2012•2013

FACULTEIT BEDRIJFSECONOMISCHE WETENSCHAPPEN

master in de verkeerskunde: verkeersveiligheid
(Interfacultaire opleiding)

Masterproef

The usage of optimization models for sustainable road transport evaluation

Promotor :
Prof. dr. Elke HERMANS

Promise Nkwenti Payne
Masterproef voorgedragen tot het bekomen van de graad van master in de verkeerskunde , afstudeerrichting verkeersveiligheid

Universiteit Hasselt | Campus Hasselt | Martelarenlaan 42 | BE-3500 Hasselt
Universiteit Hasselt | Campus Diepenbeek | Agoralaan Gebouw D | BE-3590 Diepenbeek

2012•2013
FACULTEIT BEDRIJFSECONOMISCHE WETENSCHAPPEN

master in de verkeerskunde: verkeersveiligheid (Interfacultaire opleiding)

Masterproef

The usage of optimization models for sustainable road transport evaluation

Promotor :
Prof. dr. Elke HERMANS

Promise Nkwenti Payne

Masterproef voorgedragen tot het bekomen van de graad van master in de verkeerskunde , afstudeerrichting verkeersveiligheid

universiteit hasselt
KNOWLEDGE IN ACTION

Abstract

Road transportation is today the main stream to reach many destinations not only within the EU-27 but also in the other part of the world. Passenger and freight activities have been on the top for reaching my areas for societal and business engagements. In performing these activities, desirable as well are undesirable outcomes are degenerated resulting in a call for concern of different stakeholders to evaluate its level of sustainability and make prediction for future development. In this light, a three year dataset was collected based on the various road transport activities and the resulting outcomes. The modeling technique used was the data envelopment analysis (DEA) method within which the CCR model was used. Two main aspects were taken into consideration, i.e when undesirable outcomes are ignored in DEA and the case where both inputs, desirable and undesirables outputs are being taken in to account. When the undesirable outputs were ignored from the model, feasible results were obtained. On the other hand, when both inputs and outputs were taken in to consideration specifically while using the reciprocal of the undesirable outputs, no feasible solution was achieved-; the reason seen as disparity between member states in volume of activities. To solve the problem, a cluster analysis was carried which finally lead to producing feasible outcomes on which policy makers can make a prediction with respect to the level of sustainability for future developments.

1: INTRODUCTION

The role played by road transportation has become an ever more important part within the European Union (EU-27) as well as the rest of the world of today. Economic growth, social activities and modern lifestyle have motivated inhabitants to travel more often and for longer distances and with different transport modes *[1]* and therefore required a more efficient and sustainable way. Sustainability in today's globe has become a vital goal for policy makers. Thynell et al *[2]* defines the concept of sustainability as the development process that aids in meeting the needs of the present generations without endangering the possibility of the future generations to meet theirs. It strikes on equalizing two different aspects; firstly the present with the future and secondly the consumption, transportation, social activities, economic growth with ecological integrity. Based on the view of Litman et al *[3]*, sustainable transportation is defined as a system that firstly, provides individuals and the societies the basic needs to be achieved safely and more consistently by taking into consideration human and environmental health, and with balance between generations and secondly, operate efficiently, affordable and offers choice of transport modes while considering vibrant economy and lastly limit waste and emissions within the planet and minimizes the consumption of non-renewable resources, use of land and the production of noise for sustainable achievements .

In order to evaluate road transport sustainability, a large number of performance indicators such as road passengers transport, freight transport, employment, total turnover, as well as green house gas emission, final fuel consumption and road fatalities have been obtained within the concepts of the current practices, that is the transport policies plans *[4, 5, 6]* and real perception of sustainable road transport. These indicators have been used by the government, research centers and different stakeholders to set sustainable objectives and to see whether present transport system is moving towards sustainability *[7, 8]*. These indicators reveal diverse levels that reflect the decision making process, that is, travel patterns, physical impact (emissions and accident rates), effects on persons and environment (injuries, death and ecological damages). The activities carried out by road transport do not only results in desirable activities (gross domestic product, employment, gross value added and other social benefits….) *[9]* but equally a hand-full of undesirable effects. They include; energy consumption**,** greenhouse gas (GHG) emissions, traffic congestion, noise pollution and road fatalities. In this light, one can equally gratify the effects of the future transport system on sustainable development in general. Changes within the transport sector may equally cause change in other sectors which may in return affect sustainable development. Geurs et al *[10]*, state that a relative change in the current road transport system can result to a great change in economics levels especially in trade and industry. This is seen as a result of the interaction between various road transport activities. Evaluating road transport sustainability entails taken to account the main road transport activities and its resulting desirable and undesirable's outcomes and this will lead us to finding the most effective way through which they can be incorporated together to obtain results based on different EU members for road transport policy implementation

Applying an optimization method, one of the most important techniques that have been used in evaluating situations of this nature is the Data Envelopment Analysis (DEA), a technique developed by Charnes, Cooper and Rhodes in 1978 *[11]* and further revised by Banker, Charnes and Cooper in 1984. It uses linear programming algorithms to evaluate the relative efficiency of a set of decision making units (DMU_S). Generically, DMUs are regarded as the entities responsible for converting inputs into outputs and whose performances are to be evaluated. Since its development in 1978, it has been seen as a powerful instrument for many organizations to models processes for performance evaluations and benchmarking *[12, 13]*. Within our present study, DEA models operate under the assumptions of total inputs minimization and total output maximization (such as in economic field). The DEA analyze each DMU separately and calculates a maximum performance measure for each unit *[14]* which will be used for sustainable evaluation.

1.1: Main purpose of the present study

Within the EU-27, the road transport sector has taken a step forward due to technological advancement in road transport activities and equally in traffic management system. This advancement has resulted in numerous achievements to the society (employment, increase in GDP and higher turnover) as well as some undesirable effects (climate change, Greenhouse Gas emissions, road crashes, noise and traffic congestion) within the different member countries and therefore a call for concern. Even though numerous research works *[i.e.5, 9, 15, 16]* has been carried out within the road transport sector, most of these works has been stressing much on performance measurement and production efficiency with little or no attention given to sustainable evaluations. Therefore, the main objective of this study is to find the most effective ways through which sustainability within the road transport can be evaluated with the use of optimization models.

1.2: Main research questions

In order to evaluate the sustainable nature of the road transport for the EU-27, a series of research questions were derived. Some of special mention includes;

What is the concept of sustainability in road transport? And how can it be evaluated?
What are desirable indicators and undesirable indicators from road transport?
How can optimization models in general and the technique of DEA in particular be used to evaluate sustainability in road transport within the EU-27?
Which recommendation can be made?

1.3: The structure of the paper

The rest of the paper will be structured as follows: section 2 will contain the concept of road transportation within which the input and output indicators will be defined. In section 3, the concepts of DEA will be fully exploited. The various applications used to evaluate the sustainable level of each of the EU member countries (ignoring undesirable factors in DEA model and treating both desirable and undesirable outputs in the DEA model) and the results will be discussed in section 4. Section 5 will carry the full discussion of the results obtained. Conclusions, recommendations and future study will be given in Section 6, references and appendices will end up the paper.

2: ROAD TRANSPORT INDICATORS AND DATA

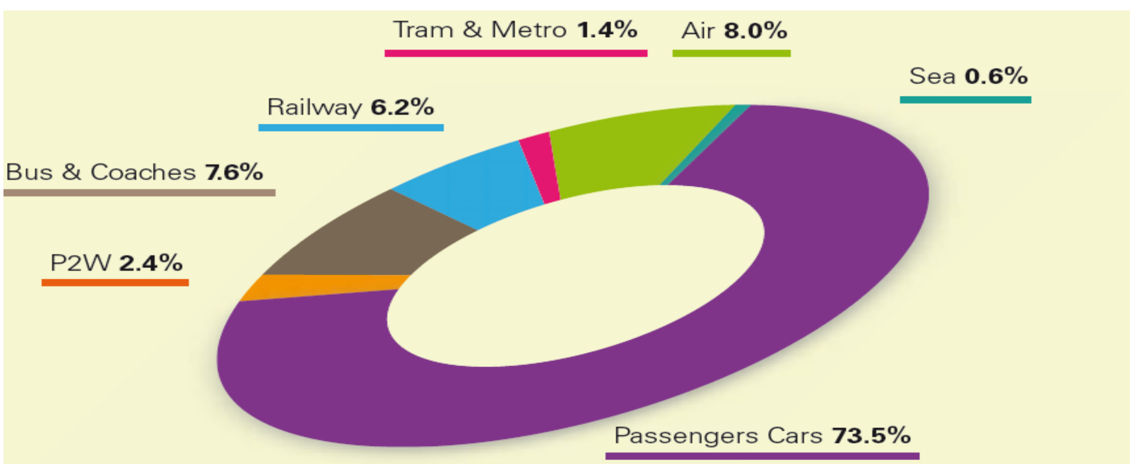
As already mentioned above, sustainability can fully be achieved when the economic, social and the environmental aspects are fully and mutually reinforced by each other. In this light, any transport system that fails to serve its societal needs due to economy instability always leads to environmental damage circumstances *[15]*. Practically, road transport is not only being graded for business and economic propositions but equally for the general quality and well being of the citizens of the globe *[16]*. Presently, most citizens use a personal mode to for most of their trips and this leads to great environmental degradation. As it is well known, the environmental impacts from road transport must be reduced at the societal level to increase efficiency. EU stands for a clean, energy-efficient, safe and intelligent road transport system with an essential and highly competitive road transport industry for a strong business community *[17]*.

The roads today are by any computation the lifeblood for the world trade and social utility for passenger and goods. Many businesses as well as social and labor activities are fully accomplished on daily basis *[18]*. Today, within the European Union's especially within the high income members' states, one or two vehicles are found in many residents and the road freight transport represent more than two thirds of the total tonnage kilometers made *[19]*. In today's view, the EU-27 has put in place actions which highly focus on controlling the multiples costs associated to road transport, thus, safety requirements as well as environmental protections must comply with transport policy when transport developments are to be put in place *[20]*. In all, promoting road passenger and freight transport services by harmonizing safer and more environmentally friendly technical standards, creating fair conditions for competitions and ensuring a degree of social and fiscal harmonization and assuring that transport rules are applicable effectively and without discriminations should be on top of the EU policy objectives for the transportation sector *[21]*. The road transport within the European Union operates different facilities (taxi, public transport, carpool….) but more attention will be geared towards in addition to car passenger and road freight transportation

2.1: Road passenger transport

Road passenger transport has been on an increase. From 2007 upwards, statistic shows that the number of passenger kilometer travelled within the EU-27 countries has grown by 1.2% and has stayed on an increase still the present *[22, 23, 24]* and car journeys were the greatest occupying 73.5% of all kilometers travelled *[22]*. The bus travel represents the second largest modal share of the passenger transport *[48]* in all, with these countries having the greatest occupancy (Germany, France, the Netherlands, Sweden, Switzerland and the United Kingdom).

FIGURE 1 ***share of inland transport within the EU-27 for passenger transport (2009)***



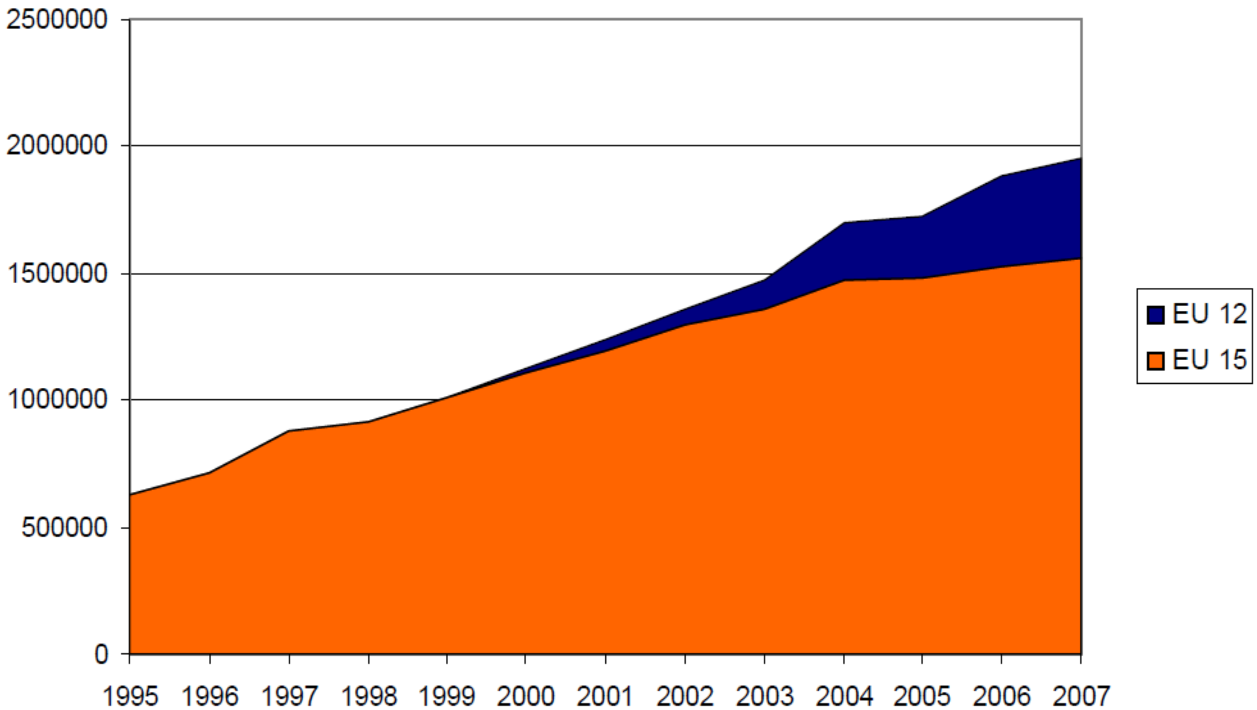
Source: EU road statistic 2011

Moreover, within the period (2000-2010), the demand in road passenger transport stays on top especially for all EU-15 member state *[23]*. Even though EU-12, has been witnessing a remarkable decrease in road transport sector, some members like; Estonia, Hungary and Slovenia have gained slight progress in their road demands since 1997 till present, *[25, 26]*. This can be attributed to the great advancements within the road transport infrastructure and traffic management systems.

