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Fuel efficiency and CO2 emissions of biomass based haulage in Ireland – A case study.

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Abstract

The purpose of this study was to analyse how biomass based haulage in Ireland performed as a measure of efficiency under 4 main criteria; distance travelled, fuel consumption, fuel consumption per unit of biomass hauled and diesel CO2 emissions. The applicability of truck engine diagnostic equipment was tested to analyse the schedule of engine data that could be recorded in real-time from a 5 axle articulated biomass truck. This identified how new on board truck technology in Ireland could be used to monitor data in real time, specifically fuel consumption, litre / km, litre / ton and distance to allow for informed analysis of how efficient new biomass trucking operations currently are in Ireland. FMS monitoring systems are a relatively new technology in biomass and log transport in Ireland. They are more common place in the food supply chain with refrigerated units travelling across continental Europe where food temperature and truck movements are controlled data from a central dispatch. A GPS asset tracking monitoring system was also installed on the truck over the test period to record trip log data. The biomass haulage truck (BT) was a 5 axle, 2004 DAF XF Euro III 430hp 4*2. Initial results showed that for the BT, the average daily fuel consumption varied from 0.23 L / km to 0.47 L / km. The thresholds of travelled distance were between 20.92 km and 434.91 km respectively with average fuel consumption per tonnage of woodchips of 0.16 L / ton and 5.68 L / ton corresponding to C02 emissions between 13.35 kgs and 469.73 kgs. When the total daily distance is limited to 1 load within 200km roundtrip versus 1 load at approximately 400 km trip, the % difference in logistic cost (€ / T) is 61%. Delivering 2 loads per 400 km trip shows a 5.4% decrease in logistic costs versus the Trip 1 scenario confirming the increased efficiency of a more localised transport approach. A maximum percentage difference in costs of 50% that exists between a 2 load and 1 load trip occurs for Trip 22 and Trip 5 but this increases to 61% when analysing for 2 load versus 1 load for distances over 400 km. Trip 7 and 12 are both below 50 km and seem to be the exception and to compare could possibly show an element of distortion. The closest logistic cost to Trip 12 is Trip 6 with 133% higher costs confirming how a 50 km roundtrip can impact significantly on lowering biomass transport costs.

Keywords: biomass haulage, fuel efficiency, litre / km, litre / ton, CO2 emissions.

1.1 Introduction

In 2007, the road freight transport sector in Ireland has seen the most increase in CO2 (carbon dioxide) emissions across all sectors at 182% above 1990 levels. From 1990 to 2007 the total CO2 emissions in transport, thermal and electricity increased by 51%, with transport accounting for 36% and with CO2 being the most dominant of the greenhouse gas emissions (GHG's) [1]. In the USA, trucks account for over 80% of the freight energy use and 19% of US oil consumption. Plans to improve the technical efficiency through new technologies, careful driving and optimal driving conditions have obtained increased efficiencies between 50% - 70% [2]. Bandivadekar et al. 2008 [3] believe that the increase in the consumption of oil for transport use in the US is a challenging environmental problem that needs to be addressed based on reducing fuel consumption through driver behaviour rather than concentrating on improving vehicle performance through new propulsion technologies and new fuels in the shorter term. Similar studies in Mexico by Rafael Morales and Cervantes de Gortar, 2002 [4] demonstrated that technical driving through optimal use of engine speed and torque brought about substantial savings in fuel consumption and pollutant emissions.

The rising cost of road diesel accounts for the majority of a haulier's overall costs. In Sweden, diesel costs rose sharply in 2008 and today accounts for 35% of total operating costs for timber haulage. Ten years ago, this figure was between 10 and 15%. According to Lofroth et al. 2008,[5] the average fuel consumption of Swedish roundwood haulage rigs is a 5.5 L / 10km. This is equivalent to approximately 0.55 L / km. This study showed values ranging from 0.23 and 0.47 L / km for woodchip haulage which shows consumption is comparable between Sweden and Ireland even though Sweden have a higher gross vehicle weight of 60,000kgs versus the 42,000kgs of the 5 axle truck used used in this study. Other factors such as higher truck axle configurations, higher payload weights etc in Sweden must be studied when comparing the fuel consumption of both the Irish and Swedish haulage sectors.

[6]estimated C02 emissions in United Kingdom for road freight data. The data came from different sources such as traffic count data, surveys and vehicle test cycle and showed how discrepancies and anomalies exist within how CO2 emission related data can vary. One part of the analysis was researching the fuel performance of the heavy goods road freight across the UK which shows an average value for a 44,000 kgs articulated truck at 7.25 mpg which is approximately 0.39 L / km. Comparing with recorded field data for this study shows a 19% better fuel efficiency for trucks in the UK than in Ireland. This perhaps could be accounted to the better standard of roads in the UK. The average recorded fuel consumption for 40,000 kgs was 7.7 mpg which is approximately 0.37 L / km and similar to the higher tonnage vehicle.

Lofroth and Lindholm, 2005 [7] believe that haulage trucks can reduce their fuel consumption between 5% and 10% simply by fitting a wind deflector and removing all unnecessary items such as signboards, extra air horns, extra lamps and other accessories that can increase drag.

