly in the middle of the road and cannot be moved which represents a great danger on other drivers on the road specially at night.

Maximum allowable weight for the roads between Khartoum and Darfur is 35 tons [2], notice that for the two cases both trucks carry a payload of 30 tons, the empty weight of the Hino 700series 4041 trucks is 9.5 tons [13], gross vehicle weight (GVW) is then 39.5 tons which is greater than the allowable maximum weight by 4.5 tons, maximum payload should not exceed 25.5 tons.

A part of fuel saving is achieved in case of complying to maximum weight and removing the extra 4.5 tones as follows:

This means it takes 215 liters of fuel to carry the extra 4.5 tones. Controlling the overload can be achieved by rehabilitating weight stations, re-establishing overload regulations and penalties, raise awareness of drivers and truck owners about the risks and effects of overload .

3.6 Fuel Availability

Between states, Sudan has a high diversity in fuel prices caused mainly by fuel scarcity which led to black market trade. Diesel prices for states along the trucks route for both cases are mentioned in Table 8.

Fuel availability is the problem, fuel (if found) will be in black market with extremely high price. Because of the fuel availability and prices in remote cities, and to support essential goods and logistics transport to these cities, government authorized trucks to take all the quantity of fuel needed for the trip directly from Khartoum. The extra amount of fuel barrels is extra weight applied on the truck and road, beside that it encourages fuel unofficial selling and black market trade. Four drivers out of six confessed of selling at least two barrels on the black market with high prices, this shows clearly the poor policy of providing fuel for trucks, as trucks are granted fuel amounts more than needed for the trip. Policy must be revised and controlled (Table 9).

Fuel (specially diesel) is a county wide problem, most of the stations on the high ways have dried out for months, government cannot terminate the black market and prohibit the fuel carriage without providing fuels in abundance.

The extra weight of diesel can be used to carry more goods resulting in more income to truck owner or dump the extra weight reducing fuel consumption.

4. Roads Upgrade

Roads Implementation costs cannot be directly compared to the fuel savings as its benefit reflects in greater scale on the country economic and growth. Roads are vital to any development agenda. Since 2002, the World Bank has constructed or rehabilitated more than 260,000 km of roads. It lends more for roads than for education, health, and social services combined. In this paper's particular case, rehabilitation costs for the road between Al-Fasher and Al-junayna can reach up to 2.8 billion SDG [15], on the other hand, since the new road will permit the usage of Tractor Semi-trailer, total annual fuel saving is approximately 11,000 liter of Diesel (see Table 10). For minimum of 600 trucks, savings can reach up to 6.6 million liter of Diesel. Such savings can be a great deal for a country like Sudan struggling with fuel and imports huge amounts to satisfy the growing demand .

5. Technical Improvements: Replacement of Lorries with Tractor Semi-Trailer Combination

From the truck owner's view point, fuel efficiency is one of the main priorities for long-haulage heavy-trucks due to its major impact on the total operating costs. It has been estimated that the cost of fuel is about 30% of the total operating costs [3]. Therefore, goods transport on roads, which is characterized by high fuel consumption, together with high weights and relatively long distances, will benefit greatly from a significant improvement in fuel efficiency. (Figure 11)

Figure 11 shows technical improvements regarding the aerodynamic drag reduction. All of the improvements are made to the tractor and trailer combination, but as mentioned before, the usage of semi-tractor trailer is limited by the bad condition of the roads and its incompleteness. But if the roads are rehabilitated, the semi-tractor trailer combination can provide high quality transport.

For the same distance, and almost for the same fuel consumption the semi-tractor can hold up to 50 tons of freight (depending in trailer configuration) with high efficiency, this can help reduce the number of trucks on the road and provide better road safety by overcoming the lorries high overhead loads.

Sudan trucks market is overwhelmed with European trucks, and trucks with newer technologies are available and already on the road, but it is mostly used for transport between the east sides of the country where roads are in good shape.

5.1 Tractor Head & Semi-Trailer

The DAF XF 105 tractor head is available today on market with a price of 3.5 million SDG, the Renault Tractor head is even cheaper with a price of only 2.8 million SDG, notice that these prices are for the tractor head without the trailer, price of semi–trailer with 4 axles is 5 million SDG. (Figure 12, 13, 14)

Paying the same money for Hino700 series 4041 (production year 2005) can buy the newer model, more efficient DAF tractor head with semi-trailer. The tractor head (figure 12) complies with the Euro 6 emission standard and equipped with drag reduction devices (cabin side wings, side skirts and fuel tank fairings). On the other hand, the semi-trailer is not equipped with aerodynamic reductions (as mentioned in figure 10) but all of techniques are well known and can be made locally, add up to that the over carriage bars prevents the over cabin's height cargo load, all of these measures can achieve a reduction in fuel consumption up to 7% [3].