2.2: Road freight transport

Freight transport activity has been on a fast growing rate within the past decades. This was attributed to the great improvements in transport efficiency which has lead to the removal of intra-EU barriers to promote higher investment and to stimulated trade *[20, 21]*.This high growth in freight activity took place within road transport in term of volume in millions of tone –km travelled within the EU-15 and EU-12 respectively.

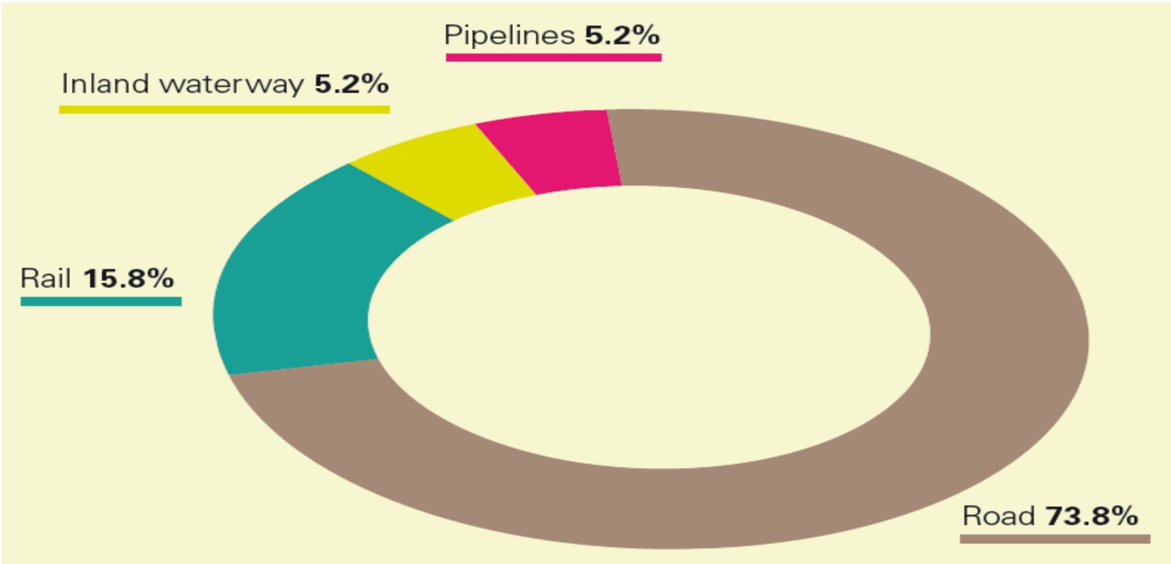
FIGURE 2: ***Road freight transport growth (in tonne-kms) in the EU-27 1999-2007)***



Source: EC 2009

Currently, based on inland transport modal split for EU-27 in general, road freight share stood at 73.8% with rail occupying 15.8% and the rest distributed to other modes. The road share equally took into account both the national and international haulers

FIGURE 3 ***share of inland transport within EU-27 for freight transport (2009)***



Source: EU road statistic 2011

This was due to a geographical orientation of the market (from East to West) because new markets were well connected with freight facilities thus creating a more adoptive road logistic to reach its target areas *[21]*. The Practice these various road transport activities has resulted in both desirable and undesirable factors within the EU-27:

2.3: Desirable outcomes from road transport

2.3.1: Employment from the road transport sector

Within the EU-27, the transport sector in general has provided enormously higher employment facilities to its citizens. In 2009, it was estimated that some 10 millions person were employed to work with the transport sector within the EU-27 *[22]*. From this figure, more than 5 million people work with the road transport sector with freight activities occupying close to 3 million in total. This is because many new business areas have been created due to the existence of open border policy (free entry and exits) amongst members states which have foster to numerous free trade zones *[21, 22, 23]*. The passenger activities equally plays an important role as it equally provides employment opportunity to citizens to manage, control and direct public transport companies as well as private companies to see that plan trips are achieved. This indicator has been seen by the citizens and government as important as it improve standard of living thus an increase in economic.

2.3.2: Total turnover from road transport activities

Total turnover has equally been seen as one of the great indicator that has contributed positively to the growth of the road transport sector within the EU-27. According to *[21,22]*, it was realized that the turnover from transport within the EU-27 at the end of 2007 amounted to €1210,000 of which €3 99,754 was recorded from road transportation activities. The share for turnover from road freight services at the national and international scale was 80% and car road passenger 20%.

At the end of 2008, fright road service witnessed a slight decrease whereas car passenger witness a slight increase but results were not available for all EU 27 countries. At the end of 2009, freight transport services witnessed another high decrease but passenger cars still return the figure obtain at the end of 2007 , no statistical result available for some EU-27 member states. Road transport has been the most attractive not only for entrepreneurs [*25, 26]* and governments. This is because of high amount of profit is ripe as trips are being carried out. Statistically, most freight road activities both national and international haulage are operated by private companies with the government playing a greater role in passenger transport *[20,26]*.

2.3.3: Other related benefits from the road transport sector

Apart from the higher employment and total turnover gained from road transport within the EU, other related benefits that have equally contributed highly in the economic growth and standard of living of the citizens are the growth Gross domestic product within the road transport sector and the increase in Gross value added. It is well noticed that the level of passenger and freight transport highly influences both the European economy and the people's quality of life that is to render and ensure mobility for all service users *[23]*. There has been a constant increase in GDP *[25,30,31]* within the EU-27 and followed by a growth in transport. Statistically, it shows that the GDP within the EU-27 stood at 12268 billion EUR in 2010 with the Germany, France, United Kingdom, Italy and Spain which are classified as the largest EU economies occupying 71% of this total. Using the GDP per capita for purchasing power parity is look upon to be a vital tool to be use for comparison between countries as it is adjusted to suit the size of an economy in term of prices differences and the populations across the various countries *[23, 24]*. Secondly, Gross value added from the transport sector has equally contributed positive in the economic growth among the EU members' states. Within the period 1998-2007, the road transport had an average share of 4.4% of the gross value added. Today the amount shares a great increase of around € 533 billion GVA at basic prices. In all, the road transport sector including the storage service sector (postal and courier activities) accounts for 5.1% with 40% from the road passenger and freight transport for the total GVA in the EU-27 *[26]*. These related benefits are not being considered in this study because there is no up to date data upon which sustainable evaluation within the road transport can be carried out.

2.4: Undesirable effects from road transport

Apart from benefits derived from the road transport activities within the EU 27, there are also some resulting undesirable indicators which have great effects on the economy, society and the environment as well *[21, 25, 26]*. Important resulting undesirable indicators from road passenger and freight transport are as follows;

2.4.1: Green house gas (GHG) emission from the transport sector.

GHGs emission from transportation comes from the combustion of fossil fuel. As it is well known, petrol and diesel [*27]* are the mostly used fuel type within the road transport sector. Its combustive activities lead to high deterioration of the environment. From all indications, it has been realize that GHG from the transport sector especially the road passenger and freight transport has taken an upwards trend. This high growth rate in transport's GHG emission can lead to a potential challenge to meet up with the awaited long term GHG emission reduction target if further efforts are not put in place. As stated in Racioppi et al *[28]*, the total GHG emissions which had an increase of 28% between 1990 to 2007 within the road passenger and freight transport has presently reduce to 19.3%. This finally motivated the EU member states to put in place directives which will help in regulating the emissions (95 g CO_2/km) of new cars sold within the EU-27 from 2010 to 2020 *[29]*.

2.4.2: Road fatalities

Within the group of undesirable factors resulting from road transport related externalities such as greenhouse gas emissions, and traffic congestion,, the World Health Organization (WHO) classified road traffic crashes as the main public health problem within the European Regions *[28]*. Looking at the statistic from European Commission *[22]*, it was notice that more than 35,000 people were killed with at least 1.500.000 injured on the EU roads in 2009. This equally led to a high societal cost which was estimated to be approximately Euro 130 billion in 2009. But in *[29, 30]*, it was mentioned that these losses were not borne equally by all the European regions. Mostly, this effect was on Earthen and Southern European member countries than the western countries. The WHO further made mentioned that road traffic injury/damages can be prevented. That is, creating authorities with sufficient funding to carry out strategic regional plans with measurable targets that contribute to arriving to a sustainable answer to the road safety problems.

Due to the fact that car within the EU member states is on an increasing scale, road traffic causalities is perceived to be the main leading cause of death within these countries. Based on the proclamation from World health Organization, a policy document 'Towards a European Road safety area initiated by the European commission based on the orientation of road safety 2011-2020" *[31, 32]* was published aimed at adopting the new EU target to half the number of road fatalities by 2020. The adoption of this EU target stimulates the combined efforts at both the national and the EU levels. The commission equally debated on a series of issues that could helps in the reducing the number of crashes and some of the mentioned ones were-; exposure risk, better vehicles, improved roads, economic trends, populations and safety interventions, speed limit and the limit imposed on alcohol consumption while behind the wheel *[33]*. According to Antonio et al *[34]*, it was discovered that there has been a great reduction in the number of road fatalities by 36% in the EU-27 within the period of 2001 and 2009. Furthermore, the EU commission forecasts an overall total of 33, 000 death in 2010 and even if the 2020 target is achieved, still more than 16, 500 will suffer from road crashes. Looking at the present trend, and with respect to *[25]*, it is seen that a total of 31,030 person were killed in road accidents within 30 days in 2010, a decrease of 10.9% as compared to 2009 (34814). Aiming to half the total number of road fatalities will entail the EU commission to reinforced safety programs to translate them urgently into determined actions.

2.4.3: Final energy consumption from the road transport sector

The EU transport sector accounts for more than 30%of the total energy consumption within which 98% is based on fossil fuel. Looking at the current situation, a more significant effort has been made since 2005 to reduce the amount of fuel consumption within the road passenger and freight transport *[36]*. Despite this projection in the global oil demand, it is expecting that the EU will be facing a higher deficit of diesel fuel and surplus gasoline by 2015 *[37]*. This is because of an increase in fleets on diesel vehicles use. As such, this automatically raised the road passenger and freight transport costs which affect the competitive global businesses operations among the member states. In EC *[21]*, it is shown that the EU has targeted to increase the share of its renewable energy use to 20% by 2020 and biofuels in road transport fuel mandatory blending production will be introduced as well all aiming at fighting against fuel shortages.

2.5: Data

In the present study, in order to evaluate the sustainable road transport situation of the EU-27 countries (Belgium **(BE),** Bulgaria **(BG),** Czech Republic **(CZ**), Denmark **(DK)**, Germany **(DE),** Estonia **(EE),** Ireland **(IE),** Greece **(EL),** Spain **(ES),** France **(FR),** Italy **(IT),** Cyprus **(CY),** Latvia **(LV),** Lithuania **(LT),** Luxembourg **(LU),** Hungary **(HU),** Malta**(MT),** the Netherlands **(NL),** Austria **(AT),** Poland (**PL),** Portugal **(PT),** Romania **(RO**), Slovenia **(SI),** Slovakia **(SK),** Finland **(FI),** Sweden **(SE)** and United Kingdom **(UK),** relevant information in relation to facts and statistics for this project was gathered using the European commission website specifically under mobility and transport. Being a source that carries all related information with respect to all modes of transportation, a series of statistical pocketbooks from 2007 to 2012.were consulted. The main concerned mode was road transportation. Aspects of greater attention were the statistical figures for; car passenger, freight transport, desirable indicators (employment from the road transport sector and the total turnover) as well as undesirable indicators (GHG emissions from road transport, final energy consumed and the road fatalities) resulting from the practice of this activity**.** For Car passenger, frieght transport, employments and road fatalities, data on three years averages were produced, for final energy consumption on a two year averages while total turnover from road transportation sector was evaluated on a one year basis. Full table of the data set can be seen below:

TABLE 1: Dataset used in this research

EU/transport indicators	The main inputs variables		The desirable indicators		The undesirables indicators		
	Passenger transport bio pkm (2007-2009)	Freight transport bio tkm (2007-2009)	Employment from road transport (000) 2007-2009	Total turnover from transport mio € (2007)	Greenhouse emission from road transport mtoe (2007-2009)	Final energy consumption from transport Mtoe (2007-2008)	Road fatalities from road transport Persons (2007-2009
BE	111.3 **(8)**	38.87 **(12)**	99.1 **(16)**	12,659 **(9)**	26.0 **(8)**	8.5 **(8)**	990 **(11)**
BG	43.3 **(19)**	15.89 **(21)**	78.4 **(17)**	1,842 **(21)**	7.6 **(19)**	2.5 **(19)**	989.3 **(12)**
CZ	72.0 **(13)**	47.99 (9)	156.2 **(9)**	8,043 **(12)**	18.3 (13)	2.9 **(18)**	1066 **(9)**
DK	51.5 **(17)**	19.10 **(19)**	65.0 **(19)**	8,952 **(11)**	12.8 **(16)**	5.9 **(12)**	371.6 **(19)**
DE	872.9 **(1)**	330.84 **(1)**	644.0 **(2)**	44,455 **(5)**	145.6**(1)**	50.7 **(1)**	4526 **(3)**
EE	10.3 **(24)**	6.37 **(25)**	20.3 **(24)**	1,095 **(25)**	2.1 **(26)**	0.75 **(25)**	142 **(24)**
IE	48.2 **(18)**	16.03 **(20)**	32.4 **(21)**	3,080 **(18)**	13.5 **(14)**	4.5 **(13)**	286 **(22)**
EL	98.6	28.41	116.1 **(12)**	5,720	20.2 **(10)**	4.4 **(14)**	1540