In Japan, Yoshioka et al. 2006 [8] examined a system for the harvesting and transporting of logging residues based on cost, energy and CO2 compared with those of European countries. It was demonstrated that Japan could only reduce the domestic CO2 emissions of the harvesting and transporting system by utilising the collected residues as an alternative fuel source. Savings within the system itself could only potentially be achieved with improving and advancing the technical developments of forwarding and transport efficiency. From the Forest Enginnering Group (FEG) conference in Scotland in 2009, Dr. Jan Fryk, president of Skogforsk stated that to reduce carbon footprint in timber harvesting, we must reduce fuel consumption from 3.7 litres / cubic metre to 2.1 litres / cubic metre. A solution to Yoshioka's study might revolve around the world's first new electric hybrid forwarder [9]. The fuel consumption of the forwarder was 20% – 50% lower than that of a conventional forwarder. It has a small diesel engine that runs a generator that can charge six batteries to provide the back up power to six electric motors in each of the six wheels. It also has a lower unladen weight which implies a higher weight to payload ratio. Other possible soultions to reducing fuel consumption and the effects of increased GHG exhaust emissions is to preplan and optimise the routes travelled by the trucks [10, 11]Frisk and Ronnqvist, 2005 [12] developed a decision support system to optimise the wood flow planning in Sweden. The findings showed that roundwood haulage costs could be cut by up to 5%. Tavares et al. 2009 [13] incorporated geographic information systems (GIS) software to model and preplan routes for the collection of municipal solid waste (MSW) in the city of Praia, the capital of Cape Verde. The GIS modelled the fuel reduction routes with results of 8% and 12% savings in fuel consumption versus previously travelled routes.

Other work by Lopez et al. 2009 [14] studied the variation in GHG emissions and fuel consumption of refuse waste trucks in the city of Madrid. Three different fuels were compared – diesel, biodiesel (30% blend) and Compressed Natural Gas (CNG). Results showed a fuel consumption of 0.77 L / km for the diesel truck and 0.89 for the biodiesel blend. While these values are higher than previously reported figures here, it must be pointed out that the refuse collection involved urban driving only.

Bergstorm and Dianthus (2000) [15] also developed a software program that uses GIS to analyse the benefits of new forest roads based on what stands are to be harvested. The maps produced help the user to identify areas where new roads are needed from a routing perspective. This sort of research is an area where Ireland's timber and biomass transport sector could follow in terms of optimising the route scheduling of trucks, particularly on the forest roads when in forest chipping occurs rather than at pre-defined comminuted depots or collected as sawmill residues.

The global transport sector (road, rail, air and water) currently account for 17% of CO2 emissions. The EU has set new measures for the reduction in CO2 emissions from transportation, for example, by including aviation under the EU Emission Trading Scheme (EU ETS) along with stringent limits on the exhaust emissions from passenger cars in grams / km.

Trucks currently account for 6% of global CO2 emissions but developments in increased fuel efficiency built around improvements in common rail injection, automated gear boxes and turbo charging have led to the incorporation of tiered emission classes in the form of Euro 0 to Euro VI. Euro VI has a planned implementation date of Jan 2013. Today, fuel efficiency in trucks is very much market driven with the rising fuel prices – estimated at between 30 – 40% of the total operating costs. Only those trucks with the highest fuel efficiency and lowest C02 emissions effectively make it to market which in turn leads to a more green procurement for businesses. While truck manufacturers specify a figure for fuel efficiency on paper from highly designed test labs, the question is, how do they perform under the *principle of work done*?[16, 17]

The purpose of this study was to analyse how biomass based haulage in Ireland performed as a measure of efficiency under 4 main criteria; distance travelled, fuel consumption, fuel consumption per unit of biomass hauled and diesel CO2 emissions. The analysis was taken on one biomass truck hauling woodchips. By identifying and presenting the usage of on-board engine diagnostic technolgy, it is hoped that the results of such truck trials can be used to inform the ITTS of the potential uses of incorportating new technologies with regards to identifying methods of real-time location data, accurate fuel recordings to help increase fuel savings and subsequent CO2 savings and identify truck driver performance. The information can assist with quantifying maximum allowable distances for delivery of biomass without becoming uneconomical.

2.1 Methodology

The biomass truck was a 2004 DAF XF 430 hp with EURO III standard exhaust gas emissions (Figure 1). It has a 12.6 litre 6 cylinder DAF engine and 16 speed manual gearbox. The d.g.v.w. is 42,000kgs with a 5 axle truck configuration - tri-axle air suspension trailer with 2 axle tractor unit (4*2).

Figure 1- DAF XF is to the left - biomass truck (BT)

The on board diagnostic (OBD) for the truck involves the installation of a GPS Blackbox with GPS tracker. The Blackbox and associated wiring is fixed under the dashboard on the passenger side of the truck (Figure 2).

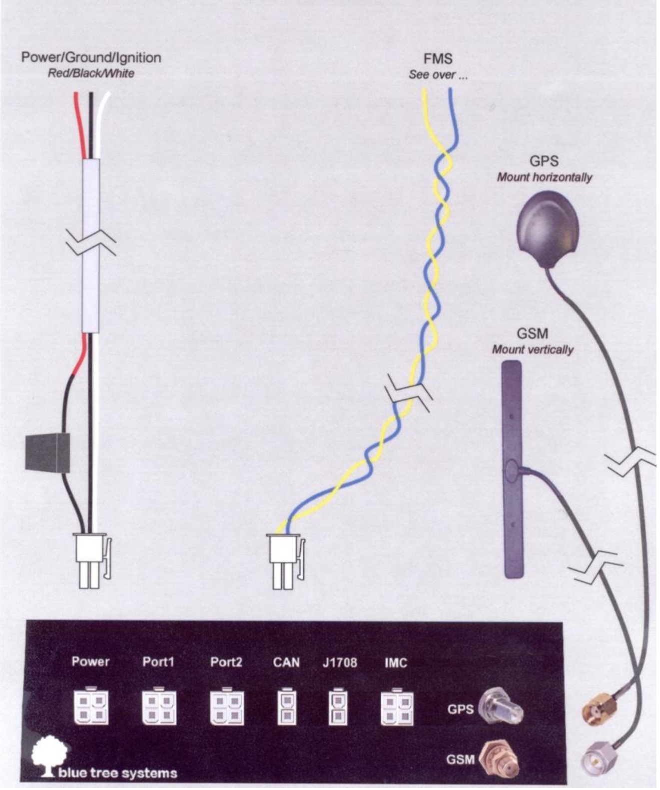


Figure 2 - Schematic of GPS Blackbox wiring (FMS wiring included for engine recording also).