More savings can be extracted from tires, super single wide tires instead of twin tires in the trailer can reduce fuel consumption by up to 2% [12].

5.2 Comparison between Hino700series 4041 and DAF XF 106 Tractor with semi-Trailer (Table 10)

Another advantage of this tractor head is the safety technologies and smart driving assistance for the driver, which makes the truck safer and easier to handle.

6. Environmental Impacts

The increase in the number of heavy duty vehicles (HDV) is inherently accompanied by increase in congestion, pollutant emissions and energy use as well as infrastructure overuse, all of which have broad societal implications. In addition to affecting the environment, contributing markedly to global warming, significant implications for the health of many residents living along traffic corridors as well as increase in the cost of infrastructure maintenance are logical consequences.

The daily 600 trucks traveling from the Khartoum towards Darfur region (regardless the transport towards other sides of the country) contributes significantly to the carbon emission and the global warming. The reduction in CO_2 emissions is a holistic task, which includes all parties involved in road traffic.

6.1 Annual Emissions for Case I & II

Values of the Euro Standard Emission are converted in various connections into emissions per ton-kilometer. They are based on assumptions of a certain type of traffic, driving method, and load utilization, and are therefore uncertain. Emissions from vehicles in traffic may differ from these data.

Emission calculation is based on the current fuel consumption of the two trucks presented in the study case which are compiled Euro II emission standard

Carbon dioxide is formed by combustion. The carbon content of the fuel determines the amount. The carbon content of the fuel determines the amount. One liter of standard diesel fuel (EN590) creates about 2.6 kg carbon dioxide [5]. (Table 11)

6.2 Annual Emission Savings When Applying the Alternative Routes (Table 12)

6.3 Annual Emissions Savings Using the DAF XF 105 Tractor Semi-Trailer Combination

The DAF tractor complies with Euro VI emission standards and can travel the same trip for almost half the fuel and half the emissions, knowing that the tractor trailer combination can hold up to 50 tons of freight. (Table 13, Table 14)

All the data presented shows a significant reduction in Emissions and fuel consumption due to the newer technologies introduced in the DAF tractor head, plus the safety measures and on road driving assistance technologies.

7. Conclusion and Recommendations

The Separation and Independence of South Sudan is the core of the problem for the fuel crisis in Sudan, the country now imports large amounts of fuel in hard currency to cover the needs .

The fuel competitiveness between Thermal Power Generation, Agricultural sector and Transport sector is major issue. Fuel shift of gasoil is recommended for power generation. Sudan already started to head towards the fuel shift, now the Country has Qarri 4 power station using Coal for power generation, but yet to meet the ever increasing demand. If all thermal power generation is shifted to Coal, the gasoil can be transferred to transport sector and agricultural sector.

Further gasoil reduction can be achieved by using solar pumps for water irrigation and thus more gasoil will be redirected to transport sector. Solar water pumping is yet a developing project in Sudan constrained by high costs and lack of funding.

All of the trucks travelling to Western States of Sudan are using the same poor road causing high traffic density and congestion. As a consequence of traffic congestion and poor infrastructure accompanied by wrong vehicle configurations, insufficient vehicle maintenance and inappropriate driving behavior, millions of liters of fuel are wasted senselessly today. Upgrading roads will notably increase transport efficiency and reduce fuel consumption per truck.

Infrastructure of Sudan is weak, rural and regional roads connectivity is weak, causing inefficient transport and high cost of freight transport. Roads infrastructure upgrade leads to economic growth and can drag down freight transport prices.

Poor quality of roads is affecting the transport efficiency and forcing the market to use older models of the rigid trucks (lorries) in transport as it can tolerate the unpaved roads but consuming excessive fuel amounts. Roads upgrade permit the usage of much higher efficiency trucks consuming less fuel and even transporting more weights per trip.

Roads upgrade without establishing rules to protect it is meaningless. Weight stations and overweight penalties must be re-established to control trucks load to protect the roads from destruction.

