Impact study to estimate the economic effects of the introduction of PTI in Turkey

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Abbreviations

ACC	Accidents
D	Dummy for the introduction of PTI
MM	Mixed models
PSEM	Pure socio-economic models
PTI	Periodic technical inspection
PTPM	Pure traffic-parameter models
PTSM	Pure time-series models
RWI	Roadworthiness inspection
t	Time trend
TÜV	Technischer Überwachungsverein

1. Objectives of this study

The main objective of this report is to analyze the impact of periodical technical inspection PTI) of passenger cars on traffic safety. Turkey, has only a few years ago, introduced or rather swapped their system of periodical revisions to a more extensive, technical one that will be described in this case study here. Other countries that have those technical revisions, already have it for too long to be relevant for the analysis; like for example Germany where the first technical revisions were introduced as early as 1906 (TÜV SÜD AG 2016). The cars in circulation and the corresponding traffic accident numbers at the time without roadworthiness inspection, are either not comparable to the technical level of current cars or there would be simply no data. In Turkey, though, the introduction dates only back to 2007 and was implemented quite fast and strict, with the help of the German TÜV Süd, thus introducing a proven system. While there will be specific details in the case of Turkey, that will be revised and considered in the course of this report, the general benefit of such an introduction will be interesting to note, in order for policy makers to decide whether it would be useful to introduce the periodical roadworthiness inspection also in other countries where it is not existent yet and which struggle with high fatality and accident rates in road traffic. In the case, that an empirical impact between PTI introduction and reduction of accidents is evident and reliable measurable, the study could be a starting point for a wider analysis of the economic benefits and costs to prove whether the introduction of PTI leads in general to reduction of resource losses and therewith to an increase of the consumer welfare in Turkey.

2. Introduction

Historically, passenger cars in Turkey were inspected by a system called “Karayollari,” which often merely just checked whether the number of the chassis was the same as the one, written in the papers, as well as whether the taxes for that car were paid (LifePR 2008). In 2004, the Turkish government decided that the EU Directive 96/96/EC (Council of the European Union 1996) should also be applied in Turkey (24 September 2004). This EU directive was decided on the 20 December 1996, it is the relevant legal starting point for the **current inspection regime** of passenger cars, and N1 vehicles (= vehicles used for the carriage of goods and having a maximum mass not exceeding 3.5 tons also named as light goods vehicles) is the European Council Directive 96/96/EC[1]. Directive 96/96/EC

[1] Directive on the approximation of the laws of the Member States relating to roadworthiness tests for motor vehicles and their trailers

contains a minimum standard for the testing frequencies of passenger cars and N1-vehicles. Private cars and light goods vehicles have to be inspected every two years after the first inspection, which is at 4 years after first use. The purpose of roadworthiness enforcement is to ensure that the benefits accruing from the original design and manufacture of vehicles are retained, where justified, throughout the life of those vehicles. Directive 96/96/EC does not cover two-wheeled motor vehicles, light trailers or agricultural tractors, while Directive 2000/30/EC (technical roadside inspection of the roadworthiness of commercial vehicles circulating in the Community) covers only commercial vehicles. However, the minimum regulation leads to a variety of national appearances.

As the Karayollari system did not offer proper technical inspections for vehicles, the government decided to tender this to private companies dividing the country into two parts and thus two tenders, for the northern part and the southern part of the country.

At the end of 2004, the German TÜV Süd won both the tenders in the south and the north and on the 15 August 2007 TÜVTürk and the Turkish government finally could sign a concession agreement for the periodical revision of cars, trucks, and busses and subsequently, TÜVTürk started to build nationwide stations for revisions of vehicles. The consortium, TÜVTürk, was initially called TÜVTurk and is comprised of the two entities Tüvturk Kuzey Taşıt Muayene İstasyonları Yapım ve İşletim A.Ş. (for the north) and Tüvturk Güney Taşıt Muayene İstasyonları Yapım ve İşletim A.Ş (for the south) but for ease and consistency will be called TÜVTürk throughout this study and consists of the mixed industries companies Doğuş, Akfen as well as the German TÜVSüd, which offers periodical revisions in Germany. The total amount invested is 633 million Euros, with 224 millions invested in the building of the service centers as well as the education of the personnel and 409 million paid for the concession (PresseBox 2008). The share of this cost was roughly 1/3 for each of the partners and the total time duration of the concession contract is 20 years (LifePR 2007).

According to Stepken, Doğuş as a general importer of foreign car brands has much knowledge of the Turkish car market and Akfen is an infrastructure specialist who cares for the proper construction of the service centers (LifePR 2007). Therefore, each of the partners was able to fulfill and perform well fitting tasks in their field of specialization.

During 2007 and in the subsequent years until today, the stations were and are built up, depending on the need, all over Turkey totaling 204 fixed as well as 89 mobile stations in November 2016 with the latest one being opened on the 16th of November 2016 in Antalya (TÜVTÜRK 2016).

Why did the Turkish government decide to renew the system and phase out the Karayollari system?
Looking at the statistics regarding traffic accidents in Turkey and comparing them to the average European Union traffic accidents, it becomes clear that there were very high numbers of fatalities in road accidents.
The next figure shows the development of the total number of passenger cars from the year 1990 to the year 2015. The number of passenger cars is growing on average by 7% per year.

