COMPETITIVE AND SUSTAINABLE GROWTH (GROWTH) PROGRAMME

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marginal costs for Transport Efficiency

Annex A1 c

Deliverable 10: Infrastructure Cost Case Studies

Road econometrics – Case study motorways AUSTRIA

Version 2.2
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Deliverable 10: Road econometrics – Case study motorways Austria

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Abbreviations

HGV	Heavy goods vehicles
LGV	Light goods vehicles
ASG	Alpenstraßen AG
ÖSAG	Österreiche Autobahn und Schnellstraßen AG
ASFINAG	Autobahn und Schnellstraßen-Finanzierungs AG
GVW	Gross Vehicle Weight
vkm	vehicle kilometres
AADT	average annual daily traffic
km	kilometres

1 Introduction

The road econometric marginal infrastructure cost case study for Austria is elaborated for the motor- and expressways in Austria only. Only for this road type cost data for a fine spatial aggregation and for a long time (at least one renewal circle) is available.

Due to data reasons and methodical reasons the case study searches for dependence between traffic and renewal and maintenance costs only.

Costs for construction and upgrading are available data, but not of interest in the scope of short run marginal infrastructure cost calculations. Costs for administration are assumed to be not dependent from traffic. Operation cost data information is not available in a necessary disaggregation.

The calculations have been made for two vehicles classes:

- Vehicles up to 3,5 t GVW
- Vehicles ≥ 3,5 t GVW

2 State of the art review (Austria)

In the recent road cost account study for Austria[1] some first trials to calculate marginal costs of road infrastructure have been done. The study is already finalised but has not yet a public status. Therefore it is not possible to give detailed information about the results.

In that work the trans-log function was used as cost function. Statistical analysis brought good results for the dependency of the costs by the traffic characteristics. The calculations have shown that one additional truck-km brings significant higher running costs than one additional car-km. So this result was plausible. But the level of the marginal costs was much to low.

Reason for this non plausibility is the used data set and the complexity of the used function. For the mentioned study the aggregation level was the federal country. So for one year only information for nine different motorway aggregations was available. These nine data points where available for 10 years (1990 to 2000).

[1] HERRY M.: Wegekostenrechnung 2000 für die Autobahnen, Schnellstraßen, Bundesstraßen B, Landes- und Gemeindestraßen in Österreich. Im Auftrag des Bundesministeriums für Verkehr, Innovation und Technologie, Wien 2001 (Externe Beratung: Dr. Heike Link, DIW Berlin, Prof. Dr. Axhausen, ETH Zürich)

3 The data

3.1 Traffic data

Four main sources have been used to generate a traffic data set over a long time for every motorway section (about 440 in the year 2000):

- Periodically (every 5th years) manual traffic counts on about 50% of all motorway sections (vehicle type distinction: cars / LGV / busses / trucks without trailers / trucks with trailers and articulated vehicles) for the years 1985, 1990 and 1995
- Forecast for 2004 for traffic volume per motorway section (vehicle type distinction: cars+LGV / busses / HGV with 2 axles / HGV with 3 axles / HGV with 4 and more axles)
- Automatically traffic counts for every year for selected motorway sections
- Proportions of cross tons and axle-loads to vehicle-km in dependence of vehicle types (by cross ton classes)

With this information a data set was generated which includes traffic information (average volume, average gross tons and average axle loads) per section for the years 1985 to 2004 and the following vehicle types:

- Vehicles up to 3,5 t GVW
- Vehicles ≥ 3,5 t GVW

This is the basic traffic data. In dependence of the available cost information aggregations of this traffic data can be made.

3.2 Cost data

Three main sources for relevant infrastructure costs of motorways could be gathered:

- Costs for federal roads (by road types) for every federal country (9) and for the special companies (ASFINAG, ASG and ÖSAG) for the years 1990 to 2000 divided by
  - Maintenance costs and renewal costs
  - Operation costs
  - Administration costs

  This data have been used for the first calculation trials and for the marginal cost calculation of the Austrian road cost account study (WKR2000), because more disaggregated data (see the next two cost data sets) were not available at the beginning of the calculations.
- Maintenance and renewal costs (as sum) for motorways excluding the costs from the special companies (ASFINAG, ASG and ÖSAG) per motorway section for the years 1987 to 1996.