Fuel availability and high fuel prices in remote states forced truckers to carry all the diesel needed for the trip directly from Khartoum. The extra diesel barrels are extra weight on the truck, thus the truck consume more energy, beside its danger factor. The extra fuel barrels also gave opportunity for black market trade. Extra fuel barrels must be prohibited, but this cannot be done unless fuel availability problem is solved. Short term solution could be in distributing fuel on fuel stations along the trucks routes dedicated only for heavy truck.

The Hino700 series 4041 which is mostly used now is a Euro II standard truck, characterized by high emission ratio and high fuel consumption comparing to newer models. Stablishing policies to replace the Euro II rigid trucks with the more efficient Euro VI tractor semi-trailer truck is a must.

Figure 1. Semi-Tractor Trailer Combination

Figure 2. Iveco Euro Trakker (2004)

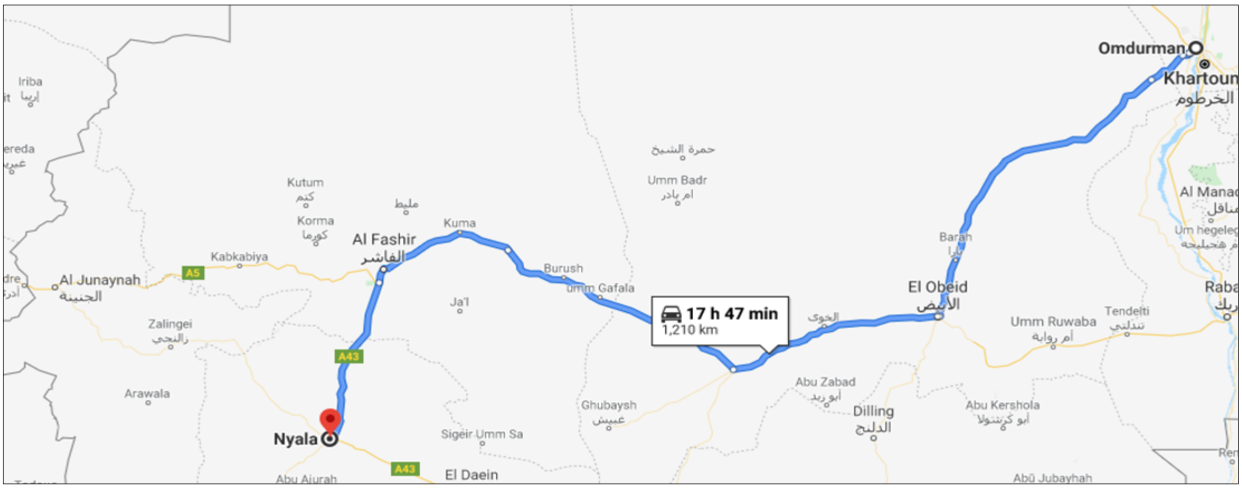

Figure 3. Case I Trip Route

Figure 4. Hino700 series 4041 (2005)

