Estimating the transportation Cost of UK Brewery spent grains using Spent Grain Costing Model (SGCM)

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Abstract

With the establishment of increasing numbers of small breweries the disposal of wet brewery spent grains (WBSG) may pose difficulties in the future particularly for urban breweries and if transport costs make collection uneconomic. The aim of this study is to estimate the transportation cost of spent grains from beverage production. This aim is investigated using a survey addressed to UK breweries. In order to achieve the aim of this study, a model was applied; namely spent grain costing model (SGCM).The SGCM model revealed that the majority of vehicles used to transport WBSG from three different sizes of brewery (small, medium and large) to farms were between 1 to 6 tonne loading capacity and the average distance from these breweries to farms was 5 miles. Data analyses were conducted by three vehicles classes and they were categorized in terms of loading capacity 1 tonne, 3 tonnes and up to 6 tonnes. This analysis was conducted to determine the average cost of transporting WBSG from breweries to farms. The results indicated that the average transport cost per tonne of WBSG for vehicle with the sizes of 1 tonne, 3 tonne and 6 tonnes were £ 10.11, £5.20 and £3.27 respectively.

Key words: Transportation, Breweries, WBSG, SGCM model.

JEL code : Agriculture: General Q100

1. Introduction

Brewery by-products can be potentially valuable resources for agriculture. Spent barley grain, hops and surplus yeast are the major by products. Spent grain has the most value because of its high levels of sugars and proteins (Mussatto et al., 2006a). As these are by products rather than waste products, they can be recycled and reused in the food and agricultural industries. As a result, the brewing industry tends to be more environmentally friendly compared to other industries (Ishiwaki et al., 2000).

Wet brewery spent grain (WBSG) is the material that is remaining after grains have been mashed to extract starch and sugars during the beer making process. These materials can be fed to cattle in the wet form (wet brewer‘s grains) or dried (dried brewers’ grains). Breweries generate more than 250 million tons of spent grains every year in the UK. Traditionally spent grain is used as cattle feed being a valuable supplement to existing feed due to its high protein content. In addition it is a good source of dietary fibre (Mussatto et al., 2006b).

Large scale brewing can provide large quantities of spent grain with up to 10 tons being produced per brew. Efficient breweries may now produce 12 brews per day allowing a continuous supply of spent grain to be available. The economics of bulk transport allow this to be delivered regularly to large dairy farms and command a reliable price to the brewery. However, small scale production may only produce between 0.25 and 2 tons per brew inconsistently often just 2 to 4 times per week. Such supplies are inappropriate for large farms and most is collected by small farms often for no charge and using farm transport. Although the brewery loses payment for the grains it does remove it from the premises preventing spoilage. In particular it avoids the brewery paying a landfill charge which would be charged if disposed of by standard waste handing.

The aim of this study is to estimate the transportation cost of spent grains from beverage production. This aim is investigated using a survey addressed to UK breweries. The data allowed the breweries to be grouped into three sizes, small, medium and large according to the scale of production of wet brewery spent grains WBSG.

2. Methodology

With the establishment of increasing numbers of small breweries, the disposal of spent grains may pose difficulties in the future particularly for urban breweries and if transport costs make collection uneconomic. This study has analyzed the economics of spent grain production and developed a model to assess the limits of profitability in different options of disposal.

The Spent Grain Costing Model (SGCM) used in this study is based on the ORWARE model (ORganic WAste REsearch) developed by the Royal Institute of Technology in Sweden (Eriksson, 2002). It is used for environmental systems analysis of waste management and provided the basis for a module able to assess the transport costs of brewery waste.

To obtain data for the model, 84 breweries were surveyed ranging in size from 320 to 6,400-liter production per batch. Production varied from 1 to 5 brews per week with a spent grain production ranging from 1 to 10 tons per week. Some breweries disposed of grain after every brew, others compiled grain for a single collection each week. For transport of spent grains, there are three types of vehicles used in this model in terms of their load capacity which are 1-ton load, 3 ton and 6 ton respectively. Data on average load, average speed etc. are used as input in all transport sub-models. The output is total energy consumption, time consumption and costs. The (SGCM) was created with the MATLAB/SIMULINK software (Math Works 1998) as shown in figures (1a- 1f).

