RESEARCH REPORT

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Cassettes vs. roll trailers - environmental considerations

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Summary

The roll trailer system has become established worldwide for transporting cargo in RoRo (roll-on/roll-off) ships. A cassette system has been developed to resolve some of the shortages of the roll trailer system. The cassette's main difference from the roll trailer is the absence of wheels. A translifter used in the handling of cassettes is a steerable lifting trailer, which together with the cassettes replaces roll trailers in RoRo and StoRo handling. The aim of this research was to compare the two loading systems — roll trailers and cassettes — and to ascertain their differences in environmental performance during ship transportation. Here, "environment" means primarily airborne emissions from a ship. The research method was to compare theoretically the cargo capacities and ship emissions of these two transport unit systems, using an existing RoRo vessel as a test ship and computer models. For the calculations two models — a loading model and an emission calculation model — were created with Excel software.

The cassette system offers two clear environmental benefits over the conventional roll trailer system. The first is the more efficient use of deck space, which means more efficient transportation and thus less fuel consumption and emissions per transported unit or tonne. The second is the more efficient loading/unloading process. If the extra time thus saved can be used to lower the speed of the ship but still providing the same level of service (timetable), the environmental advantage is remarkable.

According to our calculations, the cassette system has 11 – 14% better deck space usage than conventional roll trailers in optimum circumstances, and the reduction in fuel consumption and emissions for the ship in optimum circumstances is 10 – 13%.

The loading/unloading process is clearly faster with cassette system. If this advantage is used to lower the cruise speed of the ship e.g. from 22 to 18 knots while still offering the same service time, the reduction of fuel consumption and emissions per transported unit is 33%.

Confidentiality	

Espoo 14.6.2010

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Preface

On 24th March 2010, TTS Liftec Oy commissioned a study by VTT on the environmental benefits of a cassette system over the traditional roll trailer system. The contact person at TTS Liftec was Vice president Olli Mäkinen and at VTT Senior Research Scientist Kari Mäkelä. At VTT, Chief Research Scientist Antti Permala and Senior Research Scientist Tapio Nyman also participated in the work. The interviewed experts from ship operator companies were Cargo Superintendent Magnus Hellström (Transfennica), Cargo Superintendent Juha Kelkka (Transfennica), and Cargo Handling Superintendent Aapo Rauhio (Finnlines)

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1 Introduction

The roll trailer system has become established worldwide for transporting cargo in RoRo (roll-on/roll-off) ships. With this system, general cargo or containers are set on platforms equipped with wheels and these units are wheeled onto the ship by a special truck (Figure 1). The units are then secured (lashed) to the deck for the sea voyage. The securing requires extra space especially on the sides of the roll trailer. Roll trailers also have some drawbacks concerning manoeuvrability and maintenance.

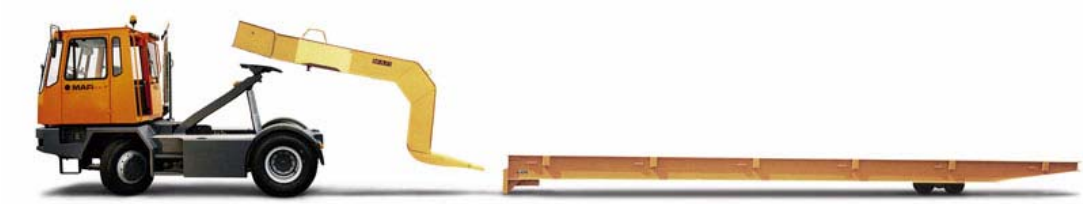

Figure 1. Terminal tractor, goose neck and a roll trailer (source: MAFI Transport-Systeme GmbH).

A cassette system has been developed to resolve some of the shortages of the roll trailer system. The cassette itself is much the same as a roll trailer but without wheels (Figure 2). The translifter used in the handling of cassettes is a steerable lifting trailer, which together with the cassettes replaces roll trailers in RoRo and StoRo handling.

Figure 2. Terminal tractor, translifter and a cassette

2 Goal

The aim of the research was to compare the two loading systems — roll trailers and cassettes — and to ascertain their differences in environmental performance during ship transportation. Here, “environment” means primarily airborne emissions from a ship.