	(10)	**(15)**		**(15)**			**(8)**
ES	345.4 **(5)**	237.92 **(2)**	593.3 **(3)**	47,544 **(4)**	93.4 **(5)**	32.9 **(5)**	3212.3 **(5)**
FR	750.5 **(2)**	199.80 **(3)**	660.8 **(1)**	54,871 **(3)**	124.1 **(2)**	42.1 **(2)**	4389.3 **(4)**
IT	691.1 **(3)**	174.83 **(4)**	505.4 **(5)**	82,098 **(1)**	115.6 **(4)**	38.2 **(4)**	4699.6 **(2)**
CY	5.7 **(26)**	1.15(26)	5.4 **(26)**	204 (26)	2.3 **(25)**	0.7 **(26)**	81 **(25)**
LV	16.5 **(23)**	11.22 **(23)**	34.4 **(21)**	1,242 **(23)**	3.1 **(24)**	1.1 **(24)**	329.6 **(21)**
LT	37.7 **(20)**	19.48 **(18)**	60.5 **(20)**	2,570 **(19)**	4.6 **(23)**	1.6 **(23)**	536 **(16)**
LU	6.6 **(25)**	9.11 **(24)**	11.7 **(25)**	1,308 **(22)**	6.5 **(20)**	2.2 **(20)**	42.6 **(26)**
HU	54.1**(16)**	24.98 **(17)**	118.3 **(11)**	5,111 **(16)**	12.5 **(17)**	4.3 **(16)**	1016.6 **(10)**
MT	2.1 **(27)**	0.25 **(27)**	2.4 **(27)**	132 **(27)**	0.5 **(27)**	0.2 **(27)**	16.6 **(27)**
NL	147.3 **(7)**	76.25 **(7)**	226.5 **(7)**	22,394 **(6)**	34.6 (7)	11.6 **(7)**	676.6 **(14)**
AT	72.6 **(12)**	33.59 **(13)**	110.3 **(14)**	11,829 **(10)**	22.0 **(9)**	7.6 **(9)**	667.6 **(15)**
PL	283.9 **(6)**	165.51 **(5)**	413.0 **(6)**	17,457 **(7)**	40.2 **(6)**	14.4 **(6)**	5197.3 **(1)**
PT	86.7 **(11)**	40.36 **(10)**	103.2 **(13)**	6,365 (**14)**	18.5 **(12)**	6.1 **(11)**	899.6 **(13)**
RO	71.1 **(14)**	50.06 **(8)**	176.4 **(8)**	5,062 **(17)**	13.4 (**15)**	4.3 **(15)**	2885.6 **(6)**
SI	25.0 **(22)**	14.91 **(22)**	30.4 **(22)**	2,136 **(20)**	5.6 **(22)**	1.8 **(22)**	226 **(23)**
SK	26.2 **(21)**	28.05 **(16)**	30.1 **(23)**	1,167 **(24)**	6.4 **(21)**	1.9**(21)**	523 **(17)**
FI	63.8 **(15)**	28.55 **(14)**	70.0 **(18)**	7,423 **(13)**	12.1 **(18)**	4 **(17)**	334.3 **(20)**
SE	99.0 **(9)**	39.32 **(11)**	137.0 **(10)**	15,079 **(8)**	19.3 **(11)**	7.6 **(10)**	408.6 **(18)**
UK	680.9 **(4)**	156.94 **(6)**	533.3 **(4)**	56,917 **(2)**	117.9 **(3)**	39.9 **(3)**	2680.3 **(7)**

**** Figures in bracket represent ranking of EU-27 states to their levels of activities**

3: METHOD USE FOR ROAD TRANSPORT SUSTAINABILITY EVALUATION

3.1: Data Envelopment Analysis (DEA)

DEA is a mathematical programming tool developed by Charnes, Cooper and Rhodes in 1978 (Charnes et al *[11]* and further revised by Banker, Charnes and Cooper in 1984. Since its development, this optimization technique has been used by different organizations to carryout operational models for performance evaluation *[38]*, benchmarking *[12]* and decision making *[39]*. In order to determine the relative efficiency of the various decision making units (DMUs), DEA uses the ratios of the weighted sum of output to the weighted sum of input with the weights being considered as a variable and not fixed as applicable in the traditional approach *[40]*. In many literatures, DEA has been recommended as a tool use for a handful of applications, in Asmild et al, [*41*], DEA the most important technique that is used in finding the most relative efficiency of a series of inputs and outputs of a uniform set of DMUs. Its development has been so important since it has opened up many possibilities in solving complex situations in different activities that were not possible with other approaches *[42]*. Not only in solving situations, DEA has equally been a great tool use in measuring effectiveness and efficiency for behavioral goals *[43]*. In the present study, with the help of the various inputs and outputs variables and the CCR model, this technique will be used to produces outcomes which will be used to evaluate sustainability in road transport among the different member countries.

3.1.1: DEA- CCR Model

The CCR model developed by Charnes, Cooper and Rhodes (1978) is a partial programming model that aids in determining within a given data set of comparable units the various efficiency score of each of the decision making units for performance evaluation. This model determines the best set of weight for each DMU when the issue to be resolved for each DMU is under consideration. Moreover, the efficiency of the DMU is being maximized by using the various weights U_r and V_i respectively for the output and the input within the objective function. The main important point to be noted here is that these weights are determined by the model in such a way that the efficiency score of the DMU under consideration is maximized and when the same set of weight is applied to the other DMUs in the sample set, their efficiency score should not exceed one. A mathematical computation is provided as follows:

$$\max_{V,U} \theta = \frac{\sum_{r=1}^{s} U_r Y_{rj0}}{\sum_{i=1}^{m} V_i X_{ij0}} = \frac{U_1 Y_{10} + U_2 Y_{20} + \dots + U_s Y_{s0}}{V_1 X_{10} + V_2 X_{20} + \dots + V_m X_{m0}} \qquad for\ DMUo$$

Subject to (1)

$$\frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}} = \frac{U_1 Y_{1j} + U_2 Y_{2j} + \dots + U_s Y_{sj}}{V_1 X_{1j} + V_2 X_{2j} + \dots + V_m X_{mj}} \leq 1 \quad for \quad j = 1, \dots, n$$

$$V_i \geq 0 \qquad i = 1 \dots m$$
$$U_r \geq 0 \qquad r = 1 \dots s$$

Since the CCR model is a fractional problem, it has to be converted into a linear program so that it can be easily solved. This is done by normalization that is, the denominator of the objective function is equated to one and the first constraint corresponding to the efficiency ratios of all the DMUs in the sample is also modified as can be seen

$$\max_{V,U} \theta = \sum_{r=1}^{s} U_r Y_{rj0} \qquad for \quad DMUo$$

Subject to

$$\sum_{r=1}^{s} V_i X_{ij0} = 1 \qquad (2)$$

$$\sum_{r=1}^{s} U_r Y_{rj} - \sum_{r=1}^{s} V_i X_{ijo} \leq 0 \qquad with\ j = 1, \dots, n$$

$$Vi \geq 0 \qquad i = 1 \dots m$$

$$Ur \geq 0 \qquad r = 1 \dots s$$

Looking critically, the above model can be considered as a multiplier model because it is developed from the fractional one and the inputs and outputs variables are multiplied with their weights.

4: APPLICATIONS AND RESULTS

Sustainable development is one of the important objectives in the European Union within which sustainable road transport is one of the pertinent issue that requires great attention. GHG emission, energy consumption and road fatalities are the essential aspect striking against this objective, thus a call of concern. In the present study, different approaches in DEA will be used to evaluate the level of sustainability in the different member states. Specifically, this will be done by incorporating the main inputs, desirable outputs and the undesirable outputs in the CCR Model.

4.1 Applications

4.1.1: Ignoring undesirable Factors in DEA models.

Basically, the general practice in sustainable evaluation and efficiency measurement within the road transport milieu has been to reduce additional products of most transformation processes that can be categorize as "Undesirable outputs" *[44]*. Even though this aspect is of great important as measuring the outcomes from the economic performance from road transport is concern, failing to include the society and the environmental aspect for sustainable evaluations becomes an economic measure of the system alone *[45 ,46]*.

4.1.2: Including undesirable factors in DEA models

4.1.2.1: Considering undesirable outputs as inputs: Practically, undesirable outputs are looked upon to be an undesirable result of a productive process and as such its production outcome must be minimized. In order to minimize it, this strategic aspect is applicable, where undesirable outputs are being modeled as inputs variables, that is ,GHG emissions, final energy consumption and road fatalities are added on to road car passenger and road freight transport in one model

4.1.2.2: Using the reciprocal of undesirable outputs: Looking at this measure, the reciprocity of undesirable outputs (GHG emissions, final energy consumptions and road fatalities) are being considered as desirable's outputs and modeled at once in the DEA-CCR models. In *[47]*, they considered this method given that when these outputs are modeled in their inverse values, they become part of the desirable outputs upon which any derived results can equally be use to evaluated the sustainable nature of the road transport for the various EU-27 countries.

4.2: Results and statistical analysis

4.2.1: Results

The software used for the data exploration was lingo 10, a statistical and programming tool used for handling optimization problems and the model applicable was the CCR Model. Within the model, DMUs represented the EU-27 countries. A minimum weight was set to avoid having a score of zero. Secondly an absolute weight restriction was applicable. In our present study, 20% was used in the model. The reason was to include some flexibility in the assigned weights but at the same time assuring that each variable contributes to the index score to some extent. In case five variables are considered, the weight on the various variables ranges between 16% and 24%, in cases two variables are considered, this ranges between 40% and 60% .More about weight restriction can be found in Allen et al. *[47]*. The data was inserted into the software based on the different measures defined above and the following results were obtained:

TABLE 2: ***Results***

EU-27	Ignoring undesirable outputs in the model		considering both inputs, desirable and undesirable outputs are being considered in the model			
			When undesirable outputs are treated as inputs in the model		When the reciprocal of undesirable outputs is used in the model.	
	No weight	20%	No weight	20%	No weight	20%
BE	0.701	0.701	0.780	0.646	0.701	
BG	0.952	0.490	1.000	0.524	0.952	
CZ	1.000	0.846	1.000	1.000	1.000	
DK	1.000	1.000	1.000	0.884	1.000	
DE	0.432	0.414	0.569	0.471	0.432	
EE	0.933	0.808	1.000	0.839	0.951	
IE	0.476	0.476	0.494	0.417	0.476	
EL	0.717	0.636	0.935	0.648	0.717	
ES	0.937	0.849	0.975	0.800	0.937	
FR	0.658	0.655	0.811	0.672	0.658	
IT	0.974	0.784	1.000	0.786	0.973	
CY	0.679	0.538	0.679	0.372	0.679	
LV	0.881	0.635	1.000	0.705	0.889	
LT	0.723	0.594	1.000	0.841	0.726	
LU	1.000	0.877	1.000	0.671	1.000	
HU	1.000	0.851	1.000	0.794	1.000	
MT	1.000	1.000	1.000	0.835	1.000	
NL	0.960	0.912	1.000	0.966	0.960	
AT	1.000	0.974	1.000	0.833	1.000	
PL	0.647	0.517	0.822	0.665	0.648	
PT	0.612	0.580	0.678	0.579	0.612	
RO	1.000	0.632	1.000	0.722	1.000	
SI	0.639	0.590	0.691	0.608	0.642	

SK	0.485	0.332	0.514	0.356	0.488	
FI	0.723	0.708	0.901	0.787	0.724	
SE	0.956	0.952	1.000	1.000	0.956	
UK	0.746	0.707	0.879	0.716	0.745	

4.2.2: Statistical analysis:

Firstly, when the undesirable outputs are ignored, and without absolute weight restriction, 7 countries are efficient. The reason being that the amount of kilometers travelled as well as the total tonnage made from these countries have produced greater employment as well as higher turnover within this sector as compared to other member states thus, a great achievement within the social and economy sector. When a weight restriction of 20% is applied, only DK and MT remain efficient.

Within the second aspect, two main measures are of great concern; the first measure is when undesirable outputs are being treated as inputs. When no weight restriction was applicable, 14 countries were found efficient. These countries are efficient because the amount of passenger kilometer and tonnage kilometers has produced as many employment facilities with a higher turnover while consuming less energy, emitting less GHG emission with less human fatalities as compared to other countries. When the weight restriction of 20% is applicable on all variables, just 2 countries remains efficient. An overall reason for the reduction in the number of efficient countries when weight restriction 20% is applicable is due to the fact that all the variable are being taken into account with no variable being attributed a value of zero as compared to the case where no weight restriction is not applicable as some variable are attributed with a zero value or not consider by the model. In this case, one can say when the weight restriction is applicable; countries that remain efficient are the countries that actually perform better than the other countries.