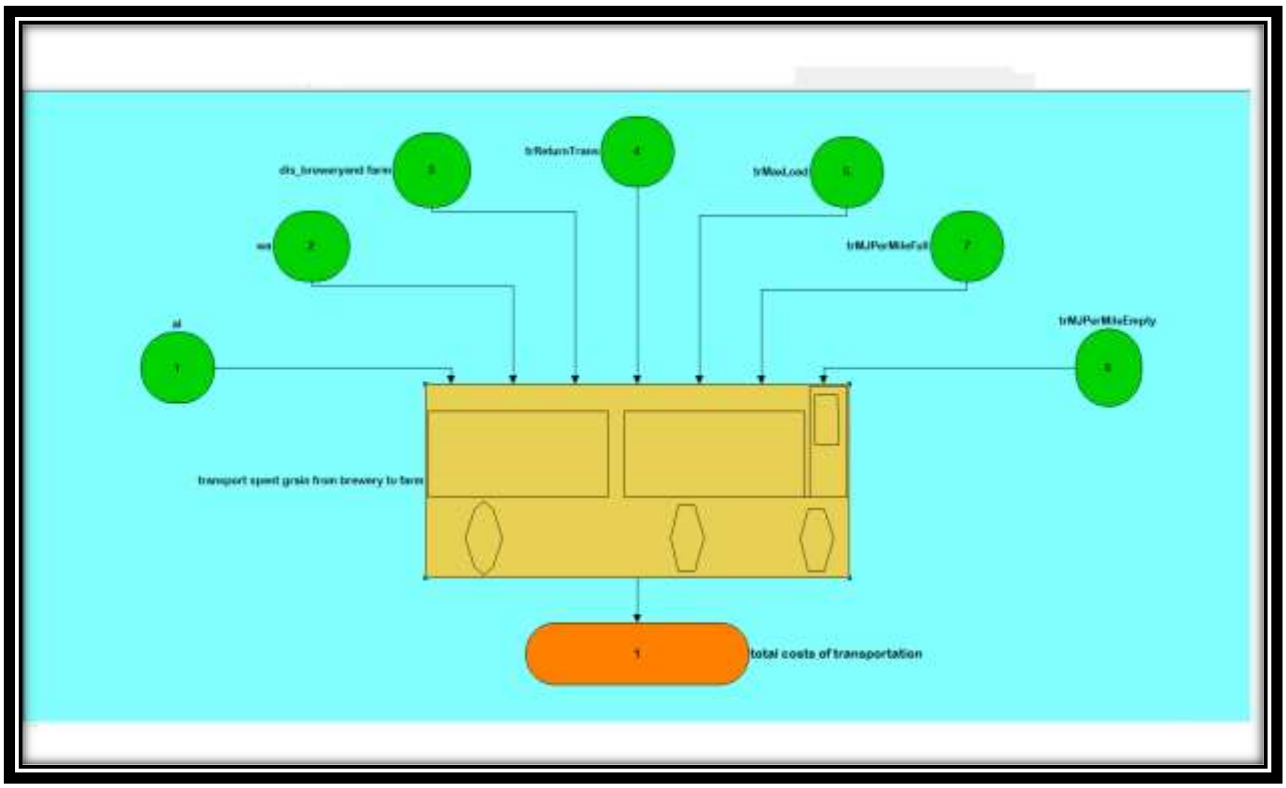

Figure 1a : Spent Grain Costing Model (SGCM)

