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Performance assessment of high capacity trucks: Understanding truck selection and deployment economics

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ABSTRACT

High capacity trucks (HCT) present an interesting opportunity to improve transportation efficiency and reduce emissions. This study focuses on implementation in Finland where legislation allows a maximum weight of 76 tonnes, 34.5 m length and 4.4 m height, which would be a 20% and 4.5% increase in weight and height compared to the current European modular system. The purpose of this paper is to evaluate the economic performance (cost and revenue) of such high capacity transportation vehicles compared to traditional smaller trucks. Data has been collected from real transport logistics service providers. A performance evaluation model called COREPE was designed to present quantitative evaluation of one year of operating data: this model evaluates the economic performance of HCT and traditional trucks on three different long hauls using telemetry data and monthly truck operating data. The results show that HCT has overall higher cost compared to traditional. The size advantage HCT has over traditional translated into moderately higher revenue and profitability based on the available data. Factors such as seasonal variability, driver attitude and truck utilisation had a noticeable impact on cost.

Introduction

One of the notable improvement projects related to transport in Europe is the introduction of the high capacity transportation vehicle, sometimes referred to as HCV, HCT, or LHV. HCT refers to a vehicle combination that exceeds the existing dimensions permitted by regulations in terms of size, weight, length, and height (Monios and Bergqvist, 2017). The European Union has defined the longer heavier vehicles (LHV) as "all transportation vehicles exceeding the limits on weight and dimensions as established in Directives 96/53/EC". These dimensions and the weight of vehicles on national and international road freights are regulated by member countries of the European Union (Monios and Bergqvist, 2017).

According to the International Transport Forum (2019), *"High capacity transportation vehicle (HCV) combinations are possible through the European modular system (EMS) through increasing the capacity of existing units…, the adoption of high capacity transportation vehicle has not witnessed favourable progress, though currently being deployed in Australia, Canada, China, Sweden, and Finland, and is under trial in countries such as Belgium, Denmark, and Germany"* (International Transport Forum, 2019).

The introduction of the high capacity truck (HCT) aimed to achieve among several objectives reductions in road congestion (fewer truck trips), improvements in traffic safety (Larsson, 2009), and creating a window of opportunity that would bring about efficiency in transportation and lower CO_2 emissions. The challenge is that the actual delivered performance would depend on how well the HCT assets are managed (International Transport Forum, 2019). One of the major challenges of hauliers using HCT is optimising loading capacity in order to achieve economic benefits (International Transport Forum, 2019). According to Sanchez-Rodrigues et al., (2015), *"the use of estimated based statistics for HCT performance assessment is a major problem, due to lack of empirical data"*.

In order to respond to the problems stated, this paper examines the following questions: (1) what are the key criteria for truck economic performance evaluation? And, (2) does HCT have better economic performance compared to traditional trucks? The research examines one-year truck performance data from a leading third-party logistic service provider to answer the two research questions. The trucks evaluated are six of the fleets the company use on its long-haul routes three high capacity transportation vehicles and three traditional smaller trucks. A performance evaluation model (COREPE) was created with the aim of

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evaluating cost and revenue associated with the six trucks during the period.

Prior work – Evaluation of the economics of truck performance

Understanding how firms allocate their trucks across routes and how this allocation changes under different situations has generated a lot of interest recently (Abate & De Jong, 2014). Performance evaluation is a process of observing and analysing actual performance against stated objectives (Litman, 2008), and it is helpful for understanding the effectiveness of transportations plans and need for improvement (Raoniar, et al., 2015).

Transportation performance measures refer to "measures of effectiveness, (and) are quantitative estimates on performance of transportation facility, service, program or project with respect to policies, goals and objectives" (Oregon Department of Transportation, 2018), and are used for planning and project development (United States Environmental Protection Agency, 2011), are tools used in transport planning to track a company's ability to attain stated objectives and give direction to transport operators and agencies (Dhingra, 2011), and give direction to planning and management decisions (Litman, 2008).

In view of these stated views, it is safe to say that performance evaluation for high capacity transportation vehicles is needed to track its conformity with objectives and serve as a guide to improvement in the future. Transport performance evaluation must be continuous: identifying potential problems and optimising productivity, and its indicators must be accurately defined. These indicators have practical applications (Litman, 2008), must be "SMART: specific, measurable, agreed upon, realistic, and time-bound", and be able to rely on empirical data (Oregon Department of Transportation, 2018).

The indicators for transportation performance evaluation are in three types: service quality, outcomes, and cost efficiency (Litman, 2008). Litman (2015) further states that cost efficiency reflects economic performance, which often measures cost per km across different transportation modes. According to Liimatainen & Nykänen (2016), truck operation data related to the number of trips, total mileage, and total fuel consumption, and CO_2 emissions were used in analysing HCT performance, while International Transport Forum (2019), expressed HCT performance in terms of fuel per cargo unit (litre/t-km) and CO_2 per cargo unit (g CO_2/t-km). While the evaluation criteria from these two focus on evaluating truck performance based on cost, this paper focuses on economic performance evaluation, which evaluates cost and revenue related elements such as fuel cost per 100 km (€/100 km), total cost per kilometre (€/km), distance travelled per trip per truck (€/km), pallet delivered per trip (€/pallet), and more.

Measuring the economic performance of high capacity trucks is important for management planning and decision making. One important performance measure according to the Oregon Department of Transportation (2018) is the volume to capacity ratio, which is a measure describing the extent to which truck capacity is utilised at any given point.

High capacity trucks represent a good possibility for logistics service providers to improve operations. Effective use of this asset is expected to contribute to better operational performance and profitability. According to Liimatainen & Nykänen (2016), this critical asset comes with potential positive impact such as fuel consumption reduction, and negative impact such as an increase in the cost of tyres and cost of general vehicle maintenance.

The Finnish government approved the use of high capacity trucks on Finnish roads in October 2013. The aim was to develop efficient transportation and improve safety on the Finnish highways. The trial period was focused on reducing emissions and improving cost efficiency in the forest industry and customised heavy goods (Liimatainen & Nykänen, 2016). For operators of HCT, larger trucks presented both opportunities and challenges (Lahti, 2018). For this reason, monitoring and evaluating the performance of this critical asset is important.

The permanent changes to the weight limits of trucks in Finland was expected to bring about a reduction in total cost savings. Below are the permanent changes to trucks as effected in Finland in 2013 (Liimatainen & Nykänen, 2016).

- 4-axle truck without trailer 32 t to 35 t (payload 18 t to 21 t, +17%)
- 5-axle truck without trailer 38 t to 42 t (payload 21 t to 25 t, +19%)
- 8-axle vehicle combination 60 t to 68 t (payload 37 t to 45 t, +22%)
- 9-axle vehicle combination 60 t to 76 t (payload 35 t to 51 t, +46%)

According to Liimatainen et al., (2020), cost savings were recorded in different industries where high capacity vehicles were deployed in Finland between 2013 and 2017 (Fig. 1). Cost saving recorded by high capacity vehicles in long-haul distribution amounted to a total of 92.3 million euros during the period, which is a significant cost saving and clear evidence that high capacity transportation achieved one of its objectives: cost saving for users.

Methodology

One year of quantitative data relating to trucking cost and revenue was collected and used to measure the economic performances of HCT and TRADT. A leading Finnish third party logistics company that operates both HCT and TRADT for long-haul services provided this data, which corresponds to each of the trucks used by the company on different routes. In order to answer the research questions, a model called COREPE was developed. This model, an acronym for cost, revenue, and profitability evaluation is specifically designed by this research to describe and evaluate the operation of long-haul truck services (Fig. 2). Trucks used by the case company come in two different capacities and operate on three routes. High capacity transportation trucks (HCT) have 104 pallet spaces, and traditional smaller trucks (TRADT) have 75 pallet spaces for a single trip.