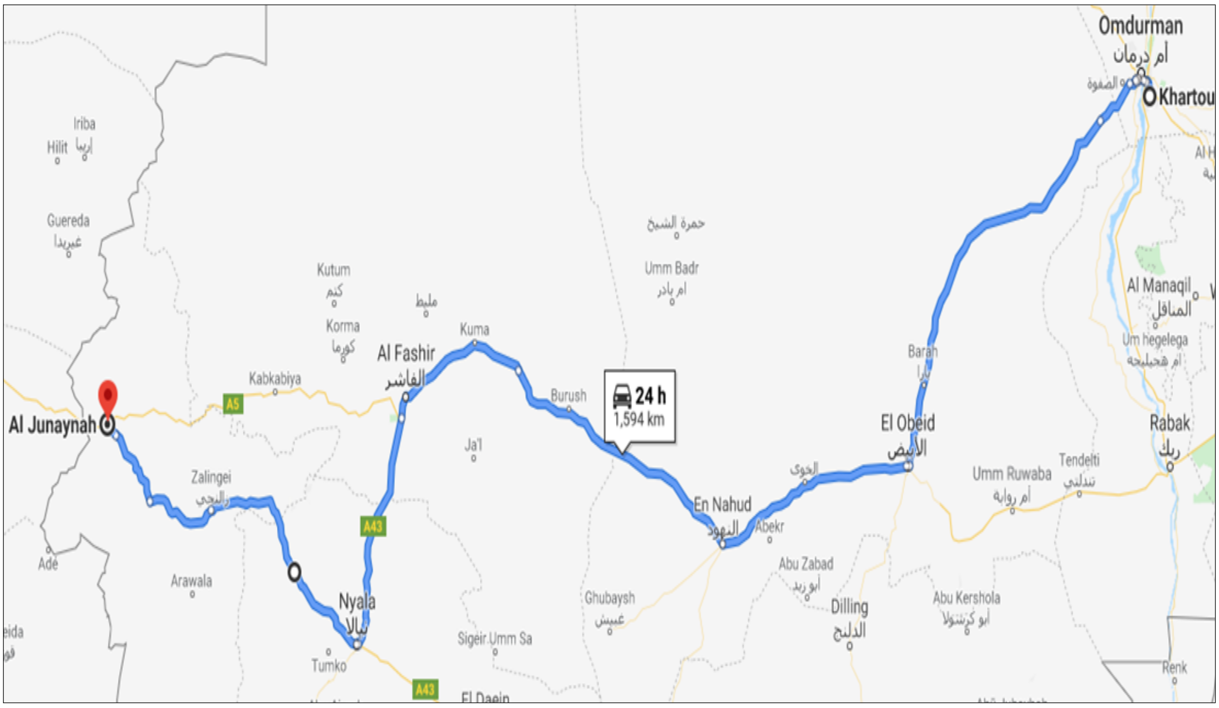

Figure 5. Case II Trip Route

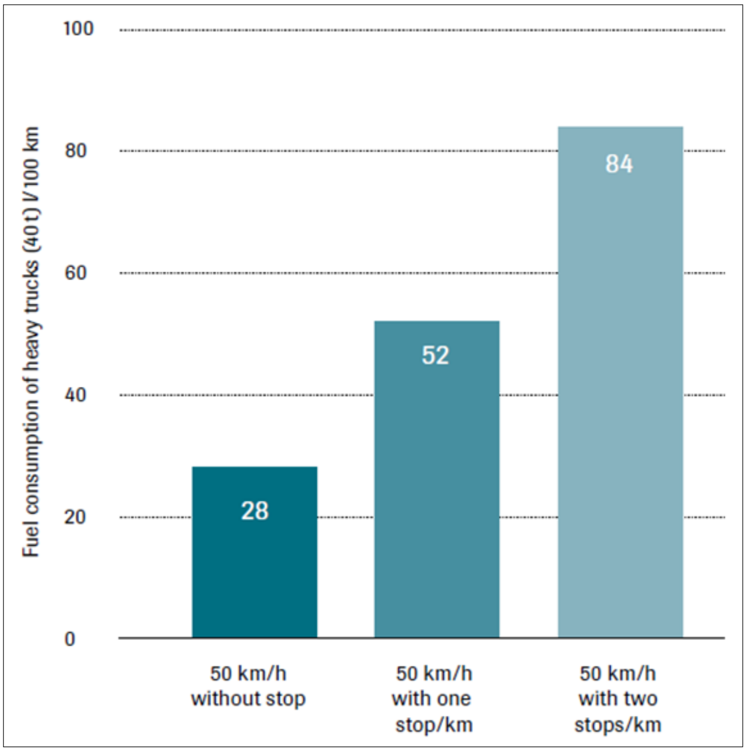

Figure 6. influence of traffic flow on fuel consumption [10]