  This data has the problem that the link of the cost data to the road sections is a code per section. This code is not valid, because it has changed during the reporting years, but the changing was not documented well. So a valid use of this data is only possible by aggregating to every motorway per federal country (46 aggregated motorway sections per year).
- Maintenance and renewal costs (with the possibility to distinguish between them) for motorways per project with the information on “km from” – “km to” for the years 1998 to

2004. With this km-information an allocation to the motorway sectiosn is possible.
The values for 2001 to 2004 are the planned costs of the ASFINAG and depend on the conditions of the road sections.

The first described data set did not lead to plausible results, although many different possible cost function have been tested. The reason for this seems to be the rather high aggregation and therefore less data points for the regression analysis.

After receiving the two more detailed data sets the aim was to connect these two data sets to get cost information for a long time on the highest possible disaggrageted level.

Due to the fact that the data from 1987 to 1996 are only valid on the disaggregation level "motorway per federal country" this aggregation was used for further regression analysis.
So, cost information on renewal and maintenance for 46 motorway sections for the years 1987 to 2004 is available. The traffic data can be aggregated on the same level.

3.3 Description of maximum possible disaggregated data

Bringing the relevant data described in the chapters above together, one data set with the cost information "renewal and maintenance" for every motorway per federal country and traffic information volume, gross tons and axle load (average number per section and total km per section) for the 1987 to 2004 was created. For every year 46 cases exist. So, the whole data set has 828 cases for the regression analysis.

Beside the cost and traffic information some additional data has been gathered in order to find some additional variables that may influence the costs.

Beside the length of the road sections (per year) the information of length of bridges and length of tunnels of every road section (per year) have been collected. With this information road sections with on average higher percentage of bridges or tunnels than the average of Austria can be identified.

Additionally for every section, the average age is available.

The following tables show

- the motorway sections and
- the list of variables.