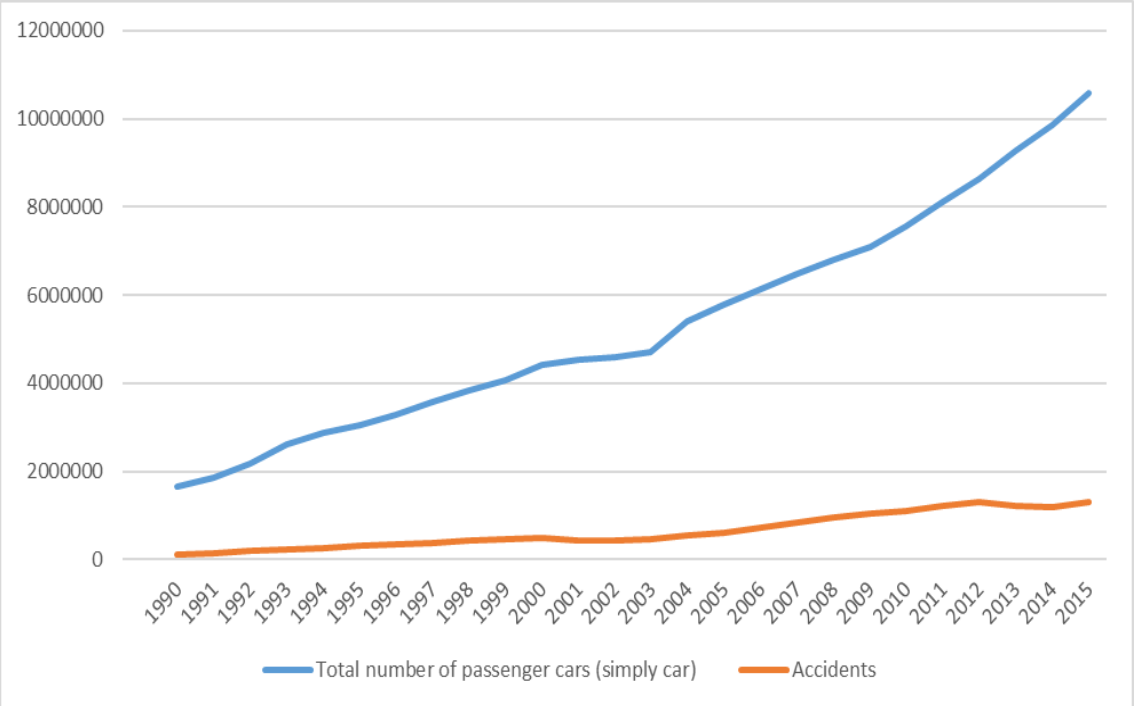

Figure 1: **Development of the total number of passenger cars and the number of road accidents (own illustration; data source: TURKSTAT 2016)**

Figure 2 illustrates the development of the number of injuries by road accidents. Compared to the average annual increase of passenger cars by 7% the number of injuries increased over proportional by 11% on average per year. Contrary to the strong increase of injuries the number of fatalities is currently reduced. Over the period from 1990 to 2015 the number of fatalities could be reduced by -2% per year (see Figure 3). Analyzing more deeply the development of fatalities shows that in the year 2001 the fatalities were sharply reduced by -20%. In 2004 the fatalities suddenly increased again by 12%. In the period from the year 2004 to the year 2007 the fatalities still increased by 5% per year. Since the year 2008, the fatalities were reduced on average by -3% per year. This development shows

that there might an impact of the introduction of PTI to the number of fatalities. However, it is even unclear, how PTI-introduction affected the development of injuries.

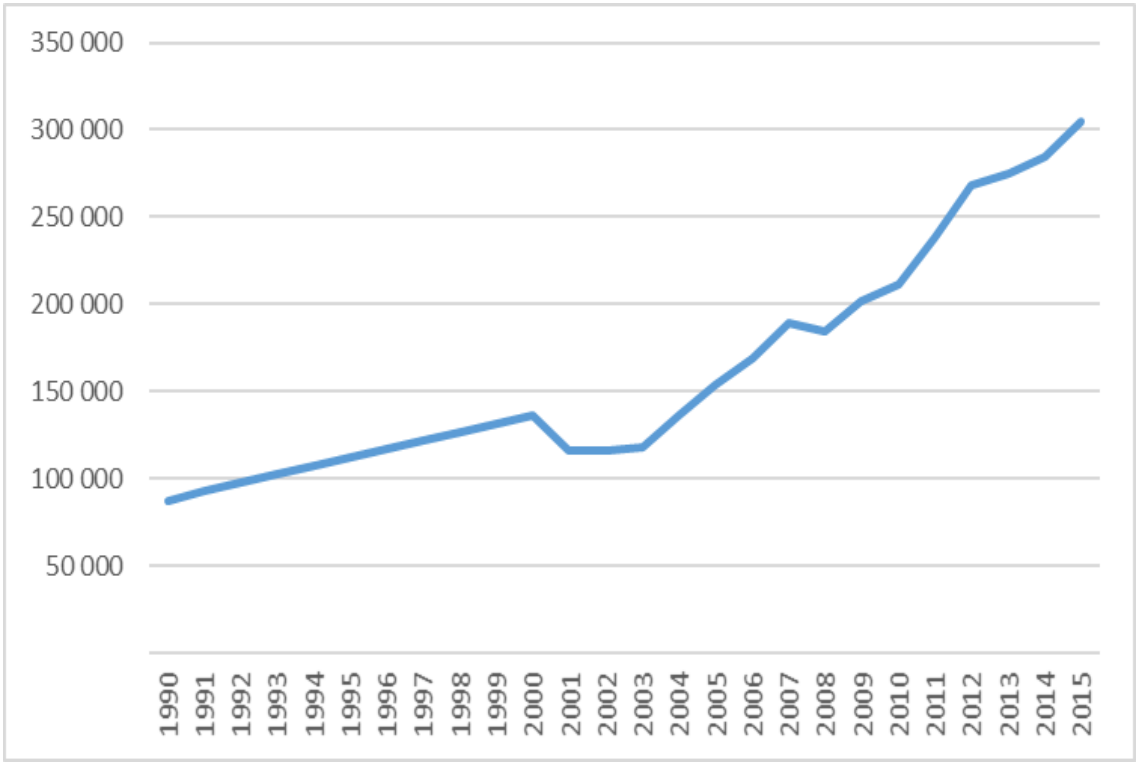

Figure 2: **Development of injuries of road accidents over the period from 1990 to 2015 (own illustration; data source: TURKSTAT 2016)**