Long-haul delivery data for HCT and TRADT on three routes were collected and classified into different categories to suit the analytical purpose. To simplify the analytics and reporting, monthly data reporting was preferred, meaning that the data used were based on monthly averages. Performance evaluation followed a simple analysis for cost, revenue, and profit accrued to each of the truck types on different routes. Data normalisation was also employed in the analysis: this was aimed at protecting the original data but most importantly gave reliability to the results of our findings.

This research required monthly data on the trucks' fuel consumption, driver's wages, and other related costs, as well as revenue data from the numbers of pallets delivered per truck per month on each route, and revenue per unit pallet delivered per route. Other data required were fuel price, the amount of fuel used per truck per month, number of delivery days per truck per month, and actual delivery per truck per day.

Based on the COREPE model, different sources of cost and revenue accrued to truck operation are identified. Revenue is mainly generated through the numbers of pallets transported on the three routes; hence, truck capacity utilisation is considered important. This is the first stage.

After the first stage, we require specifics in the data relating to daily, weekly, and monthly truck operating cost, revenue, and profit. These specifics are important to understand how utilisations of HCT

	Part load	Forestry	Long-haul distribution	Tanker and bulk	Construction	Total	Savings as % of total
Vehicle kilometres saved (million km)							
2013/Q4	0.8	1.8	0.9	0.1	0.4	4	0,7%
2014	0.1	15.8	9.5	2.4	6.3	34	1,9%
2015	0.2	19.4	12.6	5.3	5.2	42.7	2,7%
2016	0.5	30.2	18.8	5.2	8.8	63.5	3,4%
2017	0.8	36.2	23.3	7.1	13.4	80.9	4,1%
Total	2.3	103.4	65.2	20.2	34.1	225.1	2,9%
Cost savings (million €)							
2013/Q4	1	2.6	1.3	0.2	0.7	5.9	0,7%
2014	0.1	23.2	13.4	4.3	12.1	53.1	2,0%
2015	0.2	28.4	17.9	9.4	10	66	2,8%
2016	0.6	44.2	26.7	9.3	16.9	97.9	3,6%
2017	1	53.1	33	12.6	25.8	125.5	4,4%
Total	**2.9**	**151.6**	**92.3**	**35.7**	**65.5**	**348**	**3,1%**

Fig. 1. Cost savings in higher weight vehicles across different sectors 2013–2017 (Liimatainen & Nykänen, 2020).

and TRADT capacities on different routes impact the overall cost and profitability of the company.

The evaluation process numerically analyses different key performance indicators for cost and revenue sources, which are key to the research questions. Monthly average figures were used in the analyses.

The key economic performance indicators identified are cost, revenue and profits, while truck capacities and travel distances are identified as constraints. This paper also presents seasonal fuel consumption variations for HCTs and TRADTs, and drivers' performances regarding fuel usage during the winter and summer months (Fig. 3).

Research design and coding

The case company deployed two types of trucks, namely high capacity trucks (HCT) and traditional smaller trucks (TRADT) on three different routes. For the purpose of this research, the routes have been coded and shall be referred to as RT1, RT2, and RT3, with each route having two trucks; hence, the routes and corresponding trucks are code-named RT1 HCT, RT1 TRADT, RT2 HCT, RT2 TRADT, RT3 HCT, and RT3 TRADT according to their deployment routes (Table1).

Data collection

Truck performance evaluation is a continuous task in logistics companies: what to measure or evaluate will greatly depend on the nature and size of fleet operations. This section introduces the main input data used in this study.

Input data and limitation

The data used for this research are real: they were provided by a single company through access to truck telemetry and company transport management system (TMS). Hence, the research findings solely portray the activity of the case company and are expected to offer an insight for others when dealing with the same issue. Data protection and safety obligations prevent us from including any part of the raw data provided by the company. Fig. 4 below shows the nature and sources of data used for the research.

Internal data sources include the company's truck telemetry, transport management system, and financial reports, while external data used comprised the fuel pricing, which was used in calculating the total fuel cost. The data were remodelled and visually presented using different statistical analytic tools. One of the trucks (RT3 HCT) only operated for six months, hence only the six months of data captured for this truck were included in the research.

Truck telemetry data

Truck telemetry data provided this research with real-time information about truck performance. The company delivered products to customers using six trucks on three different routes, and information about route distance, travel time, acceleration, fuel used, and average speed are considered necessary to be able to evaluate differences in the efficiency of high capacity transportation trucks and traditional smaller trucks used by the company. Fig. 5 below shows a sample truck telemetry system datasheet; some of the performance related data extracted from the truck telemetry include the following:

- Kilometres travelled per truck/day/driver
- Hours worked per truck/driver
- Fuel used per truck/driver
- Fuel used per 100 km
- Average speed (km/hr)

Figures from this datasheet were automatically extracted from the company's system. The numbers under each heading are system generated; hence, there is no control over these figures. Possible fuel savings calculated in ltr/100 km explain how individual drivers attempted to effect fuel economisation through driving.