Secondly, when we use the reciprocal of the undesirable outputs, firstly without weight restriction, 7 countries are efficient, the same countries as for the first measure used above. In this case, one can conclude that the reciprocal variables for the undesirable outputs were not taken into consideration by the model or this reciprocity was taken into consideration by the model but attributed lesser influence on the final scores. When a weight restriction of 20% is applicable, no feasible solution was found. The reason is that the inverse on the various values of the undesirable outputs results in very small values compared to other bigger values of the inputs and desirable outputs variables in the same model thus, causing great disparity between members states .To solve this problem, and clustering analysis was carried out based on all the seven indicators. The aim was to help classify these countries based on various levels of activities and outputs variables, that is, countries with higher, medium and low road transport activities. This process was carried out with the use of R software. In the end, three cluster groups were obtained. Different results with respect to different cluster groups were derived. These results are presented in the table below:

TABLE 3: ***combined results for all the three different cluster groups for EU-27***

various cluster groups	EU-27	Ignoring undesirable outputs in the model		When both inputs, desirable and undesirable outputs are being considered in the model			
				When undesirable outputs are treated as inputs in the model		When the reciprocal of undesirable outputs in used in the model.	
		Without weight restriction	20% weight restriction	Without weight restrictions	20% weight restriction	Without weight restriction	20% weight restriction
Cluster 1: countries practicing high volume of road transport activities	DE	0.660	0.555	0.747	0.650	0.660	0.275
	ES	1.000	1.000	1.000	1.000	1.000	0.693
	FR	1.000	0.853	1.000	0.897	1.000	0.478
	IT	1.000	1.000	1.000	1.000	1.000	0.558
	PL	0.949	0.678	1.000	0.813	1.000	1.000
	UK	1.000	0.938	1.000	1.000	1.000	0.632
Cluster 2 : countries practicing medium in volume of road transport activities	**BE**	**0.849**	**0.759**	**0.874**	**0.657**	**0.860**	**0.476**
	CZ	**1.000**	**0.875**	**1.000**	**1.000**	**1.000**	**0.759**
	EL	**0.891**	**0.699**	**0.934**	**0.659**	**0.911**	**0.641**
	HU	**1.000**	**0.905**	**1.000**	**0.814**	**1.000**	**1.000**
	NL	**0.967**	**0.930**	**1.000**	**0.980**	**0.966**	**0.295**
	AT	**1.000**	**1.000**	**1.000**	**0.857**	**1.000**	**0.715**
	PT	**0.613**	**0.603**	**0.681**	**0.591**	**0.628**	**0.566**
	RO	**1.000**	**0.673**	**1.000**	**0.760**	**1.000**	**0.553**
	SE	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**0.681**
Cluster 3: countries practicing low volume of road transport activities	BG	1.000	0.490	1.000	0.598	1.000	0.002
	DK	1.000	1.000	1.000	1.000	1.000	0.002
	EE	1.000	0.808	1.000	1.000	1.000	0.048
	IE	0.493	0.477	0.622	0.501	0.493	0.002
	CY	0.693	0.538	0.693	0.382	0.693	0.124
	LV	1.000	0.635	1.000	0.835	1.000	0.016
	LT	0.842	0.594	1.000	1.000	0.842	0.004
	LU	1.000	0.903	1.000	0.848	1.000	0.045
	MT	1.000	1.000	1.000	0.876	1.000	1.000
	SI	0.676	0.590	0.812	0.758	0.674	0.009
	SK	0.554	0.332	0.555	0.461	0.554	0.005
	FI	0.749	0.723	1.000	1.000	0.749	0.002

Generally, the results derived from the various cluster groups produced a feasible solution when all measures are taking into account and with and without weight restriction. From cluster one, when undesirable outputs are ignored, without weight restriction, four countries (ES, FR, IT and UK) are efficient and with the weight restriction of 20%, two countries (ES and IT) remain efficient. The second measure consist of two aspects, firstly when undesirable outputs are treated as inputs in the model, and without weight restriction, five countries (ES, FR, IT, PL and UK) become efficient but with a weight restriction of 20%, only three countries (ES, IT and UK) remain efficient. Secondly, when the reciprocal of the undesirable outputs is used in the model, and without weight restriction, five countries (ES, FR, IT, PL and UK) obtained efficient scores same as in the previous measure. With a weight restriction of 20% applicable, just one country (PL) is efficient.

Based on cluster two, when undesirable outputs are not included in the model, and without weight restriction, five countries (CZ, HU, AT, RO and SE) were operating efficiently. With the weight restriction of 20% applicable, two countries (AT and SE) remain efficient. Looking at the second measure, when undesirables output are treated as inputs, and without weight restriction, six countries (CZ, HU, NL, AT, RO and SE) are efficient. With a weight restriction of 20%, two countries (CZ and SE) become efficient. Secondly, when undesirable outputs are treated in a reciprocal manner in the model, and without weight restriction applicable, five countries (CZ, HU, AT, RO and SE) are efficient. But with a weight restriction of 20% applicable, just one country (HU) is efficient.

Finally, in cluster three, when undesirable outputs are not included in the model, and without weight restriction, six countries (BG, DK, EE, LV, LU, and MT) become efficient. When a weight restriction of 20% is applied, two countries (DK and MT) remain efficient. As concerns the second aspect, two measures were taken into account; firstly, when undesirable output were treated as inputs, and without weight restriction taken into account, eight countries (BG, DK, EE, LV, LT, LU, MT and FI) became efficient. With a weight restriction of 20%, only four countries (DK, EE, LT and FI) are efficient. Secondly, when the reciprocal of the undesirable outputs is used and with no weight restriction applicable, six countries (BG, DK, EE, LV, LU and MT) are efficient. With a weight restriction of 20% applicable, one country (MT) becomes efficient.

Considering all the three cluster results above, it can be noticed that each of the efficient country is derived based on different aspects taken into consideration by the model. Based on the first aspect that deals just with economic measures, some of the member countries have higher inputs values generating high benefits (high employment facilities and total turnover) which can make these countries to be labeled efficient. Secondly, when the societal and the environmental aspects were taken into consideration, countries that were found efficient follow a different criterion. These could be due to the fact that the tones of GHG emissions as well as the amount of resulting road fatalities and final energy consumption were very low compared to other member states, high number of employment facilities created by the passenger and freight activities even if the total kilometer travelled and the total tonnage kilometer made are higher whereas some countries may actually become efficient only when all the variables are taken into consideration.

Comparatively and with respect to the two main measures, it can be realized that when no weight restriction is applicable, the results are almost the same. That is, the set of efficient countries within a cluster is rather stable when applying the various models. When the weight restriction is applicable there are great differences in the results between the different models. This shows that the imposed weight restriction in the different models actually has a great influence on the index score of the countries.

5: DISUSSIONS

The present study is aimed at using an optimization model to evaluate sustainability in road transportation for the EU-27 countries. This includes using different criteria in the sustainability evaluation. From the overall results above, an important aspect was notice. That is, in real case, countries with efficiency scores of one always remain efficient when the two main measures taken into consideration. Given a large number of efficient countries, policy makers cannot make successful predictions with respect to sustainable future development. Therefore, a weight restriction was introduced in the model. The reason was to be sure that all the variables in the model are being taken into consideration to an extent. Based on the first aspect, ie ignoring undesirable outputs in the model, when a weight restriction is applicable, the number of efficient countries reduces drastically. From the various inefficient scores within different other member countries, we can equally notice a great disparity in their various figures which is a result of different level of variables implementation and volume of activities. From the theoretical point of view, this aspect is so important to the transport policy maker, research groups and different stakeholders when it comes to evaluating the amount of economic benefits that have resulted from the main road transport activities. But for road transport sustainability evaluations, and in relations to the work of *[43, 44, 48]*, this measure is not suitable as it fail to take in to account the societal and environmental aspects which are of great important when it comes sustainability development and as such cannot be recommended to the policy maker or stakeholders for future predictions.

Secondly, in a case where undesirable outputs are jointly treated as inputs, and without weight restriction applicable, 14 countries are efficient. Considering a weight restriction of 20%, only 2 countries are efficient. Comparing with the first aspect, it is discovered that the countries have higher index values; this is due to the fact that all variables are included in the model. Even though the main inputs variables and the undesirables output are jointly considered in the model , this measure can be recommended to the different stakeholders for transport sustainability evaluation as the economic, social and environmental aspects in their real values are being taken into account in the model. Results obtain from this measure can be validated for decision making.

Lastly, considering the reciprocal of the undesirable outputs, and with no weight restriction taken in to account, 7 countries were efficient but when the weight restriction of 20% was applied, no feasible solution was obtained. As already mentioned above, a cluster analysis was carryout to solve the problem. Furthermore, a correlation coefficient was calculated with respect to the second measure resulting in the following; 1.00 for cluster 1: 0.89049 for cluster 2 and 0.9954 for cluster 3. However, for the case of 20% weight restriction, great variability between results is found which makes these measures different in their various areas of application. Therefore, a sensitivity analysis was carried out based on different weights restrictions (from 20% up to 80%). The aim was to observe the reaction that result at different points when different weights are applied and the various outcomes. (Tables and graphs can be found in the appendices). Based on the results from the sensitivity analysis, it can be noticed that in some case, when the weights increases from 20% going up to 80%, different scores are obtain but in other cases, the scores remain unchanged especially for countries which are efficient at the beginning. This shows that the weight restriction actually have an important role on some countries as it produces great influence on the various scores.

6: CONCLUSIONS, RECOMMENDATIONS AND FUTURE RESEARCH

Over all, it can be stated that road transport plays an important role to the economic development, trade and social incorporation. Moreover, it is also the sector which is liable for the great number of negative impacts on the environment and the society. Within the EU-27 as well as the rest of the world of today, more steps are being taken to evaluate sustainable improvement especially on the need to assess the impact of undesirable factors in order to determine the most effective road transport policy. In this present study, based on the information on passenger and freight transport, the desirable outputs and the undesirable outputs, the technique of DEA was resulting to two main applications (ignoring undesirable inputs and considering inputs, desirable outputs and undesirable outputs) was used to evaluate the sustainable nature of road transport within the EU-27 member countries. From the results obtained, while taking into account the seven indicators and with the weight restriction of 20% applicable, it was found that some of the member states (ES, HU, SE, DK, CZ, UK and MT) are operating efficiently in nearly all the measures used, secondly, some countries operating efficiently under a conditional role , that is base on the weight restriction or without weight restriction and for different measures and lastly others inefficiently (DE, BE, EL, PT, IE, CY, SI, SK and FI) no matter which measure is use with weight or without weight restriction . All in all, with respect to treating undesirable outputs in a reciprocal manner, and without weight restriction taken into account, in both main results in figure 2 and the clusters results in figure 3, it was found that the results obtained were same as with when undesirable outputs were ignored from model, This mean that the inverse values of the undesirable outputs attributed no value to the main inputs variable and the desirable outputs. When a weight restriction was applied, only one country obtains an efficient score of one. The rest of the countries obtain very low scores making this measure an inappropriate aspect for decision makers to use for sustainable road transport evaluation.

To be able to create important road transport policies, governments as well research groups or other stakeholders need to choose a measure that will be geared towards sustainability advancement. Selecting this measure will be based on the role under consideration to sustainability evaluation where total inputs are minimized (inputs plus undesirable outputs) and output maximized (such as in economic aspect). Therefore, in accordance to the assumption of classical DEA models *[48],* which ensures inputs minimization and output maximization, “treating undesirable outputs as inputs in the DEA model”, can be given great consideration upon which the transport policy maker can use to evaluate the level of sustainability within the various EU- 27 countries. It’s important is not attributed to the feasible results produced but on the fact that it takes into consideration all aspects (economic, society and the environment) and in their original values upon which a concrete sustainable prediction can be carried by different organizations for decision making

In this present study, and based on the output-oriented point of view toward sustainable road transport evaluation, improvement in efficiency index will entail reducing the quantities of outputs (ie, energy consumption, GHG emission and road fatalities) in relation to the various inputs. In this light, for countries like Belgium, Germany and Greece to improve on their level of efficiency, more emphasis should be geared to the passenger and freight activities. That is, citizens should be persuaded to use public transport than personal cars and other modes should be introduced to handle freight activities as this can lead to a reduction in energy consumption, thus a decrease in negative environmental degradation and a great improvement in road safety situation.

For future study, while implementing selected DEA based measure, other approach such as Malmquist productivity index should be investigated and in accordance to the main concept of sustainable road transport evaluation for value judgment (lower input values generated, higher desirable outputs achieved, and less undesirable outputs produced) can be assessed within the EU-27

Acknowledgement

The author wishes to express great thanks to Dr. Yongjun Shen for his tremendous efforts, guidance and constructive criticisms to the success of this project. My profound gratitude to Prof. Dr. Elke Hermans

8: REFERENCE

[1]: Marie Thynell, Dinesh Mohan, Geetam Tiwari, (2010) Sustainable transport and the modernisation of urban transport in Delhi and Stockholm, Transportation Research and Injury Prevention Programme. Cities 27, pages 421–429

[2]: Linda Steg Robert Gifford, (2005), Sustainable transportation and quality of life. Journal of Transport Geography, no 13, pages 59–69

[3]: Todd Litman, (2007). “Developing Indicators for Comprehensive and Sustainable Transport Planning,” Transportation Research Record 2017, 2007, pages. 10-15

[4]: Chen, M. et al. (2007). Assessing an economic dimension of sustainable transport policy: an overview, Deliverable 3.1, REFIT (Refinement and test of Sustainability indicators and tools with regard to European Transport policies) project Netherlands.

[5]: Georgina Santos, HannahBehrendt, LauraMaconi, TaraShirvani, AlexanderTeytelboymb, (2010). Part I: Externalities and economic policies in road transport, Research in Transportation Economics no 28, (2010) pages, 2–45

[6]: Georgina Santos, HannahBehrendt, LauraMaconi, TaraShirvani, AlexanderTeytelboymb, (2010). Part II: Policy instruments for sustainable road transport. Research in Transportation Economics. No 28 (2010) pages 46-91

[7]: Christy Mihyeon Jeon, S.M.ASCE and Adjo Amekudzi, M.ASCE (2005). Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics, 10.1061/ (ASCE) 1076-0342-(2005)11:1 (31)

[8]:Henrik Gudmundsson (2008) Sustainable Transportation Indicators A Recommended Research Program For Developing Sustainable Transportation Indicators and Data, Transportation Research Board (ADD40 [1])

[9]: Todd Litman (2006). Issues in sustainable transportation, Victoria Transport Policy Institute, Int. J. Global Environmental Issues, Vol. 6, No. 4, 2006

[10]: Geurs, K.T., Van Wee, G.P., 2000. Environmentally Sustainable Transport: Implementation and Impacts for the Netherlands for 2030. RIVM, Bilthoven, The Netherlands

[11]: Charnes, A., Cooper, W.W., Rhodes, E., (1978). Measuring the efficiency of decision making units, European Journal of Operational Research 2, pages 429–444

[12]: Elke Hermans, Tom Brijs, GeertWets , Koen Vanhoof, (2009) Benchmarking road safety: Lessons to learn from a data envelopment analysis, Accident Analysis and Prevention no 41, pages 174–182.