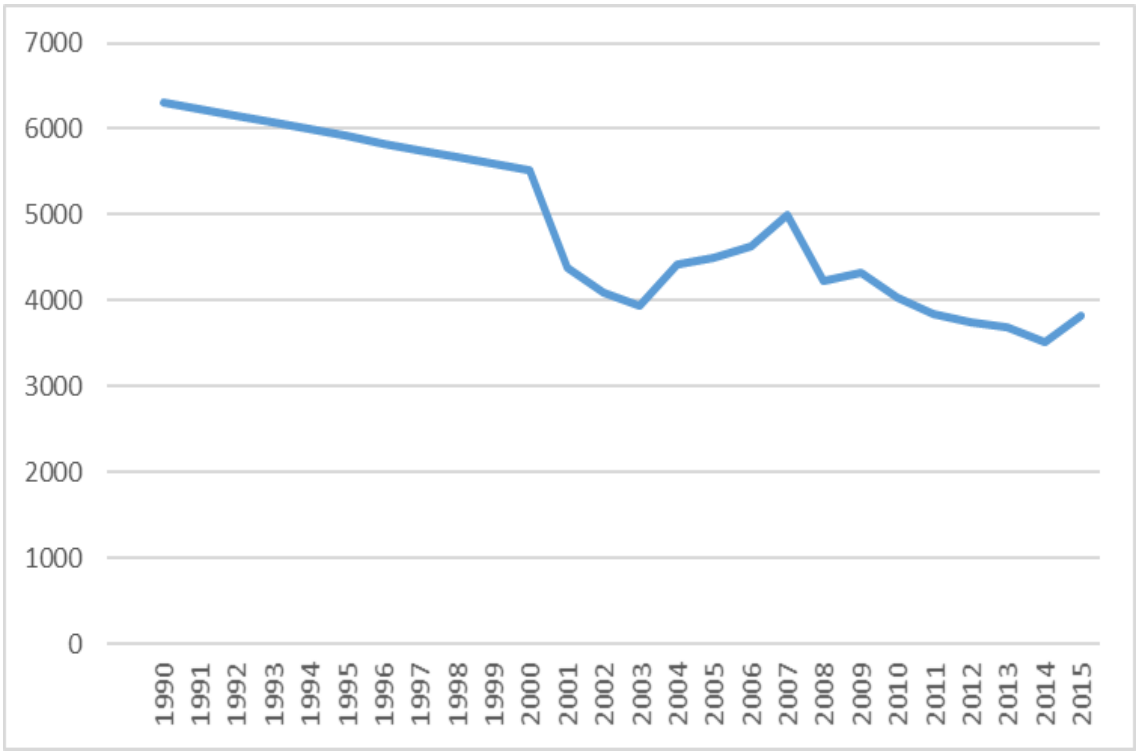

Figure 3: **Development of road fatalities over the period from 1990 to 2015 (own illustration; data source: TURKSTAT 2016)**

The fatality situation in Turkey is quite comparable with the EU 28. 25,938 fatalities were counted in 2013 in EU28 by road accidents occurred. Assuming 505,700,700 inhabitants for EU28, it can be stated that 48 people of 1 Million inhabitants were killed in road accidents. In Turkey, in the year 2013 were 51 people of 1 Million inhabitants were killed in road accidents.

3. Methodology

3.1 Statistical data

Statistical data will be used to determine whether the introduction of PTI has a measurable impact on the number of traffic accidents, the outcome of those (fatalities, injured, broken vehicle) and the cause of those accidents.
Variables that will be used in the course of this analysis can be found in both Table 1 and Table 2 below, as well as their temporal availability.
As the introduction of the periodical revisions has just happened around nine years ago, there is not a lot of data available. However, the existing data can be used to analyze some trends and correlations between the different factors.

Therefore, the following analysis will provide a qualitative review of the introduction of periodical revisions. Afterward, the data is processed statistically.
The data comes from publicly available sources like Turkstat and TÜVTürk. Some of the statistical data which was older has been obtained from Turkstat for a small fee. The data is overall data and comprises both gendarme[2] and police[3] regions.

[2] The Gendarmerie also have an independent organization for Traffic Control (Turkish: Jandarma Trafik) similar to that of the police, but they take shifts outside the cities; similar to the American highway police.

[3] The police force is responsible for law enforcement in cities and some exceptional locations, such as airports, which they protect with the help of the customs office (Turkish: Gümrük Muhafaza). Traffic Police ensure the safety of transportation and also work with registration of vehicles.

Table 1 Overview Turkstat variables

Economic and traffic parameters (from Turkstat)	Period of investigation	1990 – 2015
	Population Turkey (with data interpolated from 1991 – 1999 and 2001 – 2006)	1990 – 2015
	GDP Turkey	1990 – 2015
	Length of divided roads (state and provincial together)	1990 – 2015
	Length of all roads	1990 – 2015
	Total number of vehicles	1990 – 2015
	Total number of different types of vehicles (passenger car; minibus; bus; small truck; truck; motorcycle; tractor)	1990 – 2015
	Accidents (fatal consequences; injuries)	1990 – 2015
	Causes for accident (vehicle; road; pedestrian; drivers; passengers)	1995 – 2015
	Amount and type of vehicle involved in accident (passenger car; minibus; bus; small truck; truck; motorcycle)	2003 – 2015
	Persons injured in traffic accidents by age groups (0-9; 10-14; 15-17; 18-20; 21-24; 25-64; 65+)	2002 - 2015
	Persons killed in traffic accidents by age groups (0-9; 10-14; 15-17; 18-20; 21-24; 25-64; 65+)	2002 - 2015
	People with drivers license	2000 - 2015

Table 2 Overview TÜVTürk variables

Revision related data (from TÜVTürk)	Main Inspection	2008* – 2015
	Exhaust Emission Inspection	2009* – 2015
	Road Worthiness Inspection	2009* – 2015
	Reinspection on Main and Road Worthiness	2008* – 2015
	Exhaust Emission Reinspection	2009* – 2015
	Detection	2009* – 2015
	Total Number of Measures	2008* – 2015

*Main inspection data is only available from 2008 on because it was the year the first stations went into full effect. However the numbers are skewed as only by February 2009, nationwide testing and mobile facilities were deployed and in fully working (Thomas 2009).

The data was preprocessed and edited in Microsoft Excel and can be found in the appendix to this report. Then the data was processed with the statistical software SPSS. The time frame of the data is relatively narrow, but the model is still statistically significant and proves to be robust, giving good results for the parameters available as can be seen in chapter SPSS Results. However, there is a lack of data for some specific variables regarding the revisions of TÜVTürk, given that it was only introduced around eight years before the writing of this report. Further thought has to be given to the first (2008) and partially to the second (2009) year, which shall be considered as incomplete, given that the old system was still in place and customers could just switch the region to get their stamp there, as well as the TÜVTürk stations were not deployed in all regions at the same time, thus it can be expected that they did not operate at their full potential in those years and therefore representing only a part of the country and overall picture.

3.2 Statistical Package and Statistical Basics

As a statistical software package, the IBM SPSS Statistics release 20.0 is used. Routine procedures of SPSS are used for replacing missing data with time series. For the model estimations, the regression- and the curvefit-routines are the most convenient tool.