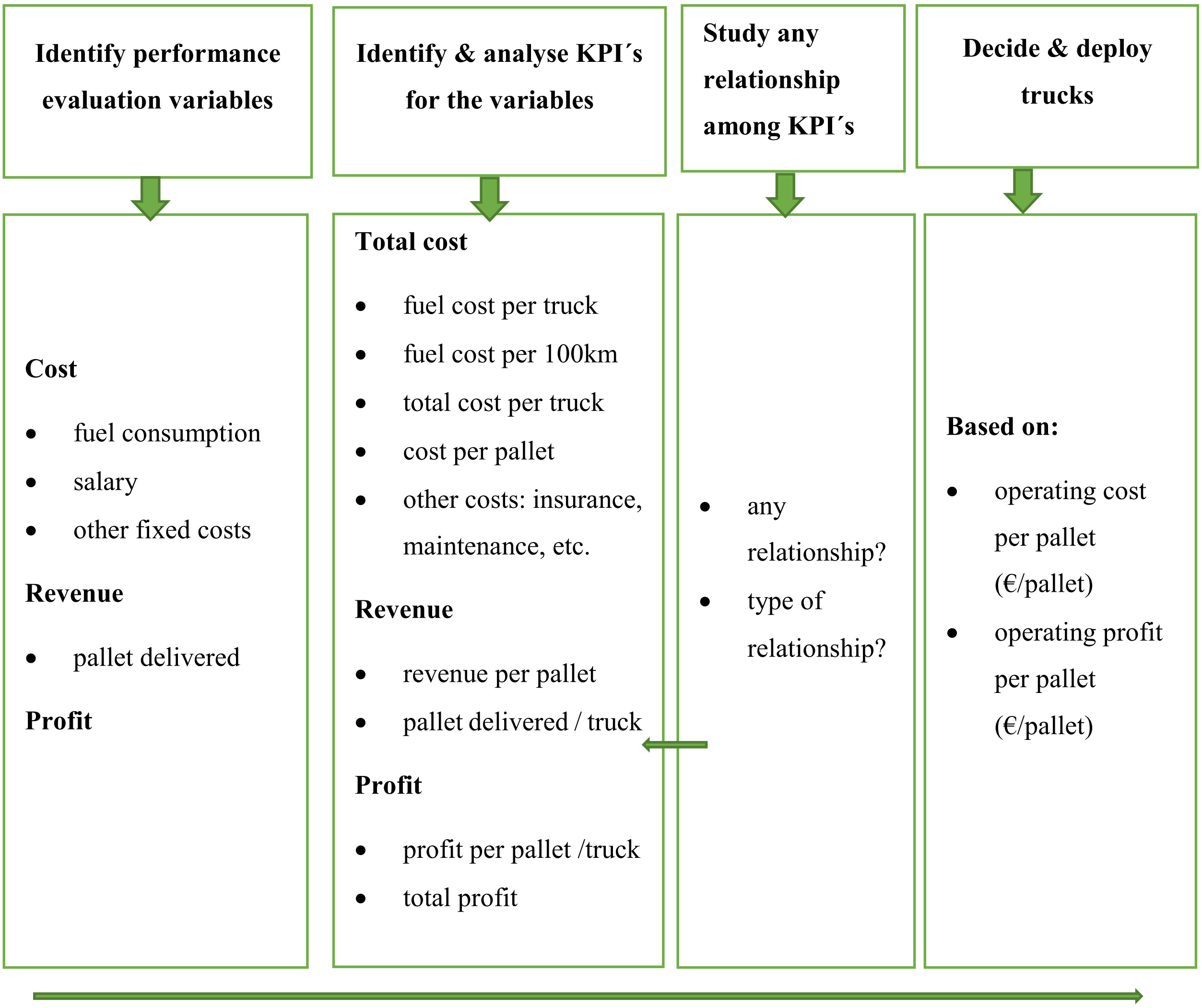

Fig. 2. Cost, revenue and profitability evaluation model (COREPE Model).

Volume delivered and delivery destinations (TMS)

Revenue was one of the two criteria used for truck performance evaluation: it is therefore important to correctly ascertain the revenue figures generated by each of the six trucks used by the company on three different routes. This trucks have different capacities in terms of the number of pallets they can transport. The total number of pallets delivered per truck was not readily available for this research, but revenue generated per pallet and monthly revenue generated per truck on each of the three routes over a period of one year were given by the company as part of the research data. These two data sets were used to calculate the daily, monthly, and yearly volume of pallets delivered per truck on each of the routes.

Routes and their characteristics

There were three routes with different single trip distances: these routes mean delivery locations. Route one has two delivery locations for HCT and TRADT. Routes two and three have equal delivery location distances for both HCT and TRADT.

Analysis

Data normalisation was employed to present our research results. Presenting real data was intentionally avoided; percentages and indexes were rather used to present the results.

Total cost, revenue, and profit performance assessment

Truck performance assessment used cost and revenue related figures contained in the operating data collected from the case company. The aim was to establish which trucks had better operational efficiency. Cost elements include fixed and variable components such as fuel cost, salary, truck leasing cost, insurance paid on the truck, and other costs. The numbers of pallets delivered represent the only source of revenue, while the profit statistics represent the final returns from each truck. Cost and revenue are the only readily quantifiable criteria considered accurate for the assessment of truck performance at the time of this study.

The cost and revenue components of HCT and TRADT have similarities as well as differences when we compare performances. Table 3 above contained cost elements and how these costs summed up for both HCT and TRADT. In order to make informed conclusions about truck performance, normalisation of data (0 to 1) was done and the cost of both trucks were compared with a monthly average.

Normalise value:

$$Z = (x - -\mu)/s \quad (1)$$

where z = normalised value
x = data value of cost or revenue for trucks
μ = mean of data set
s = standard deviation

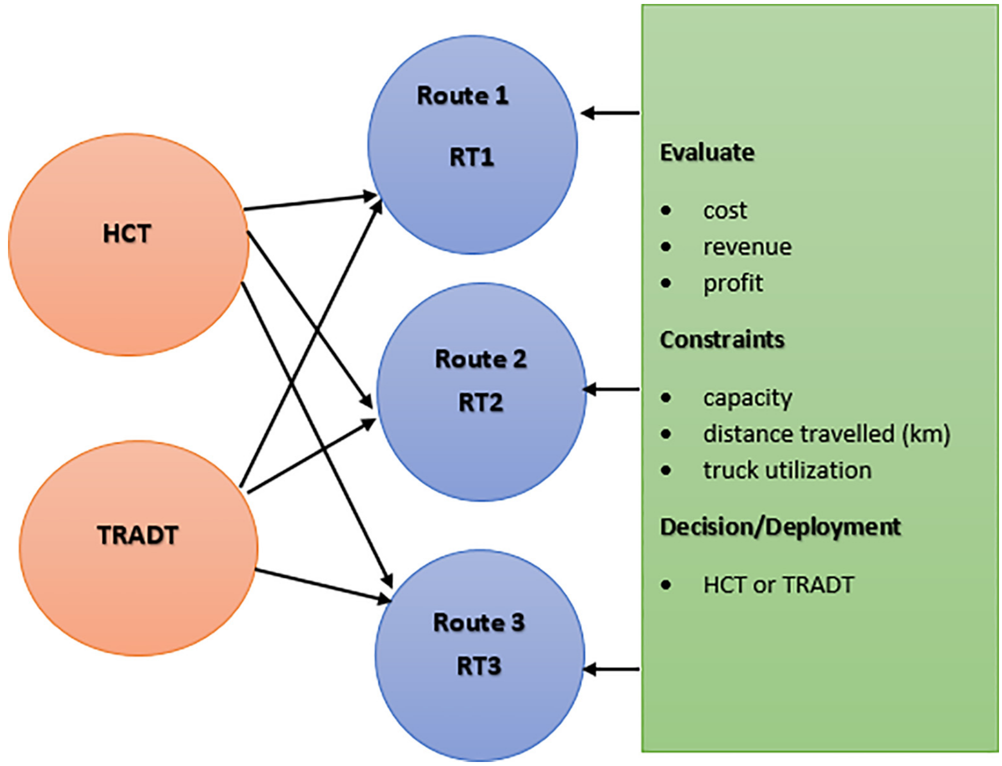

Fig. 3. Research problem design.

Table 1
Truck-route coding.

	Route 1	Route 2	Route 3
Numbers of Trucks	2	2	2
Type of Truck	HCT & TRADT	HCT & TRADT	HCT & TRADT
Route-Truck Coding	RT1 HCT, RTI TRADT	RT2 HCT, RT2 TRADT	RT3 HCT, RT3 TRADT

Table 2
Truck utilisation, capacity, and travel distance (January-December).

Route-Truck	Truck utilisation rate	Truck capacity (Pallet per Trip)	Route distance (km per trip)
RT1 HCT	>1	104	662
RT1 TRADT	>1	75	700
RT2 HCT	0.94	104	784
RT2 TRADT	>1	75	784
RT3 HCT	0.69	104	720
RT3 TRADT	0.88	75	720

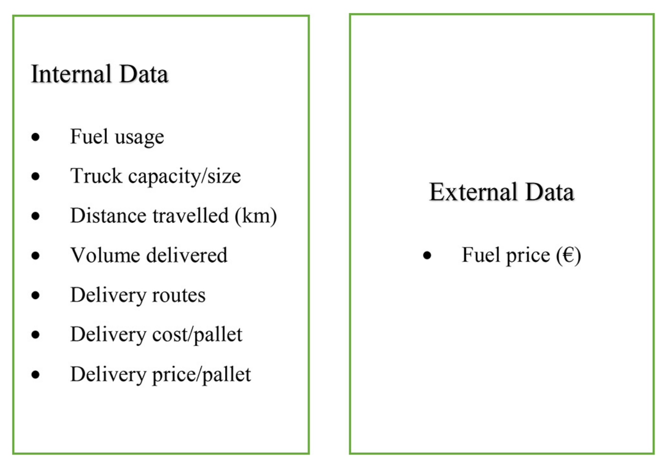

Fig. 4. Nature of data and sources.

