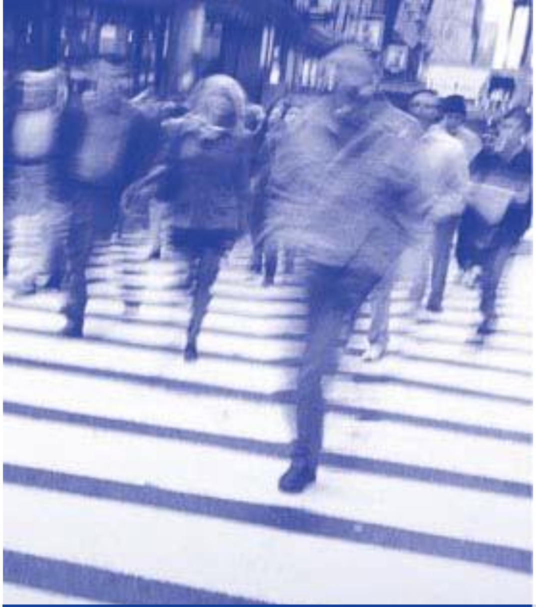

CIVITAS
Cleaner and better transport in cities

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Measure Evaluation Results

TAL 6.1 Eco Driving

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Executive Summary

The fuel consumption average of the public Tallinn Bus Company's (TBC) vehicles reached ten million litres of diesel fuel a year. It was a considerable cost for the city of Tallinn and generated negative environmental impacts in the region. However, buses of the TBC every year were involved in approximately one hundred traffic accidents. Nevertheless, it had been observed that fuel consumption and the rate of accidents were linked to driver behaviour. Based on this observation, the city decided to implement the measure 'Eco Driving' in the frame of the MIMOSA project with the aim of integrating Eco Driving modules in the current training program of the TBC. The objectives of the measure were to decrease the fuel consumption of PT vehicles, raise the eco-driving awareness among the bus drivers, and increase the traffic safety in Tallinn.

The measure was implemented in the following stages:

Stage 1/2: Tender procedure for the implementation of the measure (2009-2010) A tender procedure was prepared and conducted to select a subcontractor responsible for the implementation of the Eco Driving training module. The jury was composed of members from the TBC, the Tallinn City Government and the Tallinn University of Technology.

Stage 3: **Installing training equipment** (2010) In the scope of the training module, specific equipment was installed in 15 buses from the TBC (7 normal and 8 articulated buses).

Stage 4: **Training** (2011-2012) Eco Driving training took place. 274 of the 666 drivers in the TBC were trained in 5 working groups conducted by ten TBC trainers which were formed in the scope of the measure. The evaluation was conducted during this period.

Impact and process evaluations were conducted based on indicators measuring the current fuel consumption by public transport services from which measurement of emissions was estimated as well as measurements of the driving style index. Traffic accident statistics and a survey of bus drivers on awareness and acceptance were also used as indicators. In addition to these evaluations a Cost Benefit Analysis (CBA) was carried out, discounting benefits and costs over the whole project period 2010-2012 (the data for the 2012 were estimated). The costs included investments in the equipment and running costs and the benefits included fuel savings, emission savings and accident savings.

Key-results of the evaluation highlighted the positive impact of the implementation of Eco driving training by comparing indicators with before and after training. Regarding fuel consumption, it was reduced by 3,9% on average for the participants of the training and 0,9% total in the TBC. Consequently, the amount of emissions was reduced: the total TBC annual amount of pollutant emission was reduced to a range of 0,7-1,0%. However, the driving style index was improved by an average of 7,3% and the number of accidents involving a TBC bus was reduced by 22%. It has also shown that the bus drivers' awareness on the environmental issues rose by 29%. The results of the CBA indicated that the measure is highly cost-effective both socio-economically and financially – the CBA resulted in net present value of €67,657 in a lifespan of 3 years, benefit/cost ratio 1,6 in the case of a social discount rate (SDR) of 5,5%. Since the running costs for the training is low (TBC's own trainers and no "wasted" driver and bus time) and the installed equipment has a life expectancy of up to 10 years, the result would be even greater if a longer period was used for CBA.

The most important barrier was encountered during the running phase of the measure: the rotation of bus drivers on the training-equipped buses created a considerable amount of

additional work for the traffic planners of the TBC. Nevertheless this barrier had an insignificant effect on the outcomes.

The main driver observed during the running phase of the measure was the friendly competitive spirit among the drivers involved in the Eco driving training which contributed in motivating them to apply themselves, making it a success.

This measure has a high **potential for replication** as the concept is based on the existing public fleet and existing training programs and it does not require heavy financial resources for implementation. Each city should develop its specific concept in accordance with its own technical requirements for training equipment. From the experience of Tallinn **it is recommended** to invest efforts at the earliest stages of the measure to efficiently manage and plan the timeframe for drivers´ training according to the amount of equipped buses available. However, one of the success factors of this measure is keeping bus drivers motivated and encouraging them to participate in the training in order to achieve the best possible results.

Based on the positive results of the Eco-Driving modules implemented in the frame of MIMOSA, TBC decided to continue this initiative in the following years.

A Introduction

A1 Objectives

The measure objectives are:

(A) High level / longer term:

- Reduction of transport related pollution;
- Increase of modal split towards sustainable modes;
- Improvement of quality of life;

(B) Strategic level:

- Raise the quality of public transport (PT) service;
- Reduce the emissions of Tallinn PT;
- Promotion of an energy-efficient PT service with higher safety and comfort;
- Promotion of an attractive and high quality public transport service;

(C) Measure level:

- Decrease the fuel consumption of PT vehicles by introducing an energy efficient driving style;
- Raise the eco-driving awareness among the bus drivers and their trainers;
- Decrease the number of accidents with PT involvement;
- Increase the safety of PT users;
- Decrease the fleet reconstruction costs caused by traffic accidents;
- Increase the drivers' eco-driving habits;
- Introducing the eco-driving training procedures into regular drivers training activities by the Tallinn Bus Company

(D) Etc.

1. Fuel and maintenance cost has decreased by 10%;
2. Ride comfort in bus has increased by 25%;
3. Accidents caused by Bus drivers have decreased by 10%;
4. Material loss in accidents caused by bus drivers has decreased by 10 %;
5. Bus driver's awareness of environment has increased by 10%.

A2 Description

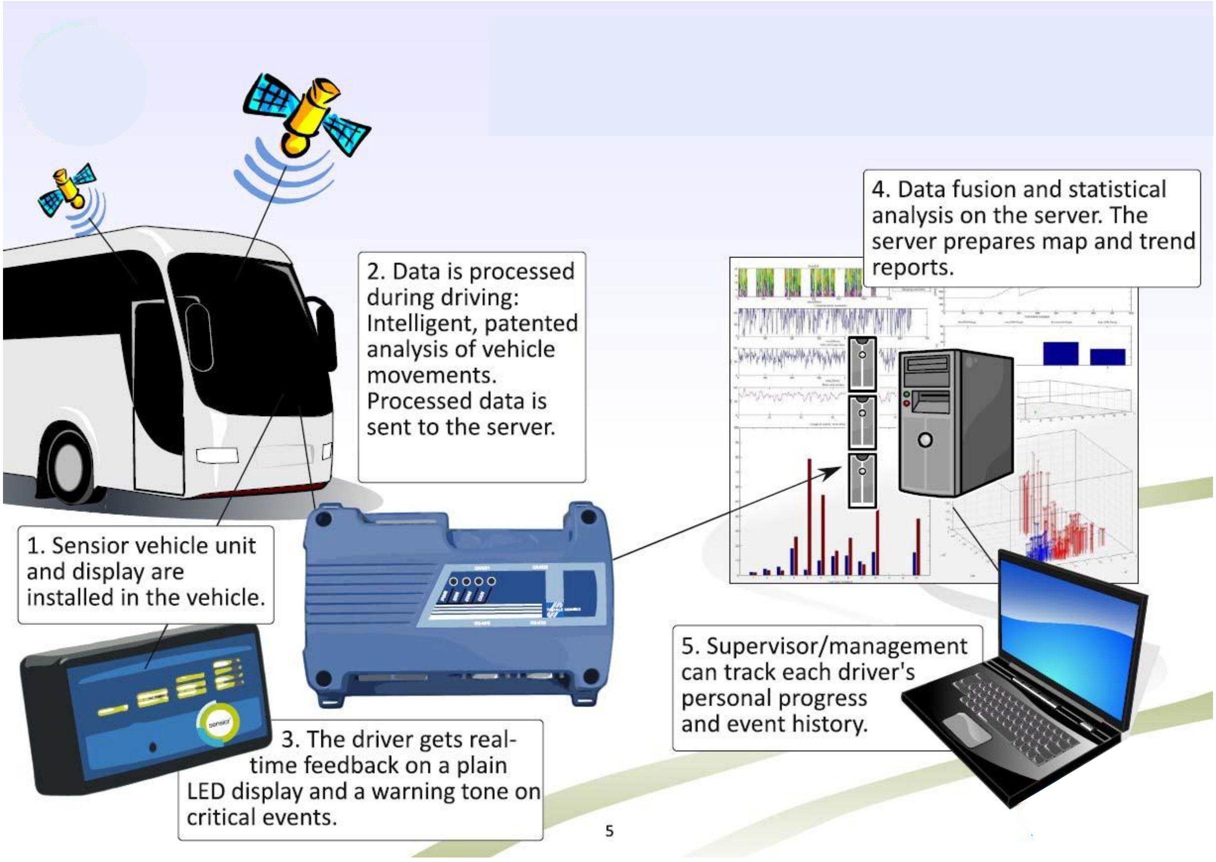
Eco-driving is a training used for improving drivers awareness on their driving behaviour and thus for improving their driving style. The aim is to teach drivers to notice, predict and imagine situations in traffic and thus to avoid hard braking, hard acceleration, excessive steering and all this while actually rising the average speed. As a result of the improved driving style fuel consumption and emission levels are reduced, ability to predict results in less traffic accidents, and smooth driving style results in increase of PT passenger comfort.

Different eco driving training programs state 10-20% fuel consumption reduction and up to 40% accident cost reduction as a result of training. The full effect of the training is temporary and trained drivers return to their old driving habits after few months but it is stated that 1/3 of the effect is long lasting. Thus the training has to be repeated.