Normally this kind of impact analysis is based on time series data, which means regarding statistical significance a minimum of 10 data points is available. This criterion is fulfilled for the whole dataset. The process of impact analysis for this data situation then would follow the following general modeling possibilities:

1. Pure time-series models (PTSM) are based on stochastic processes. The changes over time of the variable are explained by the possible internal structure of the data (such as autocorrelation, moving average, trend, seasonal variation, non-periodic fluctuation, irregular movement).
2. Pure traffic parameter based models: Only traffic parameters are considered to be used as exogenous variables. In the case that the number of accidents is an endogenous variable a pure traffic parameter based model would have only variables like a number of passenger cars, a total number of cars, and so on.
3. Pure Socio-economic explanation models: This kind of models refers to socio-economic variables like population, the number of people with driver licenses, GDP.
4. Mixed models: This category is, for practical reason, distinguishing between four types of models:
    a. Type I model is a mix of traffic parameters (PTPM) and socio-economic parameters (PSEM) used as exogenous variables.
    b. Type II is a mix of PTSM and PTPM.
    c. Type III is a mix of PTSM and PSEM.
    d. Type IV is enlarging Type I models integrating trend, moving average or autocorrelation in the explanation model (combining all three PTPM, PSEM, and PTSM).

The general objective of this study is to prove whether the introduction of PTI has a measurable impact on traffic safety in Turkey. For this reason, modeling pure time series analysis is not the first choice. Even in the case that the causal analysis shows that there are no other variables relevant to explain the development of traffic safety variables (endogenous variables could be the number of accidents, the number of road fatalities, the number of injuries, the number of fatalities due to vehicle defects).

The overall significance has to clarify whether the model approach is suitable to explain the development of the dependent variable in a trustworthy way. This testing of overall-plausibility is done by the calculation of the F-value. The F-value statistics tests the overall significance of the regression model. Specifically, the null hypothesis, which all of the regression coefficients are equal to zero is tested. This tests the full model against a model with no variables and with the estimate of the dependent variable being the mean of the values of the dependent variable. The F value is the ratio of the mean regression sum of squares divided by the mean error sum of squares. Its value will range from zero to an arbitrarily large number. For a better interpretation of the F-value, the significance as the probability is shown. A probability of 0,001 means that there is a one chance in 1000 that all regression factors are zero (=insignificant). Usually, only the F-value without significance probability is presented because the F-value has to be higher than zero for a significant model.
Further, it has to be proven whether the values of the regression coefficient are not zero. This testing is undertaken by the t-value. The t-test is computed by dividing the estimated value of the parameter by its standard error. This statistic is a measure of the likelihood that the actual value of the parameter is not zero. The larger the absolute value of t, the less likely that the actual value of the parameter could be zero. The probability illustrates like the F-test the significance of the value of the regression coefficient. 0,001 means that the probability is 0,1% that the estimated value is indeed zero.
The statistical information by the so-called Adjusted R Square shows how complete the process of model building is. Adjusted R Square is a variation of the R Square-value, which is the ratio of regression variance to the total variance. This ratio is adjusted by considering the number of variables. A value of 0,1 means that 10% of the total variance is covered by the regression variance. The R Square and the Adjusted R Square gives no indication whether the model is significant. Therefore, the t-value and F-value are really important. The R-Square shows whether there is scope for other variables and for pure time series elements like moving averages.

4. Discussion of the Data

Before the data gets statistically evaluated, some thoughts and interdependencies on the data shall be discussed in this chapter. Examining each variable and putting it into perspective with other variables, will yield some first insights that then will be tested in chapter 5 with statistical means.

4.1 Total Number of vehicles

Over the whole time frame from 1990 until 2015 the total number of vehicles grew steadily with especially notable growth in 1993, 2004 as well as 2006. The numbers for total vehicles comprises passenger cars, minibusses, buses, trucks, small trucks, motorcycles, and tractors as well as some other vehicles. For most of those vehicles, the numbers rose, with a notable high in 2004.

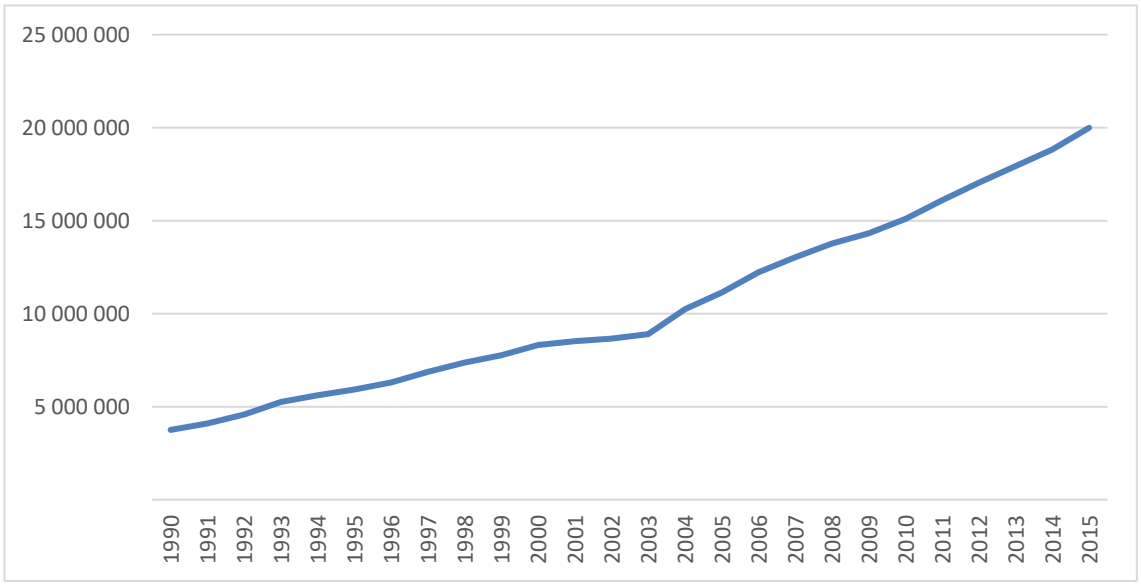

Figure 4 Total number of vehicles in Turkey (own illustration; data source: TURKSTAT 2016)

4.2 Number of accidents and consequences

For the category accidents, the total number of accidents is available for the whole time frame from 1990 until 2015. It can be seen that over the whole period, except some few years, the numbers for accidents rose. However, the outcome of the accidents differs. While the numbers of injured people rose, the number of deaths at the accident scene constantly fell over the years.