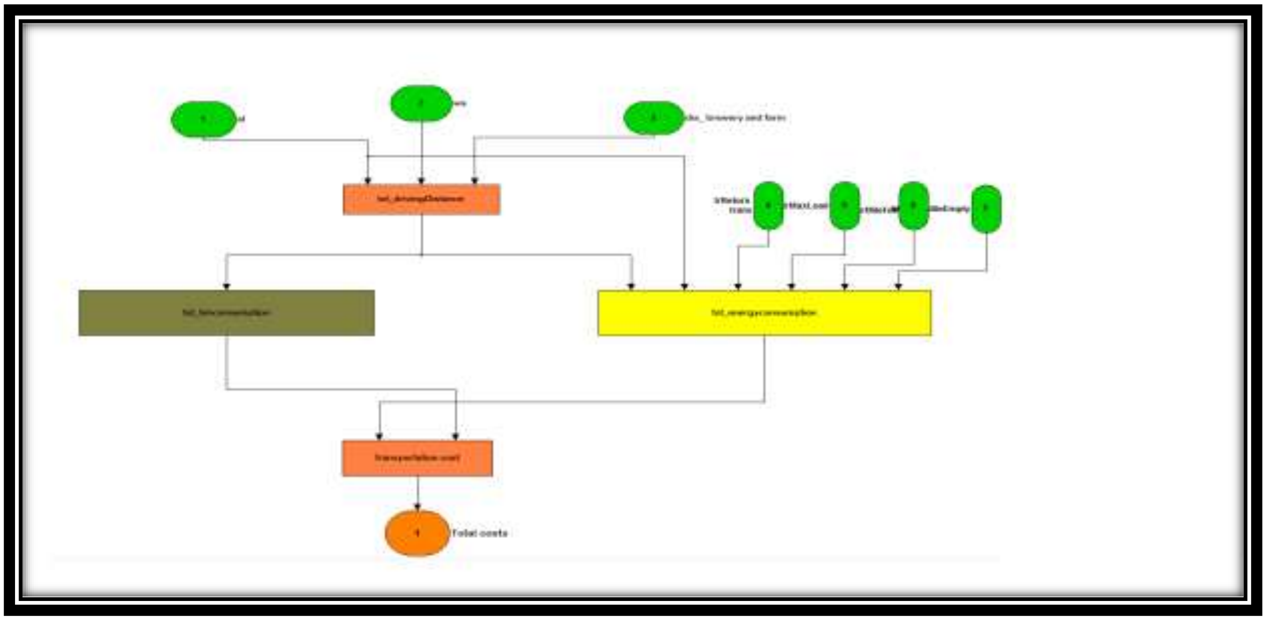

Figure 1 b : calculations in SGCM

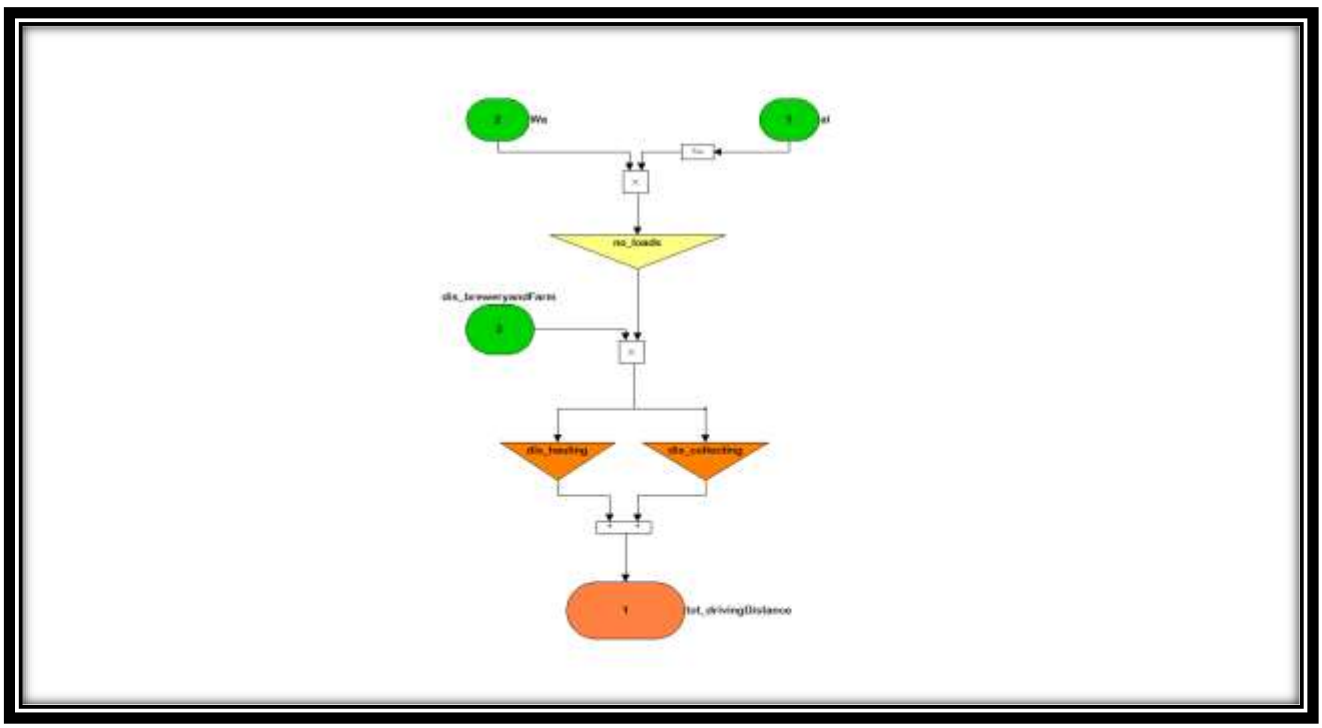

Figure 1c : Average total driving distance

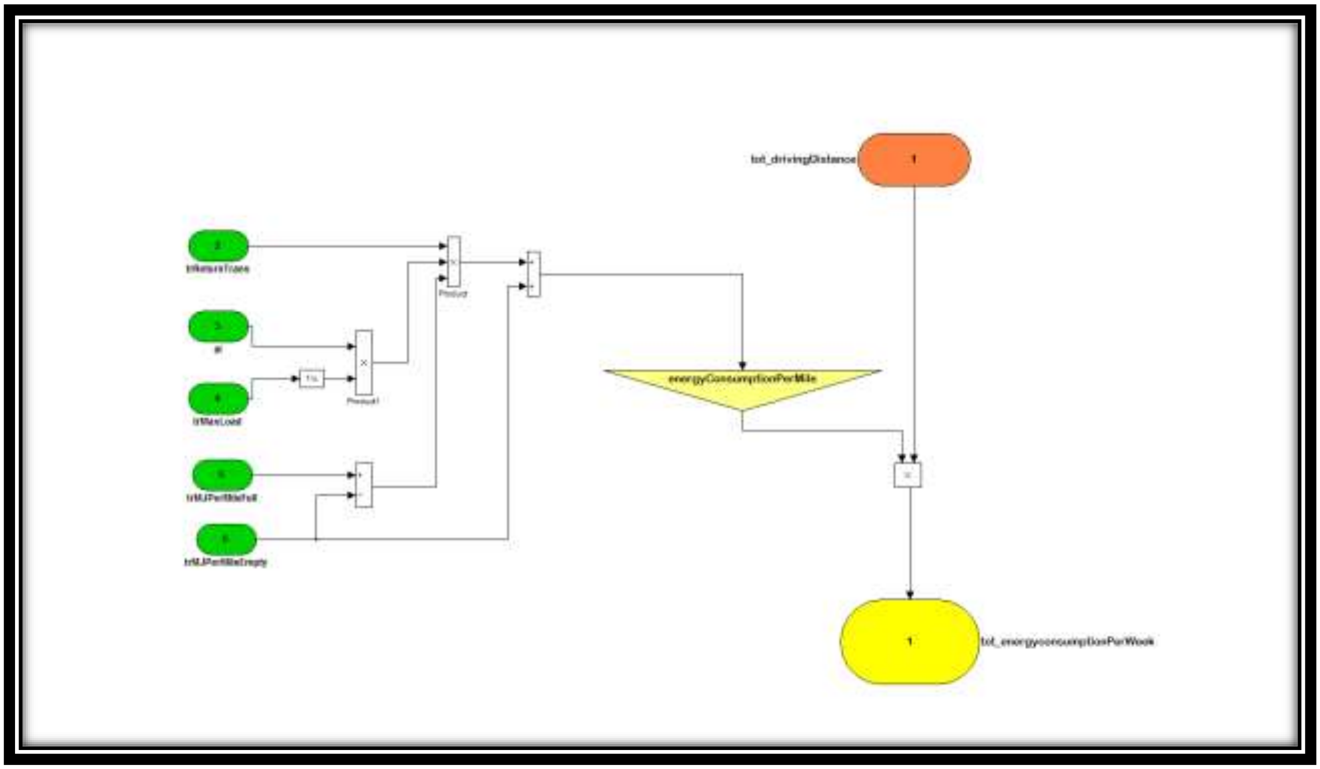

Figure 1d : Average Total Energy Consumption

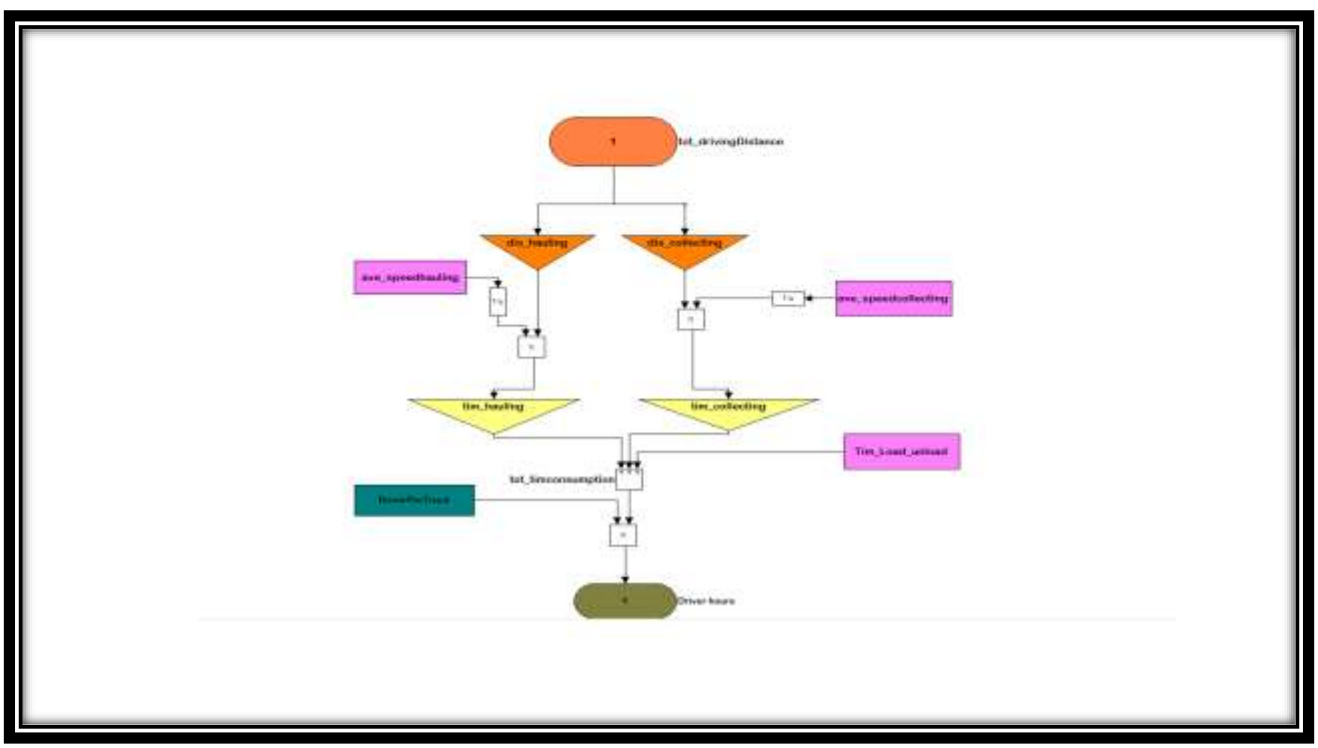

Figure 1e : Average Total Time Consumption

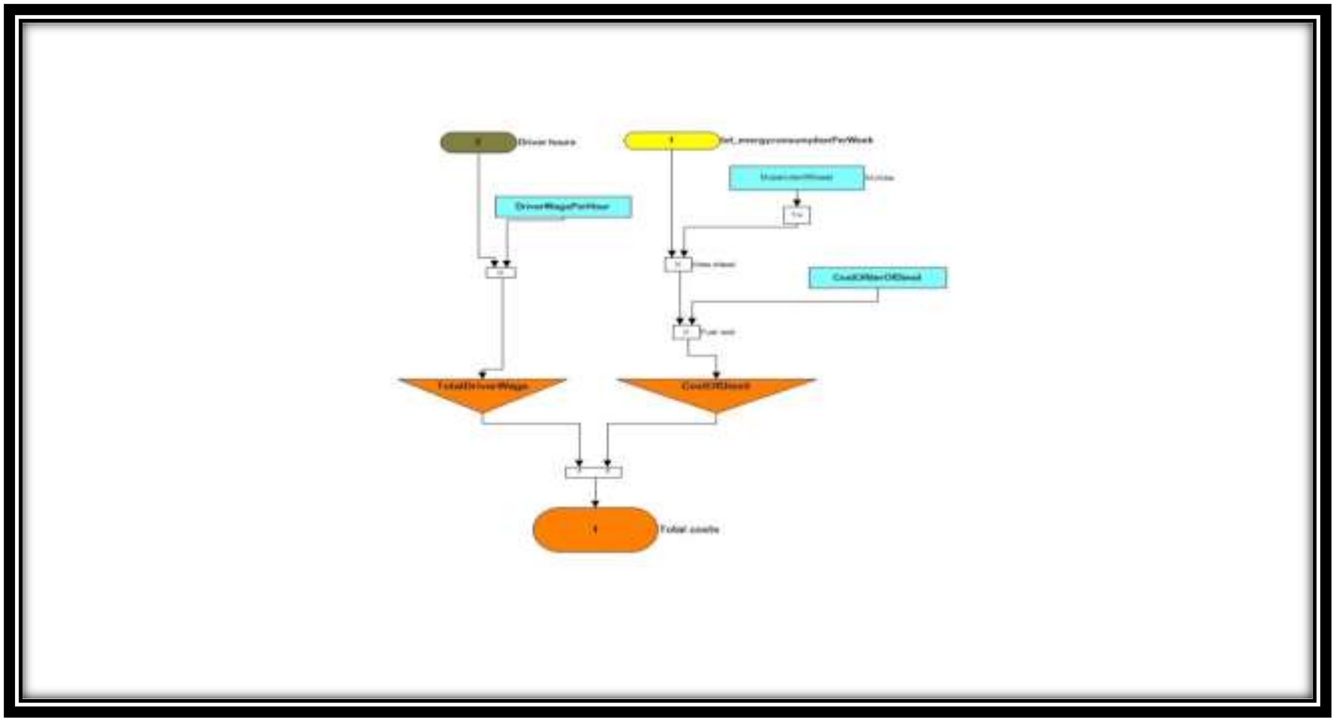

Figure 1f : Average Total Transport Cost

2.1 Sensitivity analysis

Sensitivity analysis is required the development of models in any scientific field. A model is a simplified version of a part of reality that offers a comprehensible description of a problem situation. Sensitivity analysis examines the extent of variation in predicted performance when parameters are systematically varied across a range of interest, either individually or in combination. Sensitivity analysis provides further confidence in a model, and indicates priority areas for refinement if further versions of a model are to be developed. In addition, the sensitivity analysis offers interesting possibilities to determine what the most important parameters in given model is. In this study, the sensitivity analysis was conducted for Spent Grain Costing Model (SGCM), on the cost of transporting brewery spent grain from the brewery to the farm.

3. Results

Delivery distances for wet brewery spent grain (WBSG) ranged from 0.5 to 20 miles with small volumes generally being delivered within 5 miles of the brewery. Grains from medium and larger breweries were typically delivered a longer distance but used larger vehicles. Larger breweries also produced more brews per week and as a result total driving distances differed considerably for the scale of production. From SGCM results, total driving distance per week for transporting WBSG from three scale breweries (small, medium and large brewery) by three different vehicles in terms of their load (vehicle 1, vehicle 2 and vehicle 3) were (18.3 ± 3.3), (34.9 ± 12.5) and (32.5 ± 9.7) miles per week respectively (Figure 2).

Diesel consumptions for the three vehicles were (2.5 ± 0.4), (6.1± 2.2) and (7.25 ± 2.0) litres per week respectively (Figure 3) and time consumptions were (0.7 ± 0.1), (1.2 ± 0.3) and (1.17 ± 0.4) hour per week respectively (Figure 4).

Moreover, the average transport costs for the three vehicles were calculated by the model per tonne loaded (ATCT) and they were (£10.11 ± 1.5), (£5.20 ± 1.7) and (£3.27 ± 2.3) per tonne loaded (Figure 5).