Table 1: motorway sections

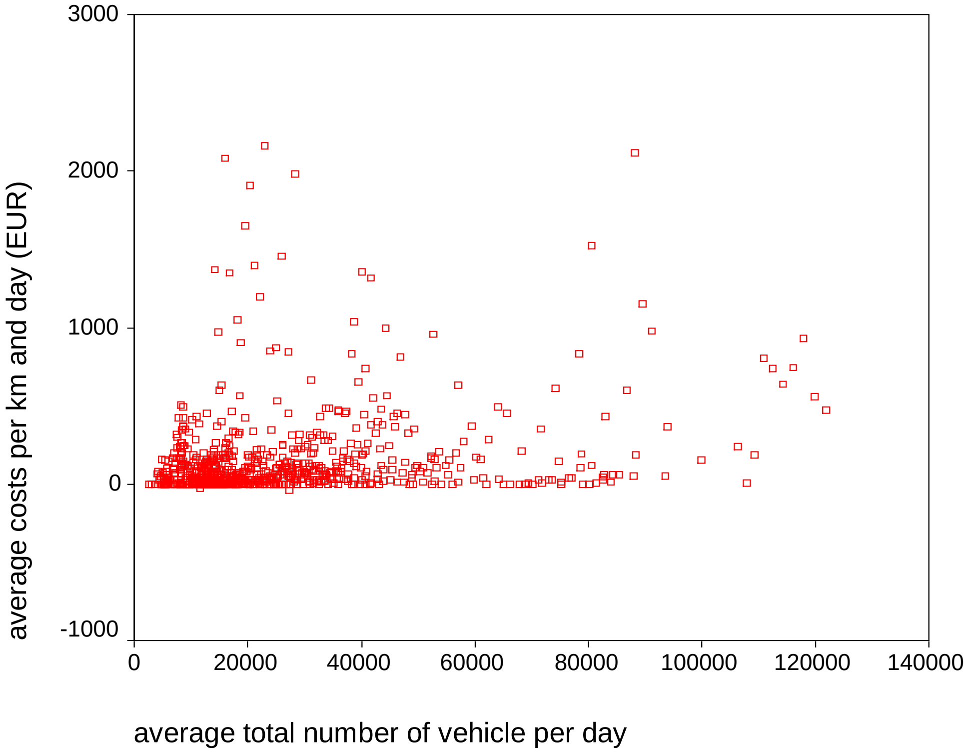
Motorway number	Motorway name	Federal country	Administration
S4	Mattersburger Schnellstraße	Niederösterreich (Lower Austria)	Federal Country
S4	Mattersburger Schnellstraße	Burgenland	Federal Country
S6	Semmering Schnellstraße	Niederösterreich (Lower Austria)	Federal Country
S6	Semmering Schnellstraße	Steiermark (Styria)	Federal Country
S16	Arlberg Schnellstraße	Tirol (Tyrol)	ASG
S16	Arlberg Schnellstraße	Vorarlberg	ASG
S16	Arlberg Schnellstraße	Vorarlberg	Federal Country
S31	Burgenland Schnellstraße	Burgenland	Federal Country
S33	Kremser Schnellstraße	Niederösterreich (Lower Austria)	Federal Country
S35	Brucker Schnellstraße	Steiermark (Styria)	Federal Country
S36	Murtal Schnellstraße	Steiermark (Styria)	Federal Country
A1	West Autobahn	Wien (Vienna)	Federal Country
A1	West Autobahn	Niederösterreich (Lower Austria)	Federal Country
A1	West Autobahn	Oberösterreich (Upper Austria)	Federal Country
A1	West Autobahn	Salzburg	Federal Country
A2	Süd Autobahn	Wien (Vienna)	Federal Country
A2	Süd Autobahn	Niederösterreich (Lower Austria)	Federal Country
A2	Süd Autobahn	Burgenland	Federal Country
A2	Süd Autobahn	Steiermark (Styria)	Federal Country
A2	Süd Autobahn	Kärnten (Carinthia)	Federal Country
A3	Südost Autobahn	Niederösterreich (Lower Austria)	Federal Country
A3	Südost Autobahn	Burgenland	Federal Country
A4	Ost Autobahn	Wien (Vienna)	Federal Country
A4	Ost Autobahn	Niederösterreich (Lower Austria)	Federal Country
A4	Ost Autobahn	Niederösterreich (Lower Austria)	ÖSAG
A4	Ost Autobahn	Burgenland	ÖSAG
A7	Mühlkreis Autobahn	Oberösterreich (Upper Austria)	Federal Country
A8	Innkreis Autobahn	Oberösterreich (Upper Austria)	Federal Country
A9	Pyhrn Autobahn	Oberösterreich (Upper Austria)	Federal Country
A9	Pyhrn Autobahn	Oberösterreich (Upper Austria)	ÖSAG
A9	Pyhrn Autobahn	Steiermark (Styria)	Federal Country
A9	Pyhrn Autobahn	Steiermark (Styria)	ÖSAG
A10	Tauern Autobahn	Salzburg	Federal Country
A10	Tauern Autobahn	Salzburg	ÖSAG
A10	Tauern Autobahn	Kärnten (Carinthia)	Federal Country
A10	Tauern Autobahn	Kärnten (Carinthia)	ÖSAG
A11	Karawanken Autobahn	Kärnten (Carinthia)	Federal Country
A11	Karawanken Autobahn	Kärnten (Carinthia)	ÖSAG
A12	Inntal Autobahn	Tirol (Tyrol)	Federal Country
A13	Brenner Autobahn	Tirol (Tyrol)	ASG
A14	Rheintal Autobahn	Vorarlberg	Federal Country
A21	Wiener Außenring Autobahn	Niederösterreich (Lower Austria)	Federal Country
A22	Donauufer Autobahn	Wien (Vienna)	Federal Country
A22	Donauufer Autobahn	Niederösterreich (Upper Austria)	Federal Country
A23	Südosttangente Wien	Wien (Vienna)	Federal Country
A25	Linzer Autobahn	Oberösterreich (Upper Austria)	Federal Country