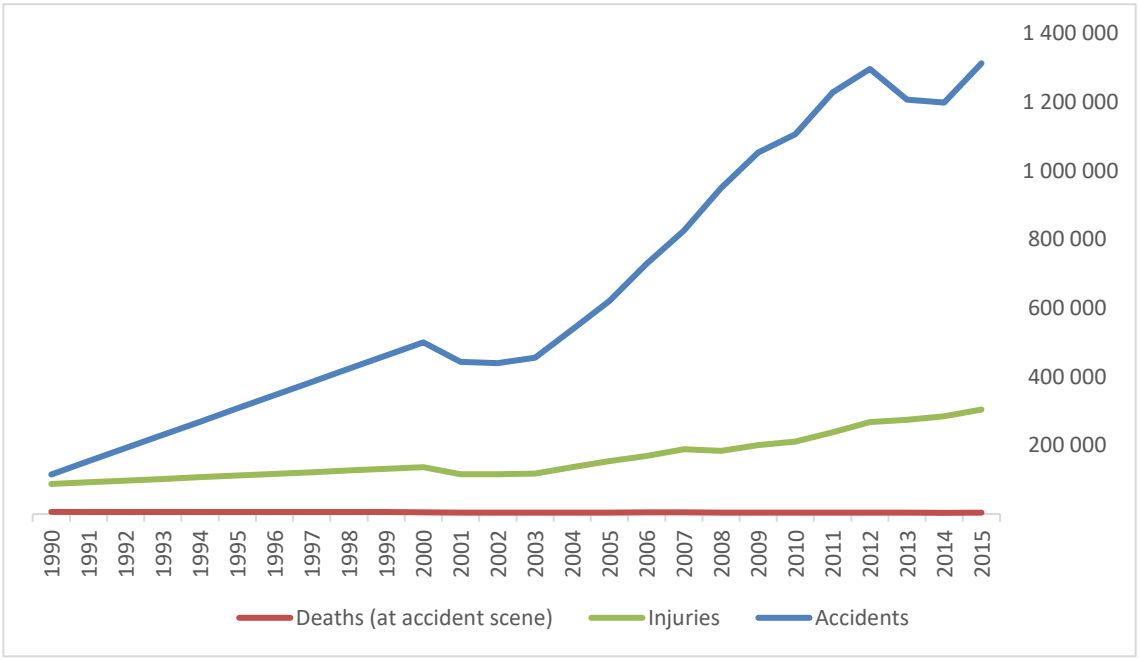

Figure 5 Consequences of accidents (own illustration; data source: TURKSTAT 2016)

To clarify the trends, the following curve is plotting deaths and injuries against each other.

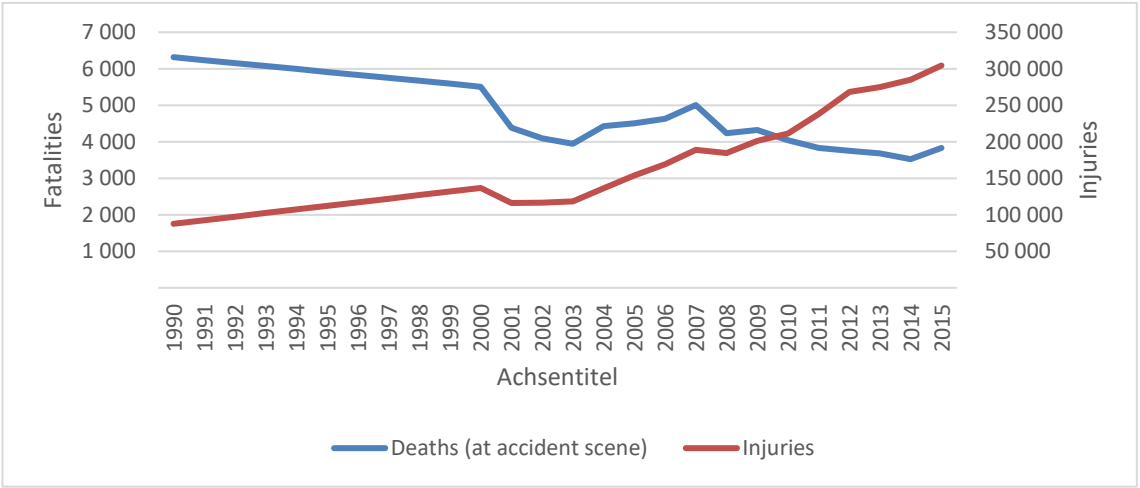

Figure 6 Deaths and Injuries due to traffic accidents (own illustration; data source: TURKSTAT 2016)

4.3 Causes for accidents

Another point that needs to be considered are the causes of the accidents. Turkstat provides some comprehensive datasets that list the courses for accidents. In this report, especially the technical side will be considered, as the periodical revisions are aiming at the technical improvements and fitness of the vehicles in circulation. Therefore, special attention must be given to the causes of accidents. If technical failures that lead to accidents become lower, but human errors increase, then the numbers might be misleading, showing a trend towards more accidents even after the periodical revision is introduced, despite the usefulness of it for technical safety. Interesting to consider could also be, whether drivers feel safer in newer and technically better cars, which then would lead to higher accident numbers due to speeding and the secure feeling in the car.
Particularly in the year 2008, the year the stricter revisions were introduced, it is very notable that the vehicle defects as a fault for accident numbers went down considerably, but also in 2006 this is very notable and close to the number of 2008. However, it should also be noted that in 2013, the number suddenly jumps to a very high level again. Overall, it can also be seen that road defects as a fault as well as driver faults decreased highly, especially in 2008. It should be noted, though, that the fault is often difficult to determine and also in other countries, statistical data on those variables proves to be unreliable.