Fig. 6 below shows the monthly normalised cost values for the trucks, as well as the year average. RT1 HCT, RT2 HCT, and RT3 HCT have standard deviations (yearly) above the mean/average total cost. This means higher costs for these trucks than average. RT1 TRADT and RT3 TRADT have standard deviation (yearly) below the average total cost.

In order to understand the numbers behind Fig. 6, a breakdown of cost components is expressed in percentages. The statistics on cost element performances from Fig. 7 show the shares of each truck for different cost elements. RT2 HCT have the highest total cost, 21.7%, followed by RT1 HCT with 18.4%, and RT2 TRADT with 18.2%. Meanwhile, RT3 HCT (9.7%) operated for only six months (January-June). The total distance travelled impacted the total cost through fuel cost and driver's salary. Other elements of total cost include truck leasing cost and insurance, which are both fixed in nature. Longer distances travelled meant higher fuel cost and salary for the drivers.

With over 25% capacity advantage, the overall performance of the high capacity truck means, on average, that it spent 4.8% less on salaries, 3% more on fuel, travelled 5.8% less, and had 1% less of the total cost compared to a traditional smaller truck for one year (Table 4).

Fig. 8 below shows monthly revenue normalized values for the trucks, as well as the year average. Revenue performances recorded from these trucks after data normalisation (0 to 1) were compared with monthly average revenue, and this resulted in RT1 HCT, RT1 TRADT, and RT2 HCT having standard deviations (yearly) above mean/average revenue. This means a higher than average revenue from these trucks. RT2 TRADT and RT3 TRADT have standard deviation (yearly) below average revenue.

Vehicles	Drivers	Possible Fuel Saving [Ltr / 100km]	Possible Fuel Saving [Ltr]	CO2 Emissions [kg]	Distance [km]	Driving Time [Hrs]	Fuel Used [Ltrs]	Fuel Used [Ltrs / 100km]	Average Speed [km/h]
RT1 TRADT	[redacted]	6.9	7231.9	115040.9	104471.49	68 days 11:48:08	49801.25	47.67	64
	[redacted]	5.4	128.3	2421.5	2362.06	1 day 13:38:39	1048.29	44.38	63
	[redacted]	5.6	246.1	4958.8	4382.24	2 days 16:11:32	2146.69	48.99	68
	[redacted]	6.7	35.9	530.9	538.84	8:02:11	229.82	42.65	67
	[redacted]	6.7	2442.6	39658.5	36270.88	23 days 01:25:29	17168.19	47.33	66
	[redacted]	6.8	2385.2	39734.7	34943.19	21 days 04:58:37	17201.15	49.23	69
	[redacted]	7	332.5	5042.9	4720.48	3 days 02:28:05	2183.07	46.25	63
	[redacted]	7.2	238.7	3799.9	3340.92	2 days 15:39:50	1644.96	49.24	52
	[redacted]	7.2	46.6	669	649.92	9:20:38	289.6	44.56	70
	[redacted]	7.5	500.1	7176.7	6651.35	4 days 09:00:46	3106.82	46.71	63
	[redacted]	8.2	870.7	11007	10577.72	9 days 01:22:14	4764.93	45.05	49
	[redacted]	15.5	5.3	41	33.9	1:40:07	17.73	52.3	20
RT1 HCT	[redacted]	11.3	10931.2	123112.1	96921.3	62 days 13:34:52	53295.28	54.99	65
	[redacted]	8.2	2993	45300.5	36417.73	22 days 06:22:02	19610.59	53.85	68
	[redacted]	11	2514.2	28148.7	22904.06	16 days 02:48:44	12185.59	53.2	59
	[redacted]	12.9	470.7	5097.7	3648.68	3 days 03:30:36	2206.82	60.48	48
	[redacted]	14.4	4880.6	44205.5	33847	20 days 06:50:16	19136.57	56.54	70
	[redacted]	16.4	5	40	30.53	1:07:57	17.32	56.73	27
	[redacted]	66.2	18.5	90.2	27.96	5:29:57	39.05	139.67	5
	[redacted]	108.6	49.2	229.5	45.35	11:25:20	99.35	219.1	4
	[redacted]	9	18163.1	238153	201392.79	131 days 01:23:00	103096.53	51.19	64

Fig. 5. Sample truck telemetry data.

Table 3
Type and nature of costs for both trucks.

	Fixed Cost Elements	Value (%)/annum	Variable Cost Elements	Vary according to:
HCT	Truck Leasing	52.1%	Fuel Cost	Price & Distance
	Insurance	3.6%	Driver's Wage	Daily Working Hours
TRADT	Truck Leasing	40.7%	Fuel Cost	Price & Distance
	Insurance	3.6%	Driver's Wage	Daily Working Hours

	RT1 HCT	RT1 TRADT	RT2 HCT	RT2 TRADT	RT3 HCT	RT3 TRADT
JAN	-0.2	0.7	1.7	-0.4	0.7	-1.1
FEB	-0.1	-0.3	1.3	-0.1	0.6	-1.5
MAR	0.2	0.6	1.3	0.5	0.8	-1.1
APR	-0.1	-0.8	1.4	-0.4	0.0	-1.4
MAY	0.3	-2.6	1.5	1.1	0.4	-1.4
JUN	0.1	-0.3	1.3	-1.0	0.6	-1.6
JUL	-0.4	-1.0	1.4	0.2		-1.4
AUG	0.6	-0.9	1.4	0.4		-1.2
SEP	-0.1	-0.7	1.1	-0.7		-1.5
OCT	0.6	0.0	1.9	0.7		-1.0
NOV	0.8	-0.1	2.1	0.5		-0.4
DEC	-0.6	-0.3	0.2	-0.9		-1.8
AVERAGE	0.1	-0.5	1.4	0.0	0.5	-1.3

Fig. 6. Revenue performances of standardized trucks.

A further breakdown of revenue components can be seen from Fig. 9 below, which are also presented in percentages. Route one trucks generated the highest revenue, 22.4% and 19.8% by RT1 HCT and RT1 TRADT, followed by RT2 HCT and RT2 TRADT with 19.1% and 16.3%, while route three trucks RT3 TRADT and RT3 HCTT generated the least revenues, 13.5% and 9% respectively.

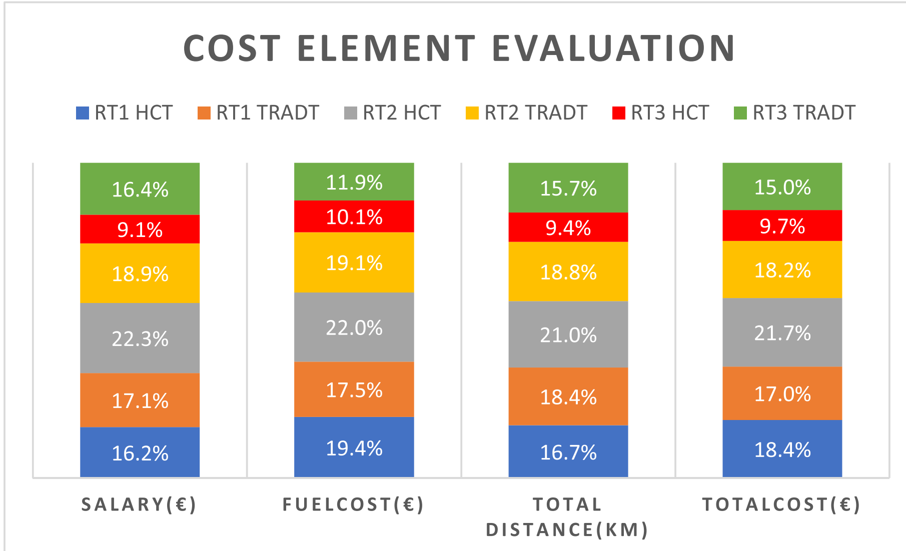

Fig. 7. Cost element evaluation.