3 Methods

3.1 General

Roll trailers and cassettes are used for the same purpose — to load and unload RoRo ships effectively. Although the systems have much in common, there are certain differences in the loading/unloading processes, process times, maintenance, etc. The research method was to compare cargo capacities and ship emissions theoretically using an existing RoRo vessel as a test ship and computer models. The results where compared with the real-world figures.

3.2 Test ship

The test ship in the calculations was Transfennica's Stena Forecaster, which is a sister ship of the Stena Forerunner (Figure 3). The ship was chosen because it is a pure RoRo vessel without special sections for other cargo types or passengers. Ship's trailer capacity is ca. 180. Fuel consumption and emission evaluations are based on theoretical calculations, not on measurements of this individual ship.

Ro-Ro Vessels

M/S STENA FORERUNNER

General Information:	The vessel was designed for Dalian Shipyard, China. Dalian Shipyard delivered 3 vessels for Stena Ro-Ro, Sweden. The design is highly advanced and the vessel will have very large capacity, high speed and very fast turn around in the harbour. The first vessel was delivered in May 2002.	
Main Particulars:	Length o.a.	195.30 m
	Length p.p.	179.20 m
	Breadth moulded	25.60 m
	Depth to main deck	8.60 m
	Design draught (approx.)	6.60 m
	Deadweight	12800 t
Capacity:	Trailer lane	approx. 3000 m
	Accommodation	12 drivers
Speed:	Service speed (85 % MCR and 15 % Sea margin)	22.30 kn
Propulsion:	Diesel propulsion	
	Main engines	4 x Wärtsila NSD 8ZAL40S
	Installed power	24000 kW
	Auxiliary engines	2 x Wärtsila NSD 9L20C
Miscellaneous:	Classification	Norske Veritas
	Number of vessels built	(3)
	Identification number	KEH 99043
	IMO number	9227259

Figure 3. The test ship

3.3 Loading model

Ship emission calculations need data on cargo and capacity. RoRo ships have different decks with different forms and dimensions. To be able to test and choose different ships and cargo for calculations a loading model was developed with Excel software.

One of the benefits of the cassette system over conventional roll trailers is the more efficient use of space. Cassettes have no moving parts (like bogies) and hence they can be stowed side-by-side without separate securing (block stowing) (Figure 4). This means that e.g. on a deck with eight lanes nine cassettes can be stowed side-by-side (Figure 5). Roll trailers are normally secured on each side but they can also be stowed head-to-head like cassettes. In that case they have to be secured (lashed) from their sides and cannot be stowed side-by-side as cassettes, thus needing a space 3 m wide (lane). Both roll trailer stowing types appear in shipping companies.

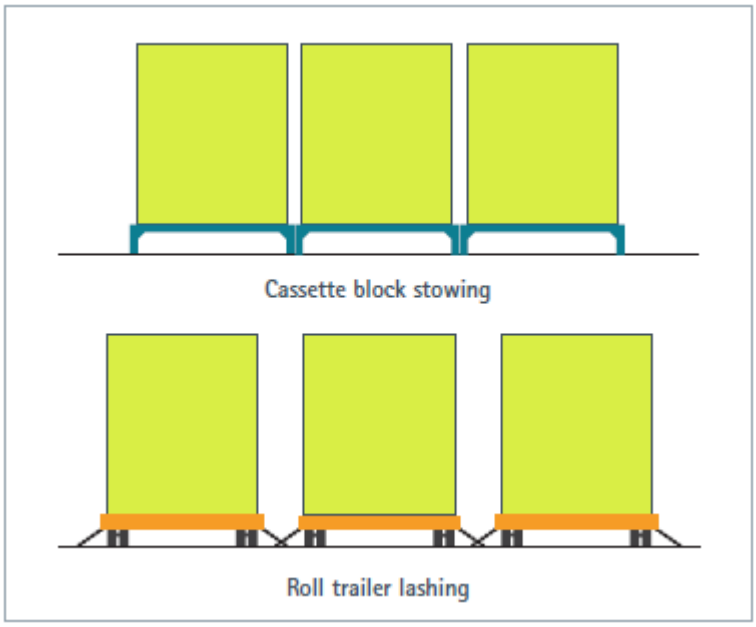

Figure 4. Stowing of cassettes and roll trailers

For the calculations of trailer, roll trailer and cassette capacity of different ship decks an Excel loading model was created. The model arranges these transport units on the deck using the dimensions of the deck and dimensions of the transport units. ”Dimension” is the “efficient” space needed for stowing, i.e. including the space needed for securing (lashing). For roll trailers two lengths appear in the model, one without head lashing (12.3m) and one with lashing (12.7m). The dimensions used in the model are shown in Table 1.