The GPS antenna is positioned on the outer side of the dashboard so that it becomes visible through the front windscreen. The GSM / GPRS (Global System for Mobile Communications / General Packet Radio Service) magnetic antenna is fixed to the inside of the windscreen for optimum signal strength. The FMS (Fleet Management System) cable is used to extract the engine diagnostic information. From figure 2, the blue wire is the CAN_High and yellow is the CAN_Low. These must be connected into the CAN Bus from the FMS gateway on the truck's engine. The GPS Blackbox is fitted with a standard mobile phone SIM card and positional Latitude and Longitude information are recorded by the GPS and sent via the GSM / GPRS phone network to the data servers. This information can then be viewed through PC/ laptop and internet web browser with username and password through the login page of the asset tracker providers. The amount of updated data depends solely on the time interval required by the user. This system operated at 3 minute intervals for each position to be refreshed.

Modern trucks use an electronic data communication protocol known as CANbus J1939 or SAE J1939 (Society of Automotive Engineers). The Fleet Management System is a standard system for reading engine diagnostics from diesel powered engines – trucks in this situation [18]. The 6 main truck manufactures in Europe developed an FMS standard protocol in 2002 to allow independent telematics engine data flow which is coded to the SAE J1939 [19]. This form the basis of the ISO 15031 standard for road vehicles – communications between vehicle and external equipment for emissions related diagnostics [20].