The training in the scope of the Tallinn Bus Company (TBC) CIVITAS MIMOSA measure was conducted by the Scania Estonia trainer from December 2010 to March 2012. 7 normal and 8 articulated buses were equipped with training equipment (

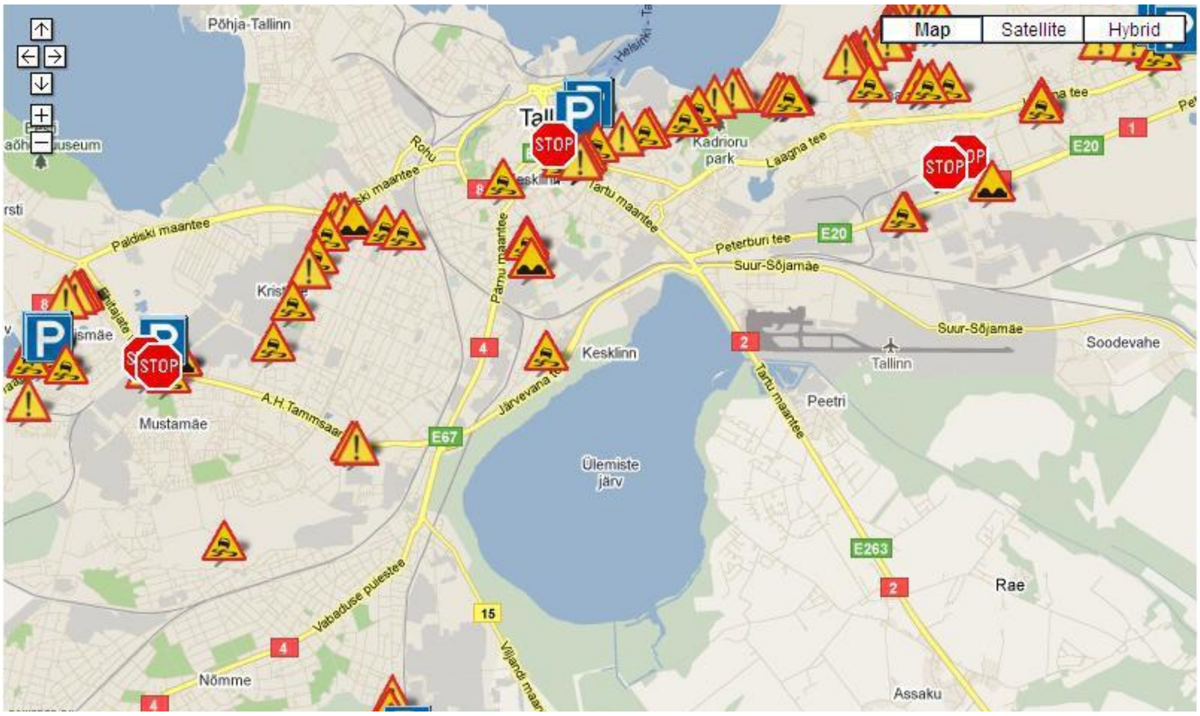
Figure 1) that recorded braking, acceleration, steering, and bumps and gave real time feedback to the drivers. The system had online connection to central server for recording and analyzing the results and the trainer had a portable tablet computer for monitoring the real time results and history of the driving.

Figure 1 Technology behind eco-driving training



100% of the driving during the training was done during the regular work servicing the public city lines. This enabled to reduce the cost of the training since no drivers' time or vehicle time was wasted. Also it enabled realistic evaluation of the training results in real life traffic and load conditions. The problematic driving events were recorded and visible for analysis for the trainer and drivers as can be seen on figure 2.

Figure 2 Problematic driving events recorded and illustrated by the training equipment



274 TBC drivers were trained in 5 groups in the scope of the measure. For continuing with the training without external assistance 10 TBC trainers were also trained.

B Measure Implementation

B1 Innovative Aspects

The innovative aspects of the measure are:

- **New conceptual approach** - eco driving training with detailed real time feedback and later results analysis have not been done among TBC or Tallinn bus drivers before;
- **New conceptual approach –** modern technological solution – equipment and software for buses for carrying out eco driving training in Public Transport (PT);
- **New conceptual approach** – driving practice lessons during regular work servicing public city lines is a new approach compared to the training on a remote training site. Thus no costly driver or vehicle time was "wasted" for practicing lessons and evaluation.

B2 Research and Technology Development

No research or technology development was done in the scope of the measure.

B3 Situation before CIVITAS

Buses in the TBC consume approximately 10 million litres of diesel fuel a year. It is a considerable cost for Tallinn city (as an owner of the TBC) and negative impact to the environment. Every year buses of the TBC are involved in approximately 100 to 120 accidents regardless of who is fault in the accident. Majority of the accidents result in no personal injuries but the accident cost to the company is 40 000-60 000€ a year.

The statistics of drivers in the TBC show that there is measurable driver to driver difference in the fuel consumption and some drivers tend to be more often involved in traffic accidents even if legally they are not always found to be the cause of the accidents. Eco-driving has been included in the training program of the TBC but it has so far not included detailed and personal analysis of driver's behaviour. Impacts of economic driving style on effectiveness of PT have not been evaluated in Tallinn. There have been neither qualified persons nor suitable technology for carrying out eco-driving training for PT drivers in the TBC.

B4 Actual Implementation of the Measure

The measure was implemented in the following stages:

Stage 1: Preparation for implementation of the measure: preparation of the public procurement. From 2009 - February 2010.

Stage 2: Public procurement: carrying out the public procurement procedures. Offers by participants were analyzed by the commission consisting of members from the TBC, the Tallinn City Government and the Tallinn University of Technology. March 2010 - September 2010.

Stage 3: **Installing equipment:** the equipment was installed and tested in the vehicles November 2010 – December 2010.

Stage 4: **Training:** carrying out the before-evaluation, eco-driving training and results evaluation in 5 training groups. January 2011 – March 2012.

B5 Inter-Relationships with Other Measures

The measure is related to the other measures as follows:

- **2.1 Developing P&R and School Bus** – safer and more energy-efficient driving style affects all services provided by TBC, including those included in the measure 2.1.
- **4.1 Mobility Management and marketing activities directed at popularizing usage of active transport modes** – measure 6.1 is also aimed at rising safety and driving comfort of passengers, thus supporting popularizing the usage of PT.

C Impact Evaluation Findings

C1 Measurement Methodology

C1.1 Impacts and Indicators

The measure had best possibilities among the Tallinn MIMOSA measures for proper evaluation. The objectives of the measure were clear and based on similar measures, impacts were all measurable technically and economically and even accident statistics was usable with small reservation regarding to short after-period. Also, the eco driving measure was the only among Tallinn measures where it was possible to carry out cost benefit analysis (CBA). Report of the CBA is added to the template as an annex.

Table C1.1: Indicators

NO.	EVALUATION	EVALUATION SUB-CATEGORY	IMPACT	INDICATOR	DESCRIPTION	DATA /UNITS
4	Economy	Costs	Operating Costs	Fuel and accident costs	Total fuel and accident costs TBC/year	€, quantitative, derived
5	Energy	Energy Consumption	Fuel Consumption	Fuel consumption	Amount of fuel used l/TBC/year	l, quantitative, derived
10	Environment	Pollution/nuisance	Emissions	CO_2 emissions	Total CO_2 emission	T/TBC/year, quantitative, derived
12	Environment	Pollution/nuisance	Emissions	NOx emissions	Total NOx emission	T/TBC/year, quantitative, derived
13	Environment	Pollution/nuisance	Emissions	particulate emissions	Total PM10 emission	T/TBC/year, quantitative, derived
TAL 6.1-1	Environment	Pollution/nuisance	Emissions	SO_2 emissions	Total SO_2 emission	T/TBC/year, quantitative, derived
15	Society	Acceptance	Awareness	Awareness level of bus drivers	Degree to which the awareness of bus drivers has changed with the training	Index, qualitative, collected, survey

16	Society	Acceptance	Acceptance	Acceptance level of bus drivers	Attitude survey of current acceptance with the measure among trained bus drivers	Index, qualitative, collected, survey
21	Transport	Safety	Transport Safety	No. of accidents involving PT vehicles	Average no. of accidents per 100 drivers per week	Accidents/ 100 drivers/ week
TAL 6.1-2	Transport	PT service quality	Driving style	Driving style	Derived driving style index from measurements of braking, acceleration, steering, bumps and curve speed	Index, derived, qualitative measurement

Detailed description of the indicator methodologies:

- **4 Operating costs –** Only the change of fuel costs and accident costs were evaluated and the data was used in cost-benefit analysis. The data was obtained from the TBC and the eco driver trainer. Although the fuel cost is directly dependent on fuel consumption, it is also dependent on change in fuel price and was needed for calculation of the cost benefit analysis (CBA).
- **5 Fuel consumption** – The change in fuel consumption was evaluated from pre-training and after-training measurements, taking into account the change in ambient temperatures during the measuring periods. The temperature dependence was estimated from all fuel consumption measurements made during the measure implementation.
- **10, 12, 13 and TAL 6.1-1 Emissions –** all emissions (CO_2, NO_x, SO_2, PM) were calculated using Finnish calculation sheet for average city bus emissions[1]. The usage of the methodology was based on the similarities of the conditions in Tallinn and Helsinki: distance between the cities is 80 km and the climate is similar, the fleet used in the TBC has so far similarly consisting mainly of Volvos and Scanias. Although the emissions are directly dependent on fuel consumption, they were calculated for the CBA.

[1] LIPASTO - a calculation system for traffic exhaust emissions and energy consumption in Finland. VTT Technical Research Centre of Finland. http://lipasto.vtt.fi/yksikkopaastot/henkiloliikenne/tieliikenne/linja-autot/bussikatu.htm

- **15 Awareness and 16 acceptance** – Awareness and acceptance of the bus drivers who had participated in the eco driving trainings were evaluated with a survey. The survey was carried out in June 2012 by TBC with six questions:
  1. How aware were you of eco-driving training before the TBC training?
  2. How do you feel, did you benefit from the training?
  3. Would you recommend the training to your colleagues?
  4. Have you used the knowledge while driving your personal car?
  5. How important do you think is the knowledge you gained from the training?
  6. How important do you think the next aspects are in eco driving training results?
     - Economical savings
     - Environmental savings
     - Improvement in traffic safety
     - Improvement in passenger comfort

  167 (61%) of the trained 274 drivers participated in the survey.
- **21 Transport safety, no. of accidents involving PT vehicles –** initially considered indicator - nr of deaths and injuries was rejected, because of statistically insufficient frequency (fortunately) of such occurrences. No. of accidents where TBC vehicles have been involved can be seen on the figure 4 in the chapter C1.3 and driving style can be expected to influence that. The average accident involvement rate was compared between trained and not trained drivers, before, during and after the training. It could have been possible to select only the accidents where TBC drivers have officially found to be causing the accident but after randomly analyzing the accidents the real cause of an accident is in many cases far from clear. Also, as the eco driving training is concentrated on learning to predict traffic ahead and thus to predict possible conflict situations, it has effect also on the accidents caused by other drivers. The average accident involvement rate was compared between trained and not trained drivers, before, during and after the training.
- **TAL 6.1-2** - The equipment that was installed in the buses calculated a driving style index from driver behaviour. It took into account deviations from ideal driving style: hard braking and acceleration, sudden steering movements, high curve speeds and hard bumps. The index varied from 97,0 to 100,0 for normal buses and from 96,6 to 99,6 for articulated buses.

Table C1.2: List of potential effects that were not assessed

Impacts category	Indicator	How does it impact	Why it was not accessed
Economy	3. Maintenance costs	If driving style is smoother and brakes, engine, transmission, suspension, tyres and other parts of buses work under smaller load, it has an influence on maintenance costs as well.	The maintenance costs vary more according to changes in various prices, according to bus models and there is no detailed bus-to-bus statistics available. Also, no study results were available linking the bus models maintenance costs to driving style index and fuel consumption change.
Energy	6. Energy consumption	The change in fuel consumption is directly meaning change in energy consumption.	As the energy consumption is directly derived from the fuel consumption, the change is exactly the same and thus the additional indicator does not give any valuable information
Transport	21. Safety, overall in Tallinn	The eco driving training teaches drivers to predict traffic situations and thus to avoid possible accidents.	The change in overall traffic accident statistics in Tallinn does not indicate the change as a result of eco driving training. Instead, statistics of TBC buses involvement in accidents was used
Transport	Ride comfort	Smoother driving style results in better ride comfort.	There are no studies available linking the change in the used driving style index to the ride comfort. As perception of ride comfort is also dependent on other factors like road roughness and overall comfort in buses, it was decided not to evaluate the passengers' perception with surveys.
Energy, environment and transport	Bus drivers behaviour in their personal vehicles	When drivers learn that it is possible to save fuel with improved driving style and catch a habit of smoother driving, they are likely to use the same skills while driving their personal vehicles.	To evaluate the possible impact one would have to make very generalizing assumptions or to put disproportional efforts to find out the effect. Since the result is negligible compared to the scale effect of whole TBC fuel consumption reduction, the indicator was not used.
Transport	Incidents of passengers falling in buses	Smoother driving and traffic situation prediction affects the number of falling incidents in buses which occur mainly due to aggressive driving style or attempts to avoid a traffic accident	No previous statistics on falling incidents was available from the TBC.