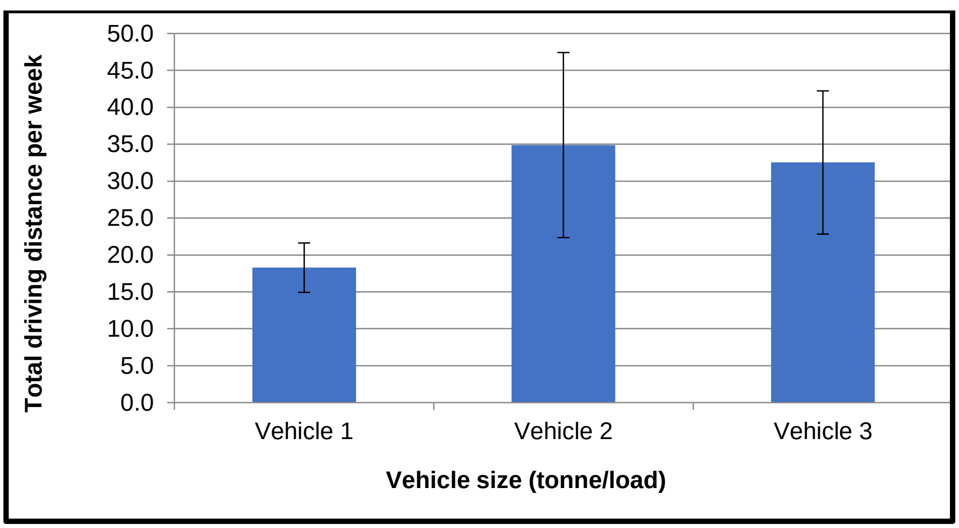

Figure 2: Average driving distances for different delivery volumes of WBSG.

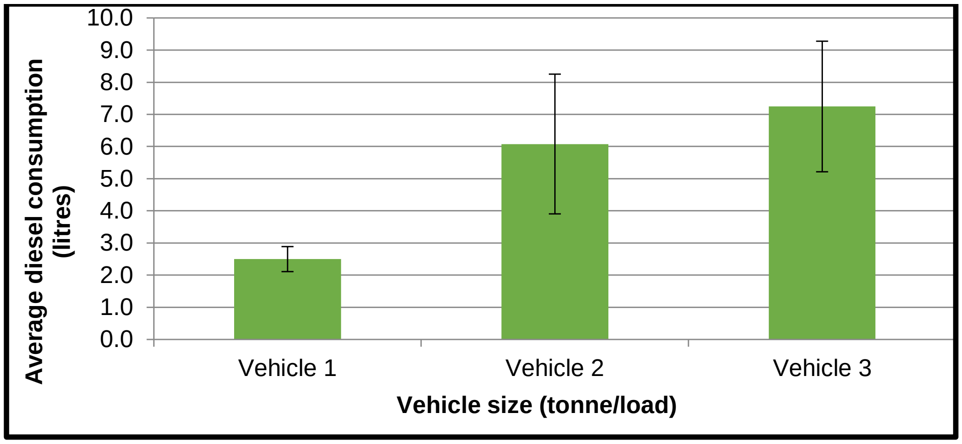

Figure 3 : Average diesel consumption for three different vehicles.

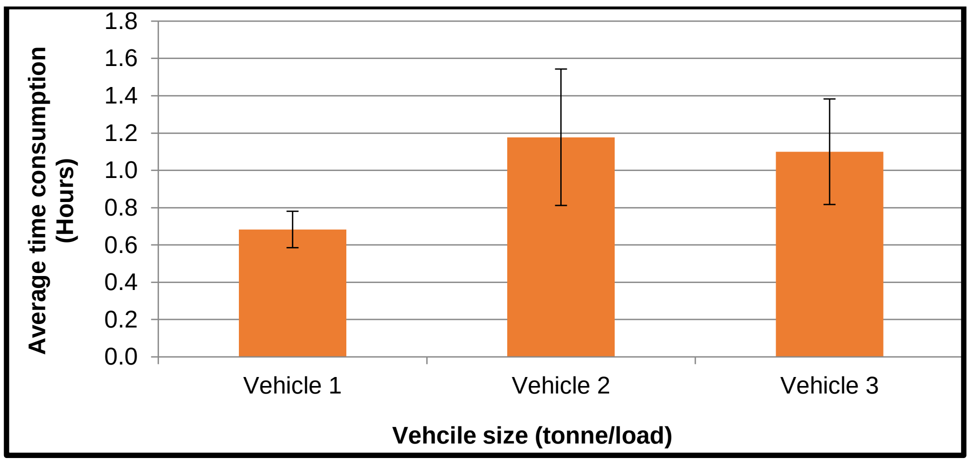

Figure 4: Average time consumption for three different vehicles

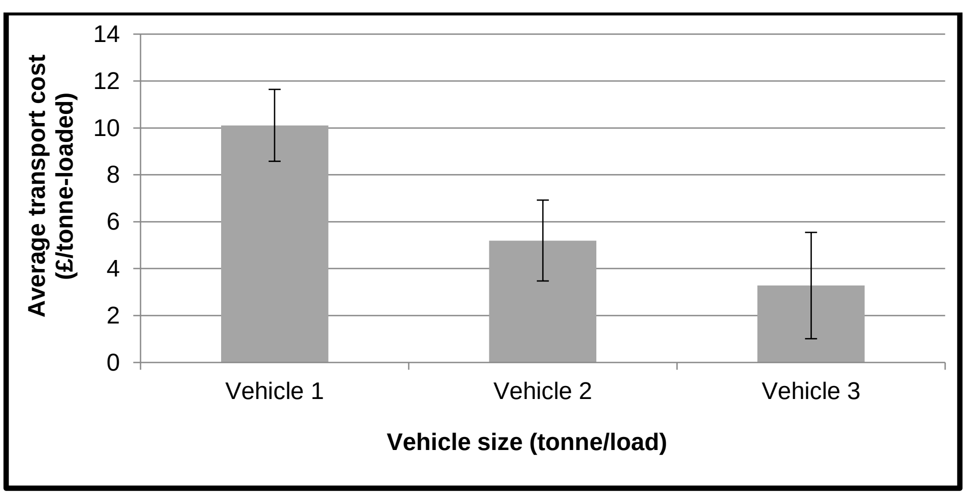

Figure 5: Average total cost per tonne for transporting brewery spent grain

3.1 Sensitivity analysis results

In this analysis, the effects on average transport cost of wet brewery spent grain (WBSG) due to increasing diesel prices, driver wages and the distances between breweries and farms were examined and evaluated.

a) Increasing driver wage and its effect on the cost of transportation per tonne.

This analysis determined the sensitivity of increasing the driver wage from £7/hour to four levels (£7/hour, £9/hour, £11/hour and £14/hour), with diesel price at (£1.19/litre) remaining constant. The transport cost was sensitive to the increase in driver wage for the three vehicles (Figure 6). However, vehicle 1 recorded the highest transport cost increase of 64% when the driver wage was increased by 100% (Table 1).