Table 1. Dimensions of transport units including securing (lashing).

Unit	Length [m]	Width [m]	Tare [t]	Net load [t]
Trailer	15.0	3.0	6.5	14
Roll trailer	12.3 – 12.7	3.0	7.0	40
Cassette	12.3	2.6	5.0	40

The loading model first calculates in how many rows transport units can be stowed, then how long those rows can be. Due to the cassettes' stowing technology they cannot be stowed in certain short areas, normally 20 metres at the head of the row. These cassette-restricted areas are taken into account in the model. In these restricted areas a roll trailer can be stowed instead. The maximum amount of transport units on one deck is calculated including this, and when all the decks of a ship have been calculated the ship's total capacity is known.

Figure 5 illustrates the loading a deck with cassettes. The figure on the right is a sketch provided by the shipyard and the figure on left is a simplified arrangement used in the model. To crosscheck the result of the model the figures were compared with the real-world data (capacities provided by the ship operator).

In the calculations the net cargo weights were the same for both roll trailers and cassettes. In fact the cassette system allows bigger unit loads to be stowed on a RoRo ship (steep ramps) because the self-loading trailer used in cassette systems has brakes (under the cassette). However, this advantage is mainly in the loading process and not in the capacity of the ship.

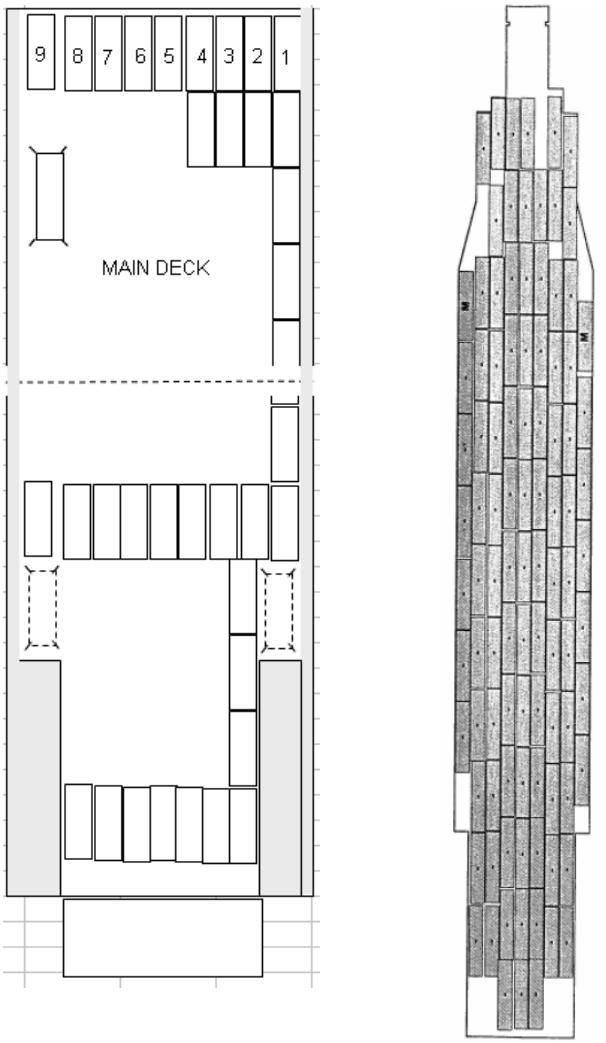

Figure5. Schematic presentation of the capacity calculation arrangements on a ship deck.

The loading model also includes the possibility to calculate loading/unloading times. However, the time used in port depends on so many other things than the speed of loading units that this feature could not be used here.

The loading and unloading practices of the cassette and roll trailer systems were followed at two Finnish ports, Hanko and Vuosaari (Helsinki), for five ships belonging to two shipping companies (Transfennica and Finnlines). Three experts from the ship operator companies were interviewed.