C1.2 Establishing a Baseline

The baseline for the different indicators was created as follows:

- Operating costs, fuel costs, accident costs – from the annual statistics of the TBC;
- Fuel consumption and accident rate
- Emissions – calculated from the fuel consumption;
- Awareness – derived retrospectively from the survey question.
- Driving style index – calculated between before and after measurements of 5 training groups during 2010-2012.

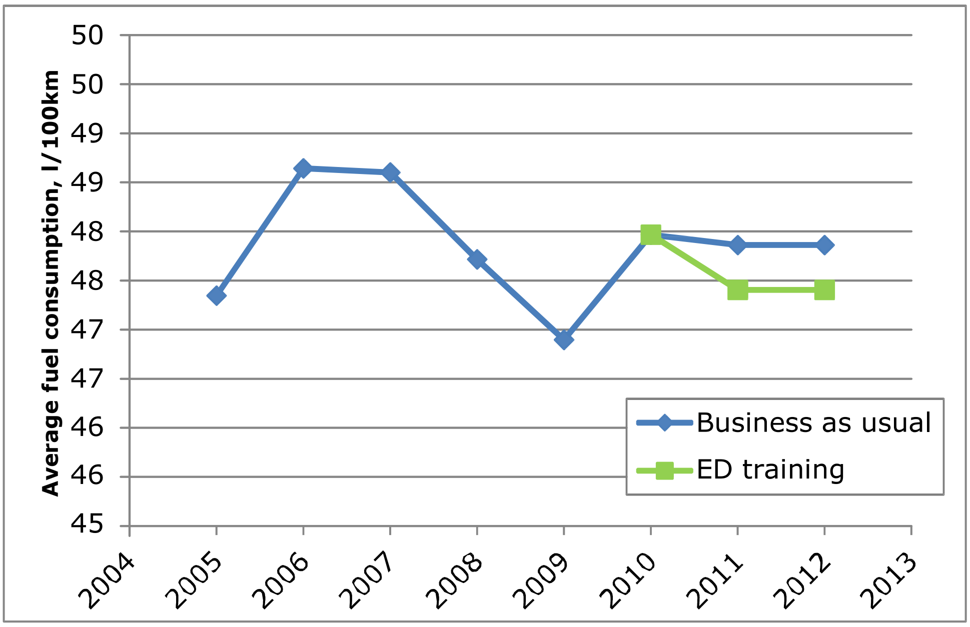
No baseline was created for the acceptance of bus drivers on eco driving training. The reason was that the acceptance was not evaluated before the trainings and trying to evaluate the change in acceptance retrospectively was decided not to be a reliable approach by the evaluation team.

C1.3 Building the Business-As-Usual Scenario

The Business-as-usual (BAU) scenario for all indicators relies on the assumption that without the eco driving training they would not have changed.

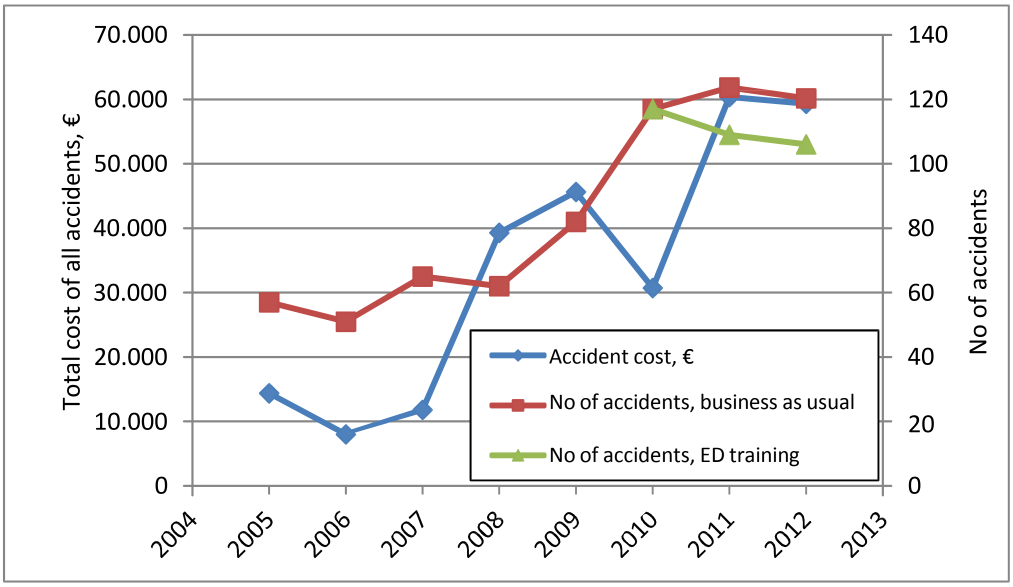
The average **fuel consumption** has been stable throughout years and the standard deviation of the consumption in the period of 2005 to 2011 is 0,65 l/100km, which in case of the average fuel consumption of 47,8 l/100km is only 1,4%. The renewal of the TBC fleet has not changed this is because the new EURO emission class vehicles have the same fuel consumption while the emissions are considerably lower with every new regulation. This is supported by the manufacturers information on new engines where for the past decades have been claimed better performance figures and less harmful emissions while the fuel consumption remains more-less the same. The average fuel consumption from the years 2005 to 2011 (**Figure 3**) was taken as estimation for the fuel consumption in 2012 in the CBA.

Figure 3 TBC fuel consumption 2005-2012



The **traffic accident** statistics is understandably less stable than the fuel consumption due to the more random nature of the accident occurrence and difference in weather and driving conditions on different years. Since the statistics from all drivers of the TBC was available (figure 4), the reduction in the accident statistics of the trained drivers was reduced with change in other (not trained) drivers' statistics, because there was overall reduction in the whole TBC accident statistics for the same period.

Figure 4 TBC accident statistics 2005-2012



For the BAU scenario for **awareness** it was assumed that without eco driving training the awareness among the TBC bus drivers would have remained constant. Since the baseline was not created for evaluation of the acceptance there was no point in assuming the BAU scenario for acceptance.

C2 Measure Results

Under this chapter the results are presented as comparison between the years 2010 and 2011. The eco driving training was introduced in December 2010 but the first group finished the training in 2011. Thus the effect from the training started from the beginning of 2011. The cost-benefit analysis was done for the period 2010-2012, discounting costs and benefits from the whole project period and has therefore somewhat different results than the comparisons presented here.

C2.1 Economy

The economical indicator used for evaluation was directly connected to fuel and accident costs. The effect of the eco driving training to the drivers' behaviour was considered to drop 2/3 in 1 year and the 1/3 to remain constant after this period both in case of fuel and accident costs. The savings were calculated only proportionally to the number of drivers trained compared to the total number of drivers in the TBC.

Table C2.1.1: Change in fuel and accident costs, €/year

Indicator	Before (date)	B-a-U (date)	After (date)	Difference: After –Before	Difference: After – B-a-U
4 Fuel costs	8 226 664 2010	9 498 958 2011	9 411 366 2011	1 184 702 (14,4%)	-87 592 (-0,9%)
4 Accident costs	30 728 2010	67 015 2011	60 382 2011	29 654 (96,5%)	-6 633(-11,0%)

The result was a slight reduction in total fuel costs and notable reduction in accident costs between After and BAU scenarios. At the same time there was an increase between Before and After scenarios, because the fuel costs were raised mainly due to increase of fuel price and accident costs were practically doubled because of hard winter/traffic conditions in 2011.

C2.2 Energy

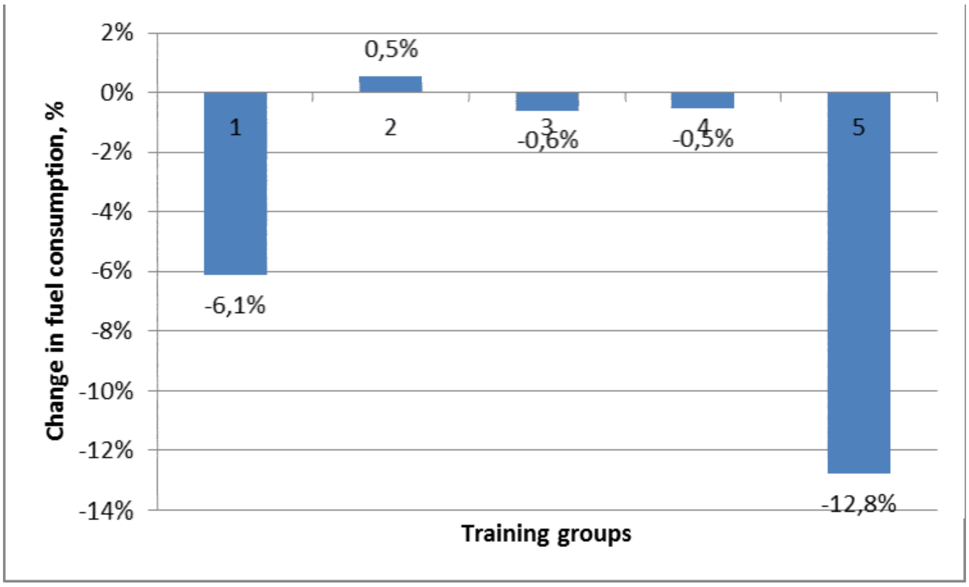
The Energy indicator used for evaluation was fuel consumption. Since the fuel cost was calculated from the fuel consumptions, same "forgetting effect" was applied as in the chapter C2.1 and the result is proportionally exactly the same as with fuel cost.

Table C2.2.1: Total amount of fuel consumed by TBC, l/year

Indicator	Before (date)	B-a-U (date)	After (date)	Difference: After –Before	Difference: After – B-a-U
5 Fuel consumption	9 510 594 2010	9 423 569 2011	9 336 673 2011	-173 921 (-1,8%)	-86 896 (-0,9%)

The result was a slight reduction in total fuel consumption between After and BAU scenarios while the total amount of fuel consumed was also reduced between 2010 and 2011. The result in fuel consumption reduction of separate training groups is presented on the figure 5. The consumption reduction is an average difference between before-driving period and after-driving period (both approx. 1 month) measured separately for all drivers and then summarised by groups.

Figure 5 Variation in fuel saving effect of different training groups



The figure 5 shows that there were considerable differences in different training groups' results. There are several factors contributing to such differences. The contributing factors are also addressed in the measure CBA, which is added to this template as an annex.

First, the training groups were selected from drivers with different skill levels. The first group consisted of drivers known by problematic driving style and increased number of traffic accidents. Thus the potential achievable fuel saving effect was higher than with the next groups. The good fuel saving result achieved by the group 5 is not explainable by this factor.

Second, the traffic conditions and vehicle load have a significant influence on fuel consumption. There is a considerable difference between traffic conditions, longitudinal road profile and vehicle load between different PT lines and time of the day and also time of the year. Thus it is difficult to compare the results and such factors can easily accumulate in one group and cause unexpected results.