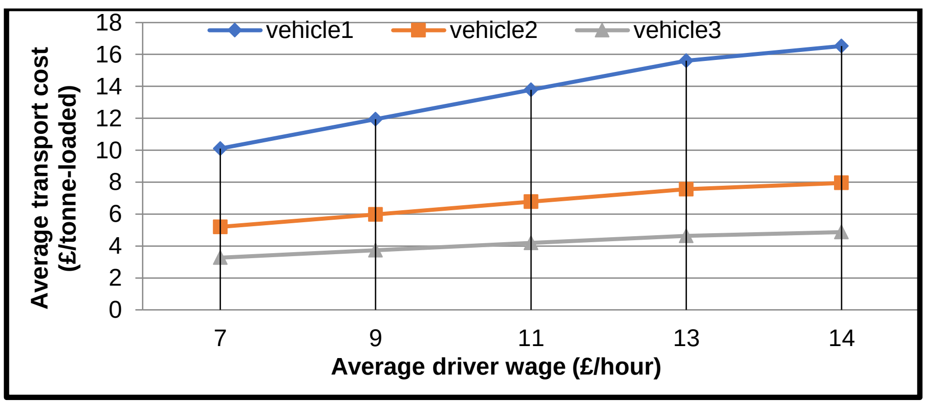

Figure.6 Transport cost per tonne when the driver wage increased from £7/hour to £14/hour.

Table 1: The percentage of average transport cost per tonne increase when the driver wage increases by 100%

	Average transport cost (driver wage £7/hour)	**Average transport cost** (driver wage £14/hour)	**Change (%)**
Vehicle 1	10.11	16.53	+ 64
Vehicle 2	5.20	7.95	+ 53
Vehicle 3	3.27	4.87	+ 50

b) Increasing diesel price and its effect on the cost of transportation per tonne.

This analysis determined the sensitivity of increasing price of diesel from (£1.19/litre) to four levels (£1.37/litre, £1.5/litre, £2.00/litre and £2.38/litre), with the driver wage remaining constant. The transport cost was sensitive to the increase in driver wage for the three vehicles (Figure 7). However, vehicle 3 recorded the highest increase in transport cost of 50% when the diesel price increased by 100% (table 2).

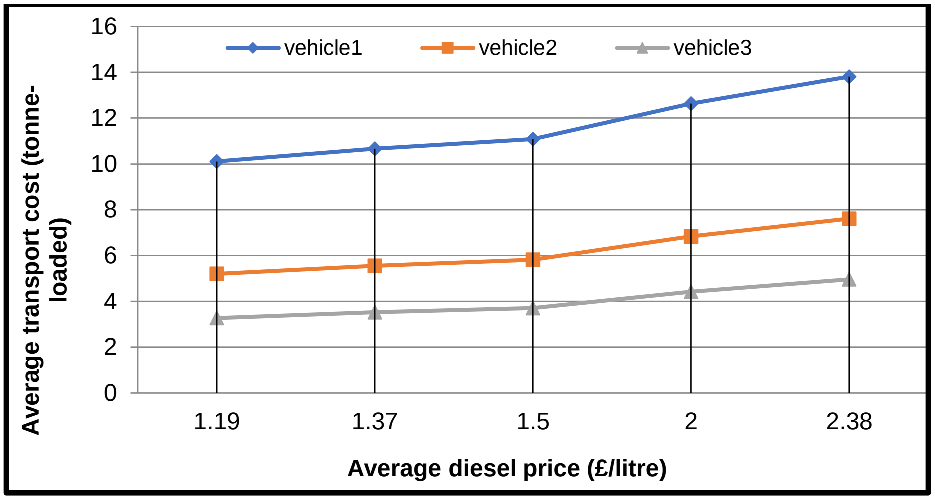

Figure 7: Average transport cost per tonne loaded of WBSG when the cost of diesel increased from £1.19/litre to £2.38/litre.

Table 2: The percentage of average transport cost per tonne increase when the diesel price increases by 100%

	Average transport cost (diesel price £1.19/litre)	**Average transport cost** (diesel price £2.38/litre)	**Change (%)**
Vehicle1	10.11	13.81	+ 36.7
Vehicle2	5.20	7.61	+ 46.3
Vehicle3	3.27	4.96	+ 51.7

c) **Increasing driver wage and diesel price at the same time and their effect on the cost of transportation per tonne (ATCT).**

This analysis determined the sensitivity of increasing price of diesel from (£1.19/litre) to four levels (£1.37, £1.5, £2.00 and £2.38/litre), with increasing driver wage from £7/hour to four levels (£9, £11, £13 and £14/hour) at the same time. The transport cost was sensitive to the increase in diesel price and driver wage together at the same time for the three vehicles. Average transport cost per tonne (ATCT) for the three vehicles increased to (£12.5 ± 1.9), (£6.34 ± 2.1) and (£3.98 ± 1.1) respectively when the price of diesel increased to £1.37/litre and driver wage to £9/hour (Figure 8). ATCT for the three vehicles increased to (£14.75 ± 2.2), (£7.40 ± 2.5) and (£4.62 ± 1.2) respectively when the diesel price increased to £1.50/litre and driver wage to £11/hour (Figure 9). ATCT for the three vehicles increased to (£18.14 ± 2.7), (£9.20 ± 3.0) and (£5.79 ± 1.5) respectively when the price of diesel increased to £2/litre and the driver wage to £13/hour (Figure 10).

ATCT increased for the three vehicles to (£20.23 ±3.1), (£10.37 ± 3.4) and (£6.55 ± 1.7) respectively when the price of diesel increased to £2.38/litre and the driver wage to £14/hour (Figure 11). However, the average transport cost for the three vehicles increased by %100 as the diesel price and the driver wage increased by 100% (table 3).

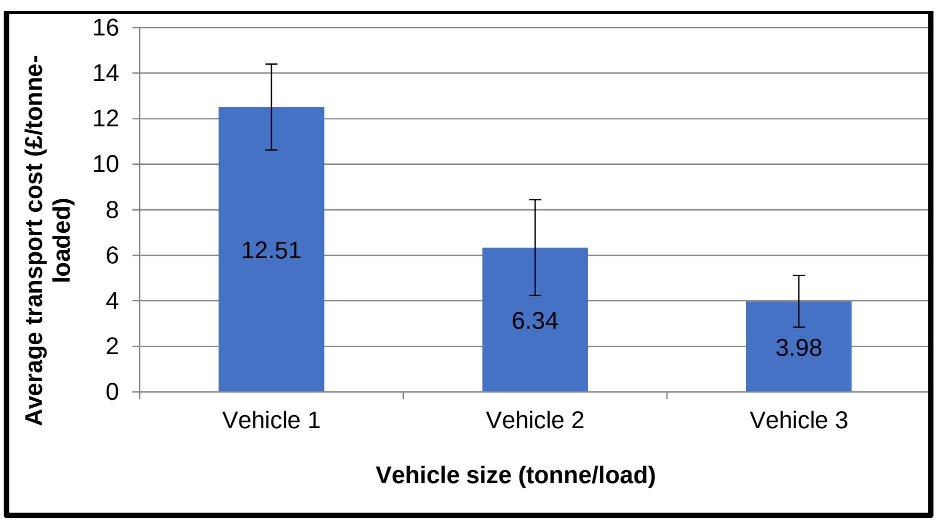

Figure 8: Average transport cost per tonne loaded of WBSG when the cost of diesel increased to £1.37/litre and driver wage increased from to £9/hour.