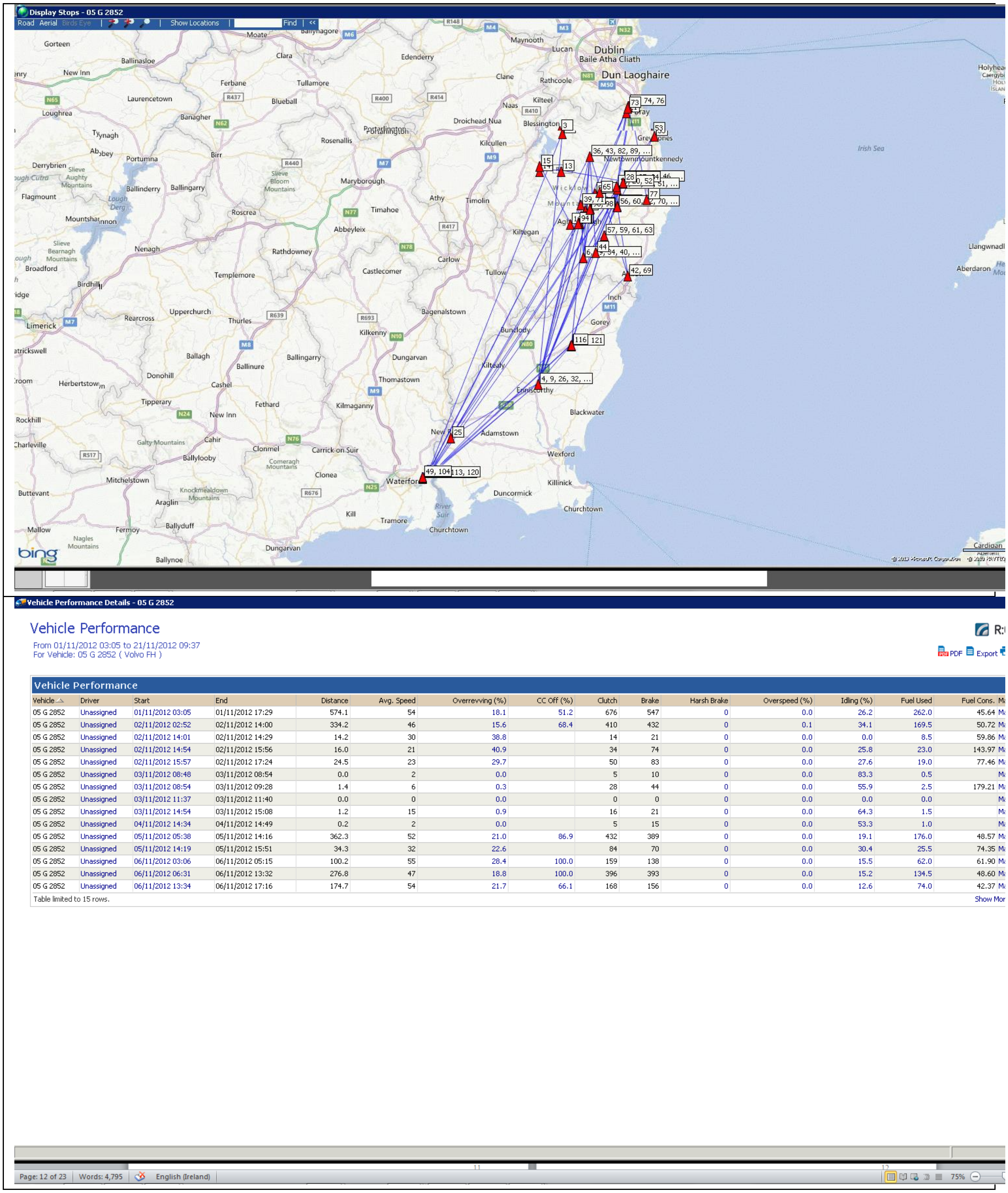
3.1 Results

The system involves connecting into the FMS of the truck and recording engine diagnostic information such as accurate fuel used, litre / km, amount of fuel in diesel tank, maximum revs per minute (rpm) and idling etc. The system can be connected to any FMS of any truck manufacturer's engine so there are no limits to recording the engine and driver performance data for different makes and models. Some stipulations apply in the form of older trucks (older than 1999) where fuel data recording is not possible.

The following results show tabulated data (Table 1) for the BT. Figure 3 shows a screenshot of the web application used to Login and view the data that include parameters such as

- distance travelled,
- speed
- RPM
- Idling
- miles per gallon (mpg),
- fuel litres used
- diesel CO2 emissions.*

*Diesel CO2 emissions are not recorded in real-time but calculated based on the fact that 1 litre of diesel equates to 2.672 kgs of CO2 direct from the tailpipe [21].



Vehicle Performance

From 01/11/2012 03:05 to 21/11/2012 09:37
For Vehicle: 05 G 2852 (Volvo FH)

Vehicle Performance

Vehicle	Driver	Start	End	Distance	Avg. Speed	Overrevving (%)	CC Off (%)	Clutch	Brake	Harsh Brake	Overspeed (%)	Idling (%)	Fuel Used	Fuel Cons.	Ma
05 G 2852	Unassigned	01/11/2012 03:05	01/11/2012 17:29	574.1	54	18.1	51.2	676	547	0	0.0	26.2	262.0	45.64	Ma
05 G 2852	Unassigned	02/11/2012 02:52	02/11/2012 14:00	334.2	46	15.6	68.4	410	432	0	0.1	34.1	169.5	50.72	Ma
05 G 2852	Unassigned	02/11/2012 14:01	02/11/2012 14:29	14.2	30	38.8		14	21	0	0.0	0.0	8.5	59.86	Ma
05 G 2852	Unassigned	02/11/2012 14:54	02/11/2012 15:56	16.0	21	40.9		34	74	0	0.0	25.8	23.0	143.97	Ma
05 G 2852	Unassigned	02/11/2012 15:57	02/11/2012 17:24	24.5	23	29.7		50	83	0	0.0	27.6	19.0	77.46	Ma
05 G 2852	Unassigned	03/11/2012 08:48	03/11/2012 08:54	0.0	2	0.0		5	10	0	0.0	83.3	0.5		Ma
05 G 2852	Unassigned	03/11/2012 08:54	03/11/2012 09:28	1.4	6	0.3		28	44	0	0.0	55.9	2.5	179.21	Ma
05 G 2852	Unassigned	03/11/2012 11:37	03/11/2012 11:40	0.0	0	0.0		0	0	0	0.0	0.0	0.0		Ma
05 G 2852	Unassigned	03/11/2012 14:54	03/11/2012 15:08	1.2	15	0.9		16	21	0	0.0	64.3	1.5		Ma
05 G 2852	Unassigned	04/11/2012 14:34	04/11/2012 14:49	0.2	2	0.0		5	15	0	0.0	53.3	1.0		Ma
05 G 2852	Unassigned	05/11/2012 05:38	05/11/2012 14:16	362.3	52	21.0	86.9	432	389	0	0.0	19.1	176.0	48.57	Ma
05 G 2852	Unassigned	05/11/2012 14:19	05/11/2012 15:51	34.3	32	22.6		84	70	0	0.0	30.4	25.5	74.35	Ma
05 G 2852	Unassigned	06/11/2012 03:06	06/11/2012 05:15	100.2	55	28.4	100.0	159	138	0	0.0	15.5	62.0	61.90	Ma
05 G 2852	Unassigned	06/11/2012 06:31	06/11/2012 13:32	276.8	47	18.8	100.0	396	393	0	0.0	15.2	134.5	48.60	Ma
05 G 2852	Unassigned	06/11/2012 13:34	06/11/2012 17:16	174.7	54	21.7	66.1	168	156	0	0.0	12.6	74.0	42.37	Ma

Table limited to 15 rows.

Show Mor

Figure 3 - Screenshot of the R:COM screen showing map and summary performance table.

Table 1 – Sample Schedule of information from BT (blue = minimum value, yellow = maximum value).

Trip	Daily Distance (kms)	Fuel used (litres)	Litre / km	Payload (Tonnes)	Litres / ton	CO2 emissions
1	179.73	85.01	0.47	29.94	2.84	226.98
2	218.02	88.65	0.41	31.12	2.85	236.69
3	265.81	109.56	0.41	31	3.53	292.52
4	288.65	122.74	0.43	29.91	4.10	327.72
5	127.11	57.73	0.45	30.15	1.91	154.15
6	153.02	61.83	0.40	30.36	2.04	165.07
7	20.92	5.00	0.24	30.8	0.16	13.35
8	243.60	91.83	0.38	28.3	3.24	245.18
9	334.67	130.47	0.39	56.75	2.30	348.36
10	410.62	155.47	0.38	58.44	2.66	415.11
11	333.22	125.47	0.38	59.2	2.12	335.00
12	49.88	11.37	0.23	29.4	0.39	30.34
13	430.73	170.93	0.40	30.1	5.68	456.38
14	407.88	156.84	0.38	30.99	5.06	418.75
15	416.41	161.84	0.39	31.45	5.15	432.11
16	411.58	155.93	0.38	30.78	5.07	416.33
17	434.91	164.57	0.38	30.96	5.32	439.39
18	274.66	80.46	0.29	57.7	1.39	214.84
19	411.26	160.47	0.39	59.79	2.68	428.47
20	412.87	161.38	0.39	57.13	2.82	430.89
21	411.26	170.93	0.42	58.12	2.94	456.38
22	423.81	175.93	0.42	57.9	3.04	469.73