Third, weather conditions have also a considerable influence on fuel consumption, both directly and indirectly. The direct influences are both temperature and snowfall but these have impact also on surrounding traffic. Temperature differences were taken into account in the calculations but since the effect was estimated from the measured fuel consumptions and ambient temperatures in Tallinn, the actual influence curve can differ from the estimated curve. Also, only cold temperatures were compensated because there was sufficiently data available for estimation and the result showed statistical significance. Higher temperatures have also a negative impact on fuel consumption but there was not sufficiently data available to get statistically significant estimation result.

While training on public city lines has clear advantages in efficiency of the measure it creates challenges for evaluation to make the results comparable. This field requires further research and cooperation with eco driving trainer and also with bus manufacturers to find out about dependencies of fuel consumption on different factors.

Interestingly the fuel consumption was lower by 1,5% in average while the drivers were logged in to the system under their name compared to when they had not logged themselves into the system. This difference was surprisingly stable throughout the different training groups and different persons and indicates to a need of monitoring the driver behaviour.

C2.3 Environment

As the emissions were calculated directly from fuel consumption the same "forgetting effect" as explained in the chapter C2.1 had an influence on emissions.

Table C2.3.1: Total amount of emissions by TBC, T/year

Indicator	Before (date)	B-a-U (date)	After (date)	Difference: After –Before	Difference: After – B-a-U
10 CO_2 emissions	22 470 2010	22 273 2011	22 060 2011	-410 (-1,8%)	-212 (-1,0%)
12 NOx emissions	245,2 2010	233,5 2011	231,6 2011	-13,6 (-5,5%)	-1,9 (-0,8%)
13 Particulate emissions (PM)	5,05 2010	4,76 2011	4,73 2011	-0,50 (-10,0%)	-0,03(-0,7%)
TAL 6.1-1 SO_2 emissions	0,153 2010	0,157 2011	0,156 2011	-0,003 (-1,9%)	-0,0015 (-1,0%)

Although the emissions were calculated directly from the fuel consumption, the changes in the different emissions (Table C2.3.1) vary also according to the changes in percentages of buses with different EURO emissions standards in the TBC fleet (see Table C2.3.1). As different emissions are affected by the different EURO emission standard technologies in different ways, the results are not exactly proportional to the change in the fuel consumption.

Table C2.3.1: Changes in the TBC fleet, number of buses and their share in percentage

	2010		**2011**	
Emission level standard	No of buses		No of buses	
EURO 1 and before 1993	118	33%	82	24%
EURO 2	128	36%	128	38%
EURO 3	45	13%	61	18%
EURO 4	66	18%	66	20%
EURO 5	0	0%	0	0%
TOTAL	357	100%	337	100%

Especially the changes in the particulate emissions show that changes in the fleet can influence some emissions considerably (between Before and After scenarios) even if the change in fuel consumption is relatively little. The difference between After and BAU scenarios show that the change in emissions is in the same magnitude with the change in fuel consumption.

C2.4 Transport

The changes in transport were evaluated with **driving style index** calculated by the training equipment. The indicator varied from 97,0 (poor result) to 100,0 (good result) for normal buses and from 96,6 to 99,6 for articulated buses. The change was evaluated between before- and after-the training measurements of all 5 training groups in a time period of 12.2010 – 04.2012. The results are presented in the Table C2.4.1 as a percentage of the scale between minimum and maximum.

Table C2.4.1: Changes in driving style index, % of the result between minimum and maximum.

Indicator	Before (date)	B-a-U (date)	After (date)	Difference: After –Before	Difference: After – B-a-U
TAL 6.1-2 Driving style	58,5%	58,5%	65,9%	7,3%	7,3%

The result was a considerable average improvement in driving style but it is not possible to link the result to the perception of the improvement by the passengers without further research.

The changes in **traffic safety** were evaluated with the change in involvement rate of trained TBC drivers in traffic accidents. The change in trained driver accident statistics was evaluated between the one months before- and after-periods of all 5 training groups. The change for overall TBC driver accident statistics was evaluated from the 1 year period prior to the trainings and 1 year period during the trainings.

Table C2.4.2: Changes in traffic safety, involvement rate of TBC drivers in accidents, accidents per 100 drivers per week.

Indicator	Before (date)	B-a-U (date)	After (date)	Difference: After –Before	Difference: After – B-a-U
21 Transport safety	1,42	0,78	0,64	220%	22%

The result was a notable reduction in accident rate for the trained drives, even when it was reduced by larger reduction of overall accident rate of the TBC drivers.

C2.5 Society

The change in awareness was evaluated with a survey from the answers to the question 1: “How aware were you of eco-driving training before the TBC training?” The acceptance was evaluated from the questions 2 and 5: “How do you feel, did you benefit from the training?”, “How important do you think is the knowledge you gained from the training?” . The acceptance was confirmed with the questions 3 and 4: “Would you recommend the training to your colleagues?”, “Have you used the knowledge while driving your personal car?”

Table C2.5.1: Change in awareness and acceptance

Indicator	Before (date)	B-a-U (date)	After (date)	Difference: After –Before	Difference: After – B-a-U
15 Awareness	71% 11/2010	71% 06/2012	100% 06/2012	29%	29%
16 Acceptance	71% 11/2010	71% 06/2012	86% 06/2012	29%	29%

The result for awareness “before” was derived from the survey: 29% of the drivers who participated in the survey were not aware of eco driving training before the TBC trainings, thus 71% of the drivers were aware of eco driving training before. 39% of the drivers had heard about it, 26% knew well about it and 6% had participated an eco driving training before. The awareness after the training was considered to be 100%.

The awareness was somewhat reflected with the answers to the 6th question (see chapter C1.1 Impacts and Indicators). The importance of different factors was considered to be important or very important: improvement of the environment – 88%; improvement of the passenger comfort – 87%; improvement of traffic safety – 84%; economical savings – 81%. The result indicates that the environmental topic is in the bus drivers’ awareness, they are also aware how sudden driver moves affect passenger comfort. The final (although quite close) position of economical savings is also understandable, because this is the topic the drivers have not been educated on nor informed of.

The acceptance was evaluated from the opinion of the drivers on usefulness of the training: 8% thought it was not useful, 6% did not know if it was useful, 42% thought it was somewhat useful and 44% thought it was very useful.

The high degree of acceptance was confirmed with the answers to the questions 3, 4 and 5: 75% of the drivers who participated in the survey would recommend the training to their colleagues, 82% of the drivers are trying to use the learned skills or are using the learned skills successfully when driving their personal vehicle, 75% of the drivers thought that the gained knowledge from the training was useful or very useful.

The positive acceptance of participating drivers was also reflected by overall positive attitude and slight competitive spirit. This was noticed both by eco driving trainer and TBC management.

C2.6 Cost-Benefit Analysis

A cost-benefit analysis (CBA) was carried out to find the socio-economical and financial effects of the measure. The costs and benefits were discounted from the beginning of project costs in 2010 to 2012, when the last group finished their training. The effect for the period in 2012 after the training (from May to December) was estimated.

In the following ENPV is socio economic net present value, EB/C is socio-economic benefit cost ratio, EIRR socio economic internal rate of return, FNPV is financial net present value, FB/C is financial benefit cost ratio, FIRR is financial internal rate of return and SDR is social discount rate.

The main conclusions from the CBA are following:

1. The eco driving training is highly cost effective even if the effect from the training is moderate 3,9% saving in fuel consumption, 22% saving in accident costs and the benefits from the investments are taken into account only over 2 years;
2. Lifetime of the training equipment can be estimated to at least 5 years, thus giving the possibility for additional savings without investment into the new equipment;
3. The running costs for the training are low because it is carried out during normal working on public city lines and 10 TBC eco driving trainers have been trained in the scope of the measure;
4. There are other benefits besides the ones taken into account in the current CBA: reduction of fleet maintenance costs, better ride comfort in public transport and savings through driver behaviour change in their personal vehicles;
5. The measure is highly cost effective showing the socio-economic performance indicators: **ENPV** 67 657€; **EB/C** 1,567; **EIRR** 620% with **SDR** 5,5%;
6. The measure is also financially (excluding socio-economical effects) cost effective showing the performance indicators: **FNPV** 41 356€; **FB/C** 1,347; **FIRR** 283% with **SDR** 5,5%;
7. The measure is greatly sensitive to the fuel saving effect from the eco driving training. Just a drop from 3,9% to 2,9% results in **FNPV** 0 and **EB/C** to only 1,16. Accordingly the fuel saving effect of 5% would result in the **FB/C** 1,70;
8. The measure is also greatly sensitive to the variations in fuel price. The unlikely drop of the fuel price to the level of 0,8€/liter would reduce the **FB/C** to 1,049 and accordingly the likely fuel price rise to 1,2€ would result in the **FB/C** 1,531;
9. The measure is moderately sensitive to the reduction in accidents. In case of no reduction the **FB/C** would still be 1,263;
10. The measure is insensitive to the variations of **SDR** to 3,5% and 8%, giving the **EB/C** 1,575 and 1,558 accordingly.

C3 Achievement of Quantifiable Targets and Objectives

No.	Target	Rating
1	The target on fuel cost reduction was achieved 0,9% instead of the targeted 10%.	**O**
2	Ride comfort was assessed in a form of driving style index and it was improved 7,3% instead of the targeted 25%	**O**
3	Instead of bus drivers caused accidents the total number of accidents was evaluated and instead of the targeted reduction of 10% a reduction of 22% was achieved.	⋆⋆⋆
4	Instead of material loss in bus drivers caused accidents the material loss of total number of accidents was evaluated and instead of the targeted reduction of 10% a reduction of 22% was achieved.	⋆⋆⋆
5	Bus drivers' awareness on the environment was raised by 29% instead of the targeted 10%.	⋆⋆⋆
NA = Not Assessed O = Not Achieved ⋆ = Substantially achieved (at least 50%) ⋆⋆ = Achieved in full ⋆⋆⋆ = Exceeded		

The table showing the achievement of quantifiable results does not reflect well the overall result of the measure. The most reliable and important indicator of the result was the cost benefit analysis that showed high effectiveness of the measure in different aspects. However, looking at the change in overall fuel costs, the 0,9% change does not look very impressive. This is due to several facts:

- Only 42% of TBC bus drivers were trained, thus the average saving result 3,9% had only effect to the trained TBC drivers fuel consumption;
- The learned effect on fuel consumption is known to reduce in time, in CBA estimations it was considered that only 1/3 of the learned effect remains after 1 year;

The initial target for fuel cost reduction was set to too high. This is understandable, because many eco driving training providers claim 10-15% fuel reduction and up to 40% reduction in number of accidents. These numbers were individually achieved during the training but in case of already effective and considerate driving style the improvement cannot be that high and in several cases the result was negative if already effective driver was trying too hard to improve the result.

The connection between the driving style index and perceived ride comfort was not known at the time of evaluation of the measure. Therefore the index is not very good representative of the achieved change. Evaluating the change in the perceived ride comfort requires therefore a further research. Also, the perceived ride comfort is to a large degree affected by different roughness of streets that drivers cannot do much about.

The reduction in accident statistics seems to be very impressive but to be valid the accident statistics should be analyzed for at least 3 years to reduce the influence of randomness. However it could not be done in the time scope of the MIMOSA project.

The bus drivers' awareness on the environment was improved but the result does not indicate directly the result qualitatively.