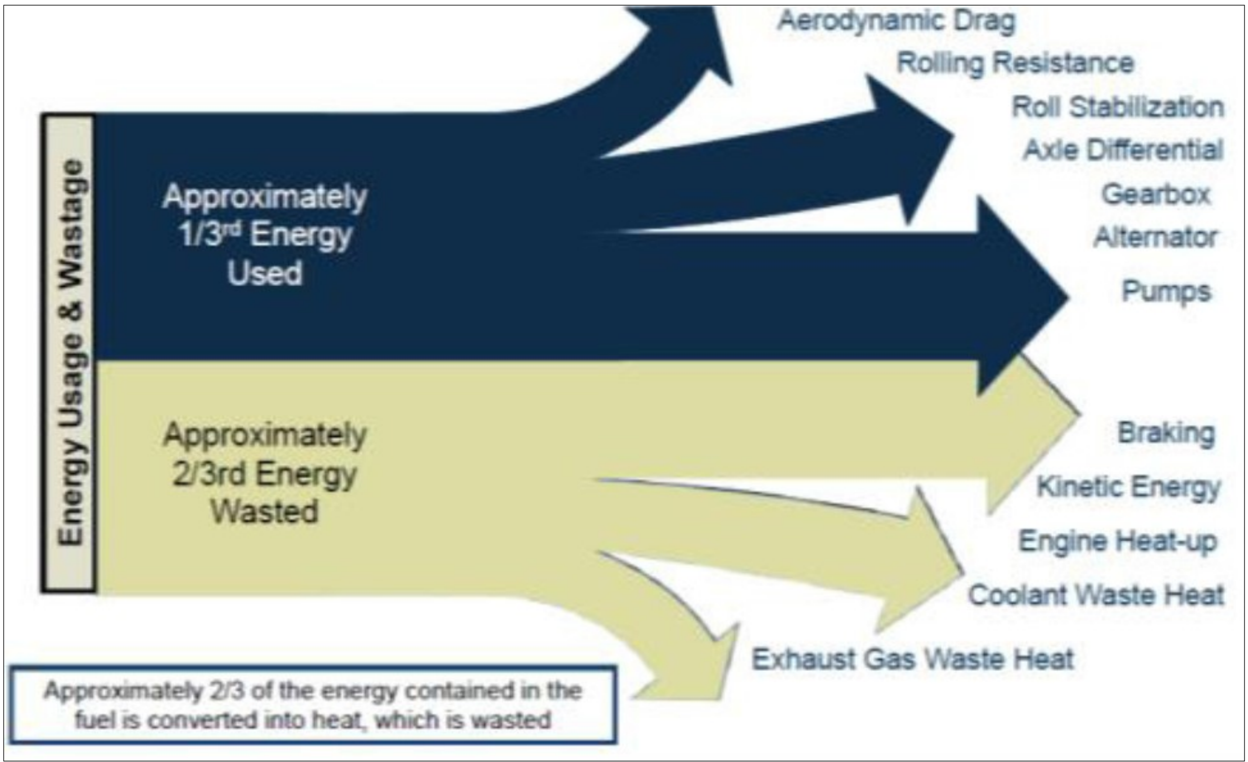

Figure 7. Truck Energy Losses

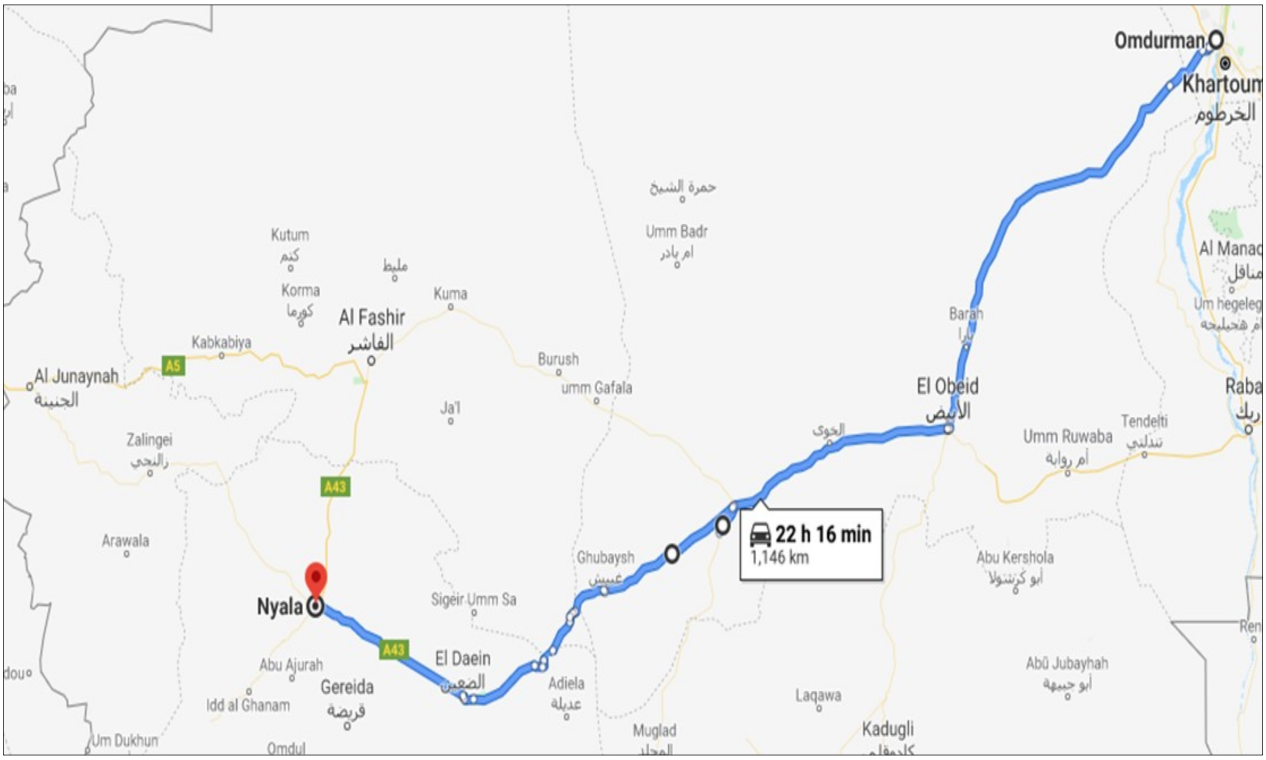

Figure 8. Case I Alternative route (Omdurman-Bara-Ghubaysh-El Daein-Nyala)

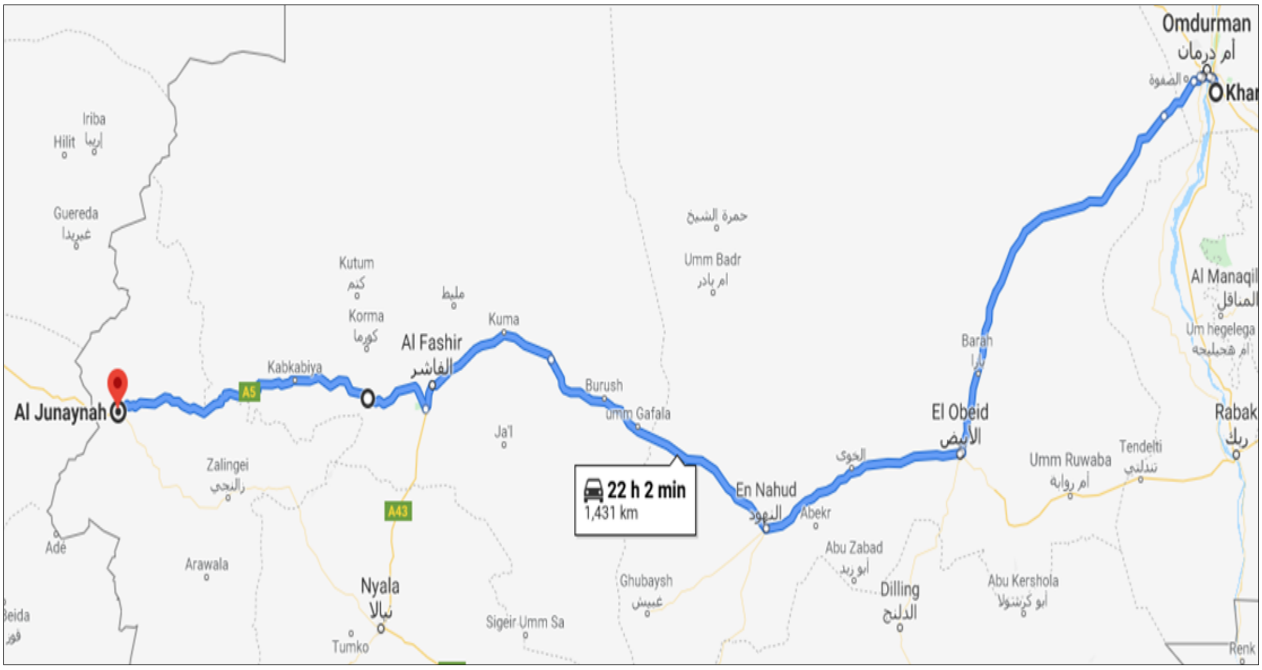

Figure 9. Case II Alternative Route (Omdurman-Bara-Al-Fasher-Kabkabya-Al-Junayna)