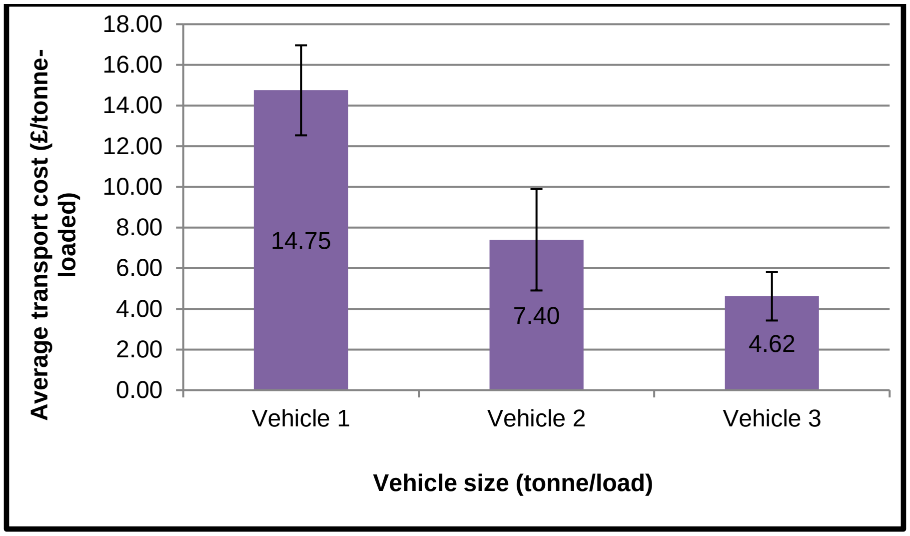

Figure 9: Average transport cost per tonne loaded of WBSG when the cost of diesel increased to £1.50/litre and driver wage increased from to £11/hour.

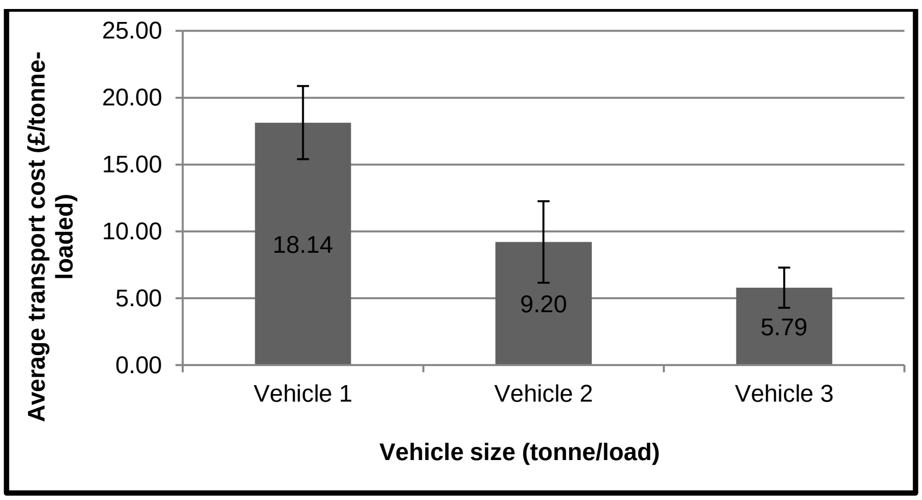

Figure 10: Average transport cost per tonne loaded of WBSG when the cost of diesel increased to £2/litre and driver wage increased to £13/hour.

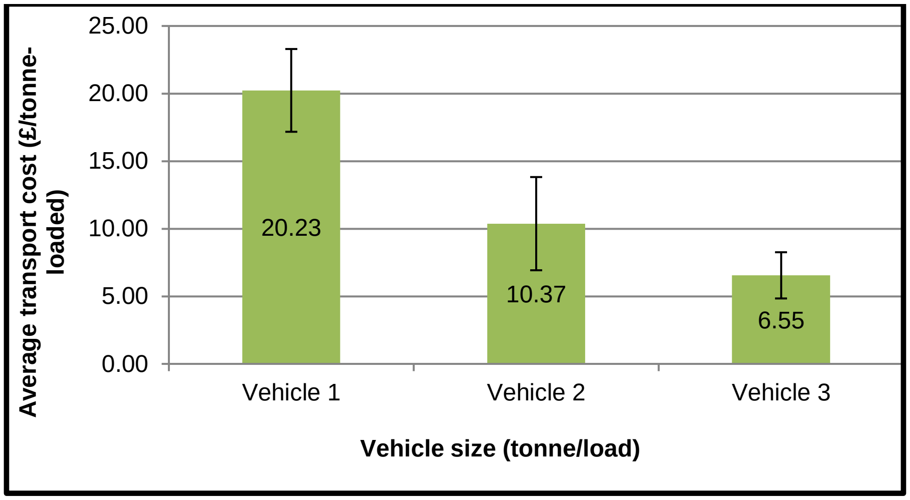

Figure 11: Average transport cost per tonne loaded of WBSG when the cost of diesel increased to £2.38/litre and driver wage increased from to £14/hour.

Table 3: Average transport cost (ATC) for tonne loaded of WBSG when the distance between the brewery and farm increases to up to 100 miles

	ATC (10 miles)	**ATC** (20 miles)	**ATC** (40 miles)	**ATC** (60 miles)	**ATC** (100 miles)
Vehicle 1	20.51	**39.61**	77.83	116	192.50
Vehicle 2	8.86	17.35	**34.32**	51.29	85.23
Vehicle 3	6.40	12.50	24.70	**36.90**	61.28

4. Discussion of Spent Grain Costing Model (SGCM) results

Analysis of the current collection pattern of wet brewer spent grain WBSG from independent breweries indicates that most is collected within a close proximity to the breweries, generally within a range of 0.5 - 7 miles. Three size scales of independent breweries were investigated to determine the efficiency of using WBSG. These three scales reflected common size patterns of the independent brewing industry.