[13]: William W. Cooper, Lawrence M. Seiford and Joe Zhu (2009). Data Envelopment Analysis: History, Models and interpretations.

[14]: Milan M. Marti, Marina S. Novakovi , Alenka Baggia (2009) Data Envelopment Analysis - Basic Models and their Utilization. Research paper, Volume 42, DOI: 10.2478/v10051-009-0001-6

[15]: Walter J. Sweeting ,n Patricia H. Winfiel (2012) .Future transportation: Lifetime considerations and framework for sustainability assessment, Department of Mechanical Engineering and Mathematical Sciences, Sustainable Vehicle Engineering Centre, Oxford Brookes University, Oxford, OX33 1HX, UK, Energy Policy no 51, pages 927–938

[16]: Forum of European National Highway Research Laboratories (2007) vision: road transport in Europe, 2025

[17]: ERTRAC, (2009). *ERTRAC Road Transport Scenario 2030+: Road to Implementation*. European Road Transport Advisory Council, October 2009. Available at: www.ertrac.org/?m=49&mode=download&id_ file=341 [Accessed 12 April 2010].

[28]: EUROSTAT – Competitiveness in EU road freight transport (Statistics in focus. (97/2008)

[19]: CE Delft (2009). Internalization measures and policy for the external cost of transport – Produced within the study. –Transport (IMPACT) – Deliverable 3.

[20]: European Commission – DGTREN – EU Energy and Transport in Figures – Statistical Pocketbook 2007/2008 – 2008.

[21]: European Commission, (2009). Road Freight Transport Vademecum , Directorate General Energy and Transport Directorate E – Inland Transport Unit E.1 – Land Transport Policy

[22]: European Commission (2010) Towards a European Road Safety Area: policy orientations on road safety 2011-2020, COM (2010) no 389

[23]: European Commission – DGTREN – EU road Transport indicators in Figures – Statistical Pocketbook 2006/2007 – 2007

[24]: EUROSTAT – Competitiveness in EU road passenger and freight transport (Statistics in focus. (2011)

[25]: EUROSTAT – Competitiveness in EU road passenger and freight transport (Statistics in focus. (2012)

[26]: European Environment Agency (2009). Towards a resource-efficient transport system: indicators tracking transport and environment in the European Union Policy Orientations on Road Safety 2011-2020

[27]: Doll, C. and Wietschel, M. (2008) Externalities of the transport sector and the role of hydrogen in a sustainable transport vision. Energy Policy, 36 (11), pages 4069–4078. Hart, D. (2004)

[28]: Francesca Racioppi, Lars Eriksson, Claes Tingvall, Andres Villaveces (2004), preventing road traffic injury. A public health perspective for Europe

[29]: ETSC (2006). Intelligent Speed Assistance - Myths and Reality, ESTC position on ISA, European Transport Safety Council, 2006.

[30]: Brenda Wilmots, Elke Hermans, Tom Brijs & Geert Wets (2009). SETTING UP AN INDICATOR SYTEM FOR MONITORING ROAD SAFETY USING THE ROAD SAFETY

TARGET HIERARCHY, Transportation Research Institute (IMOB) – Hasselt University BE-3590 DIEPENBEEK Belgium

[31]: José I. Castillo-Manzano, (2009). Could being in the European Union save lives? An econometric analysis of the3rd European Road Safety Action Program, *Facultad de Ciencias Económicas y* Empresariales, University of Seville (Spain) Mercedes Castro-Nuño, Facultad de Ciencias Económicas y Empresariales, University of Seville (Spain) Xavier Fageda (xfageda@ub.edu).Dep. of Economic Policy, University of Barcelona (Spain)

[32]: B T Bayliss (2011) Report of the High Level Group on the Development of the EU Road Haulage Market

[33]: Bosetti, S. et al (2009) Ex Post Evaluation of the 3rd Road Safety Action Programme, TM Leuven

[34]: Antonio Avenoso, Ellen Townsend (2010). Future Road Safety in the EU At Stake? ETSC Response to the EC Communication "Towards a European Road Safety Area

[35]: J.M. Cansino M.del P Pablo-Romero, R. Roma´n, R. Yn˜iguez (2012) . Promotion of biofuel consumption in the transport sector: An EU-27 perspective, Renewable and Sustainable Energy Reviews 16 (2012) pages 6013–6021

[36]: Wood-MacKenzie, (2008). The long and short of it: European product imbalances and their implications. Wood-MacKenzie energy consultants

[37]: Yongjun Shen, Elke Hermans, Da Ruan , Geert Wets , Tom Brijs & Koen Vanhoo f(2011). A generalized multiple layer data envelopment analysis model for hierarchical structure assessment: A case study in road safety performance evaluation, Expert Systems with Applications 38 (2011) pages 15262–15272

[38]: Ertay, T., Ruan, D., (2005). Data envelopment analysis based decision model for optimal operator allocation in CMS. European Journal of Operational Research 164, pages 800–810

[39]: William W. Cooper, Lawrence M. Seiford and Joe Zhu (2009) Data Envelopment Analysis: History, Models and interpretations

[40: Gholam R. Amin M. Toloo, (2006), "Finding the most efficient DMUs in DEA": An improved integrated model Computers & Industrial Engineering 52 (2007) pages71–77

[41]: Sergey Samoilenko, Kweku-MuataOsei-Bryson (2013) .Using Data Envelopment Analysis (DEA) for monitoring efficiency-based performance of productivity-driven organizations: Design and implementation of a decision support system

[42]: Mette Asmild Joseph C. Paradi , David N. Reese , Fai Tam (2007) Measuring overall efficiency and effectiveness using DEA, European Journal of Operational Research 178 (2007) pages 305–321.

[43]: Fare, R.,S. Grosskopf (2004a) modeling undesirable factors in efficiency evaluations. Comment" European Journal of operational research 157, pages142-175.

[44]: Sieford, L.M, J,zhu (2002), “modeling undesirable factors in efficiency evaluations”, European journal of operational research 142, pages 16-20.

[45]: Sieford, L.M, J, zhu (2005) “A response to comments on modeling undesirables factors in efficiency evaluations” .European journal research 161, pages 579-581

[46]: G Gomes, MPE Lins (2007). Modelling undesirable outputs with zero sum gains data envelopment analysis model, Journal of the Operational Research Society (2007), pages 1 -8

[47]: R. Allen, A. Athanassopoulos, R.G. Dyson and E. Thanassoulis, (1997) Weights restrictions and value judgements in Data Envelopment Analysis: Evolution, development and future directions, Annals of Operations Research 73 (1997) pages 13 – 34

[48]: Sperling.D & Gordon.D (2008). Two billion cars: trans-forming a culture. Transportation Research News (259), pages 3-9.

9: APPENDICES

Appendix 1: Other related indicators from road transport

1.1: desirable indicators

1.1.1: Gross domestic product (GDP)

The main policy objective of the EU is to "bring about a significant outcome of transport growth from GDP growth" (EC, 2001). Based on the operational objective, it is stated that economic growth and growth in transport should work hand-hand in order to reduce environmental impact. Further it is seen that the volume of freight transport to GDP ratio measures the outcome of freight transport growth from the real GDP growth. Looking at all perceptions, it is well notice that the level of passenger and freight transport highly influences both the European economy and the people's quality of life, that is to render and ensure mobility for all service users. They have been a constant increase in GDP within the EU-27 and followed by a growth in transport. Statistically, the annual growth in GDP within the EU-27 stood at 2.5%, and in transport, passenger traffic growth rate was 1.7% whereas freight transport shows 2.7% (Chen, M. et al. (2007). Making a comparative trend with the GDP and the road transport shows an annual fluctuation in economic growth. That is, the 5.1% of annual economic growth was not fully supported by a constant growth in road passenger and road freight transport. For road passenger transport, the average growth rate stood at 5.7% per annum and 6.8% for road freight transport. Based this figures, it can be concluded that the development of road transport have stronger support for other factors of economic and social activity. The reasons are maybe due to firstly great changes within the other modes of transport within a given period and secondly based on re-application of new rules and regulative acts within the member states.

1.1.2: Gross Value Added (GVA) from the transport sector.

Gross value added from the transport sector has equally contributed positive in the economic growth among the EU members' states. Within the period 1998-2007, the road transport had an average share of 4.4% of the gross value added. Today the amount shares a great increase of around € 533 billion GVA at basic prices. From the figure, the transport sector including the storage service sector (postal and courier activities) account for 5.1% with 40% from the road passenger and freight transport for the total GVA in the EU-27 (euro stat 2012). The GVA from transport equally take into considerations the tone-kilometers made within the members states and the importance of international transport performance were given some priority as well. For instance the share of the national road transport from Luxemburg accounted 45% in tonnages moved but looking on the perspective of tone-kilometers; it was realize that this accounted just 6% the real basic.

1.2: undesirable indicators

1.2.1: Road Transport noise

Noise from road traffic and freight transport has equally been classified as one of the undesirable's factors that affect the public's health and quality of life. This is special in area of large agglomeration where there is constant road traffic for a longer period. Based on World health Organization (WHO, 2011) in accordance with European Environment Agency (EEA, 2010), the environmental noise were derives from two main strategic noise maps: the first being the Lden which is a long term noise and averaged over a year and equally based on average daily within the year. In this light, it combines together the Lmorning, Levening and Lnight levels and within the Levening and Lnight, the component are weighted by adding 5 decibels (db) and 10 decibels respectively. It is then from this level that the annoying overall assessment of noise for the population is known.The second indicator is the Lnight. It is the annual long term average noise level for an eight hours night time period that is normally consider being from 23:00 hours to 07: hours. It enables the indicator to assess the scale of sleep disturbance for a given populations. As further analyze, it is seen that Lday and Levening are always long average daily noise commonly from 07:00 to 19:00 hours and evenings from 19hours to 23 hours. Up to date, these indicators have been reported separately for road, rail and aircraft and that has aid in identifying the highest modes that produces the highest noise for a certain population.

Currently most EU countries have not provided much data and report as concerns this factor. Some have provided update, some less and some nothing and this make it continues exploitation difficult. Furthermore, the EU have equally created a web based database for Noise in general, that is noise observation and information service for Europe (NOISE) and more information can be digested through the following link: http://NOISE.eionet.europa.eu.

1.2.2: Traffic congestion:

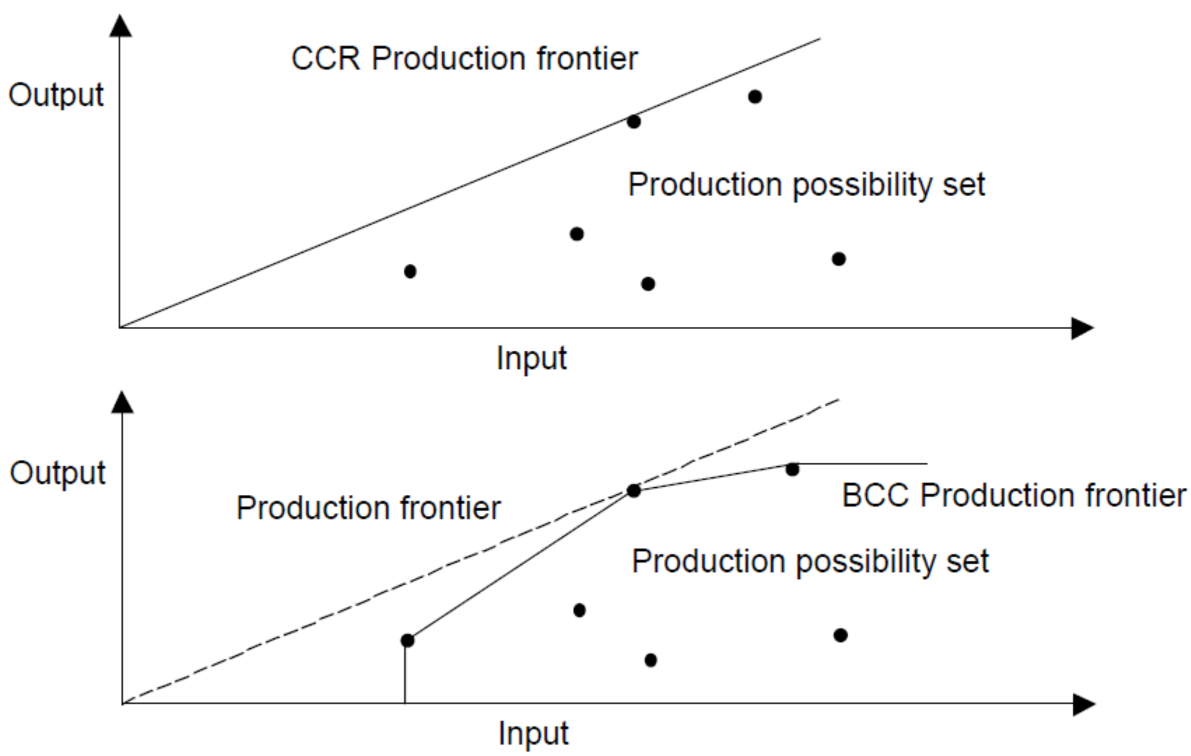
The European Union has been facing a fast increase in the transport sector in the last decades. This persistent was witness mostly within the road transport due to a rapid increase in road passenger and freight transport and this increase is expected to keep on in the coming years Y. Chung et al (2011) . Due to the fact that the road networks within most of the EU states has not be opened up in a comparable size has finally lead to a reduction in available space for both passenger cars and trucks thus, causing a lot of traffic congestion. Looking at the real meaning of traffic congestion entails the situation where transport participants cannot move in a normal or desirable way. In most cases, this has been the cause of many accidents on the road ways as many drivers' gets stress up and driver recklessly to meet up with time lost in traffic Chao Wang et al (2009). The cause of congestion can be as results of a reduction or closure of a particular one or more lanes caused by unplanned event, a planned reduction in road traffic capacity due to construction and maintenance of the lane, or a smaller flow capacity for a larger traffic demand. These phenomenons contribute several negative impacts to the economic as well as social and the environmental situations and as such need to be evaluated. For instance, the continue acceleration and deceleration produces a lots of greenhouse gas emission and CO_2 which damages the infrastructures and the environment as well. The total cost of congestion was estimated to be 63 billion for the EU15, with additions to Switzerland and Norway Maibach et al, (2004). This further account for 0.7% of GDP and constitute of 13% of the system external cost of road transport. This shows how the impact of traffic congestion is costly to the various societies in general.