Figure 10. Weight Distribution on the truck

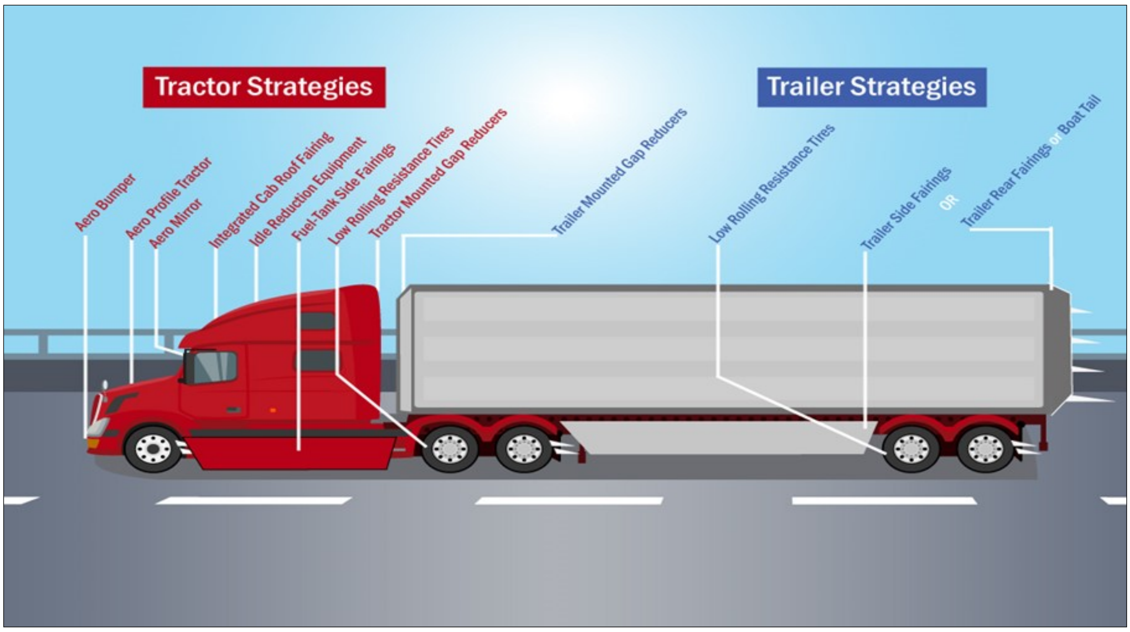

Figure 11. Aerodynamic Drag Reduction Strategies

Figure 12. DAF XF 105 tractor head (2015)

Figure 13. Renault Tractor head (2015)

Figure 14. Semi-Trailer with over carriage bars

Figure 15. Weight Distribution on the truck

Table 1. Case I Trip Details. (Note that for the total distance the back trip is included)

Route	Total Distance (km)	Standard Fuel consumption*1 (Liter)	Current Fuel consumption*2 (Liter)	Total trip time (hr.)	Wasted Fuel (Liter)
Omdurman-Bara-Alfasher-Nyala	2426	1092	1503	56	411

*1 Standard fuel consumption is obtained from researches and tests of different vehicle in different cycles.

*2 Current fuel consumption is the actual value consumed now days obtained from drivers and truck owners on the market

Table 2. Case II Trip Route (Note that for the total distance the back trip is included)

Route	Total Distance (km)	Standard Fuel Consumption*1 (Liter)	Current Fuel Consumption*2 (Liter)	Total Trip time (hr)	Wasted Fuel (Liter)
Omdurman-Bara-Al-Fasher-Nyala-Junayna	3190	1435	2004	86	569

Table 3. Road Description for case I & case II

Trip	Distance (km)	Trip Time (hr.)	Road Condition	Average driving speed (km/hr.)
Omdurman-Bara-Obyied	420	8	Well Paved	80
Obyied-Alnohod	210	5	Poorly Paved	40
Alnohod-Al-Fasher	398	6	paved	80
Al-Fasher-Munwashie	70	5	Unpaved	40
Munwashie-Nyala	125	4	Paved	70
Total	1223	28		
Case II:				
Nyala-Nertite	147	4	Well paved	80
Nertite-Zalengi	67	6	Poorly paved	40
Zalengi-Al-Junayna	158	5	Paved	70
Total	1595	43		

Table 4. Case I Alternative road description

Trip	Distance (km)	Trip time (hr.)	Road Condition
Omdurman-Bara-Obyied	420	8	Well paved
Obyied-Alnohod	210	5	Poorly paved
Alnohod-Ghubayesh	140	4	Unpaved
Ghubaysh-Aldean	174	7	Poorly paved
Aldean-Nyala	161	3	Paved
Total	1105	27	