3.4 Emission calculation model

To determine the differences in exhaust gas emissions of a ship using a roll trailer system or cassette system, an emission calculation model was created using Excel software. Input for the model were the following data of the ship: Installed main engine power (24 000 kW), auxiliary engine power (3 000 kW), main engines' power use at sea (60%), main engines' power use in port (0%), auxiliary engines' power use at sea (0%), auxiliary engines' power use in port (30%), speed (22 knots), time at sea (2.67d), time in port (1.33d), distance (2 100 km), specific fuel consumption and emission factors (8 compounds). Input from the loading model was the number of freight units and gross and net weight of the cargo. Fuel consumption and emissions of the ship were the same for loaded and unloaded ships, as the difference is small.

The model calculates first the energy use at sea and in port using the installed power and the power use in each circumstance. The total used power is then multiplied by specific fuel consumption and emission factors. Total fuel use and emissions are then divided by ship kilometres, number of freight units and net weight of the cargo.

The model shows the results for different sections of the voyage: emissions at sea and in port, per day, per ship kilometre etc. For the purposes of this study the main results are fuel consumption and emissions per ship kilometre, per freight unit kilometre and per net tonne kilometre. The calculation methodology and result reporting was the same as with the LIPASTO emission model. The LIPASTO model and the main results (25 ship types) are described here: http://lipasto.vtt.fi/yksikkopaastot/tavaraliikennee/vesiliikennee/tavara_vesie.htm

Operation cases: For the ship operations the following two cases were studied:

1. A roundtrip of 2 100 km with both legs loaded full of cargo on roll trailers or cassettes.
2. A roundtrip of 2 100 km, out-freight full of cargo on roll trailers or cassettes, back-haul empty roll trailers and cassettes stacked and the area left free on the decks filled with trailers.

The transport distance has a minor effect on the results as the fuel consumption and emissions are expressed per kilometre (ship, freight unit and net tonne).

4 Results

The cassette system has two clear environmental benefits over the conventional roll trailer system. The first is the more efficient use of deck space, which means more efficient transportation and thus less fuel consumption and emissions per transported unit or tonne. The second is the more efficient loading/unloading process. If the extra time saved can be used for lowering the speed of the ship while still providing the same level of service (timetable), the environmental advantage is remarkable. The following text reviews these two options.

4.1 Capacity usage

The loading model above was used to study the capacity of the test ship. The ship was the Stena Forecaster owned by Transfennica (Figure 3). This ship was chosen because it is a pure RoRo vessel without special sections for other cargo types or passengers.

In the calculations of deck space use, the following results were obtained for the test ship in the operation case 1 (Operation cases are described in the chapter 3.4) The figure +6 (table 2) in the cassette system row means those six roll trailers that can be stowed in areas where cassettes cannot be stowed. The net weight of the cargo on the cassettes and roll trailers (40 t) is an input value and represents the maximum when the ship is fully loaded (mainly paper rolls). This is not the maximum that can be loaded on the roll trailer or cassette but the average weight that produces the maximum capacity use of the ship. The weight of the cargo per freight unit is not essential when comparing the two systems as long as the weight is the same on both transport units.

The capacity (number) of the roll trailers varies from 220 to 214 depending on whether the roll trailers are stowed head-to-head (220) or a 40 cm securing space is left between the roll trailers (214). Thus the advantage of the cassette system (245+6) varies by 11 – 14% in the net tonne capacity.

Table 2. Key figures for the operation case 1 (only cassettes or roll trailers).

	Number of units	Net weight of the cargo [t/unit]	Gross weight of the cargo [t]	Total net weight of the cargo [t]
Cassettes	245 (+ 6)	40	11 037	9 800
Roll trailers	214 – 220	40	10 058 – 10 340	8 560 – 8 800
Difference	25 – 19		979 – 697	1 260 –1 000
Difference **[%]**	14 – 11		9.7 – 6.7	**14 – 11**

Regarding the operation case 2, in the back haul leg all the empty roll trailers and cassettes are stacked (5 unit stacks) and the area left free on decks is filled with trailers (mixed freight). The remaining space allows 138 trailers in maximum in the roll trailer system and 127 trailers in the cassette system. The difference is due to the fact that in out-bound leg the number of cassettes is higher than the number of roll trailers thus leaving less space for trailers during the back-haul leg. Still, using the cassette system the total cargo capacity in a round trip is 423 tonnes (8%) higher than using the roll trailer system.