Table 4
Overall cost performance evaluation.

	Salary (€)	Fuel Cost (€)	Distance Travelled (€)	Total Cost (€)	Cost/Km (€/km)
%Diff					
(+/-) HCT	–	+3	–		+9.9
(+/-) TRADT	+4.8	–	+5.8	+1	–

RT1 HCT, RT2 HCT, RT1 TRADT, RT2 TRADT, RT3 TRADT delivered 22.1%, 20.9%, 19.5, 17.9%, and 11.7% of the total pallets respectively, while RT3 HCT, which operated for six months, delivered the least amount, 7.8%. RT1 HCT and RT1 TRADT generated the highest overall profits, 36.8% and 29.8%; RT2 HCT and RT2 TRADT generated 9.8% and 9.4%, while RT3 HCT and RT3 TRADT generated the lowest overall profits, 6.2% and 8% respectively.

With 27.8% capacity advantage, the overall performance of the high capacity truck means, on average, that during the year it generated 1% more revenue, delivered 1.6% more pallets, and generated 5.6% more profit compared to the traditional smaller truck (see Table 5).

$$Revenue = (Total\ pallets\ delivered * €/unit\ palletdelivered) \quad (2)$$

$$\text{Profit} = (\text{Revenue - Total cost}) \quad (3)$$

Intra-route truck performance analysis

Fig. 10 shows the intra-route truck performance statistics. The summary is expressed in percentages, which indicate the intra-route truck performance evaluation. The figures were recorded for each truck. High capacity trucks (HCT) were operationally more expensive than traditional smaller trucks (TRADT) on all three routes: higher fuel consumption per 100 km, higher cost per kilometre, higher working hour cost, and higher fixed and fuel costs. The smaller trucks (RT1 TRADT and RT3 TRADT) had higher unit costs only for pallets, and higher

	RT1 HCT	RT1 TRADT	RT2 HCT	RT2 TRADT	RT3 HCT	RT3 TRADT
JAN	0.5	1.0	0.2	-0.8	-0.2	-1.5
FEB	0.7	0.6	-0.5	-0.9	-0.4	-1.6
MAR	0.8	1.4	0.0	-0.7	0.4	-1.4
APR	1.6	0.2	0.4	-1.1	-0.7	-1.5
MAY	2.5	0.9	0.3	-0.3	0.1	-1.6
JUN	1.9	1.1	0.1	-0.7	0.4	-1.7
JUL	0.7	-0.7	0.5	-0.3		-1.6
AUG	2.0	-0.3	0.6	-0.2		-1.6
SEP	1.1	-0.2	0.1	-0.8		-1.6
OCT	1.6	0.9	0.8	-0.4		-1.1
NOV	1.8	0.6	0.5	-0.4		-1.1
DEC	0.3	0.3	0.2	-0.4		-0.8
AVERAGE	1.3	0.5	0.3	-0.6	-0.1	-1.4

Fig. 8. Revenue performances of standardised trucks.

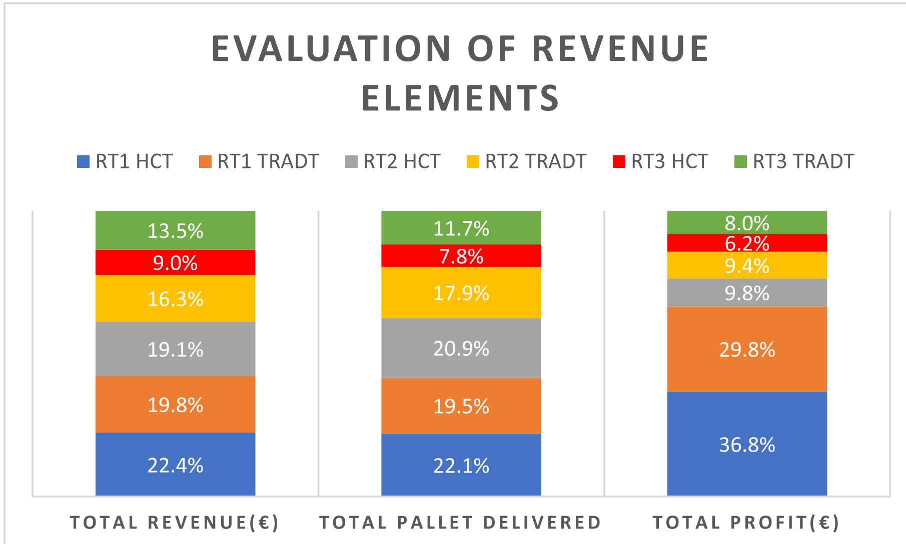

Fig. 9. Evaluation of Rrvenue elements.

Table 5
Evaluation of overall revenue and profit performance.

	Revenue (€)	Pallets delivered	Total profit (€)
%Diff			
(+/-) HCT	+1%	+1.6%	+5.6%
(+/-) TRADT	–	–	–

salary costs due to longer working hours from the longer distances travelled.

The capacity advantage of high capacity trucks made them more operationally cost efficient than traditional trucks, with the statistics from Fig. 10 showing higher returns for HCT on all routes in terms of the number of pallets delivered, total revenue, profit per pallet, and total profit made. The plus signs attached to the statistics indicate

	(ONE YEAR)				(SIX MONTHS*)	
	Route 1		Route 2		Route 3	
	RT1-HCT % Diff	RT1-TRADT % Diff	RT2-HCT % Diff	RT2-TRADT % Diff	RT3-HCT % Diff	RT3-TRADT % Diff
Cost variable elements						
Avg. fuel consumption (l/100km)	(+)17.2	-	(+)2.4	-	(+)34.4	-
Avg. cost/km (€)	(+)15.9	-	(+)6.1	-	(+)8.7	-
Avg. cost/pallet (€)		(+)4.6	(+)1.7	-	-	(+)4.3
Avg. cost/working hour (€)	(+)12.2	-	(+)1.1	-	(+)16.8	-
Distance (km)	-	(+)9.7	(+)10.8	-	(+)16.6	-
Fixed cost (€)	(+)21.9	-	(+)21.9	-	(+)21.9	-
Fuel cost (€)	(+)9.6	-	(+)13.1	-	(+)45.3	-
Avg. fuel cost/km (€)	(+)18.4	-	(+)3.6	-	(+)34.4	-
Salary (€)	-	(+)5.4	(+)15.2	-	(+)8.4	-
Working hour	-	(+)5.4	(+)15.2	-	(+)8.4	-
Revenue variable elements						
Actual pallets delivered	(+)11.8	-	(+)14.7	-	(+)27.4	-
Avg. profit/pallet (€)	(+)8.4	-	-	(+)13.9	(+)24.9	-
Profit margin (€)	(+)19	-	(+)4.1	-	(+)46.9	-
Revenue (€)	(+)11.8	-	(+)14.7	-	(+)27.4	-

Fig. 10. Evaluation of intra-route truck performance in percentages.