Table 1 shows the daily distance in kilometres, daily fuel litres burned, average daily L / km, the daily total payload weight in tonnes and the corresponding litres / ton together with the corresponding CO2 emissions in kilograms. On some days it can be seen that the payload is in the 50 ton region which implies that 2 load were delivered on that day.

What is important from table 1 is that the minimum and maximum of each recorded variable do not always correspond. For example, the min and max litre / km do not correspond to the min and max distance travelled. The best correlated parameter is the minimum values of distance, fuel litres used, litres / ton and CO2 emissions for trip 7.

In analysing the graphs in figures 4 - 6 below the Linear function used for the regression model was in the form y = a (x) + b

where:

x - independent variable

y - dependent variable

a, b - coefficients

The coefficients are established by the regression analysis at 95% confidence interval.

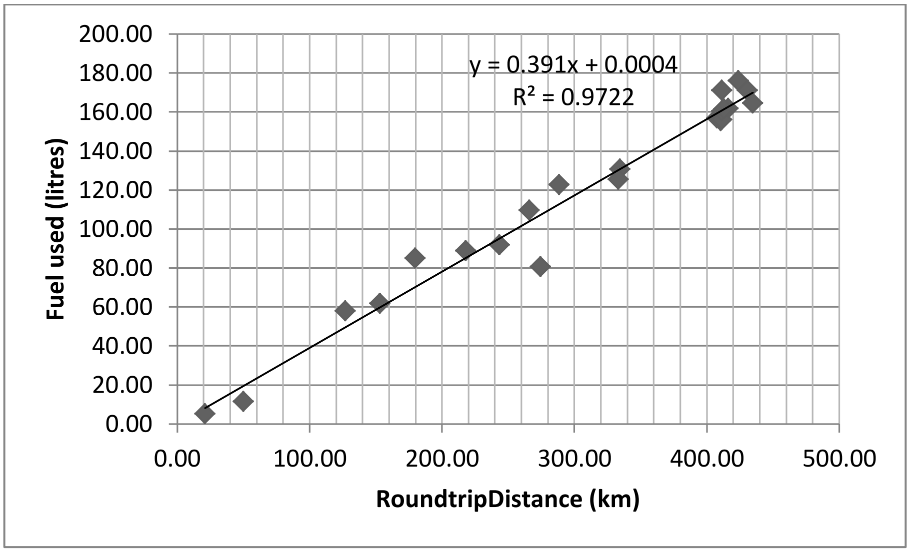


Figure 4 – Trend of fuel used for distance travelled for BT.

Figure 4 above shows regression analysis for fuel litres used versus distance travelled with an R square of 0.9722. For increased distance there will be increased fuel usage but the important thing is that it has been quantified for biomass haulage and the associated travel distances.