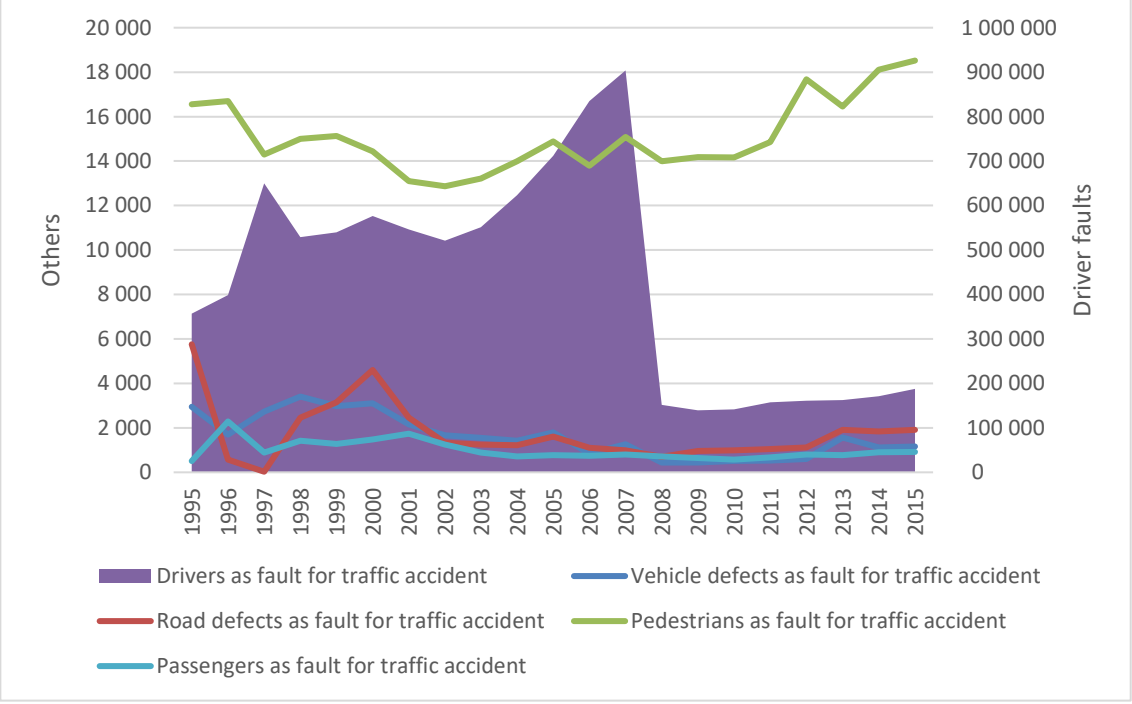

Figure 7 Causes for accidents (own illustration; data source: TURKSTAT 2016)

4.4 General Statistical Data

The population of Turkey grew steadily over the last 25 years, from around 56 million to almost 79 million people. Turkstat provides data on people with drivers licenses from 2000 on, until 2015. Those numbers also grew steadily and shall be considered for the analysis, providing information about the number of people that are allowed to drive and thus increasing numbers could also have a correlation with higher accident rates as the kilometers traveled are likely to increase as well, with more people having their license as well as more cars on the roads.

4.5 Comparison between GDP and traffic incident statistics

From the data, it becomes clear that in the years 1990 until 1994, the number of incidents per 1 million cars was very high. In the years following, it rapidly fell. Therefore, politics as well as economic factors need to be considered to understand, whether this was due to political decisions that improved the safety on Turkish roads or whether it was a general upswing of the economy that leads to newer and safer cars. While the GDP generally grew over the years, really big improvements and jumps were only observable from 2002 on. Therefore, a connection between the incidents in the years of 1990 until 1994 can be ruled out.

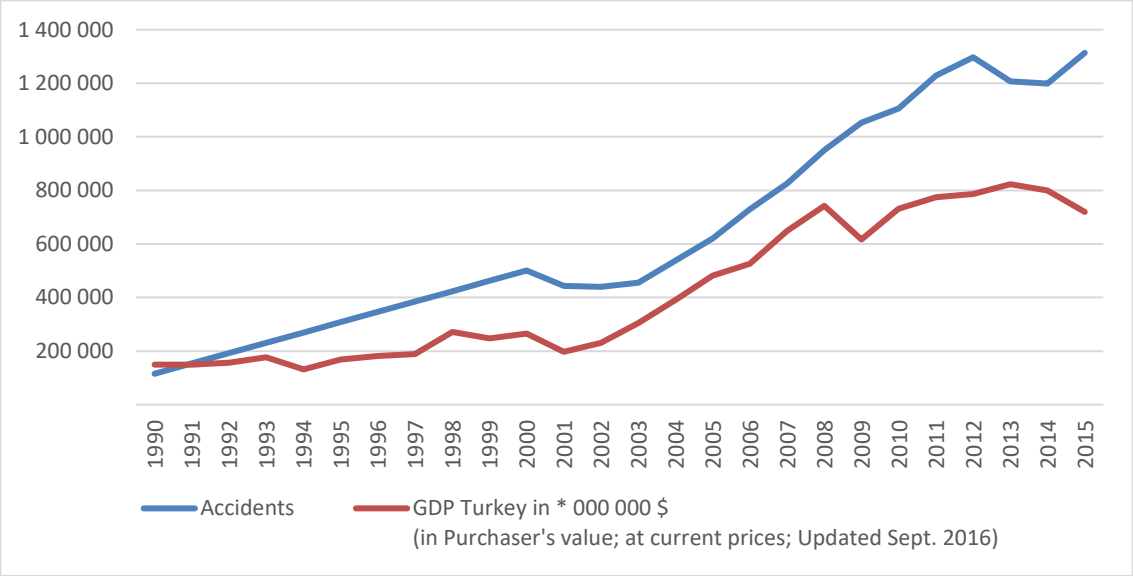

Figure 8 Accidents and GDP (own illustration; data source: TURKSTAT 2016)

A rising GDP and thus more prosperity in a country might lead to lower fatalities in accidents, due to the possibility that people might be able to afford safer and newer cars. Figure 8 will show this relationship.