Table 5. Case I Savings

Route	Total Distance Saving (km)	Total Distance Saving (km)	Trip Time Saving (hr.) *
Omdurman-Alnohod-Ghubaysh-El Daein-Nyala	216 (9%)	96.3 (9%)	1

*The time saving is not very accurate and may vary more or less depending on the unpaved parts of the road and driving behavior. The road condition controls the average driving speed and average trip

Table 6. Case II Savings

Route	Total Distance (km)	Distance Savings (km)	Fuel Saving (Liter)	Trip Time Saving (hr.)
Omdurman-Bara-Al-Fasher-Kabkabya-Junayna	2834	356 (11.2%)	160 (11%)	4

Table 7. Annual fuel savings

	Case I	Case II
Fuel Consumption (Liter/Year)	24,017	31,581
Fuel Saving (Liter)	2119 (9%)	3520 (11%)
Average fuel savings from 600 trucks	1.7 million liter	

Table 8. Fuel Prices

City	Price (SDG/Liter)	Price (SDG/barrel)
Khartoum	4.11	686
Obied	7.18	1200
Nyala	8.98	1500
Al-Junayna	11.9	2000 (2.9 times higher than Khartoum)

*Prices are subjected to increase depending on the availability. The fewer available fuel, the higher the price, on the black market, the barrel price in Al-Junayna can reach up to 4000 SDG.

Table 9. Weight of extra diesel outside tanks

	Case I	Case II
Fuel Quantity (barrel)	6	8
Weight (kg)	756	1177

*For both Trucks in the Two Cases fuel tank capacity is 600 Liter.

Table 10. DAF XF Tractor Semi-Trailer Combinations Compared to Hino700 series 4041 lorry

		Hino700series 4041		DAF XF with Semi-Trailer	
Price (million SDG)		8.5			
Maximum payload (tons)		30		Up to 50 (depending on Trailer configuration)*1	
Vehicle Empty Weight (tons)		9.5		7.5	
Engine Horse Power		420		450	
Euro Emissions		Euro II		Euro VI	
Drive Configuration		6*4		4*2	
Fuel tank Capacity (Liter)*2		600		Up to 1500	
Fuel consumption Rate (liter/ton-km)		0.015		0.011	
For Case II Trip:					
Payload (ton)		30			
Trip Distance (km)	With Original Route	3190			
	Using Alternative Route*3	2834			
Standard fuel consumption per trip (liter)		With Original Route	Using Alternative	With Original Route	Using Alternative
		1435	1275	1053	935
Annual Fuel savings *4		11,000 liter			

1*Trailers come with different axles configurations, there is Tandem axles (4 axles), Tri axles (6 axles) the more axles the more weight trailer can tolerate

2*The large fuel tank capacity helps in preventing fuel barrels use which contribute to black market impedance.

3*Assuming the alternative route is rehabilitated and usable for tractor semitrailer truck

4*Annual fuel savings is calculated assuming usage of DAF tractor head plus the alternative route. Alternative route provided greater boost to fuel economy, trip distance and time.

Table 11. Emissions per Trip

Pollutant	Euro II Standard (g/liter)	Case I emission (kg)	Case II emission (kg)
NOx	25	37.5	50
PM	0.7	1.1	1.4
CO	4	6	8
HC	1.1	1.6	2.2
CO2		3910	5200

Table 12. Annual Emission savings when applying the alternative routes

Pollutant	Annual emission (kg)		Annual emissions reduction (kg)	
	Case I	Case II	Case I	Case II
NOx	825	1100	53	88
PM	24.2	30.8	1.5	2.5
CO	132	176	8.5	14.1
HC	35.2	48.2	2.3	3.9
CO2	86020	114400	5509	8800

Table 13. Euro VI emission standard

Pollutant	Emission (g/liter)
NOx	0.9
PM	0.01
CO	0.13
HC	0.06

Table 14. DAF XF tractor semi-trailer emissions compared to Hino 700series 4041 lorry (Annual kg)

Pollutant	Hino700	DAF XF	
		With Original Route	Using Alternative Route
NOX	1100	20.8	18.5
PM	30.8	0.23	0.2
CO	176	3	2.7
HC	48.2	1.4	1.2
CO2	114400	60213	53482

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