C4 Up-Scaling of Results

Up-scaling of the results is partly planned and can be put into practice in several areas:

- After implementation and evaluation of the measure the Tallinn Bus Company has decided to continue with the measure as a permanent and mandatory part of regular drivers' training procedure;
- Besides Tallinn Bus Company the experiences of the measure could be implemented in other public transport companies in Tallinn, in other Estonian cities (Tartu, Pärnu, Narva, etc) and also partly in regional and intercity bus traffic network;
- The experience can be used also for improving efficiency and safety of all motorized transport modes but the exact methodology used has economic effect with heavy vehicles (the cost of equipment and analyses compared to the effect);

C5 Appraisal of Evaluation Approach

The approach for evaluation has proven to be generally working well. The most important part of the evaluation was the fuel consumption that gave the main benefit of the measure in the CBA and was also the basis for the emission calculations.

One aspect of the results presentation could be difficult to understand for the readers of the evaluation. While the data was summed and discounted over the project period and beyond (full years 2010 to 2012), it was calculated from the measurements before and after the particular training groups and bus drivers. However the data for several indicators was presented here as a change between the Baseline and the BAU or After scenarios. The difference between these approaches gives different results and should be avoided in future evaluation.

The fuel consumption measurements were accurate and detailed, based on the actual consumptions of the logged-in drivers while servicing public city lines. The only aspect that requires more attention is the comparison of the fuel consumptions. The results have to be compensated for changes in ambient temperatures, different public line altitude profiles, weather conditions (especially on winter) and traffic conditions to be comparable. If the before-measurement is done in warm weather, off-peak traffic on a flat terrain line with only few passengers, the after-measurement result is probably higher consumption in case of cold weather, snowy roads, hilly line and peak hour traffic with fully loaded bus despite all improvements in driving style. More research has to be done with the methodology for compensating for the named and possible other factors to make the comparison results more accurate. Also, separate detailed statistics on every vehicle's refuelling statistics would give possibility to compare the data of direct and indirect fuel consumption measurements. Currently this data was not available from the TBC.

The accident statistics for the before and the after period were too short for making conclusions. The variation between winters, variation of overall traffic behaviour and also random nature of accidents require the statistics to be at least from a 3-year period for making conclusions over the change. This is not achievable in a 2-year measure so it is important that analyzing of accidents is continued after the end of the measure.

The driving index is a good tool for the trainer to monitor and analyze the results of the training without being present in a bus. However there was no data or methodology available to connect the index to the perceived passenger comfort. As the perceived passenger comfort is dependent on many factors besides the measured events the topic requires further research to connect the index to the passenger comfort.

As the better driving style results in lower fuel consumption, it means a lower physical load on the buses. This in turn should result in lower maintenance costs. Originally the maintenance costs were planned to be part of the evaluation but to be able to measure any change, the data collection, a detailed (vehicle based) maintenance data is needed. This data was not available from the TBC.

The evaluation of change in awareness of bus drivers was possible retrospectively with a survey but it was considered not to be reasonable approach to evaluate the acceptance in a same way. Therefore the evaluation of awareness and acceptance should have been done to all training groups before and after the training.

C6 Summary of Evaluation Results

The key results are as follows:

- **Fuel consumption was reduced as a result of the eco driving training –** the fuel consumption was reduced by 3,9% in average for the participants of the training and 0,9% total in the TBC.
- **The number of accidents involving a TBC bus was reduced as a result of the eco driving training –** the number of accidents was reduced by 22%.
- **The amount of emissions was reduced as a result of the eco driving training –** depending on the type of emission the amount was reduced by 0,7-1,0%.
- **The driving style index was improved** – the index was improved by 7,3% in average.
- **The bus drivers' awareness on the environment was improved -** the awareness was improved by 29%.
- **The measure is highly cost-effective both socio-economically and financially –** the CBA resulted in **NPV** 67 657€, **B/C ratio** 1,567 and **IRR** 620% in case of **SDR** 5,5%;

C7 Future Activities Relating to the Measure

After implementation and evaluation of the measure the Tallinn Bus Company has decided to continue with the measure as a permanent and mandatory part of regular drivers' training procedure.

D Process Evaluation Findings

D0 Focused Measure

The reasons for selecting the measure as focused measure were (listed according to importance):

- The possibility of carrying out a good Cost Benefit Analysis
- The measure is regarded as an example measure
- The expected impact on the transport system, environment, economy and/ or society / people is very high

D1 Deviations from the Original Plan

The deviations from the original plan comprised:

- **Delay in the procurement process** – Contract with a training company (Finnish) was days away from signing when the company was accused of high scale corruption and as a result management of the company was discharged from the company. No contract was signed and the process of finding a training company was restarted. New contract was signed in November 2010 to start training in December 2010. As a result, the implementation of the measure was delayed by 3 months.

D2 Barriers and Drivers

D2.1 Barriers

Preparation phase

- The whole management of the chosen training company was discharged with charge of corruption just days before signing the contract in July 2010. This event delayed implementing of the measure by 3 months.

Operation phase

- The rotation of bus drivers to the training-equipped buses and bus-lines created a considerable amount of hand-work for the (driver-vehicle-line) schedule planners. This was a barrier for organizing public transport generally, thus a factor that consumes additional energy that could otherwise be put into rising the quality of PT service.
- The training equipment was installed to 15 relatively new buses (partially for technical reasons). In TBC drivers have their own “personal” bus which they share with a partner. Because the equipment was installed on new buses, many drivers lost their “own” bus and had to move to older buses, which was demotivating for the drivers. This reduces also fleet longevity as the particular 15 buses have shown. Reducing the fleet longevity raises the cost of PT. This counteracts rising the quality of PT service since resources are always limited.
- Giving the new training-equipped buses to new inexperienced drivers turned out to be a problem. Several times the training-equipped buses were out of order for weeks due to inexperienced drivers. If the training-equipped buses break down, it also reduces the possibilities for achieving an effect with the training. This counteracts rising the quality of PT service since resources are always limited.

- In the beginning of training cycles many drivers tried too hard to achieve a very smooth driving style and ended up being late in bus schedule, which resulted in customer complaints that drivers have started to drive too slowly. This was a direct reduction of quality of PT service.
- There was no possibility found to motivate the best drivers with incentives in a way it would be and seem fair. The results from the trainings are not directly comparable, because the initial skills of drivers are different, even theoretically identical buses have different fuel consumptions, driving conditions and load are different throughout a year, etc.

D2.2 Drivers

Overall Drivers

- Clear understanding of contents and aims of the measure by all partners involved in the measure. This helped cooperation and achieving of the objectives in all measure phases.
- Active and focused operation from all partners involved in the measure. This helped cooperation and achieving of the objectives in all measure phases.

Operation phase

- Cooperation on the organisational level inside the TBC was very supportive to the whole training process.
- Right from the first trainings a quite remarkable competition came up by itself between the drivers being trained and continued until the end of the measure. This helped to keep the driver motivation high.
- Speeding especially after the end of the last trip of a shift was a common problem from the viewpoint of traffic safety and also fuel consumption. Since the training equipment registered driving style all the time and it affected the driver statistics, this made drivers to apply better driving style while off the PT service.

D2.3 Activities

Overall activities

- The reaction to the named barriers was to discuss them in several meetings among the TBC team to find solutions when possible.
- No actions were taken for the named drivers.

Preparation phase

- After failing with first procurement a new one was organised promptly and successfully.

D3 Participation

D3.1 Measure Partners

- **Tallinn Bus Company (TBC) –** leading partner, responsible for preparation, implementation and running of the measure. The measure leader is employee of the TBC
- **Tallinn City Government –** principal partner in the MIMOSA project, owner of the Tallinn Bus Company. The city site leader is employee of the Transportation Department of Tallinn city.
- **Tallinn University of Technology –** principal partner, responsible for impact and process evaluation of the measure, including the cost benefit analysis.
- **Scania Estonia –** principal partner, responsible for installing the training equipment on buses, for carrying out the training and for providing the data for evaluation.

D3.2 Stakeholders

- **Bus drivers –** the ones who were trained with this measure. Their attitude and actions has the biggest influence on the outcome of the measure. However it is not fully up to them to decide if they participate in the training.
- **Citizens of Tallinn –** the ones who are benefitting from the measure in several ways. Saving of costs is useful for saving taxpayers money, reduction of emissions is good for air quality both in Tallinn and globally, reduction of traffic accidents is good for the people participating in Tallinn traffic.

D4 Recommendations

D4.1 Recommendations: Measure Replication

- The measure should be easily replicable in any city given the fleet of the city is in accordance with technical requirements of the training equipment. There should be no problems with newer buses. The most important aspect of the training is that 100% of the driving is done during the ordinary work servicing public city lines, thus no driver and no vehicle time is “wasted” for training and evaluation.
- The most positive lessons from the measure are:
  - it is cost effective;
  - it reduces the impact of transport to the environment;
  - it reduces the number of traffic accidents;
  - the change is accurately measurable;
  - bus drivers see, understand and accept the difference they make with the new learned skills.
- There are no general negative lessons to share from the measure. The barriers explained earlier in the document are city specific and did not have notable influence on the possibilities of achieving objectives of the measure.

D4.2 Recommendations: Process (Related to Barrier-, Driver- and Action Fields)

- It is important to consider thoroughly the plan for driver-vehicle arrangement if only some buses are equipped for the training. It may create considerable amount of additional work for the schedule planners and demotivate drivers in case “personal buses” principle is used in the bus company.
- It is important to put effort into keeping bus drivers motivated in participating the training for getting the best possible results. Luckily it just worked out with the TBC bus drivers without additional incentives but it might not be the case in other cities. As explained earlier in the document it is difficult to motivate the drivers based on the training results so motivation of bus drivers is very much up to specific local conditions and creativity of the persons organizing the training.
- The evaluation of the measure can be more effective if more detailed data and analyzes are available from the transport company already before

F Annex

Cost benefit analysis for the Tallinn measure 6.1. Eco driving

Project: CIVITAS MIMOSA

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LIST OF ABBREVIATIONS

BAU	Business-as-Usual
CAN-bus	Controller Area Network bus is a standard for specialized vehicle internal communications network connecting components inside a vehicle
CBA	Cost-benefit analysis
CO_2	Carbon-dioxide
EC	European Commission
ED	Eco driving
EIRR	Socio-economical Internal Rate of Return
ENPV	Socio-economical Net Present Value
FIRR	financial Internal Rate of Return (indirect costs and benefits excluded)
FNPV	financial Net Present Value (indirect costs and benefits excluded)
NO_x	Nitrous-oxides
PM	particle matters
SO_2	Sulphur-dioxide
TBC	Tallinn Bus Company
TUB	Technical University of Berlin
TUT	Tallinn University of Technology

INTRODUCTION

Measure 6.1 Eco-driving (ED) for Tallinn Bus Company (TBC) bus drivers was a measure among 11 Tallinn CIVITAS MIMOSA measures for sustainable transport. ED training for bus drivers was introduced for the first time on this scale in Estonia. The whole training was carried out by the Scania Estonia, including installation of the equipment and training of the TBC drivers and the local trainers. The methodology of the training could be considered innovative because 100% of driving and evaluation data collection was done during regular work driving the public city lines e.g. no resources were "wasted" to training. The training methodology enabled TBC to:

1. save from otherwise "wasted" vehicle time, mileage and drivers time;
2. evaluate the results in real life conditions, not on a separated site;
3. evaluate the results on ordinary TBC fleet.