4.2 Emissions

The cassette system's capacity usage is better than the roll trailer system's. According to the calculations, the direct emission benefit for the cassette system due to the capacity usage is from 10% up to 13% (Table 3). This benefit is seen in the table, e.g. in the result of 32 g/tonne kilometre (g/tkm) for the roll trailer system and 28 g/tonne kilometre for the cassette system. However, this requires the optimisation of space use and full capacity use. The optimum is best attained with a uniform freight type like paper rolls and when both ports are equipped with a cassette handling system. In the case of mixed freight composition (operation case 2) this emission benefit is lower.

Table 3. Emissions per different units in the operation case 1, optimum

Roll trailer system

RoRo, 22 kn	CO	HC	NOx	PM_{10}	$PM_{2,5}$	CH_4	N_2O	SO_2	CO_2	CO_2 eq.	Fuel
[g/ship km]	228	47	5 689	133	107	23	8	2 427	275 246	278 110	86 360
[g/roll trailer/km]	1.1	0.22	27	0.62	0.50	0.11	0.036	11	1 286	1 300	404
[g/tkm] net freight	0.027	0.0055	0.66	0.016	0.012	0.0026	0.0009	0.28	32	32	10

Cassette system

RoRo, 22 kn	CO	HC	NOx	PM_{10}	$PM_{2,5}$	CH_4	N_2O	SO_2	CO_2	CO_2 eq.	Fuel
[g/ship km]	228	47	5 689	133	107	23	8	2 427	275 246	278 110	86 360
[g/cassette/km]	0.9	0.19	23	0.54	0.43	0.09	0.031	10	1 123	1 135	352
[g/tkm] net freight	0.023	0.0048	0.58	0.014	0.011	0.0023	0.0008	0.25	28	28	9
Difference cassette / roll trailer	-13%	-13%	-13%	-13%	-13%	-13%	-13%	-13%	-13%	-13%	-13%

Freight flows consist mostly of mixed freight. The case 2 described in the chapter 3.4 assumes a full heavy load on roll trailers or cassettes (e.g. paper rolls) in one direction and trailers in back-haul (stacked empty roll trailers or cassettes and the free area full of trailers). The average of net freight load in the loaded trailers according to the statistics in Finland being 14 tonnes, the net freight weight of the test ship on the back-haul trip is essentially lower (around 1 900 tonnes) than on the out-freight (ca 9 000 tonnes). This greatly affects the average emission figures (Table 4). However, the emission benefit of the cassette system also in this case is from 7% to 9%.

Table 4. Emissions per different units, operation case 2, mixed freight

Roll trailer system

RoRo, 22 kn	CO	HC	NOx	PM_{10}	$PM_{2,5}$	CH_4	N_2O	SO_2	CO_2	CO_2 eq.	Fuel
[g/ship km]	228	47	5 689	133	107	23	8	2 427	275 246	278 110	86 360
[g/tkm] net freight	0.043	0.0089	1.1	0.025	0.020	0.0043	0.0015	0.46	52	53	16

Cassette system

RoRo, 22 kn	CO	HC	NOx	PM_{10}	$PM_{2,5}$	CH_4	N_2O	SO_2	CO_2	CO_2 eq.	Fuel
[g/ship km]	228	47	5 689	133	107	23	8	2 427	275 246	278 110	86 360
[g/tkm] net freight	0.039	0.0081	1.0	0.023	0.018	0.0039	0.0013	0.42	48	48	15
Difference cassette / roll trailer	-9%	-9%	-9%	-9%	-9%	-9%	-9%	-9%	-9%	-9%	-9%

4.3 Emission mitigation through speed reduction

The cassette system offers a clear speeding up of the ship loading/unloading process. If the extra time saved can be used for lowering the cruise speed of the ship while still providing the same level of service and timetable, the environmental advantage is remarkable. The difference in the fuel use of a ship is the speed difference to the power of two (to the power of three in point speed but to the power of two if also taking the time into account). This means that e.g. a ship cruising at a speed of 18 knots instead of 22 knots has 33% less fuel use and emissions per transported unit.