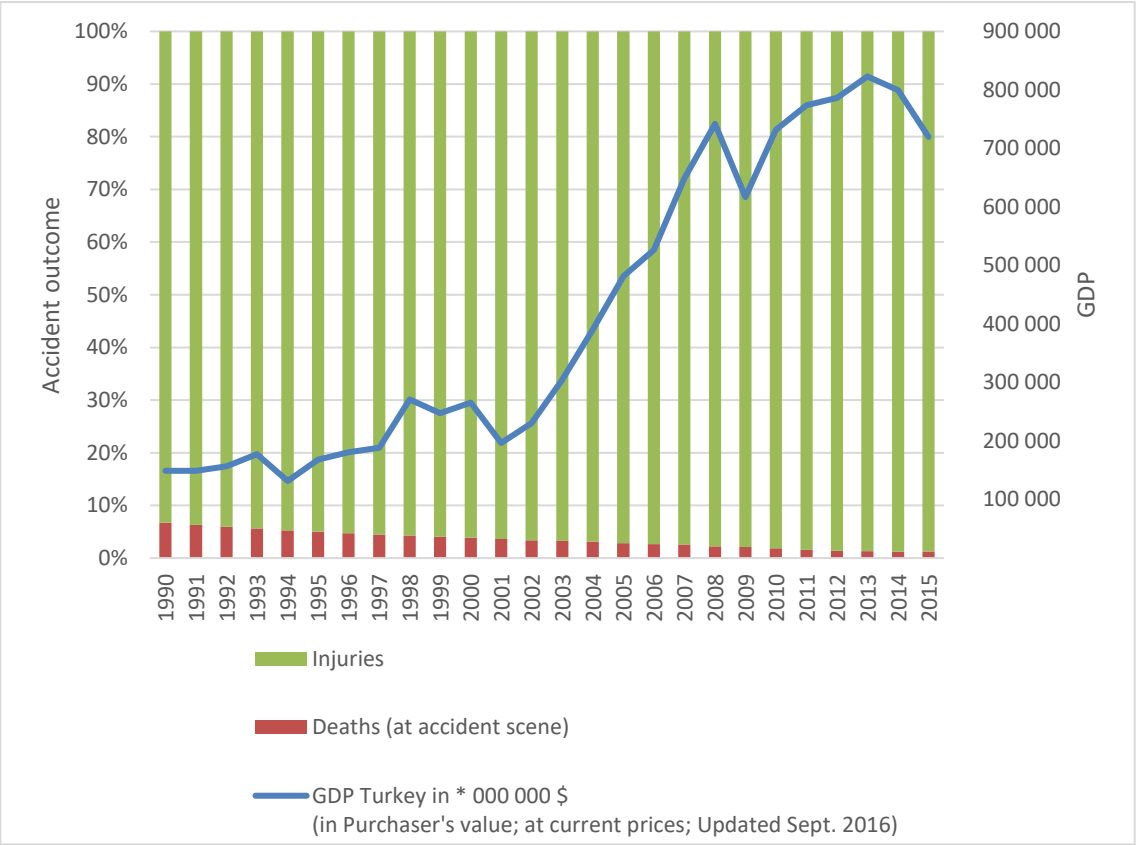

Figure 9 Consequences of accidents and GDP (own illustration; data source: TURKSTAT 2016)

4.6 Importance of road improvements

Important to analyze will also be, whether the roads were significantly improved during the time under observation, to rule out that the road conditions are the main cause of accidents.

4.7 Length of roads

While the length of divided roads on both state and provincial level, grew steady from 1990 until 2015, the length of all roads increased little and in some years even decreased. The cause for this is not yet clear, but the numbers shall be of interest regardless, as the length of roads would also determine the kilometers driven in a country and the longer the roads, the more cars are expected to be driven and such the more likely it is that accidents will happen. This is also related

to chapter 4.4, where a higher GDP and higher numbers of people with drivers licences as well as more cars are linked to more kilometers traveled.

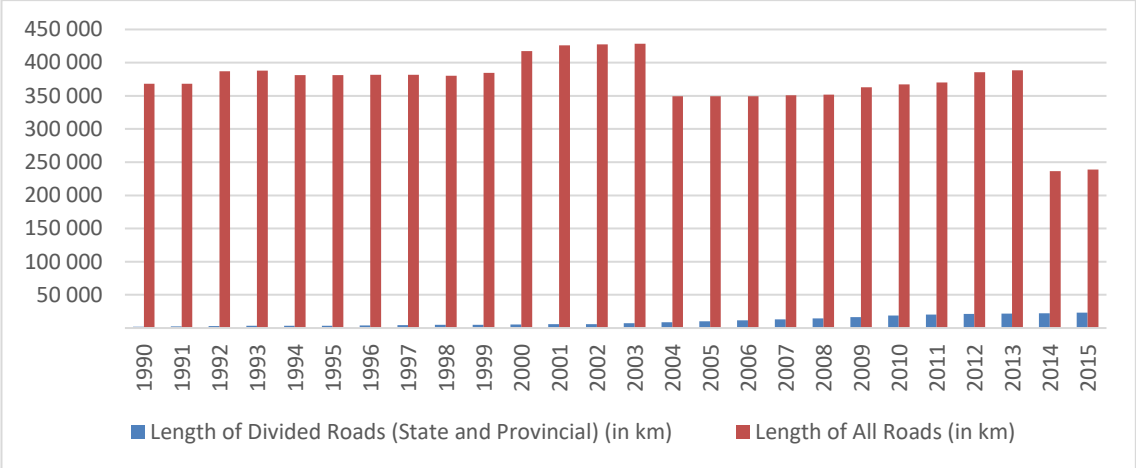

Figure 10 Lengths of roads in Turkey (own illustration; data source: TURKSTAT 2016)

4.8 Economic effects on the country

Installing such a PTI-system has effects on the economy of the host country. Jobs are created by the newfound organization, which amounts in the case of TÜVTÜRK to around 2000 jobs created, controlling and exercising the revision as well as for the mechanics that are hired by the car owners to fix the technical problems of the cars. These effects are outside the scope of this report but should be noted for effects on the industry and GDP.

4.9 TÜVTÜRK numbers on inspections

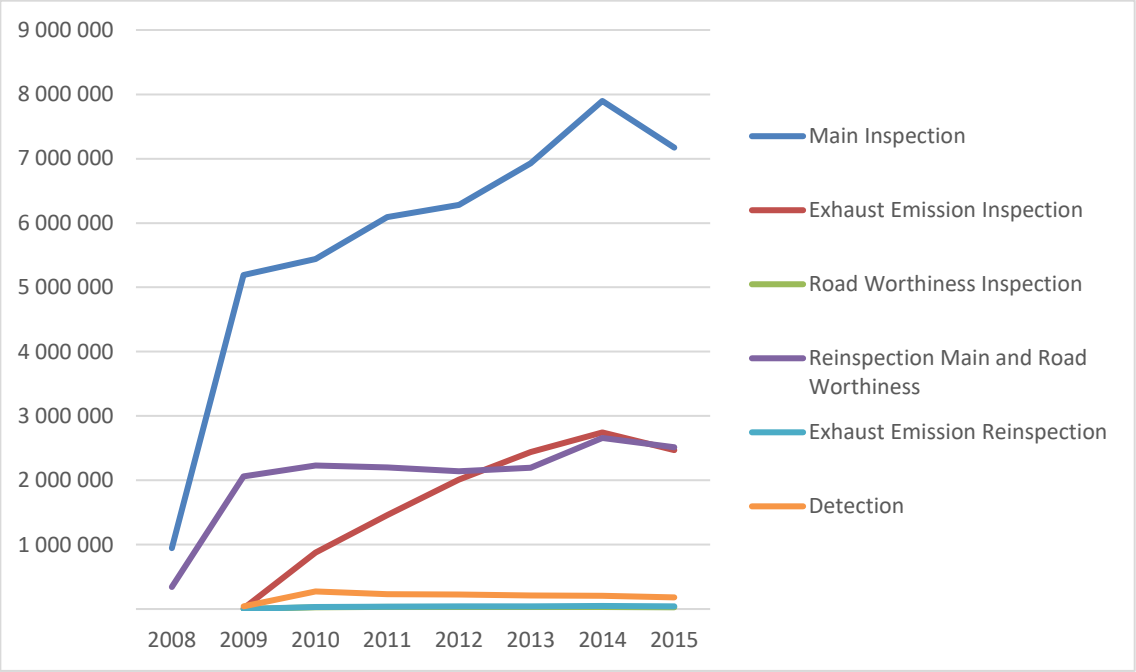

Figure 11 Data on inspection (own illustration; data source: TÜVTürk presentation)