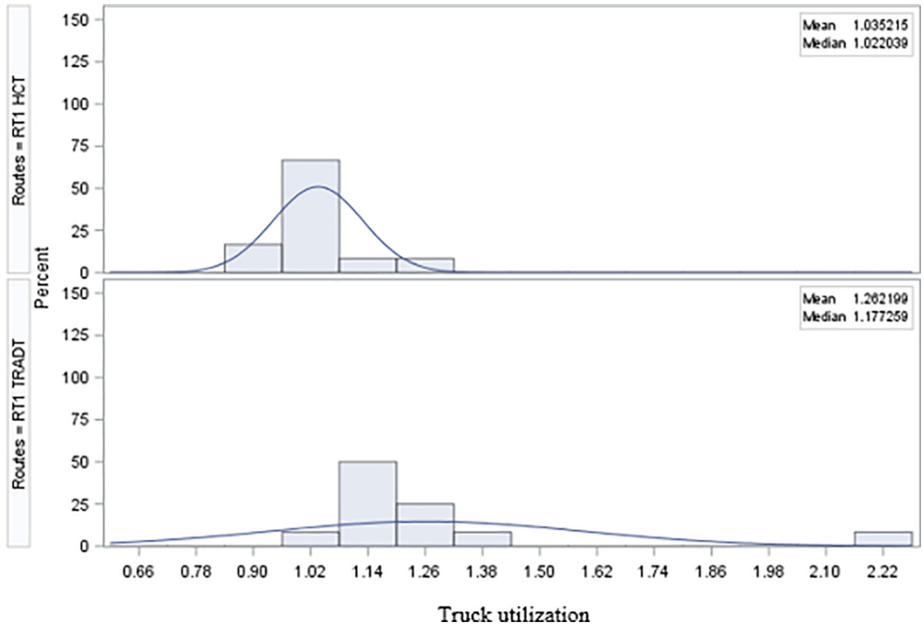

Fig. 11. Route 1 Truck utilisation (Annual distribution in %).

the trucks that generated higher cost and revenue figures on the same route.

Evaluation of truck utilisation

The findings as presented by Fig. 11,12, and 13 show different utilisation rates for the six trucks. The utilisation rate explains the utility of trucks on long-hauls, resulting from demand and other factors during the period captured in the research (one year). The truck utilisation rates of all the trucks for operating period of one year covered in this research are presented in Table 2.Fig. 12. Fig. 13.

Trucks from route one and two recorded the highest utilisation rates over a long duration of 0.95 and 1.05 50% of the times they are used for deliveries. RT1 HCT and RT2 HCT achieved utilisation rates of 0.9 and 1.0 for nine months out of one year. RT1 TRADT and RT2 TRADT had utilisation rates of 1.25 50% (six months) of the times they are used for delivery, whilst route three trucks had the lowest utilisation rates during the period.

Relationships among the evaluated criteria

In order to evaluate and analyse the possible relationships of cost and profit elements, a correlation analysis was conducted. Pearson correlation coefficient testing was used to study the existence of possible relationship between the elements of cost and revenue evaluated. This indicator is referred to as linear or product-moment correlation as it

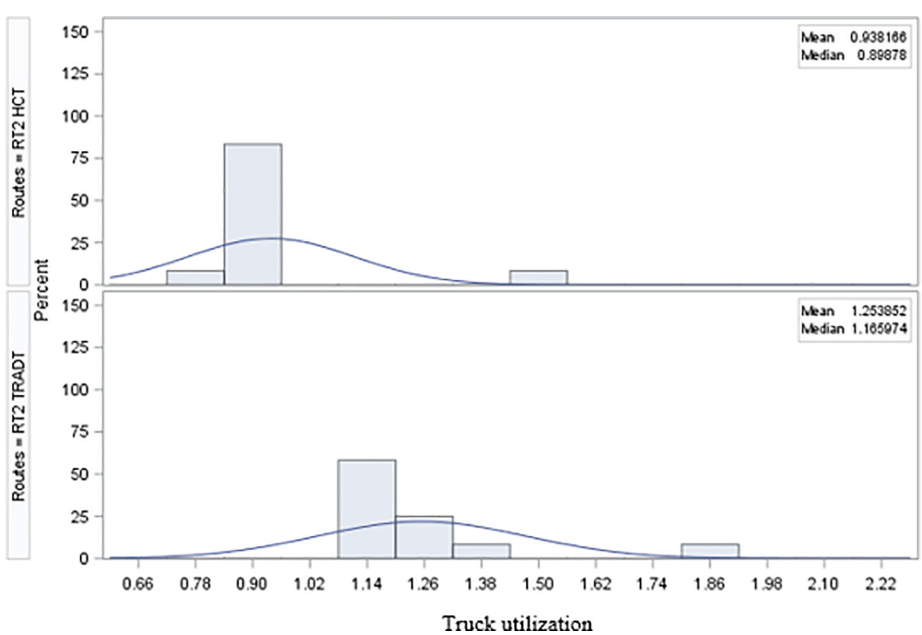

Fig. 12. Route 2 Truck utilisation (Annual distribution in %).

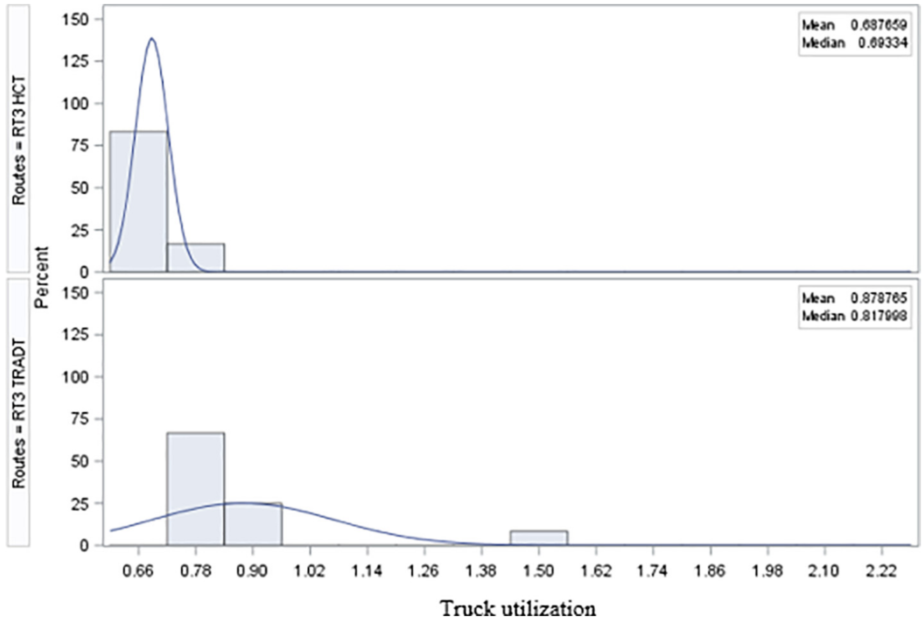

Fig. 13. Route 3 Truck utilisation (Annual distribution in %).