Eco-driving training

Important facts about the training:

1. In the beginning of the measure, November 2010, 4 articulated buses and 6 normal buses were equipped with the training equipment. The equipment was tested throughout November 2010.
2. In 2011 4 articulated buses and 1 normal bus were additionally equipped with the training equipment to increase the capacity of the training.
3. The equipment consisted of a vehicle CAN-bus connected computer, a display for the driver being trained, a communication system for real time (update every 5 minutes) data transfer between the vehicle, a central Scania server and a portable tablet computer of the trainer to see the driving results in real time.
4. The driver display gave real time visual and audible feedback to the drivers on driving style and driving errors. The driver display took into account fuel consumption, acceleration, braking, bumps and steering.
5. All drivers had a personal key to log in to the training system as they started their work. Thus all data was collected on an individual basis. Only the drivers who drove at least 100km were included in the statistics, the selection was done automatically.
6. 258 bus drivers were trained in 5 separate groups during a period from 1.12.2010 to 26.02.2012.
7. 10 TBC trainers were trained in the scope of the measure to be able continue the training on the equipped buses with TBC-s own resources.

Measure impact evaluation

The measure impact evaluation was concentrated on TBC operating cost and environmental impact reduction through fuel savings and traffic safety improvement through moving to more rational driving style.

The measurement data needed for the evaluation indicators was collected separately from all drivers. The data from both pre-training and after-training was gathered during 6 weeks on average per training group.
During the training the data was gathered on fuel consumption and driving style. Later additional information was gathered on accidents statistics, ambient temperatures and snow conditions during the evaluation periods.

A driving style index was calculated and recorded by the ED training equipment and it was based on fuel consumption, acceleration, braking, bumps and steering. All sudden and notable actions in these areas resulted in lower index for the driver. Fuel consumption has lesser influence on the index, the main idea of it is to concentrate on the driver behaviour to increase passenger comfort.

Main results from impact evaluation:

1. As an average, the fuel consumption was reduced by 3,9% between measurements before and after the ED training. The reduction is corrected for low ambient temperatures and difficult driving conditions during snowfall. The detailed fuel consumption changes are presented in chapter 0.

2. The accident rate was reduced by 22% between the periods before and after the training. The reduction is corrected for the overall change in TBC accident statistics which is explained in the chapter 0.

3. The environmental impact in a form of emissions was considered to be reduced proportionally to the fuel consumption. The emissions reductions calculations are presented in the chapter 0.

4. Driving style index was improved by average 7,3% as a result of the ED training.

ANALYSIS

The cost benefit analysis (CBA) is based on the guidelines for CBA in the CIVITAS MIMOSA project (1). Only direct benefits and costs were taken into account to avoid adding too much estimation into the analysis that would lower the validity of the result.

The full years from 2010 to 2012 were used to include all costs and benefits. The costs started already in the beginning of 2010 in preparing the implementation of the measure. Although the demonstration phase of the measure has ended with the first quarter of the year 2012, the benefits from the whole of 2012 were estimated. The reason is that the lifetime of the investment is at least 5 years and including only 1 year of benefits in the analysis would give underestimated results. Lifetime of the training equipment can be estimated to 5 years and the running costs for training are low because the training is carried out during normal working. Ten TBC trainers have been trained in the scope of the measure. Thus for at least the next 3 years the training costs would be low (with no need for investments) and the benefits would be similar to the years 2011-2012.

Addition of several years for the analysis period was considered but this would have resulted in rather large amount of estimation in fuel prices, mileage and other factors. From the other factors the biggest is the decision of Tallinn city government to introduce full scale free public transport from the beginning of 2013 and the next biggest is to unite so far separate Tallinn Bus Company and Tallinn Tram- and Trolleybus company. Both decisions probably influence the total mileage of the TBC, in the latter case due to ageing fleet of trolleybuses and plans to replace some trolleybus lines with buses.

Some data was already gathered during the training for the measure impact evaluation - fuel consumption and driving style index. Additional CBA input data was gathered after the training: accident number and costs, ambient temperature and snowfall.

The results in the analysis were calculated both as socio-economical and financial. The reason for presenting the latter is to show that the measure is highly cost effective also when excluding the indirect benefits in a form of emission savings which do not appear directly on the budget of the TBC. The Social Discount Rate (SDR) of 5,5% was used for the CBA.

Baseline and Business-as-usual

The baseline was taken to the beginning of the project implementation, beginning of the year 2010. Although the equipment was installed and tested in November and December 2010, costs for preparation of the implementation were already present throughout the year. Both accident statistics and average TBC fuel consumption were also taken from the year 2010. Accident statistics of 1 year were taken prior to the first training and the fuel consumption has remained relatively stable for years. The baseline data for the year 2010:

1. The total mileage of the whole TBC fleet was 19 827 100 km;
2. The total amount fuel used by the whole TBC fleet was 9 510 594 litres;
3. The average total fuel consumption of the TBC fleet was 47,97 l/100km.
4. The average fuel purchase price for the TBC was 0,865 €
5. The number of drivers in the TBC was 666.
6. The number of traffic accidents where the TBC fleet was involved was 117
7. The average cost of traffic accidents was 581 €[2]

[2] The accident cost for 2010 was exceptionally low compared to the years 2008, 2009 and 2011. Thus an average cost of the years was used for the year 2010.

The Business-as-usual scenario relies on the assumption that without the ED training the fuel consumption and traffic accidents would not have changed.

The average fuel consumption has been stable over many years and the standard deviation of the fuel consumption in the period of 2005 to 2011 is 0,65 l/100km which in case of the average fuel consumption of 47,8 l/100km is only 1,4%. The renewal of the TBC fleet has not changed this, because the new EURO emission class vehicles have the same fuel consumption while the emissions are considerably lower with every new regulation. This is supported by the manufacturers information on new engines where for the past decades have been claimed better performance figures and less harmful emissions while the fuel consumption remains more-less the same. The average fuel consumption from the years 2005 to 2011 (figure 6) was taken as an estimation for the fuel consumption in 2012.

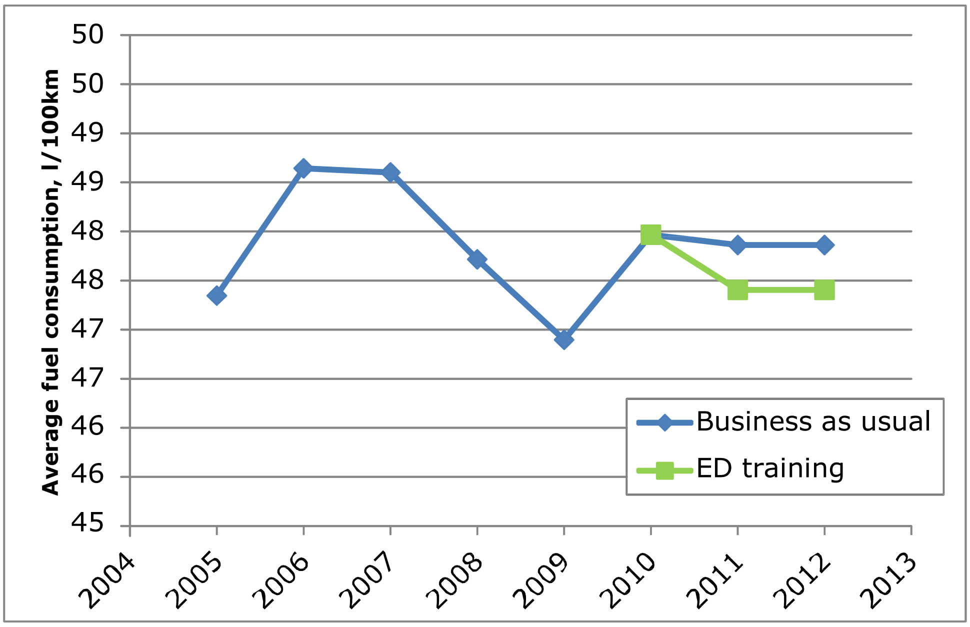

Figure 6 TBC fuel consumption 2005-2012

The traffic accident statistics is understandably less stable than the fuel consumption due to the more random nature of the accident occurrence and difference in weather and driving conditions on different years. Since the statistics from all drivers of the TBC is available (figure 2). The reduction in the accident statistics of the trained drivers was reduced with change in other (not trained) drivers' statistics, because there was overall reduction in the whole TBC accident statistics for the same period.

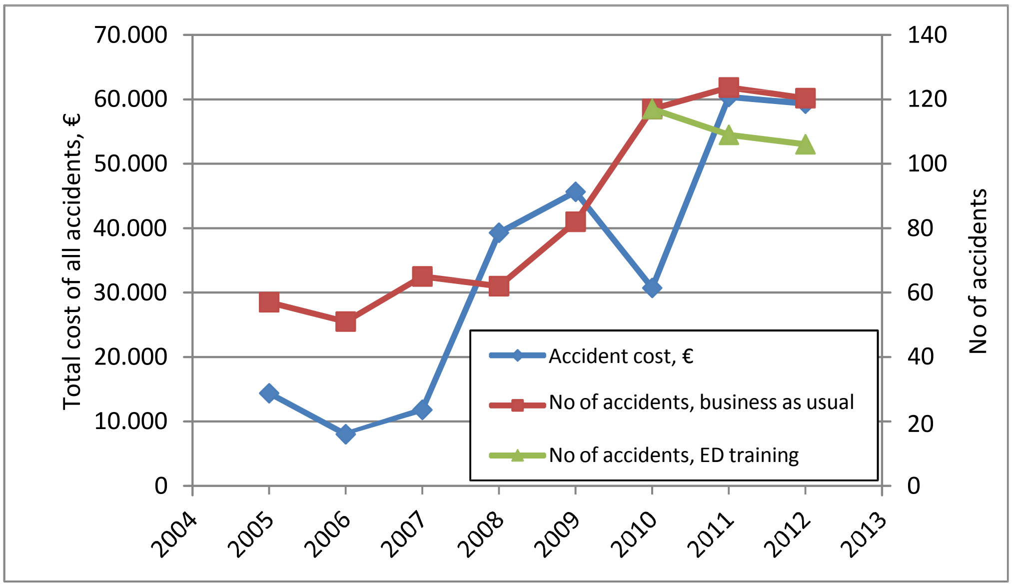

Figure 7 TBC accident statistics 2005-2012

Costs

Training

The training costs included purchase of the equipment, installation, theoretical lessons, project management, project preparation, data communication and analysis of the results by the trainer. The costs include also purchase and installation of additional equipment in 2011. The drivers' time and bus operating cost were not included on the cost side because the training was done during the ordinary working time and cannot be considered as cost in that sense. That was also the main idea behind the training methodology. The training periods for the 5 groups are given on the Figure 8.

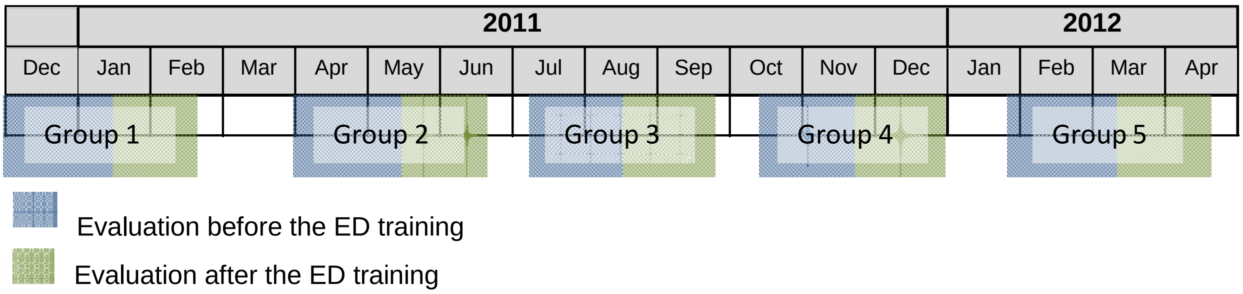

Figure 8 Training and evaluation periods for the 5 training groups

Other costs

The costs related specific to the CIVITAS MIMOSA project were excluded from the CBA. Running the pilot project with visiting a considerable number of meetings and forums in Tallinn and in the other MIMOSA cities during 3 years, carrying out detailed impact evaluation by the Tallinn University of Technology evaluation team (incl. the CBA) - these are not common costs for an ordinary training and were therefore excluded. This does not apply to the ordinary project management costs, which were included as stated in the previous chapter 0.