5. SPSS Results

Using the data given by 06.12.2017 a first model to explain the impact of PTI introduction and the number of accidents could be derived. This model is a MM Type IV model combining traffic parameter (PTPM) with socio-economic variables (PSEM). Table 3 shows the general results for this model. R is close to 1 and the adjusted R-square reaches a value by 0.999. Autocorrelation can be denied because the Durbin-Watson coefficient is with 2.595 lower than 2.6. Autocorrelation and moving average processes seems to be not relevant. The F-value is close to 1613 and still significant, which shows that the variables in the model are reasonable, and multicollinearity could be denied. Table 4 gives an overview of the impact of the used exogenous variables. The model explains the endogenous variable, which is the number of accidents. The exogenous variables are:

- Trend-Variable: The assumption is that there is a general trend existing to buy more cars and to increase the number of vehicle-kilometers per year because of economic growth. To capture a trend then single time trend variable is the only approach.

The functional relation is:

$$ACC_t = \beta_1 LR_t + \beta_2 LDR_t + \beta_3 NPC_t + \beta_4 GDP_{t+1} + \beta_5 GDP_{t+3} + \beta_6 GDP_{t+7} + \lambda t + \sum_{j=1,2,3,4,5,6,7,8}^{T-1} d_j D_j + e_{i,t}$$

Where dj is the coefficient of the Dummy Dj for introducing PTI, the latter equal to one-year j, zero elsewhere.
Where λ is the coefficient on the time trend increasing with equal step.

Table 3: Model Summary R square, Durbin-Watson, F-Value

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	1.000[a]	.999	.999	33132.793	2.595

a. Predictors: gdplag8, length of all roads, Dummy TUV Einführung, gdplag2, gdplag4, length of dived road, Trend, Total number of passenger cars (simply car)
b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.
c. Dependent Variable: Accidents
d. Linear Regression through the Origin

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	14164370635785.217	8	1770546329473.152	1612.840	.000[c]
	Residual	10977819562.782	10	1097781956.278		
	Total	14175348455348.000[d]	18			

a. Dependent Variable: Accidents
b. Linear Regression through the Origin
c. Predictors: gdplag8, length of all roads, Dummy TUV Einführung, gdplag2, gdplag4, length of dived road, Trend, Total number of passenger cars (simply car)
d. This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.

Table 4: Regression coefficients.

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Trend	-74104.729	17571.158	-1.524	-4.217	.002
	Dummy TUV Einführung	-82925.159	19491.987	-.315	-4.254	.002
	length of all roads	.241	.152	.100	1.586	.144
	lenght of dived road	59.438	10.369	.986	5.732	.000
	Total number of passenger cars (simply car)	.143	.053	1.107	2.709	.022
	gdplag4	.751	.215	.381	3.495	.006
	gdplag2	.283	.167	.166	1.695	.121
	gdplag8	.175	.304	.061	.577	.577

a. Dependent Variable: Accidents
b. Linear Regression through the Origin

6. Benefit estimation

The study of Özen, Genç et al. (2014) tries to estimate the costs of traffic accidents in Turkey. Özen, Genç, and Kaya state that the cost of traffic accidents is $4,307,546,932 in 2012. Combining this with the number of accidents in that year would give us a cost unit rate of $3342 per accident.

Using the findings of the model means that the introduction of PTI in 2008 lead to a reduction of 82,925 traffic accidents. Using the cost-unit rate derived by Özen, Genç et al. (2014) the benefits caused by PTI in 2008 would be $277,135,350. Estimating this effect for the period from 2008 to 2015 PTI reduces the costs of accidents by 9% every year.

7. White-Spot Analysis

In the following some white spots based on the current findings are presented:

1. From the year 2008 on, the PTIs were in effect, such that sudden changes in the data could be explained by the introduction of the technical revisions. However, sudden changes before are hard to explain and hard to figure out, due to which changes or events they happened.

2. TÜVSÜD listed as one impact on road safety that due to the inspections traffic fatalities have been reduced by 40 percent[4]. This reduction is cannot be found in the official statistical data by Turkstat.

3. Obviously the GDP has an important influence. The economic reason is that the GDP affects the number of passenger cars and the vehicle-age structure. Therefore some evidence is needed on how the vehicle-stock age changed in the last years parallel to the introduction of PTI.

4. The separate examination of accidents caused by technical defects could not be explained at the moment. Therefore, it is necessary to find out something on the procedure how accidents are classified.

8. Recommendation for further research steps

Due to a delivery lag, the final data by Turkstat arrived on December 8. The model building was finalized on December 6.

In order to be able to estimate the magnitude and influence of the introduction of PTIs in Turkey, the time series from 1990 until 2007 should be modeled and then projected in the future. As the PTIs were introduced in 2008, the results shall then be compared. The existing or non-existing gap between the data would then explain the magnitude of the introduction of the PTIs. With more years passing, the result will then also get more precise, thus by the end of the concession of TÜVTÜRK in the year 2027, the analysis should be conducted again in order to see in how far predictions and reality would overlap. The method used for this analyis is called shift and share analysis (Eckey, Klemmer 1977). The focus in this analysis shall especially be the developing of the fatality numbers, wether the introduction had a measurable impact on the casualties of traffic accidents or whether there was no measurable effect.
In general, it might be possible to perform a cost-benefit analysis. The annual costs of PTI are available. The investment costs are also available. However, the depreciation period is needed for an accurate calculation of the annual costs.

[4] http://www.tuv-sud.com/industry/automotive-transportation/road-safety-traffic-solutions/tuevtuerk

The calculation of the benefits can be based on the findings of Özen, Genç et al. (2014). However, it could be considered to calculate the benefits using the EU28 cost-unit rates. This would give a better comparison. Likewise, it might ease the recalculation of PTI benefits in EU28.

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