Apppendice 3: other application in DEA

3.1: BCC Models

BCC models are the revised version to the CCR models. Banker, Charnes and Rhodes (1984) modified the CCR model by adding a constraint to account for the variable return to scale. The main different between these two models is that firstly, the CCR model has its production frontiers spanned by the linear combination of the existing DMUs and more to that equally assume the constant return to scale while determining the efficiency of the DMUs. The BCC models have its production frontiers spanned by curveted hull of the existing DMUs.

3.2: diagram of the CCR and the BCC model



Appendix 4: lingo codes used in running the models

4.1: when undesirable outputs are ignored from the model

```
MODEL:
	! Data Envelopment Analysis of Decision Maker Efficiency ;
	SETS:
	DMU/BE BG CZ DK DE EE IE EL ES FR IT CY LV LT LU HU MT NL AT PL PT RO 
SI SK FI SE UK/:  !The decisionmaking units;
	SCORE;! Each decision making unit has a score to be computed;
	FACTOR/I1 I2 O1 O2/;
	! There is a set of factors;
	DXF(DMU, FACTOR): W, F; ! F1( I. J) = Jth factor of DMU I;
	ENDSETS
	DATA:
```

```
      NINPUTS = 2; ! The first NINPUTS factors are inputs;
      F=
      111.3 38.87    99.1           12659
      43.3  15.89    78.4           1842
      72.0  47.99    56.2           8043
      51.5  19.10    65.0           8952
      872.9 330.84   644.0          44455
      10.3  6.37     20.3           1095
      48.2  16.03    32.4           3080
      98.6  28.41    116.1          5720
      345.4 237.92   593.3          47544
      750.5 199.80   660.8          54871
      691.1 174.83   505.4          82098
      5.7   1.15     5.4            204
      16.5  11.22    34.4           1242
      37.7  19.48    60.5           2570
      6.6   9.11     11.7           1308
      54.1  24.98    118.3          5111
      2.1   0.25     2.4            132
      147.3 76.25    226.5          22394
      72.6  33.59    110.3          11829
      283.9 165.5    413.0          17457
      86.7  40.36    103.2          6365
      71.1  50.06    176.4          5062
      25.0  14.91    30.4           2136
      26.2  28.05    30.1           1167
      63.8  28.55    70.0           7423
      99.0  39.32    137.0          15079
      680.9 156.9    533.3          56917;

      WGTMIN=0.000001; !Min weight applied to every factor;
      BIGM=999999; !Biggest a weight can be;
      a=0.2;
    ENDDATA
      !----------------------------------------------------------;
      ! The Model;
      ! Try to make everyone's score as high as possible;
      Max = @SUM( DMU: SCORE);
      ! The LP for each DMU to get its score;
      @FOR(DMU(I):
            [RSS] SCORE(I) = @SUM( FACTOR(J)|J #GT# NINPUTS: F(I, J)* W(I,
J));
            ! Sum of inputs(denominator) = 1;
            [BEP_IND] @SUM( FACTOR(J)| J #LE# NINPUTS: F(I, J)* W(I, J)) = 1;
            ! Using DMU I's weights, no DMU can score better than 1,
            Note Numer/Denom <= 1 implies Numer <= Denom;
            @FOR(DMU(K):
                  [BEP_1] @SUM( FACTOR(J)| J #GT# NINPUTS: F(K, J) * W(I, J))
                  - @SUM( FACTOR(J)| J #LE# NINPUTS: F(K, J) * W(I, J)) <= 0
                   )

);

@FOR (DXF(I, J):
 @BND (WGTMIN, W, BIGM);
 );
```

```
@FOR (DXF (I,J)|J #GT# NINPUTS:
[BEP_LO] W(I,J)*F(I,J)>=1/2*(1-a)*SCORE(I);
[BEP_UO] W(I,J)*F(I,J)<=1/2*(1+a)*SCORE(I);

);

@FOR (DXF (I,J)|J #LE# NINPUTS:
[BEP_LI] W(I,J)*F(I,J)>=1/2*(1-a);
[BEP_UI] W(I,J)*F(I,J)<=1/2*(1+a);

);

END
```

4.2: when both inputs, desirable and undesirable outputs are taken into consideration in the model

4.2.1: Treating undesirable outputs as inputs

```
MODEL:
      ! Data Envelopment Analysis of Decision Maker Efficiency ;
      SETS:
      DMU/BE BG CZ DK DE EE IE EL ES FR IT CY LV LT LU HU MT NL AT PL PT RO
SI SK FI SE UK/:  !The decisionmaking units;
      SCORE;! Each decision making unit has a score to be computed;
      FACTOR/I1 I2 I3 I4 I5 O1 O2/;
      ! There is a set of factors;
      DXF(DMU, FACTOR): W, F; ! F1( I. J) = Jth factor of DMU I;
      ENDSETS
      DATA:
      NINPUTS = 5; ! The first NINPUTS factors are inputs;
      F=    111.3   38.87   26      8.5     990       99.1      12659
            43.3    15.89   7.6     2.5     989.3     78.4      1842
            72.0    47.99   18.3    2.9     1066      156.2     8043
            51.5    19.10   12.8    5.9     371.6     65        8952
            872.9   330.84  145.6   50.7    4526      644       44455
            10.3    6.37    2.1     0.75    142       20.3      1095
            48.2    16.03   13.5    4.5     286       32.4      3080
            98.6    28.41   20.2    4.4     1540      116.1     5720
            345.4   237.92  93.4    32.9    3212.3    593.3     47544
            750.5   199.80  124.1   42.1    4389.3    660.8     54871
            691.1   174.83  115.6   38.2    4699.6    505.4     82098
            5.7     1.15    2.3     0.7     81        5.4       204
            16.5    11.22  3.1    1.1     329.6     34.4      1242
            37.7    19.48  4.6    1.6     536       60.5      2570
            6.6     9.11   6.5    2.2     42.6      11.7      1308
            54.1    24.98  12.5   4.3     1016.6    118.3     5111
            2.1     0.25   0.5    0.2     16.6      2.4       132
            147.3   76.25  34.6   11.6    676.6     226.5     22394
            72.6    33.59  22     7.6     667.6     110.3     11829
            283.9   165.51 40.2   14.4    5197.3    413.0     17457
            86.7    40.36  18.5   6.1     899.6     103.2     6365
            71.1    50.01  13.4   4.3     2885.6    176.4     5062
            25      14.91  5.6    1.8     226       30.4      2136
            26.2    28.05  6.4    1.9     523       30.1      1167
            63.8    28.55  12.1   4       334.3     70        7423
```

```
          99      39.32  19.3   7.6     408.6     137        15079
          680.9   156.94 117.9  39.9    2680.3    533.3      56917;

    WGTMIN=0.000001; !Min weight applied to every factor;
    BIGM=999999; !Biggest a weight can be;
    a=0.2;
   ENDDATA
    !-------------------------------------------------------;
    ! The Model;
    ! Try to make everyone's score as high as possible;
    Max = @SUM( DMU: SCORE);
    ! The LP for each DMU to get its score;
    @FOR(DMU(I):
          [RSS] SCORE(I) = @SUM( FACTOR(J)|J #GT# NINPUTS: F(I, J)* W(I,
J));
          ! Sum of inputs(denominator) = 1;
          [BEP_IND] @SUM( FACTOR(J)| J #LE# NINPUTS: F(I, J)* W(I, J)) = 1;
          ! Using DMU I's weights, no DMU can score better than 1,
          Note Numer/Denom <= 1 implies Numer <= Denom;
          @FOR(DMU(K):
                [BEP_1] @SUM( FACTOR(J)| J #GT# NINPUTS: F(K, J) * W(I, J))
                - @SUM( FACTOR(J)| J #LE# NINPUTS: F(K, J) * W(I, J)) <= 0
                 )

          );

    @FOR (DXF(I, J):
         @BND (WGTMIN, W, BIGM);
          );

@FOR (DXF (I,J)|J #GT# NINPUTS:
[BEP_LO] W(I,J)*F(I,J)>=1/2*(1-a)*SCORE(I);
[BEP_UO] W(I,J)*F(I,J)<=1/2*(1+a)*SCORE(I);

);

@FOR (DXF (I,J)|J #LE# NINPUTS:
[BEP_LI] W(I,J)*F(I,J)>=1/5*(1-a);
[BEP_UI] W(I,J)*F(I,J)<=1/5*(1+a);

);

END
```

4.2.3: when the reciprocal of the undesirable outputs is consider in the model.

```
MODEL:
    ! Data Envelopment Analysis of Decision Maker Efficiency ;
    SETS:
    DMU/BE BG CZ DK DE EE IE EL ES FR IT CY LV LT LU HU MT NL AT PL PT RO
SI SK FI SE UK/:
   !The decisionmaking units;
    SCORE;! Each decision making unit has a score to be computed;
    FACTOR/I1 I2 O1 O2 O3 O4 O5/;
    ! There is a set of factors;
    DXF(DMU, FACTOR): W, F; ! F1( I. J) = Jth factor of DMU I;
```

```
ENDSETS
DATA:
NINPUTS = 2; ! The first NINPUTS factors are inputs;
F=
111.3   38.87    99.1    12659   0.038461538     0.11764705      0.001010101
43.3    15.89    78.4    1842    0.131578947     0.4             0.001010816
72      47.99    156.2   8043    0.054644809     0.344827586     0.000938086
51.5    19.1     65      8952    0.07812         0.169491525     0.002691066
872.9   330.84   644     44455   0.006868132     0.019723866     0.000220946
10.3    6.37     20.3    1095    0.476190476     1.333333333     0.007042254
48.2    16.03    32.4    3080    0.074074074     0.222222222     0.003496503
98.6    28.41    116.1   5720    0.04950495      0.227272727     0.000649351
345.4   237.92   593.3   47544   0.010706638     0.030395137     0.000311303
750.5   199.8    660.8   54871   0.008058018     0.023752969     0.000227827
691.1   174.83   505.4   82098   0.008650519     0.02617801      0.000212784
5.7     1.15     5.4     204     0.434782609     1.428571429     0.012345679
16.5    11.22    34.4    1242    0.322580645     0.909090909     0.003033981
37.7    19.48    60.5    2570    0.217391304     0.625           0.001865672
6.6     9.11     11.7    1308    0.153846154     0.454545455     0.023474178
54.1    24.98    118.3   5111    0.08            0.23255814      0.000983671
2.1     0.25     2.4     132     2               5               0.060240964
147.3   76.25    226.5   22394   0.028901734     0.086206897     0.001477978
72.6    33.59    110.3   11829   0.045454545     0.131578947     0.001497903
283.9   165.51   413     17457   0.024875622     0.069444444     0.000192408
86.7    40.36    103.2   6365    0.054054054     0.163934426     0.001111605
71.1    50.06    176.4   5062    0.074626866     0.23255814      0.000346548
25      14.91    30.4    2136    0.178571429     0.555555556     0.004424779
26.2    28.05    30.1    1167    0.15625         0.526315789     0.001912046
63.8    28.55    70      7423    0.082644628     0.25            0.002991325
99      39.32    137     15079   0.051813472     0.131578947     0.002447381
680.9   156.94   533.3   56917   0.008481764     0.025062657     0.000373093;


WGTMIN=0.000001; !Min weight applied to every factor;
BIGM=999999; !Biggest a weight can be;
a=0.2;

ENDDATA
!-------------------------------------------------------;
! The Model;
! Try to make everyone's score as high as possible;
Max = @SUM( DMU: SCORE);
! The LP for each DMU to get its score;
@FOR(DMU(I):
      [RSS] SCORE(I) = @SUM( FACTOR(J)|J #GT# NINPUTS: F(I, J)* W(I,
J));
      ! Sum of inputs(denominator) = 1;
      [BEP_IND] @SUM( FACTOR(J)| J #LE# NINPUTS: F(I, J)* W(I, J)) = 1;
      ! Using DMU I's weights, no DMU can score better than 1,
      Note Numer/Denom <= 1 implies Numer <= Denom;
      @FOR(DMU(K):
            [BEP_1] @SUM( FACTOR(J)| J #GT# NINPUTS: F(K, J) * W(I, J))
            - @SUM( FACTOR(J)| J #LE# NINPUTS: F(K, J) * W(I, J)) <= 0
            )
      );

@FOR (DXF(I, J):
      @BND ( WGTMIN, W, BIGM);
);
@FOR (DXF(I,J)|J #GT# NINPUTS:
      [BEP_SO] W(I,J)*F(I,J)>=1/5*(1-a)*SCORE(I);
```

```
          [BEP_OU] W(I,J)*F(I,J)<=1/5*(1+a)*SCORE(I);
    );

    @FOR (DXF(I,J)|J #LE# NINPUTS:
         [BEP_LI] W(I,J)*F(I,J)>=1/2*(1-a);
         [BEP_UI] W(I,J)*F(I,J)<=1/2*(1+a);
   );
 END
```