Benefits

Fuel savings

Fuel savings are the main source of benefits in the ED training measure as the TBC consumes over 10 million litres of fuel annually. The average result was rather low (3,9% reduction) compared to the results that can be found on various ED training and equipment providers claims. The average is low but the different results are similar to what Swedish Road Administration has studied (Figure 9) – according to them the fuel consumption is reduced by 10-20% by ED training and the learned effect remains at 3-6% for longer period (2).

In the CBA the "forgetting" effect from the ED training was similarly assumed to fall by 2/3 in 1 year due to drivers forgetting the learned skills. After one year 1/3 of the learned skills (thus all the effects) were assumed to remain constant. The effect was calculated with one month's accuracy taking into account when the training of the different groups took place. The reduction resulted in the average remaining effect of 78% to the year 2011 compared to the case if there was no "forgetting" effect. The effect for the year 2012 would have been 47%.

The effect was further reduced considering the fact that only 200 of the 652 drivers were trained by the end of the year 2011 and 250 of the (estimated) same number of drivers were trained by the end of 2012. The total number of trained drivers in scope of the measure was 258 but 8 of them had left the TBC by May 2012.

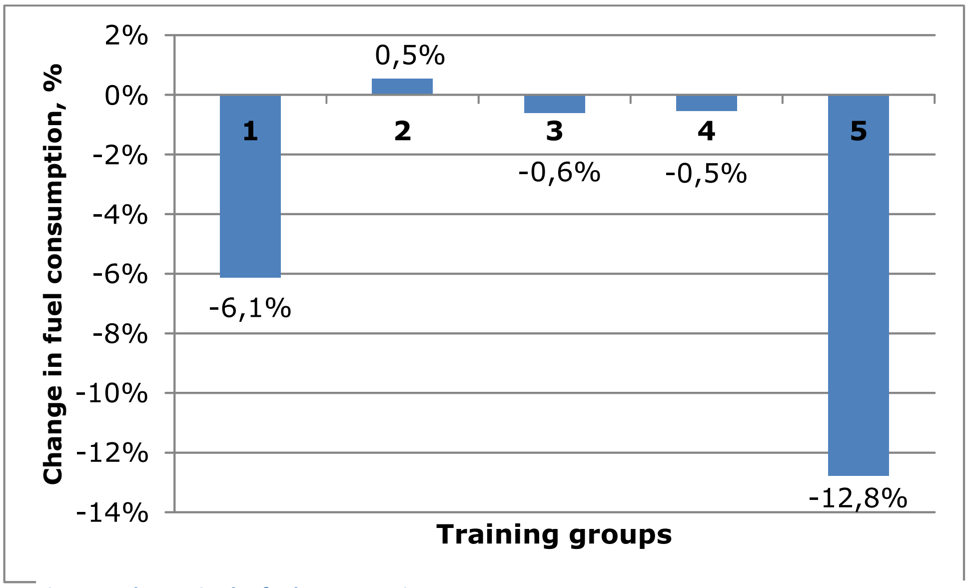

Figure 9 Change in the fuel consumption

As can be seen from the Figure 9 the fuel savings results varied considerably and the reasoning behind the results is not fully clear. The number of participants in all groups was around 50 and they were driving the same vehicles on same city lines which practically eliminates the possibility of a large random error. It is possible that some groups with lower savings results happened to consist of a drivers who have otherwise good driving style combined with drivers who are not so good learners but this needs further analysis.

Two factors were taken into account to compensate for different driving conditions – **ambient temperature** and **snowfall**. The ambient temperature correction was applied for the temperatures between -12C° and +6C°. The correction factors were estimated from the all fuel consumption measurements with a simple linear regression (see Figure 10). The fuel consumption is higher at cold and hot temperatures and the dependency should therefore be a curve with a low point somewhere around 0° to +5°C, however in the current study the higher temperature statistical data had for unknown reason large variance with R^2 below 0,001 and was therefore omitted. The R^2 of the linear regression used in the current analyze was for normal buses 0,18 and for articulated buses 0,28. See Figure 10 for example of linear regression of the articulated buses.

The snowfall over 20 mm is considered notably affecting driving conditions by the Estonian Rescue Service. Both factors were derived from the statistics of the trainings but would actually need further investigation for future use.

Snowfall correction was also varied according to the ambient temperature, because around 0C° in combination with the snowfall the increase in fuel consumption was notably higher than with lower temperatures. Both correction factors had bigger influence on the articulated buses. The fuel consumptions and corrections are shown in table 1. The weather data was taken from the weather observations of the Estonian Meteorological and Hydrological Institute homepage. For the ambient temperature the average value between daily average and daily maximum temperature in Tallinn Harku measurement point was used to take into account the fact that public transport is not in use at night when temperatures are below the average. For the snowfall data the percentage in the table 1 shows on how many days of the evaluation period the snowfall was higher than 20 mm.

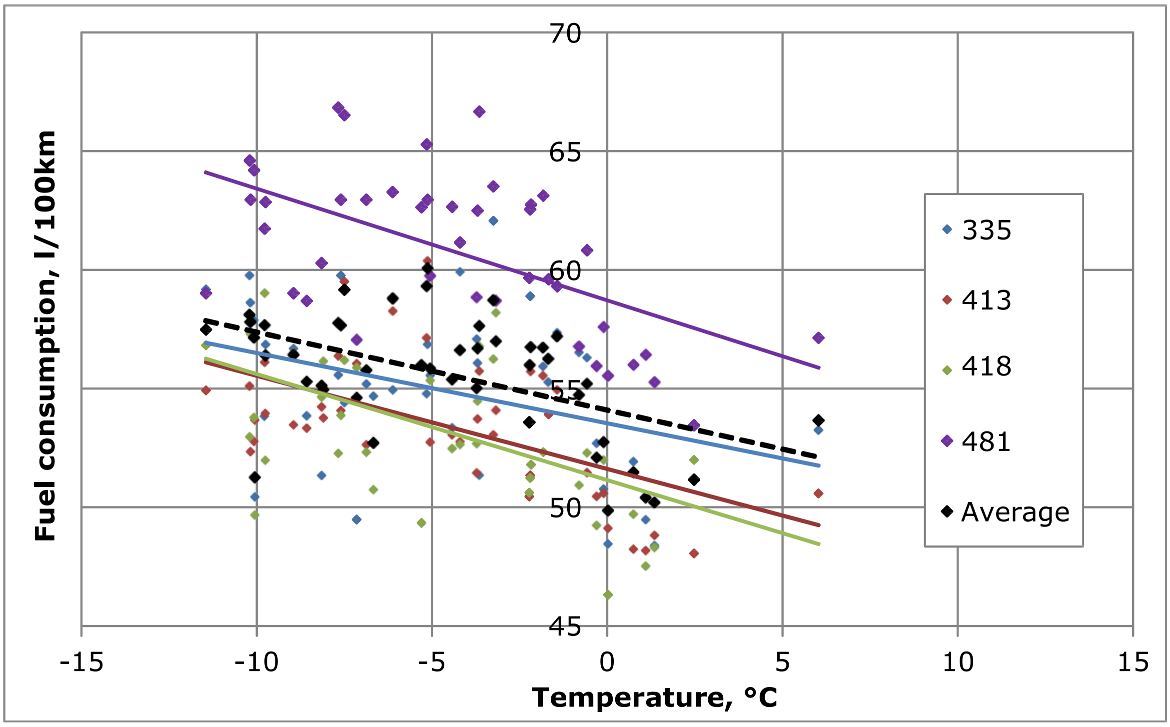

Figure 10 Fuel consumption dependency on the ambient temperature: four different articulated buses and their fuel consumption on different trips.

Table 1 Ambient temperature and snowfall corrections for fuel consumption on before and after evaluation periods.

Training group number	1	2	3	4	5
Fuel consumption, l/100km					
Normal before	42,1	39,8	39,2	38,7	41,9
Normal after	39,8	39,9	38,8	39,8	39,5
Articulated before	56,3	51,9	51,2	51,0	55,5
Articulated after	52,5	52,4	51,1	50,4	51,2
Temperature correction, l/100km					
Average temperature before	-5	8	22	8	-8
Average temperature after	-6	20	15	3	4
Normal before	0,8	0	0	0	1,3
Normal after	0,9	0	0	-0,5	-0,6
Articulated before	1,8	0	0	0	2,9
Articulated after	2,2	0	0	-1,1	-1,5
Snowfall correction, l/100km					
Amount of snowing days before	45%	0	0	0	19%
Amount of snowing days after	15%	0	0	4%	0
Normal before	0,5	0	0	0	0,2
Normal after	0,2	0	0	0	0
Articulated before	0,6	0	0	0	0,3
Articulated after	0,2	0	0	0,2	0

The fuel savings for the year 2012 were calculated using TBC-s prognosis for the year 2012 total mileage, the average fuel consumption of the years 2005-2011 and the effect of the training being reduced by 2/3 in one year. The TBC total mileage prognosis is based on the amount of service Tallinn city government has ordered in the contract for the year. This figure has varied only 3% during the last 7 years. The fuel price data for the year 2012 was based on the TBC purchase price in the first quarter of 2012. The average fuel purchase price for the year 2012 will be probably higher considering the global trends but this would even increase the benefit side of the CBA so using the average price of the first quarter can be considered as a conservative approach.

One factor that was surprisingly stable with fuel consumption was the difference in the fuel consumption between logged-in and not logged-in state during the training and evaluation period. The fuel consumption was in average lower by 1,5% (with standard deviation of 0,9%) while the drivers were logged in to the system compared to the anonymous drivers (often the same persons) on the same vehicles. Most of the drivers seem to be clearly disciplined by the knowledge that their driving style and fuel consumption is being logged by their name. The fact is not important for the CBA but is something to consider for the TBC.

The reduction of the average TBC fuel consumption between 2010 and 2011 was 1,2% when calculated directly from the total mileages and consumed total fuel amounts. When calculating from the same average consumption as in 2010 and removing the reduced effect (only part of the TBC drivers have been trained and there is also the “forgetting” effect) of average ED training 3,9% saving, the result is 0,9% reduction in the fuel consumption, which is of the same magnitude as the 1,2%. This does not prove directly the accuracy of the calculated ED training influence as there can certainly be other factors contributing to the changes in total fuel consumption but can be interpreted as an indirect indicator of the magnitudes of effects analyzed in the CBA.

The amount and cost of saved fuel are presented in the Table 2.

Table 2 Fuel savings

Year	2011	2012*
Total mileage, km	19 695 520	20 500 000
Consumed fuel amount, liters	9 336 673	9 798 310
Fuel saved, liters	86 896	68 356
Fuel cost saved, €	87 591	75 191

*- estimated

Accident savings

According to the different sources (mostly training or monitoring equipment providers so the claims should be taken with reservations) the reduction in accidents as a result of an ED training can be up to 40%. As a result of the current training the number of accidents was found to be reduced by 22% on average. The effect of training on accident reduction was reduced by the same principles as described in the BAU chapter 0 and in the beginning of the fuel savings chapter 0, taking also into account the “forgetting” effect and the percentage of trained drivers.