In summary, however, the smallest size produced 0.5 tonnes per brew, the medium size 1 tonne per brew and the larger size up to 5 tonnes per brew. Small brewery production was collected within a shorter average distance of 4.5 miles compared to the collection distance for medium size and large size breweries, 5.2 and 6.5 miles respectively. However, some collection distances were longer with a maximum of 20 miles. This pattern of delivery will allow a good return value on the use of WBSG in general but some farmers may be incurring reduced value due to excessive collection distances. 11% of breweries produced WBSG which was used directly on site by an adjacent farm so obtaining maximum benefit. In assessing the efficiency of use of WBSG three sizes of vehicle were profiled against the three brewery sizes. The unit comparison of costs is measured on a weekly basis due to the requirements of the ORWARE programme but final comparison of efficiency is made on a cost per tonne basis. The three sizes of breweries show different patterns of brewing with larger breweries brewing more regularly 4 times per week compared to medium and smaller breweries which produce 3 and 2 times respectively.

As a result the total collection tonnage per week is about 1 tonne for small breweries, 3 tonnes for medium and 5 tonnes for larger breweries. Analysis of the data is made on the assumption that collection reflects the brewing profile and that WBSG is not collated due to the hygiene hazards of storing a perishable by product near fermenting beer. On this basis the diesel consumption for weekly collection of small brewery WBSG is 2.5 litres while the consumption for collection from medium size breweries is 6.1 litres and from larger breweries is 7.25 litres. Time required for loading and unloading also differs and on a weekly basis is 0.7 hours for collection from small breweries, 1.2 hours for collection from medium breweries and 1.12 hours for collection from larger breweries. Despite these differences the average load of WBSG in the three different vehicles used differed considerably with vehicles for collection from small breweries carrying on average 0.645 tonnes, vehicles for collection from medium breweries 1.397 tonnes and vehicles for collection from large breweries carrying 2.630 tonnes.

As a result overall the average cost per tonne was much smaller for collection from larger breweries (£3.22) than for collection from medium (£5.20) or from smaller breweries (£10.11). The % difference in collection cost of WBSG from a smaller brewery is 68% compared to that from a larger brewery. Sensitivity analysis showed that increasing driver wage by 100% resulted in increasing average transport cost per tonne loaded by 64% for vehicle 1, 53% for vehicle 2 and 50% for vehicle 3. However, increasing diesel cost per litre by 100% that increased average transport cost per tonne loaded for vehicle 1, vehicle 2 and vehicle 3 by 36.7%, 46.3% and

51.7% respectively. Increasing the distance between the brewery and the farm to 100 miles resulted in increasing in average transport cost per tonne loaded for vehicle1, vehicle2 and vehicle3 by 1804%, 1539% and 1774% respectively (Table 4).

Table 4: Average transport cost per tonne loaded of WBSG when the price of diesel increases by 100%, increasing in driver wage by 100% or increasing distance between the brewery and the farm to 100 miles.

Vehicle size	ATC change (%) (Driver wage £14/hour)	ATC change (%) (Diesel price £2.38/litre)	ATC change (%) (Distance 100 miles)
Vehicle 1	+64%	+36.7%	1804%
Vehicle 2	+53%	+46.3%	1539%
Vehicle 3	+50%	+51.7%	1774%

Average transport cost per tonne loaded of WBSG for vehicle 1 was more sensitive to increases in driver wage than vehicle 2 and vehicle 3, when the driver wage increases by 100% vehicle 1 recorded the greatest increase in average transport cost (64%). However, average transport cost for vehicle 3 was more sensitive to increases in diesel price per litre than vehicle 1 and vehicle 2, as when the price of diesel increases by 100% vehicle 3 recorded the highest increase in average transport cost per tonne (51.7%) while vehicle 1 recorded the lowest increase (36%). Moreover, when the distance between brewery and farm increases to up to 100 miles the average transport cost per tonne loaded increased more than 1500% for the three vehicles, however, vehicle 2 recorded less increase (1539%) than Vehicle 1 and Vehicle 3.

Overall, Average transport cost per tonne loaded for small vehicles (1 tonne or less/load) was more sensitive to changes in driver wage than changes in diesel prices. However, Increases in diesel prices affect average cost per tonne loaded and large vehicles (4 to 6 tonnes/load) were more sensitive to this increase than medium vehicles (2 to 3 tonnes/load) and small vehicles (1 tonne or less/load).In addition, medium vehicles (2 to 3 tonnes/load) recorded less increase in average transport cost per tonne loaded in long distances (100 miles) than small and large vehicles (vehicle 1 and vehicle 3).

5. Conclusion

For The SGCM model, the results showed that the average cost of transporting brewery spent grain by the three vehicles (vehicle1, vehicle2 and vehicle3) were £10.11, £5.20 and £3.27/tonne-loaded respectively. Moreover, average transport costs for collection from breweries (small, medium and large) increase by 63.5%, 52.9% and 48.9% respectively when labour costs are doubled and by 36.6%, 46.4% and 51.7% when fuel costs are doubled. This indicates that the increase in the driver wage had the greatest effect on small vehicles (vehicle1), while the increase in fuel cost had the greatest effect on large vehicles (vehicle3).

In addition, collection distance is major limit to collection economics. Collection from smaller breweries shows that costs over 20 miles become uneconomic. However, collections from medium and large breweries are still economic at a much greater range- up to 60 miles. Most collections from small breweries are within 5 miles and so are economic at present. The effect of the increase of distance between the brewery and farm on the average transport cost has been examined using linear regression analysis. The results obtained from the linear regression model indicated that the average transport cost per tonne loaded of WBSG rises by £1.99, £1.31 and £0.45 per one mile increase in the distance between small, medium and large breweries and farms respectively.

6. Recommendations for future Work

1. Environmental analysis to determine additional costs e.g. due to CO2 output, Carbon Footprint, etc.. SGCM model can be expanded and used to calculate the environmental impacts.

2. Use ORWARE model to determine outputs to compare to published applications of ORWARE model.

3. Re-analyse on collaborative basis using collection points or collection service- possibly to reduce distance. SGCM model can be modified to be suitable for this analysis.

4. Drying costs of WBSG and their effects on the reduction of transport costs

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