Appendix 5: R codes for clustering analysis and results

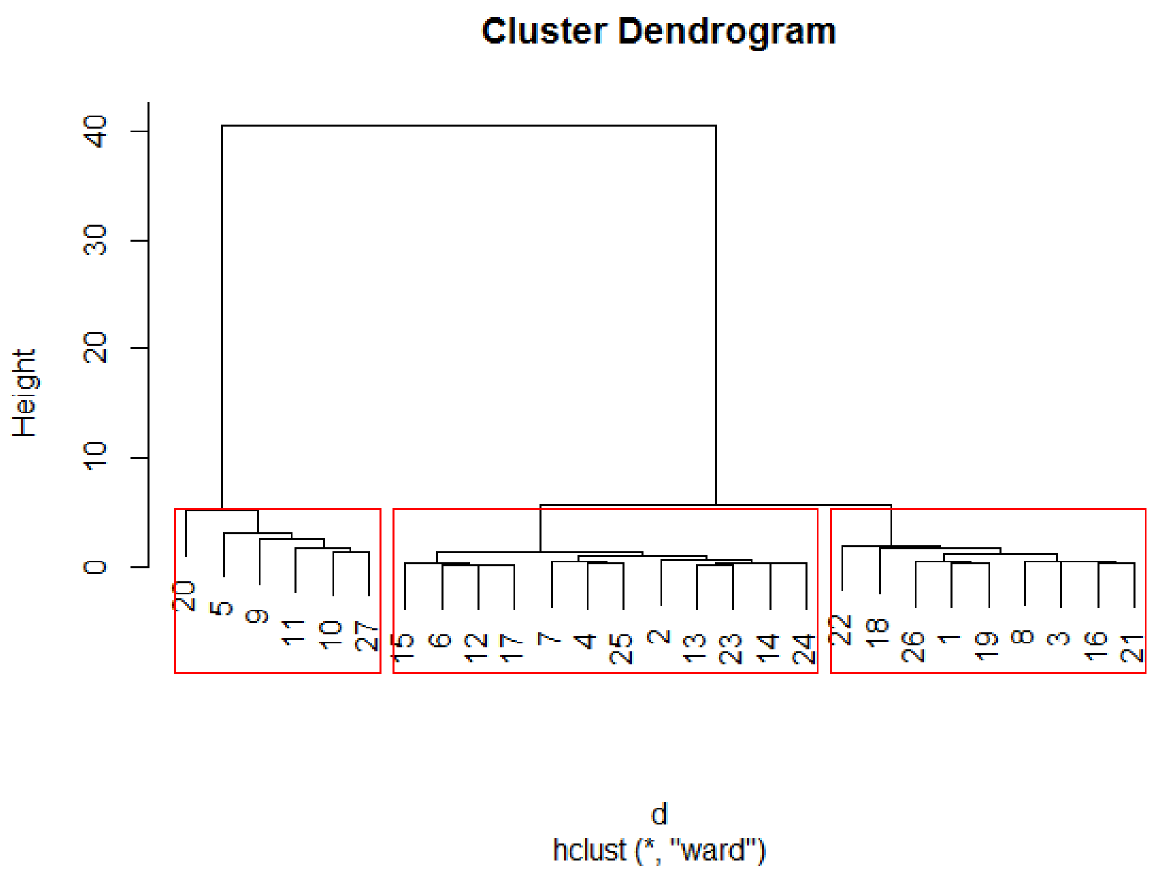
```
### code##

#reading data

thesis_data = read.table(file.choose(),header=F)

View(thesis_data)

colnames(thesis_data) = c("cpt","ft","et","tpft")

View(thesis_data_scled )


# Ward Hierarchical Clustering

d <- dist(thesis_data_scled, method = "euclidean") # distance matrix

fit <- hclust(d, method="ward")

plot(fit) # display dendogram

groups <- cutree(fit, k=3) # cut tree into 3 clusters

# draw dendogram with red borders around the 3 clusters

rect.hclust(fit, k=3, border="red")


new_data_1 = thesis_data[c(5,9,10,11,20,27),]

new_data_2 = thesis_data[c(2,4,6,7,12,13,14,15,17,23,24,25),]

new_data_3 = thesis_data[c(1,3,8,16,18,19,21,22,26),]

View(new_data_1)

View(new_data_2)

View(new_data_3)
```

print(new_data_3)

print(new_data_2)

print(new_data_1)

Cluster distribution of the EU-27 countries

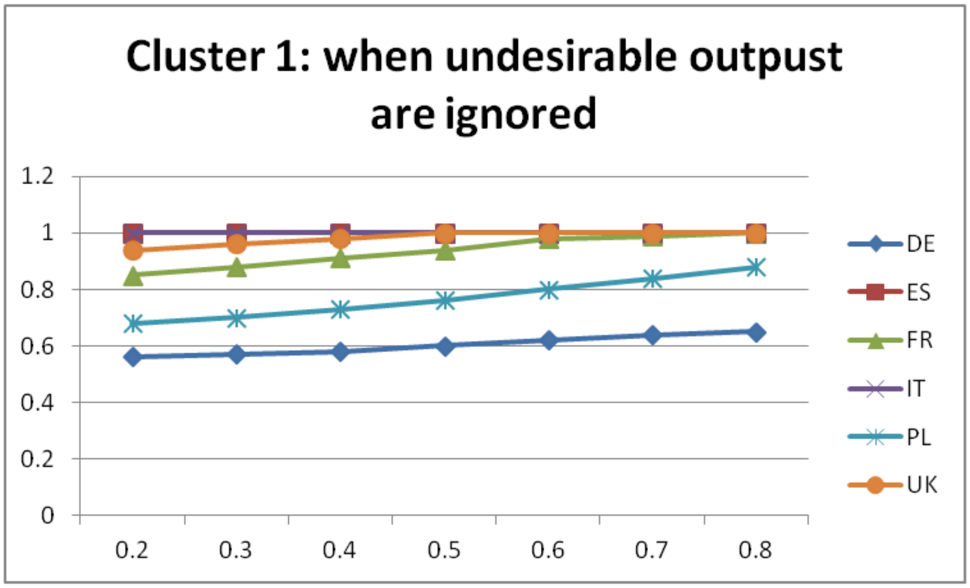


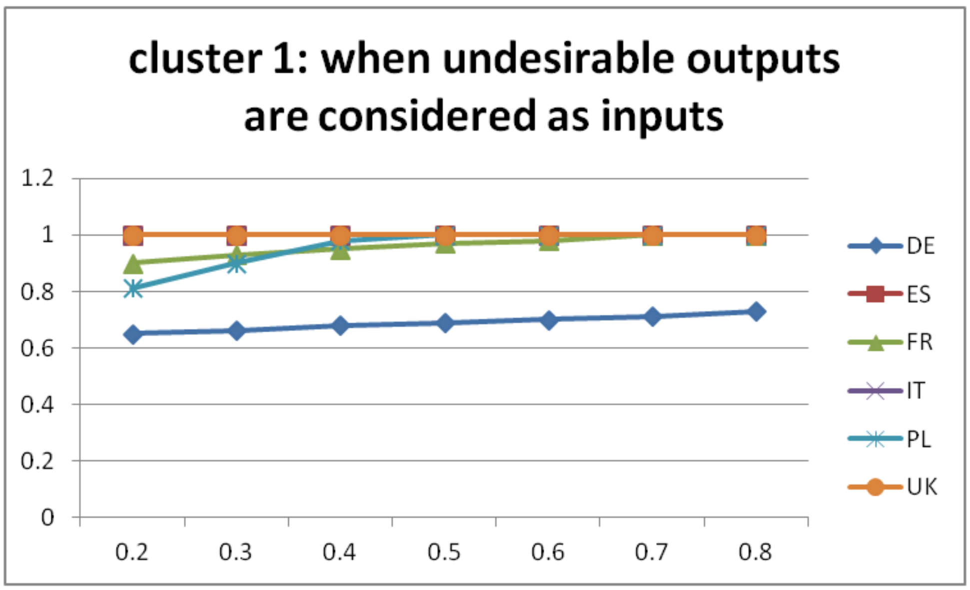
Appendix 6: sensitivity analysis carried out based on different measures and different weight restriction applicable within the different clustering groups

Table 1: cluster group 1

EU/ measures	When undesirable output are ignored in the model							When both inputs, desirable and undesirable outputs are taken into consideration in the model													
								When undesirable outputs are treated as inputs in the model							When the reciprocal of undesirable outputs is use in the model						
	0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**
DE	0.56	0.57	0.58	0.60	0.62	0.64	065	0.65	0.66	0.68	0.69	0.70	0.71	0.73	0.27	0.30	0.34	0.38	0.43	0.46	0.51
ES	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.69	0.75	0.81	0.88	0.97	1.00	1.00
FR	0.85	0.88	0.91	0.94	0.98	0.99	1.00	0.90	0.93	0.95	0.97	0.98	1.00	1.00	0.48	0.53	0.60	0.68	0.75	0.77	0.79
IT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.56	0.62	0.69	0.78	0.87	0.90	0.93
PL	0.68	0.70	0.73	0.76	0.80	0.84	0.88	0.81	0.90	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

UK	0.94	0.96	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.63	0.71	0.80	0.92	1.00	1.00	1.00





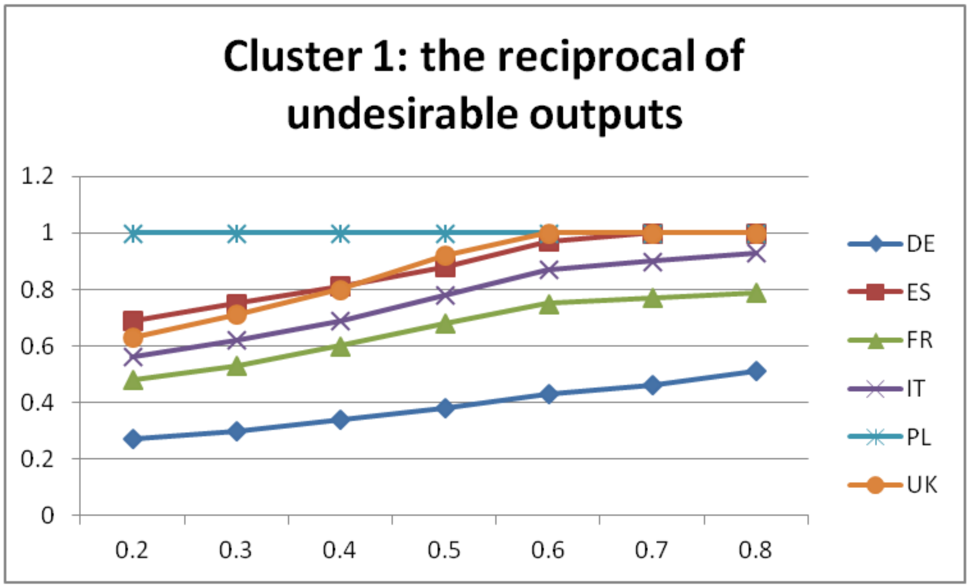
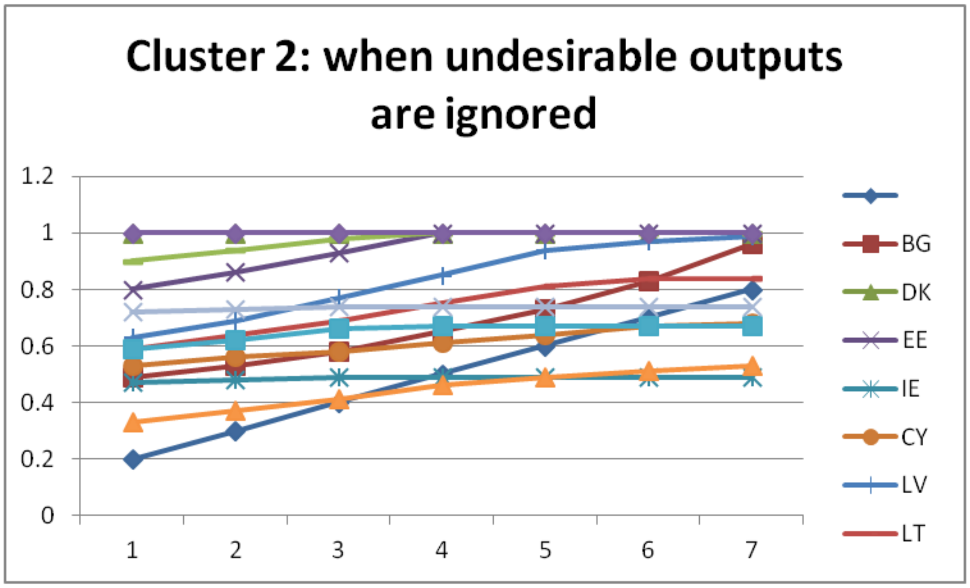
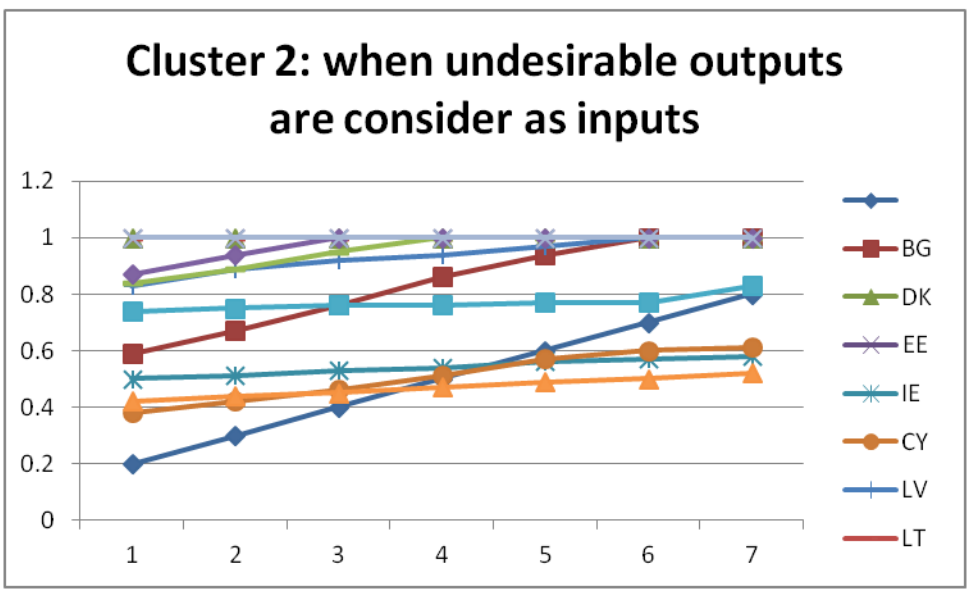