The data used for the before-period was taken from 1 year prior to the training but the time for after-statistics was lower in average due to the limited length of the measure. The reason for using only one year’s data was a considerable rise in the number of accidents which would have resulted in the negative effect from the ED training if last 3 years average statistics would have used. Therefore the results should be taken as indicative only because the time for accident statistics should be at least 3 years to reduce the random nature of accident occurrence.

For the year 2012 the number of accidents was assumed to be proportional to the year 2011 statistics according to the TBC-predicted mileage of the year 2012.

The average accident cost was taken from 3 previous years statistics excluding the year 2010 with notably different number of accidents and thus different cost per accident. The average cost of one accident used in the CBA is 581 €.

The indicator used for evaluation was number of accidents per week per 100 drivers. The result was reduced by the factor of 1,82 because that was the reduction in accident statistics of all other TBC drivers between the before and after evaluation periods.

No correction was applied to the accident statistics for difficult driving conditions, because the training groups faced various seasons and conditions and the accident statistics were taken over the full year compared to the separate average before and after evaluation periods of 4 weeks.

An interesting fact is that the percentage of accidents caused by the bus drivers was significantly lower in case of the trained drivers compared to the overall TBC accident statistics. But to remain on the conservative side with the results from accident savings, the fact of lower percentage of caused accidents was ignored, because it would have multiplied the effect to unrealistic results.

The ED training concentrates on drivers’ ability to predict the traffic ahead and the trained bus drivers should in some cases be capable of predicting conflict situations (caused by other drivers) that can lead to an accident and thus should be able to avoid them. Also, some drivers in the ED training statistics tended to be more often involved in accidents which they did not cause (at least officially). This supports also the decision to take into account statistics of all accidents.

Emission savings

The emissions were calculated using the Finnish calculation sheet for average city bus emissions (3). The usage of the methodology was based on the similarities of the conditions in Tallinn and Helsinki: distance between the cities is 80 km and the climate is similar, the fleet used in the TBC is similarly consisting of mainly Volvos and Scanias.

The emissions were calculated according to the average fuel savings assuming that the fuel that was saved would have created the same emissions as with driving with the average TBC fuel consumption. The emissions in table were reduced according to the average TBC fuel consumption by linear interpolation between the partly occupied (18 persons) and fully occupied (80 persons) buses. The bus weight difference is considerable with different loads and on the Finnish calculation sheet (3) the emissions are given for different loads. The interpolation was performed as the TBC average consumption was between the given values and emissions are directly dependent on fuel consumption.
The emissions were calculated separately to all EURO emission standard vehicle groups. The EURO emission standard distribution of the TBC fleet in 2011 and 2012 is given in the Table 3.

Table 3 TBC average fleet distribution according to emission standards

	2011		2012	
EURO 1 and before 1993	82	24%	68	20%
EURO 2	128	38%	125	37%
EURO 3	61	18%	61	18%
EURO 4	66	20%	66	19%
EURO 5	0	0%	20	6%
Total:	337	100%	340	100%

The emission reduction is presented in the Table 4.

Table 4 Emission savings

	2011		2012*	
	Amount, T	**Cost, €**	**Amount, T**	**Cost, €**
NOx	2,2	4 346	1,6	3 231
SO_2	0,0014	2	0,0011	2
PM	0,042	6 091	0,039	5 575
CO_2	2075	5 133	162	4 038
Total:		**15 572**		**12 846**

*- estimated

Other benefits

There are several other benefits with ED training but they either cannot be monetized easily or require too much estimation and presumption, thus lowering trustworthiness of the cost benefit analysis. The benefits are briefly described in this chapter to give the reader an idea of other possible positive effects.
Driving style index. The index (described in the chapter 0) is a calculated reflection of bus driver behaviour and thus indicates the ride comfort of passengers in public transport. However there are no studies known to the authors of the analysis on relations between the particular driving style index and passenger perception on ride comfort (which would in turn shift the modal share towards public transport) and thus the index cannot be monetized with high degree of trustworthiness. However as a result of the training the average driving style index was improved by 7,3%.
Change in maintenance costs. The TBC maintenance costs of previous years are given by the TBC in detail and most probably the lesser load on engine, transmission, breaks and tyres results in lower cost for maintenance. However the influence of ED training is not directly visible from the maintenance costs, because other factors in the maintenance can have greater variation than the driving style. Price

changes of lubricants, tyres and spare parts are some examples, extreme cold and hot weather conditions also affect the maintenance need. The average engine oil consumption of the TBC fleet has also shown continuous increase since 2007 when the previous bigger fleet renewal was done. Thus the effect of ED training could be only estimated if the author of the current analysis could be aware of practical studies in this particular field or the maintenance need for separate vehicles would be available along with all other contributing factors to the cost of maintenance.

Change in driver behaviour in their personal vehicle. If the 250 TBC drivers see the real benefit of ED and get the habit of driving rationally during their everyday work they will probably also use the knowledge gained in their personal cars. The types of benefits would be the same as the TBC had but the amounts would have to be fully estimated with rather great uncertainty based on the average car use in Estonia. Therefore the benefits from personal car usage were not taken into account in this cost benefit analysis.

Results

The results from the analysis showed the high cost effectiveness of the measure despite its short time of showing the benefits created. The results are cost effective both socio-economically and financially, thus TBC has a good reason to continue with the training even when considering only the company budget. The project has has also direct and indirect benefits to the society by reducing the number of traffic accidents and emissions from public transport.

The main results of the CBA are presented in Table 5.

Table 5 Main CBA results of the ED training measure, €

	2010	2011	2012*	Total
Costs				
Training	-1 563	-82 762	-27 532	
Additional equipment	0	-10 000	0	
Project management	-1 770	-1 770	-1 770	
Sum of costs	***-3 333***	***-94 532***	***-29 302***	***-127 167***
Sum of discounted costs	**-3 333**	**-89 604**	**-26 326**	**-119 263**
Benefits				
Fuel savings	0	87 591	75 191	
Accident savings	0	6 633	4 174	
Emission savings	0	15 572	12 846	
Sum of benefits	*0*	*109 797*	*92 211*	*202 008*
Sum of discounted benefits	0	104 073	82 847	186 920
Sum of financial benefits		*94 225*	*79 366*	*173 590*
Sum of discounted financial benefits		89 312	71 306	160 619
Total	**-3 333**	**15 265**	**62 909**	**74 841**
ENPV	**-3 333**	**14 469**	**56 521**	**67 657**

* - estimated

The main performance indicators of the CBA are presented in the Table 6. The FNPV, FIRR and FB/C are presented as financial values excluding the socio-economic effects, in the current case the emission savings. The purpose is to give reader to see the influence of the ED training to the budget of the company.

Table 6 Main CBA performance indicators

Indicator	Value
SDR	5,5%
FNPV **ENPV**	41 356 € 67 657 €
FIRR **EIRR**	283% 620%
FB/C **EB/C**	1,347 1,567

Sensitivity analysis

The sensitivity analysis was done for four possible variables:

1. varying SDR from 5,5% to 3,5% and 8%;
2. varying the fuel saving effect (3,9% as a result from ED training) to the situation where the FNPV would be 0 and where the fuel savings would be 5%;
3. varying the fuel price from the average 1,05€ to 0,8€ and 1,2€;
4. removing the effect of accident reduction.

Since the measure period was short and the measure economic balance became positive already on the second year, the benefit cost ratio was relatively insensitive to the change of the SDR as can be seen from the **Table 7**.

Table 7 SDR change sensitivity analysis

Indicator	Value		
SDR	**5,5%**	**3,5%**	**8,0%**
FNPV	41 356	43 105	39 304
ENPV	67 657	70 142	64 736
FB/C	1,347	1,353	1,339
EB/C	1,567	1,575	1,558

Varying the fuel saving effect had great influence on the cost effectiveness of the measure as can be seen from the Table 8. Just a small drop (although difference to 3,9% is 34%) to a fuel saving effect of 2,9% results in FNPV to be 0, yet keeping the EB/C ratio 1,16. The rise of the fuel saving effect to 5% raised the FNPV to 83 504 and FB/C ratio to 1,70.

Table 8 Fuel saving effect change sensitivity analysis

Indicator	Value		
ED fuel saving effect	**2,8%**	**3,9%**	**5,0%**
FNPV	0	41 356	83 504
ENPV	19 078	67 657	117 168
FB/C	1,000	1,347	1,700
EB/C	1,160	1,567	1,982

The fuel price variation had lesser (but also great) effect on the cost-effectiveness than the fuel saving effect. This is due to the fact that saving fuel also reduces the emissions. The unlikely drop in diesel fuel price to the historical year 2010 level 0,8€ per litre (31% drop compared to the average fuel price used in the CBA) would result in reduction of the FNPV to 5 799 and FB/C ratio to 1,049. The likely fuel prise rise results in FNPV 63 311 and FB/C ratio of 1,531 as can be seen in the Table 9.

Table 9 Fuel price change sensitivity analysis

Indicator	Value		
Fuel price	**0,8€**	**1,05€**	**1,2€**
FNPV	5 799	41 356	63 311
ENPV	32 101	67 657	89 613
FB/C	1,049	1,347	1,531
EB/C	1,269	1,567	1,751

The removal of the 22% reduction in accident statistics had a moderate influence on the cost-effectiveness of the measure as can be seen from the Table 10.

Table 10 Accident reduction sensitivity analysis

Indicator	**Value**	
Accident reduction	**22%**	**0%**
FNPV	41 356	31 318
ENPV	67 657	57 619
FB/C	1,347	1,263
EB/C	1,567	1,483

CONCLUSIONS FROM THE CBA

The main conclusions for the CBA are following:

11. The ED training is highly cost effective even if the effect from the training is moderate 3,9% saving in fuel consumption, 22% saving in accident costs and the benefits from the investments are taken into account only over 2 years;

12. The moral and physical lifetime of the training equipment can be estimated to at least 5 years, thus giving the possibility for additional savings without investment into the new equipment;

13. The running costs for the training are low because it is carried out during normal working on public city lines and 10 TBC ED trainers have been trained in the scope of the measure;

14. There are other benefits besides the ones taken into account in the current CBA: reduction of fleet maintenance costs, better ride comfort in public transport and savings through driver behaviour change in their personal vehicles;

15. The measure is highly cost effective showing the socio-economic performance indicators: **ENPV** 67 657€; **EB/C** 1,567; **EIRR** 620% with **SDR** 5,5%;

16. The measure is also financially cost effective showing the performance indicators: **FNPV** 41 356€; **FB/C** 1,347; **FIRR** 283% with **SDR** 5,5%;

17. The measure is greatly sensitive to the fuel saving effect from the ED training. Just a drop from 3,9% to 2,9% results in **FNPV** 0 and **EB/C** to only 1,16. Accordingly the fuel saving effect of 5% would result in the **FB/C** 1,70;

18. The measure is also greatly sensitive to the variations in fuel price. The unlikely drop of the fuel price to the level of 0,8€/liter would reduce the **FB/C** to 1,049 and accordingly the likely fuel price rise to 1,2€ would result in the **FB/C** 1,531;

19. The measure is moderately sensitive to the reduction in accidents. In case of no reduction the **FB/C** would still be 1,263;

20. The measure is insensitive to the variations of **SDR** to 3,5% and 8%, giving the **EB/C** 1,575 and 1,558 accordingly.

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