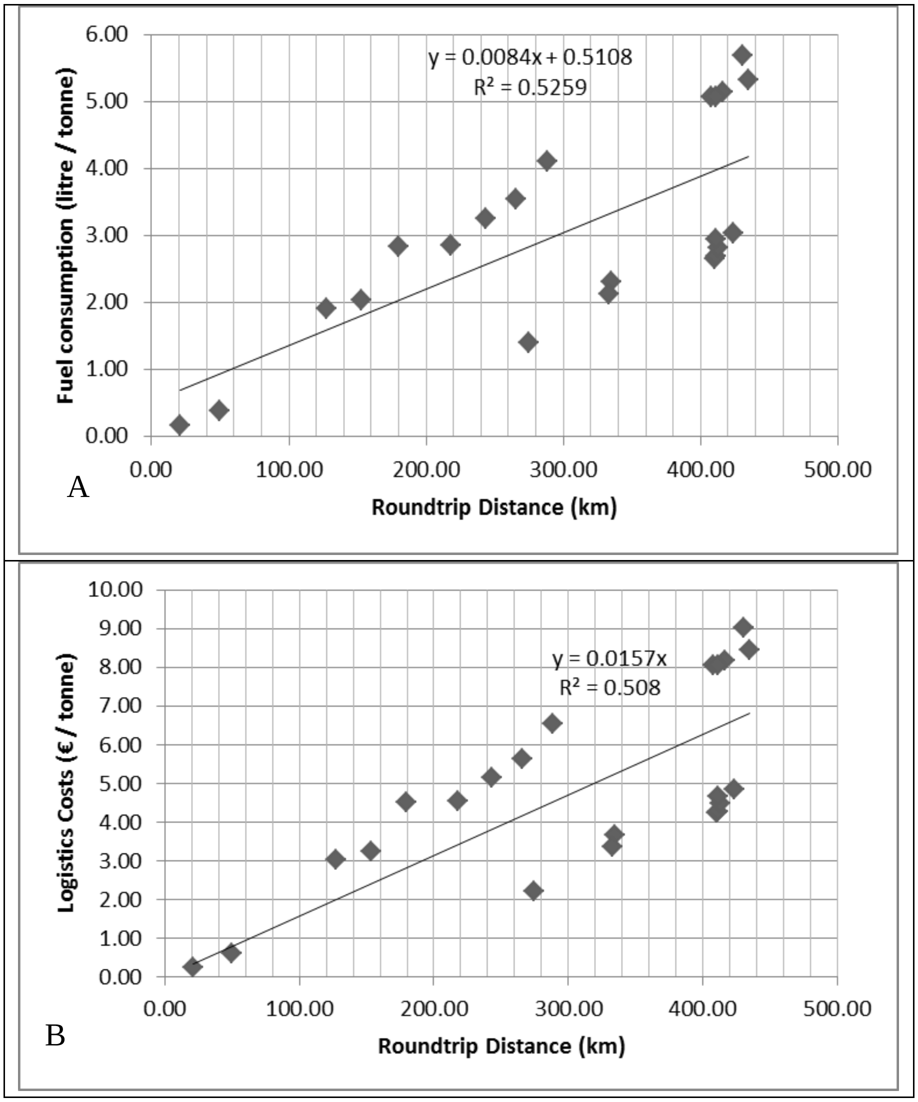


Figure 5A/5B – Trend of litres / ton and logistics costs versus roundtrip distance travelled.

Taking a selection of the data from table 1 and fiure 5A/5B, if the total daily distance is limited to 1 load within 200km (Trip 1 = 179.73 km and 29 940 kgs payload) roundtrip versus 1 load at approximately 400 km trip (Trip 17 = 434.91 km and 30 960 kgs payload) then the % difference in logistic cost (€ / T) is 61%. Delivering 2 loads per 400 km trip (Trip 21 = 411.26 km and 59 790 kgs payload) shows a 5.4% decrease in logistic costs versus the Trip 1 scenario confirming the increased efficiency of a more localised transport approach. A maximum percentage difference in costs of 50% that exists between a 2 load and 1 load trip occurs for Trip 22 and Trip 5 but this increases to 61% when analysing for 2 load versus 1 load for distances over 400 km (Trip 14 versus Trip 22). Trip 7 and 12 are both below 50 km and seem to be the exception and to compare could possibly show an element of distortion. The closest logistic cost to Trip 12 is Trip 6 (153.02 km and 30 360 kgs) with 133% higher costs confirming how a 50 km roundtrip can impact significantly on lowering biomass transport costs. In Finland, raw materials for pellet production can be very high due to the long transportation distances. Subsequently, 300 km is seen as the maximum profit pellet delivery radius [22]. [23] looked at the wood fuel production costs of 3 different systems – chipping at roadside, chipharvester system and chipping and transport system. The latter being the most cost efficient when the transport distance ranges between 40 and 80 km.

Vehicle utilisation is an important aspect when analysing loads per day versus fuel efficiency per unit of production. It has a direct effect of transport cost as the truck must be working in order to make money when payment is based on distance or tonnage delivered. Excessive loading and unloading times can effect this efficiency but results show here that potential multiple biomass deliveries per day in a localised manner with roundtrip distances limited to a maximum of 200km can keep transport fuel consumption per unit of production low and efficiency high [24-26]. Studies in Eastern Finland at how to maximise the forest fuel supply for power plants suggest increasing the forest procurement area by increasing transport distance from 60km to 100km [27]. Similar work by [28] looked at analysing the supply chain costs of long distance transportation of energy wood in Finland in a multi modal type approach. For distances under 60km, trucks transport of loose residues to end facility is cheapest. Longer distances showed chipping at roadside as opposed to end facility comminution and truck transport more cost efficient. However, when transport distance went from 135 km to 165km then train transport became the preferred and cheaper option. Rail freight of biomass in Ireland is currently non-existent and will continue to be dominated by truck. At present, only pulpwood from Ballina and Westport, Co Mayo (Ireland West) is delivered in 600 ton payloads to Waterford Port (Ireland South East) once a week for either export or use by the wood based panel mill, SmartPly Ltd.

3.1.1 Calculation of Carbon Emissions

Ireland, as a member of the European Union must adhere to set limits and regulations for vehicle emissions under Directive 2005/55/EC [29]. The BT was registered in 2004 and thus adheres to EURO III emissions standards. According to the standards, there are in fact no limits set for carbon dioxide (CO2) emissions. The limits represent an “ultimate CO2” which effectively refers to all the carbon being emitted from the tailpipe in the form of carbon monoxide (CO), nitrogen oxide (NOx), hydrocarbons (HC) and particulate matter (PM) (RSA, 2012 and [30]. According to [6], measuring CO2 emissions from freight transport is not an exact science. Depending on the trucking activity and the method of measuring, estimates can vary by as much as 30%. Attention has focused a lot on vehicle related emissions in recent years and more so freight transport as this is the largest share of emissions within EU countries [16, 17, 31]. The main methods of CO2 estimating revolve around 5 different techniques [6]. Vehicle emission testing involves testing under laboratory conditions on a dynamometer where the truck can be run at different speeds to simulate drive cycles and tailpipe emissions are recorded. This is part of the certificate of roadworthiness for all goods vehicles in Ireland. A survey of road freight operators aims to record distance travelled and fuel usage over a defined period of time allows CO2 estimates to be calculated. National road traffic surveys are perhaps a more comprehensive method to record truck-kms as manual and automated traffic flows are recorded on numerous routes by vehicle type. The National Atmospheric and Emissions Inventory in the UK is the main database of emissions from all sources. The data is mainly retrieved from the methods mentioned above [32]. The use of on board diagnostics can provide the most realistic method to record C02 emissions as it allows fuel consumption to be accurately recorded. From there, conversion factors are more reliable to use simply because the recorded data is more real and reliable. To determine the carbon footprint of the routes travelled for this study (figure 6), C02 emissions were calculated based on amount of recorded diesel fuel used and that 2.672 kg of CO2 is emitted into the atmosphere from the tailpipe for every litre of diesel burned. Figure 6 below shows how CO2 emissions and Payload vary over distance indicating how tonnages and distance travelled affect the concept of carbon friendly routing.