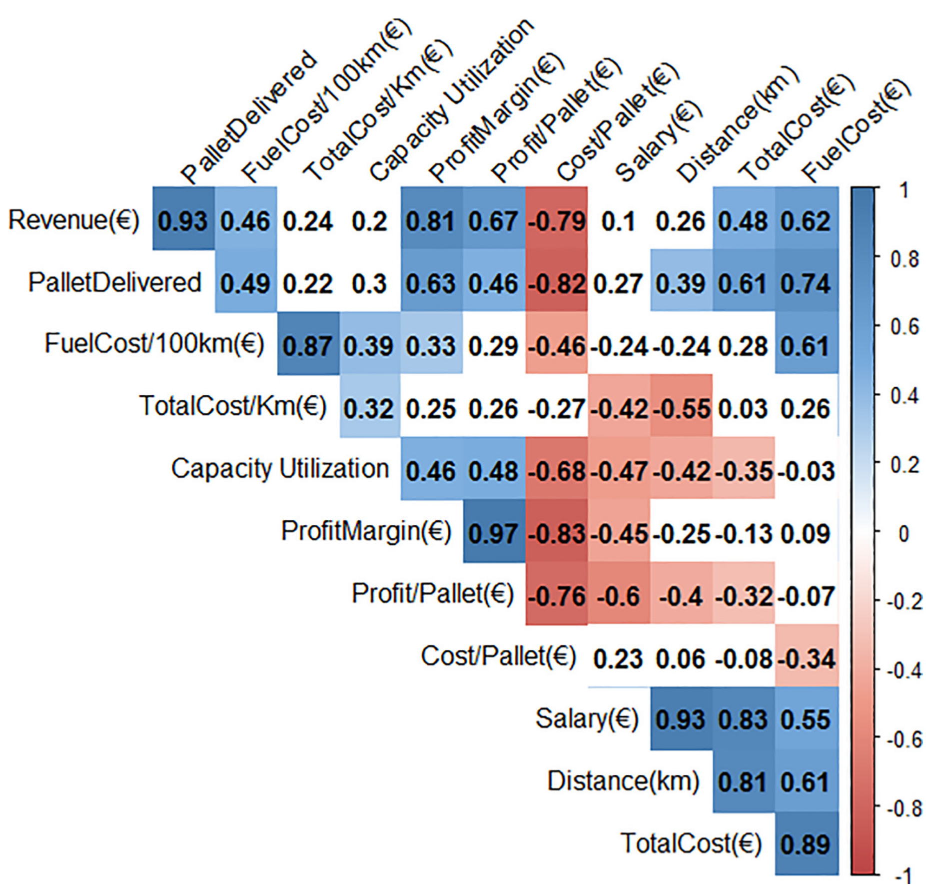

Fig. 14. Correlation coefficient of cost and revenue variables.

measures a linear association between two variables. Fig. 14 is a correlogram visualising the relationships and correlation coefficients between truck utilisation and other elements of cost and revenue as mandated by the COREPE model.

There are different levels of relationships that exist between truck utilisation and cost elements such as fuel cost per 100 km (+0.39) due to longer travel distance, cost per pallet (-0.68) when higher truck utilisation means more pallets transported, resulting in a

Table 6
Pearson correlation coefficient. in the figure below write standardised, not standardized.

Pearson Correlation Coefficients, N = 66 Prob > lrl under H0: Rho = 0	Profitability	Truck utilisation	Total cost	Distance travelled
Profitability	1.00000	0.46221 < 0.0001	−0.13420 0.2827	−0.25098 0.0421
Truck utilisation	0.46221 < 0.0001	1.00000	−0.34647 0.0044	−0.42409 0.0004
Total cost	−0.13420 0.2827	−0.34647 0.0044	1.00000	0.81274 < 0.0001
Distance travelled	−0.25098 0.0421	−0.42409 0.0004	0.81274 < 0.0001	1.00000

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Heteroscedasticity Consistent Standard Error	Heteroscedasticity Consistent t Value	Heteroscedasticity Consistent Pr > |t|	Standardized Estimate
Intercept	1	17006	4447.39080	3.82	0.0003	4387.40089	3.88	0.0003	0
Distance(km)	1	-0.52981	0.25543	-2.07	0.0421	0.24251	-2.18	0.0326	-0.25098

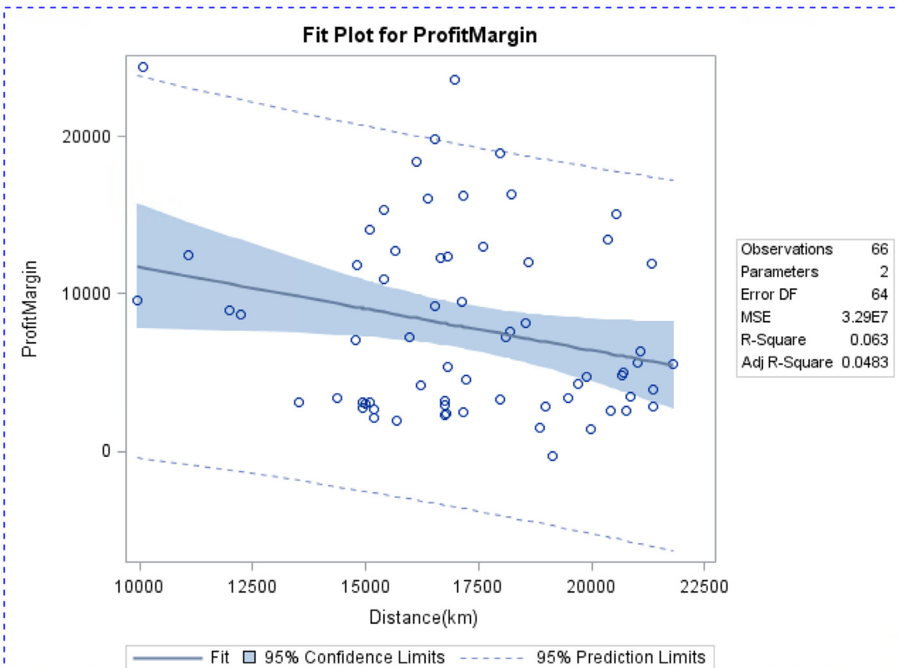

Fig. 15. Distance and profitability plot.

decrease in unit price, and total cost (-0.35) when higher truck utilisation brings the total cost down. Truck utilisation also has different levels of positive relationships with revenue elements such as pallets delivered (+0.30), total profit (+0.46), and profit per pallet (+0.48).

From our data analysis shown in the Pearson correlation coefficient in table 6 and Figs. 15 and 16 below, profitability and truck utilisation have a moderately positive linear relationship, but a negative non-linear relationship between profitability and total cost. Truck utilisation has a negative correlation with total cost.

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Heteroscedasticity Consistent Standard Error	Heteroscedasticity Consistent t Value	Heteroscedasticity Consistent Pr > |t|	Standardized Estimate
Intercept	1	-9507.59349	2717.73451	-3.50	0.0009	2105.66958	-4.52	<.0001	0
ActualPallets	1	8.26801	1.26284	6.55	<.0001	1.14575	7.22	<.0001	0.63334