Table 2: cluster group 2:

EU/ measures	When undesirable output are ignored in the model							When both inputs, desirable and undesirable outputs are taken into consideration in the model													
								When undesirable outputs are treated as inputs in the model							When the reciprocal of undesirable outputs is use in the model						
	0.2	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**
BG	0.49	0.53	0.58	0.65	0.73	0.83	0.96	0.59	0.67	0.76	0.86	0.94	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DK	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE	0.80	0.86	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.04	0.05	0.06	0.07	0.09	0.11	0.13
IE	0.47	0.48	0.49	0.49	0.49	0.49	0.49	0.50	0.51	0.53	0.54	0.56	0.57	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CY	0.53	0.56	0.58	0.61	0.64	0.67	0.68	0.38	0.42	0.46	0.51	0.57	0.60	0.61	0.12	0.13	0.01	0.01	0.01	0..21	0.24
LV	0.63	0.69	0.77	0.85	0.94	0.97	0.99	0.83	0.89	0.92	0.94	0.97	1.00	1.00	0.01	0.01	0.02	0.02	0.03	0.04	0.05
LT	0.59	0.64	0.69	0.75	0.81	0.84	0.84	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
LU	0.90	0.94	0.98	1.00	1.00	1.00	1.00	0.84	0.89	0.95	1.00	1.00	1.00	1.00	0.04	0.05	0.06	0.08	0.10	0.13	0.18
MT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.87	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SI	0.59	0.62	0.66	0.67	0.67	0.67	0.67	0.74	0.75	0.76	0.76	0.77	0.77	0.83	0.09	0.01	0.01	0.01	0.01	0.02	0.02
SK	0.33	0.37	0.41	0.46	0.49	0.51	0.53	0.42	0.44	0.45	0.47	0.49	0.50	0.52	0.00	0.00	0.00	0.00	0.01	0.01	0.01
FI	0.72	0.73	0.74	0.74	0.74	0.74	0.74	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00


Cluster 2: when undesirable outputs are ignored
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
BG
DK
EE
IE
CY
LV
LT


Cluster 2: when undesirable outputs are consider as inputs
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
BG
DK
EE
IE
CY
LV
LT

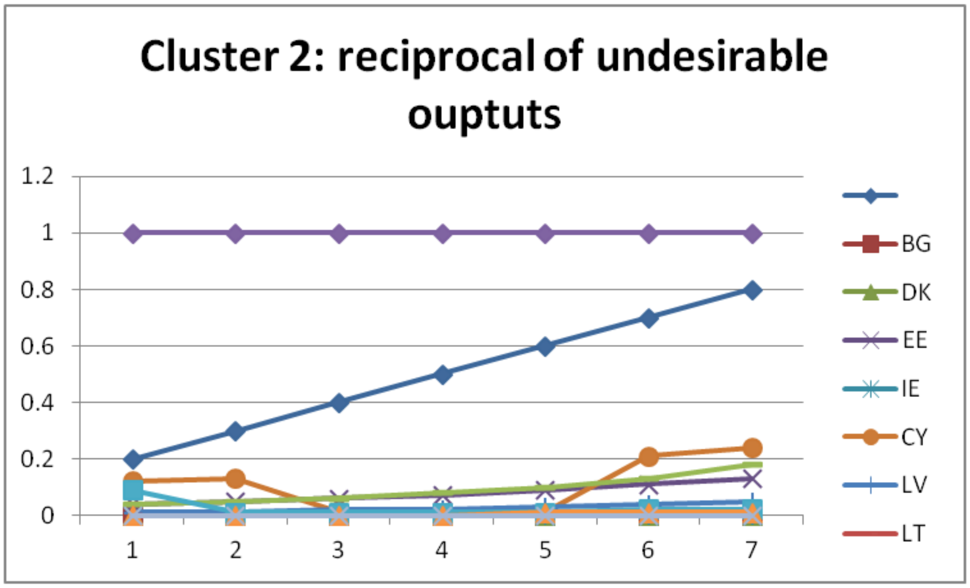
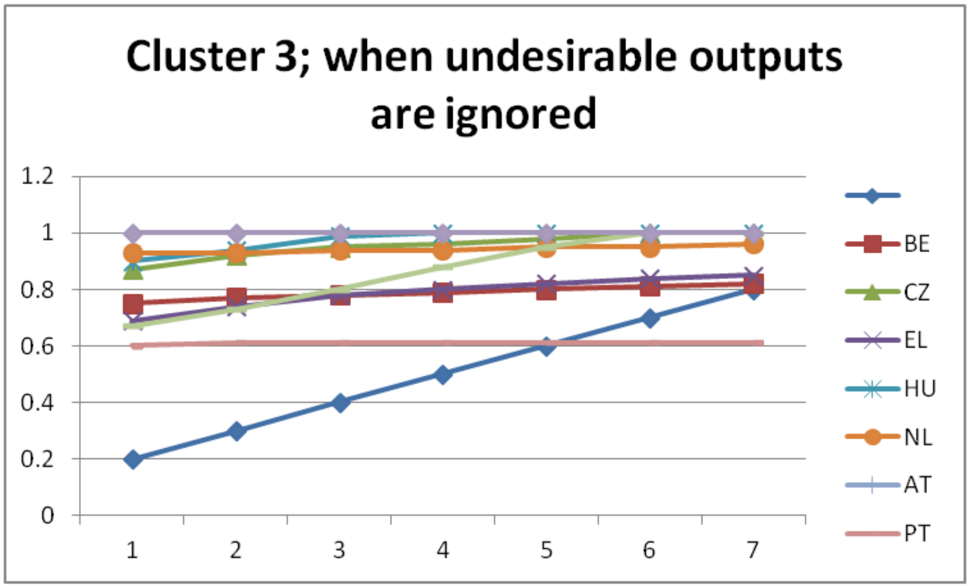
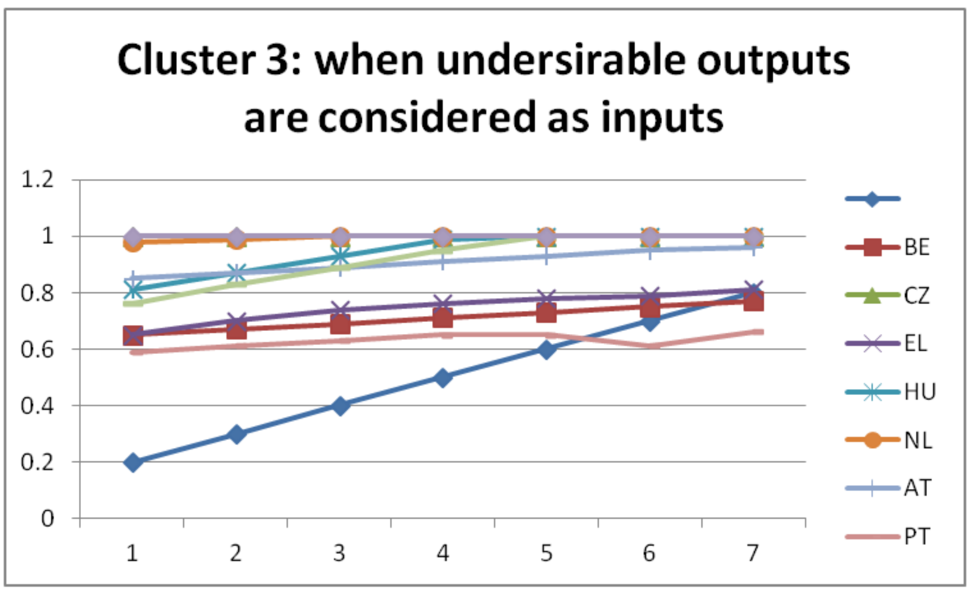
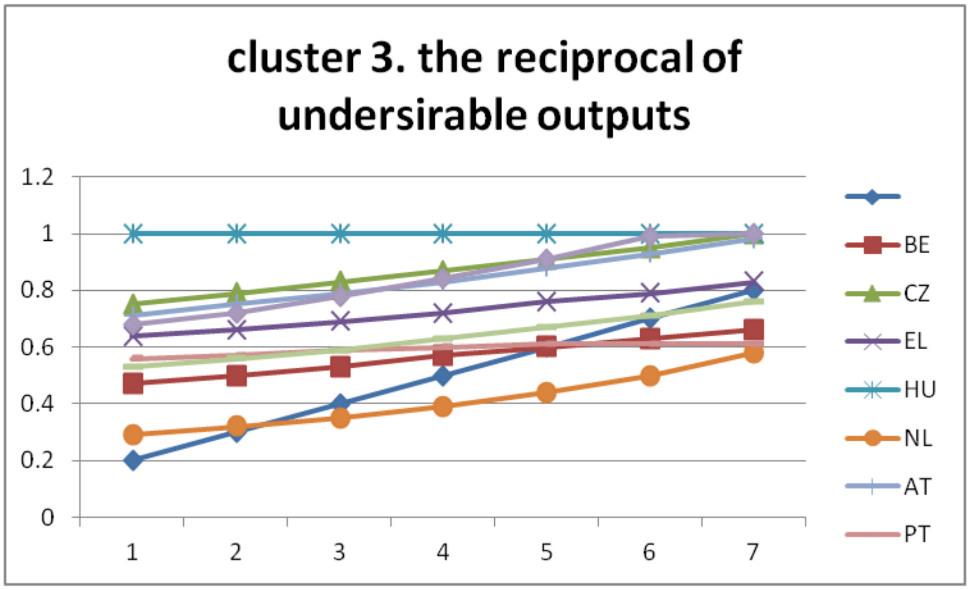


Table 3: Cluster group 3:

EU/ measures	When undesirable output are ignored in the model							When both inputs, desirable and undesirable outputs are taken into consideration in the model													
								When undesirable outputs are treated as inputs in the model							When the reciprocal of undesirable outputs is use in the model						
	0.2	0.3	0.4	0.5	0.6	0.7	0.8	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	0.2	0.3	0.4	0.5	0.6	0.7	0.8
BE	0.75	0.77	0.78	0.79	0.80	0.81	0.82	0.65	0.67	0.69	0.71	0.73	0.75	0.77	0.47	0.50	0.53	0.57	0.60	0.63	0.66
CZ	0.87	0.92	0.95	0.96	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.79	0.83	0.87	0.91	0.95	1.00
EL	0.69	0.74	0.78	0.80	0.82	0.84	0.85	0.65	0.70	0.74	0.76	0.78	0.79	0.81	0.64	0.66	0.69	0.72	0.76	0.79	0.83
HU	0.90	0.94	0.99	1.00	1.00	1.00	1.00	0.81	0.87	0.93	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
NL	0.93	0.93	0.94	0.94	0.95	0.95	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	0.29	0.32	0.35	0.39	0.44	0.50	0.58
AT	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.85	0.87	0.89	0.91	0.93	0.95	0.96	0.71	0.75	0.79	0.83	0.88	0.93	0.98
PT	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.59	0.61	0.63	0.65	0.65	0.61	0.66	0.56	0.57	0.59	0.60	0.61	0.61	0.61
RO	0.67	0.73	0.80	0.88	0.95	1.00	1.00	0.76	0.83	0.89	0.95	1.00	1.00	1.00	0.53	0.56	0.59	0.63	0.67	0.71	0.76
SE	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.68	0.72	0.78	0.84	0.91	0.99	1.00


Cluster 3; when undesirable outputs are ignored
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
BE
CZ
EL
HU
NL
AT
PT


Cluster 3: when undersirable outputs are considered as inputs
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
BE
CZ
EL
HU
NL
AT
PT


cluster 3. the reciprocal of undersirable outputs
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
BE
CZ
EL
HU
NL
AT
PT

Auteursrechtelijke overeenkomst

Ik/wij verlenen het wereldwijde auteursrecht voor de ingediende eindverhandeling:
The usage of optimization models for sustainable road transport evaluation

Richting: **master in de mobiliteitswetenschappen-verkeersveiligheid**
Jaar: **2013**

in alle mogelijke mediaformaten, - bestaande en in de toekomst te ontwikkelen - , aan de Universiteit Hasselt.

Niet tegenstaand deze toekenning van het auteursrecht aan de Universiteit Hasselt behoud ik als auteur het recht om de eindverhandeling, - in zijn geheel of gedeeltelijk -, vrij te reproduceren, (her)publiceren of distribueren zonder de toelating te moeten verkrijgen van de Universiteit Hasselt.

Ik bevestig dat de eindverhandeling mijn origineel werk is, en dat ik het recht heb om de rechten te verlenen die in deze overeenkomst worden beschreven. Ik verklaar tevens dat de eindverhandeling, naar mijn weten, het auteursrecht van anderen niet overtreedt.

Ik verklaar tevens dat ik voor het materiaal in de eindverhandeling dat beschermd wordt door het auteursrecht, de nodige toelatingen heb verkregen zodat ik deze ook aan de Universiteit Hasselt kan overdragen en dat dit duidelijk in de tekst en inhoud van de eindverhandeling werd genotificeerd.

Universiteit Hasselt zal mij als auteur(s) van de eindverhandeling identificeren en zal geen wijzigingen aanbrengen aan de eindverhandeling, uitgezonderd deze toegelaten door deze overeenkomst.

Voor akkoord,

Nkwenti Payne, Promise

Datum: **3/06/2013**