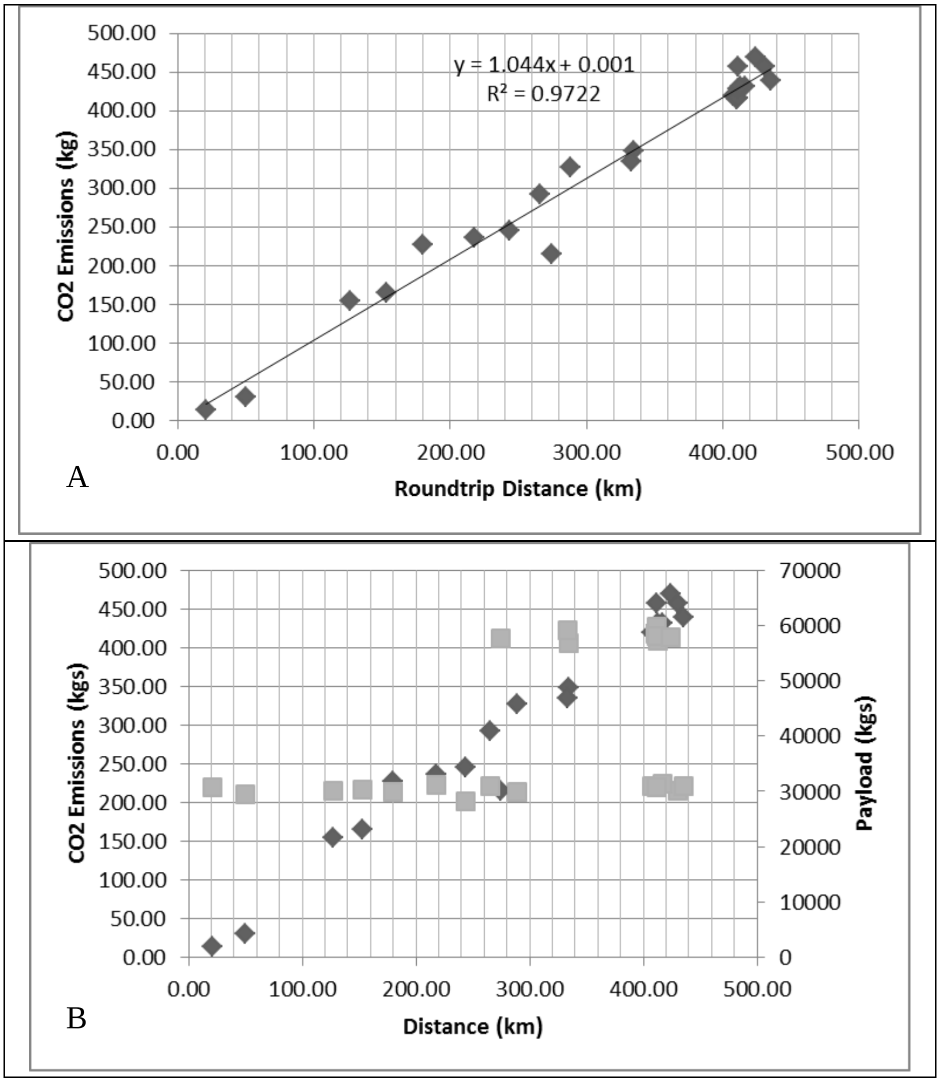


Figure 6A/6B - Trend of CO2 emissions and Payload to distance.

As perhaps expected, figure 6A shows a good correlation between CO2 emissions and distance. Figure 6B quantifies the delivered payload with associated CO2 emissions for a specific distance travelled.

When analysing the GHG (greenhouse gas) emissions of co-firing versus biomass based power plants [33] used LCA (life cycle assessment) techniques and set optimal transport distances of 100 km for the herbaceous biomass residues and 50 km for the dedicated energy crop resources. Other studies in Croatia limited the transport distance to 50km for different sized power plants ranging from 100 kt – 300 kt biomass intake [34] while [35] considered the logistic costs of baled rice straw for power generation in Thailand at various transport radii of 20 km, 40 km and 80 km.