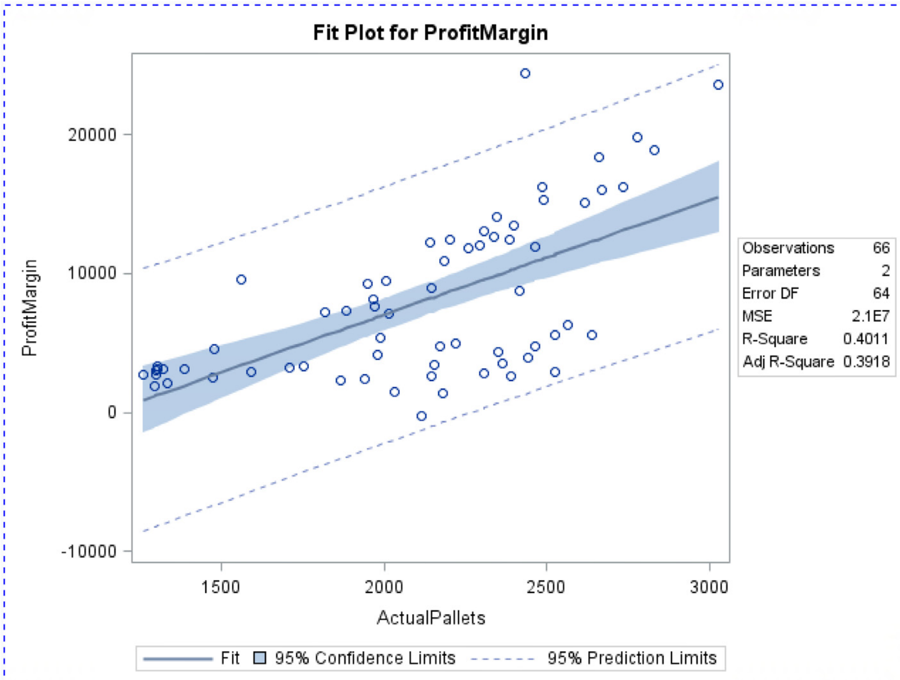

Fig. 16. Pallets and profitability plot.

	Truck utilisation	Total cost	Distance travelled	Volume of pallets transported
Profitability	moderate positive linear relationship	negative but less significant relationship	negative linear relationship	positively significant linear relationship
Causal effect explained	higher utilisation means more revenue	higher truck utilisation increases total cost and consequently reduces profit	longer distance = higher overall cost and reduced profit.	high volume of pallets transported means more revenue, leading to higher profit

Table 7
Seasonal truck fuel consumption.

January (Winter month)			June (Summer month)		
Trucks	**Fuel used (ltr/100 km)**	**Normalised fuel value**	**Trucks**	**Fuel used (l/100 km)**	**Normalised fuel value**
RT1 HCT	56.6	**1.1**	RT1 HCT	52.5	**1.1**
RT1 TRADT	48.5	**−0.1**	RT1 TRADT	46	**0.0**
RT2 HCT	51.4	**0.3**	RT2 HCT	45.7	**−0.1**
RT2 TRADT	48.7	**−0.1**	RT2 TRADT	48.03	**0.3**
RT3 HCT	55.1	**0.9**	RT3 HCT	51.1	**0.8**
RT3 TRADT	36.5	**−2.0**	RT3 TRADT	33.8	**−2.1**
MEAN	**49.5**			**46.2**	
STDEV	**6.5**			**5.9**	

Seasonal variations and drivers' impact on performance

Seasonal impact on truck performance

Truck telemetry data revealed the differences in fuel usage during the winter and summer months. Statistics from Table 5 show the differences in fuel consumption between the winter and summer months for high capacity trucks and traditional smaller trucks. Lahti and Tanttu (2016) suggested that the winter fuel consumption of HCT increases during cold and snowy weather, and the difference in fuel consumption during winter and summer months can be as high as 10 l/100 km depending on the road condition.

After data normalisation, the statistics from Table 5 show HCT's with higher standard deviation values from mean fuel usage, which means higher fuel consumption than TRADT's on all routes during the winter months. The only exception was on route two, where RT2 HCT had a slightly lower fuel consumption than average in June (-0.1).

Table 8
Route one drivers' performance (Jan-Feb).

RT1 HCT Drivers	Distance (km)	Avg speed (km/h)	Fuel used (ltr/100 km)	Normalised fuel value	RT1 TRADT Drivers	Distance (km)	Avg speed (km/h)	Fuel used (ltr/100 km)	Normalised fuel value
RT1 HCT1	14,757	70	59.0	1	RT1 TRADT1	14,765	65	49.2	−1
RT1 HCT2	14,705	68	53.5	−1	RT1 TRADT2	12,183	69	51.5	1
MEAN	14,731	69	56.2			13,474	67	50.3	
STDEV	26	1	2.8			1291	2	1.2	

Table 9
Route one drivers' performance (Jun-July).

RT1 HCT Driver	Distance (km)	Avg speed (km/hr)	Fuel used (l/100 km)	Normalised fuel usage	RT1 TRADT Driver	Distance (km)	Avg speed (km/hr)	Fuel used (l/100 km)	Normalised fuel usage
RT1 HCT1	10,092	67	51.5	1	RT1 TRADT1	10,456	67	42.6	−1
RT1 HCT 2	16,323	62	51.0	−1	RT1 TRADT 2	11,563	68	45.7	1
MEAN	13207.5	64.5	51.2			11009.5	67.5	44.1	
STDEV	3115.5	2.5	0.3			553.5	0.5	1.6	

Drivers' behaviours

The drivers' performance is one of the key metrics used to understand truck fuel usage during the different seasons. With relatively little data about individual drivers' performance on different routes, it is difficult to argue for the reliability of the conclusion, but we feel it is worth mentioning. Only route one provided data for four of its drivers during the winter months and four of its drivers during the summer months.

This data can be regarded as small, but it provided us with an opportunity to show the fuel consumption of trucks when they were driven by different drivers. Tables 6 and 7 show drivers with similar travel distances, but with differences in speed and fuel consumption during the winter and summer months. The focus here is not about the season, but the actual driving behaviours of different drivers using the same truck.Table 8.Table 9.

RT1 HCT1 and RT1 HCT2 are two different drivers, but drove the same truck on route one during January and February. Their average travel distance and fuel usage are 14,731 and 56.2, respectively. The same table shows the performance of two truck drivers for TRADT: RT1 TRADT1 and RT1 TRADT2.

Discussion and conclusions

Deploying high capacity transportation vehicles on roads within European Union member countries has been on the rise over the years, and the benefits as expected include cost saving and safety on road through less truck traffic. Finland has approved the use of HCT on its roads since October 2013, and dairy logistics is one of the few sectors that has deployed HCT in Finland. The focus in this sector is to measure the cost efficiency and other benefits of using HCT over traditional smaller trucks (TRADT).

This study analysed one year of data from a Finnish haulier, with truck capacities of 104 pallets for HCT and 75 pallets for TRADT in its fleet. Cost and revenue were identified as two key variables for performance evaluation under our research circumstances, and truck utilisation, which can be affected by both internal and external factors impacts greatly on the overall bottom-line.

Liimatainen and Nykänen (2016) showed a significant cost saving recorded over a five-year period (2013 to 2017) in their study. Our study compares intra-route performances for both HCT and TRADT, as well as their overall performances. Our research findings showed HCT had higher total cost (Fig. 6) across all three routes when compared with the average cost from both HCT and TRADT trucks. Intra-route cost performance is higher for HCT: this has a direct correlation with the truck utilisation rate, where HCT had higher utilisation during the period on many of the routes.

The impact of size advantage of HCT over TRADT can be seen in its higher revenue recorded where a higher truck utilisation rate was shown. Overall performance evaluation of the six trucks showed that revenue from HCT was higher than average on two routes and had an overall 1% revenue and 5.6% profit more than TRADT. With the benefit of extended data of more than a one year period and dynamism in truck deployment, there is a likelihood of higher revenue and consequently better overall profitability.

Other identified factors that impacted performance in this study are seasonal variability and drivers' attitudes. These two factors evidently affected fuel consumption, which in turn contributed to the cost performances of both HCT and TRADT. HCT consumed more fuel than TRADT during the winter months, but the same cannot be said of the summer months. Route one (Curtis and Scheurer, 2017) presented this study with driver data relating to fuel consumption per kilometre, distance travelled, and average speed. Variation in the fuel consumption of drivers with similar travelling distances offers an opportunity for further study.

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