This shows the potential of the process management in environmentally friendly logistics. The sharp rise in fuel prices coupled with the economic downturn of recent years has forced shipping companies to find all possible means to reduce costs. Lowering of the speed of ships has proved to be the most profitable way of immediately cutting the running costs of a ship, and as a secondary benefit also its environmental burden. Speeding up the ship loading/unloading process through the use of a cassette system enables a remarkable reduction in speed of ships with the optimal use of cassettes. This necessitates the optimisation of the whole transport chain, which itself is in the best interests of transport companies.

5 Conclusions

The aim of the research was to compare two loading systems — roll trailers and cassettes — and to identify their differences in the environmental performance of ship transportation. Here, “environment” means primarily airborne emissions from a ship.

The cassette system has two clear environmental benefits over the conventional roll trailer system. The first is the more efficient use of deck space, which means more efficient transportation and thus less fuel consumption and emissions per transported unit or tonne. The second is the more efficient loading/unloading process. If the extra time saved can be used for lowering the speed of a ship while still providing the same level of service, the environmental advantage is remarkable.

The research carried out shows that the direct emission benefit of the cassette system over the traditional roll trailer system due to better capacity usage is from 10% to 13%. However, this requires the optimisation of space use and full capacity use. The optimum is best attained with a uniform freight type like paper rolls and when both ports are equipped with a cassette handling system. In the case of a mixed freight composition this emission benefit is lower. In the case of unbalanced freight flow where the out-freight is fully loaded with heavy freight but the back-haul is trailers, the emission benefit is still from 7% to 9% in favour of the cassette system.

A far better environmental advantage is achieved if the better loading/unloading capacity of the cassette system over the traditional roll trailer system is exploited in lowering of the cruising speed of ships. The difference in the fuel use of a ship is the speed difference to the power of two. This means that e.g. a ship cruising at

a speed of 18 knots instead of 22 knots has 33% less fuel use and emissions per transported unit.

The cassette is a technical means of bettering the transport efficiency of a RoRo ship. However, its full benefits are best achieved if the freight and loading systems are optimal and the main benefit — more rapid loading/unloading — is exploited by lowering the cruise speed of ships, thus markedly reducing fuel use and emissions.

6 Summary

The roll trailer system has become established worldwide for transporting cargo in RoRo (roll-on/roll-off) ships. With this system, general cargo or containers are set on platforms equipped with wheels and the units are wheeled onto the ship by a special truck.

A cassette system has been developed to resolve some of the drawbacks of the roll trailer system. The cassette's main difference compared to the roll trailer is the absence of wheels. The translifter used in the handling of cassettes is a steerable lifting trailer, which together with the cassettes replaces roll trailers in RoRo and StoRo handling.

The aim of this study was to compare the two loading systems — roll trailers and cassettes — and to ascertain their differences in environmental performance during ship transportation. Here, "environment" means primarily airborne emissions from a ship.

The research method was to compare cargo capacities and the ship emissions of these two transport unit systems theoretically, using an existing RoRo vessel as a test ship and computer models. For the calculations two models were created with Excel software: a loading model and an emission calculation model.

For the ship operations the following cases were studied:

3. A roundtrip of 2 100 km with both legs loaded full of cargo on roll trailers or cassettes.
4. A roundtrip of 2 100 km, out-freight full of cargo on roll trailers or cassettes, back-haul empty roll trailers and cassettes stacked and the area left free on the decks filled with trailers.

The cassette system offers two clear environmental benefits over the conventional roll trailer system. The first is the more efficient use of deck space, which means more efficient transportation and thus less fuel consumption and emissions per transported unit or tonne. The second is the more efficient loading/unloading process. If the extra time saved can be used for lowering the speed of the ship while still providing the same level of service (timetable), the environmental advantage is remarkable.

According to the calculations the cassette system has 11 – 14% better deck space usage than conventional roll trailers in optimum circumstances, and the reduction in fuel consumption and emissions for the ship in optimum circumstances is 10 – 13%.

The cassette system is clearly faster in the loading/unloading process. If this advantage is used to lower the cruise speed of the ship e.g. from 22 knots to 18 knots while still providing the same level of service, the lowering of fuel consumption and emissions per transported unit is 33%.