4.1 Discussion

The ability to monitor the fuel in the tank is a massive bonus for haulage companies who can now compare fuel bills with live and recorded used fuel data for each truck. In most cases in the ITTS, diesel fuel bills are itemised based on truck registration so cross referencing between paper invoices and recorded data becomes a lot easier to identify any potential fuel theft in the form of siphoned diesel. From the author's experience, the issue of siphoned diesel is a major concern for truck companies. Using a system like this can prevent this to improve fuel usage as a result. The system does this by recording the exact amount of litres of diesel in the tank, this figure can be checked once the truck has finished the days work on the PC. If, on re-starting the truck the next morning there is a discrepancy in the amount of diesel without the truck having actually travelled anywhere (which can be checked from the GPS tracklog) then the most logical assumption is that diesel is being siphoned from the tank for use elsewhere. Being able to eliminate this would be an automatic money saving tactic, especially in today's markets where the biggest expense for transport companies is diesel fuel.
Litre / km for the BT varies from 0.23 to 0.47. This compares reasonably well with 0.55 L / km (16% less efficient) for Swedish timber haulage [5]. The average figure of 0.39 L / km for articulated trucks travelling on UK roads shows a 19% better efficiency [6] . Trends in fuel consumption for all road freight for Finland for similar type truck (Euro III) suggest approximately 0.54 L / km at the 60 000 kg dgvw. This reduces back to approximately 0.46 L / km for a 44 000 kg dgvw which is effectively the same as the Irish scenario [22, 36, 37]. Carbon dioxide (CO2) emissions are directly related to amount of diesel burned and 1 litre corresponds to 2.672kgs of CO2. This helps identify the carbon footprint of each analysis purely from a Tank-to-Wheel (TTW) evaluation. TTW accounts for the energy and greenhouse gases (GHG) emissions from the use of the fuel in the trucks. Total CO2 emissions for the month amount to 6953.76 kg. CO2 emission calculation through TTW allows route planners to designate more carbon friendly routes when pre-planning pick and delivery along with other factors such as distance and litre / km [10]. Being able to reduce CO2 emissions through effective route planning and optimized vehicle use is a big issue now in Ireland.

Ireland, like all EU 27 countries has a legal binding to the EU Directive 2009/28 EC which sets a target of 20% of all energy consumption to come from renewables by 2020 [38]. Ireland's contribution to this target is set out in the National Renewable Energy Action Plan which ensures that 16% of all national energy consumed from transport, electricity and heat will come from renewable sources by 2020 [39]. This will be achieved in the form of 40% electricity generation from renewable energy sources (RES), 12% for the consumption of heat and 10% for the transport sector.

In 2010 the main fuel sources for electricity generation in Ireland was comprised of natural gas (61%), coal (17.6%) and peat (10%). Other sources included wind (4.9%), fuel oil (2.1%), landfill gas, biomass and other biogas (1.5%) with the remainder being made up from electricity imports (0.8%) and 0.7% of gas oil and refinery gas [40].

Renewables for electricity generation in total accounted for 7.4% in 2010 with 1.3% being biomass. Renewables in this scenario include wind, hydro, landfill gas, biomass and other biogas. In 2009 and 2010 the energy output was 13.7% and 14.8% respectively (normalized). The target for Ireland in 2010 was 15% (which was effectively met) and the target for 2020 is set at 40%. Ireland is heavily depended on imported fossil fuels with net imports of approximately 86% in 2010 of the total primary energy requirement (TPER) down from a peak of 90% in the year 2006. Ireland's overall energy use declined by 0.3% in 2010 mainly due a contraction in the economy of 7% in 2009 followed by 0.4% in 2010 [1]

Fleet engine diagnostic technology is still relatively new to Ireland and it is hoped through this work that it can assist truck companies to make the informed decisions by being able to continually analyse engine data and knowing then how to best to reduce the associated costs. This can be achieved in the form of a "score-carding" system for individual drivers to determine the performance and efficiency of each truck and it's driver. The score-card will be based around how well driver's perform around idling, harsh braking or acceleration, speeding, over revving (green band rpm versus red band rpm), lack of use of cruise control and gear shifting. This will lead to the concept of a monitoring system for eco-driving. The data will present a "good", "bad" or "poor" monthly driver performance relative to fuel consumption targets and RPM bands that will assist transport managers in driving transport costs down.

It is envisaged that all trucks operating in the biomass sector in Ireland will be fitted with the similar tracking and communication technology. This will pave the way for a central dispatch system to monitor the biomass truck movements to deliver the required levels of service to customers at an optimum transport cost by optimising vehicle utilisation, minimising travel distances through routing, reduce CO2 emissions and decrease fuel consumption for an overall increase in the biomass truck sector performance.

5.1 Summary

The GHG analysis adds to the environmental aspect and the concept of eco-friendly truck driving where Ireland are committed to reducing CO2 levels to 13% above 1990 levels under the Kyoto Protocol. Skogforsk, the Swedish Research Forest Institute have published many articles on the idea of optimal and integrated logistics of timber haulage including work on Central Tyre Inflation (CTI) projects to minimize internal and public road damage and increase access to forests during the spring thaw and help decrease transport costs for roads with reduced passability [41]. The TRANSMIT project showed that better EcoDriving (driver training) reduced fuel consumption across designated reference roads up to 15%. Forsberg and Lofroth 2003 [42] concluded that the quality of the road is crucial. The worst roads caused 25 to 40% higher fuel consumption.

The transport share of energy related CO2 emissions in Ireland accounted for 36% of the total primary energy supply in 2007. Road freight alone recorded the largest growth from 1990 to 2007 where CO2 emissions were 182% higher in 2007 than in 1990. Growth in 2007 alone was 5.3%, slightly below the rate of economic growth of 6% [1]. It is clear that in order to attempt to reduce fuel consumption and CO2 emissions, there must also be a proven method to accurately record the data.

Devlin et al. 2008 [10] showed how the incorporation of in cab GPS and engine and fuel diagnostic technology could be managed, used and benefit the Irish Timber transport sector. Today there are currently 80 trucks instrumented in the contracted Irish timber fleet with a total of 230 trucks to be fitted with this technology by the middle of 2013. It is estimated that using this new technology will offer 5% savings on energy usage per year which equates to reducing 189 000 litres of diesel fuel representing an annual saving in GHG emissions of 508 000 kgs and cost savings in monetary terms of €230 000.

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