Table 2: List of variables

Variables	Description
Road length	Length of motorway section (see list above)
Bridge length	Length of bridges per motorway section
Tunnel length	Length of tunnels per motorway section
Age	Average age of the motorway section
Cost	Costs of maintenance and renewal per km per motorway section
Total number of vehicles	Average total number of vehicle per motorway section
Number of vehicles up to 3,5 t GVW	Average number of vehicle up to 3,5 t GVW per motorway section
Number of busses more than 3,5 t GVW	Average number of busses up to 3,5 t GVW per motorway section
Number of HGV more than 3,5 t GVW, 2 or 3 axles	Average number of HGV up to 3,5 t GVW with 2 or 3 axles per motorway section
Number of HGV more than 3,5 t GVW, 4 or more axles	Average number of HGV up to 3,5 t GVW with 4 ore more axles per motorway section
Total number of gross tons	Average total number of gross tons per motorway section
Number of gross tons of vehicles up to 3,5 t GVW	Average number of gross tons of vehicles up to 3,5 t GVW per motorway section
Number of gross tons of busses more than 3,5 t GVW	Average number of gross tons of busses up to 3,5 t GVW per motorway section
Number of gross tons of HGV more than 3,5 t GVW, 2 or 3 axles	Average number of gross tons of HGV up to 3,5 t GVW with 2 or 3 axles per motorway section
Number of gross tons of HGV more than 3,5 t GVW, 4 or more axles	Average number of gross tons of HGV up to 3,5 t GVW with 4 ore more axles per motorway section
Total number of standard axle	Average total number of standard axle loads per motorway section
Number of standard axle loads of vehicles up to 3,5 t GVW	Average number of standard axle loads of vehicles up to 3,5 t GVW per motorway section
Number of standard axle loads of busses more than 3,5 t GVW	Average number of standard axle loads of busses up to 3,5 t GVW per motorway section
Number of standard axle loads of HGV more than 3,5 t GVW, 2 or 3 axles	Average number of standard axle loads of HGV up to 3,5 t GVW with 2 or 3 axles per motorway section
Number of standard axle loads of HGV more than 3,5 t GVW, 4 or more axles	Average number of standard axle loads of HGV up to 3,5 t GVW with 4 ore more axles per motorway section

The following scatter plot shows the primary relation between the costs and average total number of vehicles for every motorway section for all years.

Figure 1: (renewal and maintenance) costs per km and average total number of vehicles per motorway section



3.4 Descriptive analysis of data (characterisation of data)

The following table describes the basic statistics of the data per motorway and federal country for the years 1987 to 2004.

Table 3: Descriptive statistic of the most important variables

variable	N	Minimum	Maximum	Mean	Standard diviation
average construction year	808	1947	1993	1979	9
lenght of section (km)	808	2	146	41	39
lenght of bridges per section (km)	808	0	24	3	4
lenght of tunnels per section (km)	808	0	16	2	4
average costs per day and km (EUR)		0	2.162	144	269
average number of					
vehicles up to 3,5t GVW per day	808	2.156	111.248	22.607	18.969
busses per day	808	32	859	204	156
vehicles more than 3,5t GVW, 2 or 3 axles per day	808	132	5.681	1.105	991
vehicles more than 3,5t GVW, 4 or more axles per day	808	218	5.654	1.634	1.101
gross tons of vehicles up to 3,5t GVW per day	808	1.346	69.447	14.113	11.841
gross tons of busses per day	808	345	9.191	2.187	1.675
gross tons of vehicles more than 3,5t GVW, 2 or 3 axles per day	808	1.294	55.890	10.870	9.746
gross tons of vehicles more than 3,5t GVW, 4 or more axles per day	808	5.979	155.200	44.865	30.224
standard axle loads of vehicles up to 3,5t GVW per day	808	0	1	0	0
standard axle loads of busses per day	808	0	13	3	2
standard axle loads of vehicles more than 3,5t GVW, 2 or 3 axles per day	808	0	11	2	2
standard axle loads of vehicles more than 3,5t GVW, 4 or more axles per day	808	5	123	36	24

4 The model (functional form) applied

4.1 "History"

Before describing the final used model(s) and the final used data set a short overview about the "history" to reach a good working data set and model is given.

4.1.1 Models with basis data set

Within a first step models have been applied on the basis data set described in chapter 3.3.

It is tested a function between the costs and the use of the motorways. The use can be described by average daily traffic (or by vehicle-km), by average daily gross tons or by average daily axle load equivalents.

(1) *Cost per km = f (Use $_{AADT,\ gross\ tons,\ axle\ load\ equivalents}$)*
or
(2) *Cost of section = f(Use $_{vkm,\ gross\ tons,\ axle\ load\ equivalents}$)*

The data set was tested with different version of these two general functions:

- Linear with different Use-characteristics (all of them, some of them) for total traffic
- Linear with different Use-characteristics (all of them, some of them) for the vehicle categories separately
- Linear with different Use-characteristics (all of them, some of them) for the vehicle categories in one step
- Log-Linear with different Use-characteristics (all of them, some of them) for total traffic
- Log-Linear with different Use-characteristics (all of them, some of them) for the vehicle categories separately
- Log-Linear with different Use-characteristics (all of them, some of them) for the vehicle categories in one step

All trials let to either non significant statistical results (low r^2, low T-value, …) or non plausible coefficients.

4.1.2 Models with longwise aggregation view over the time

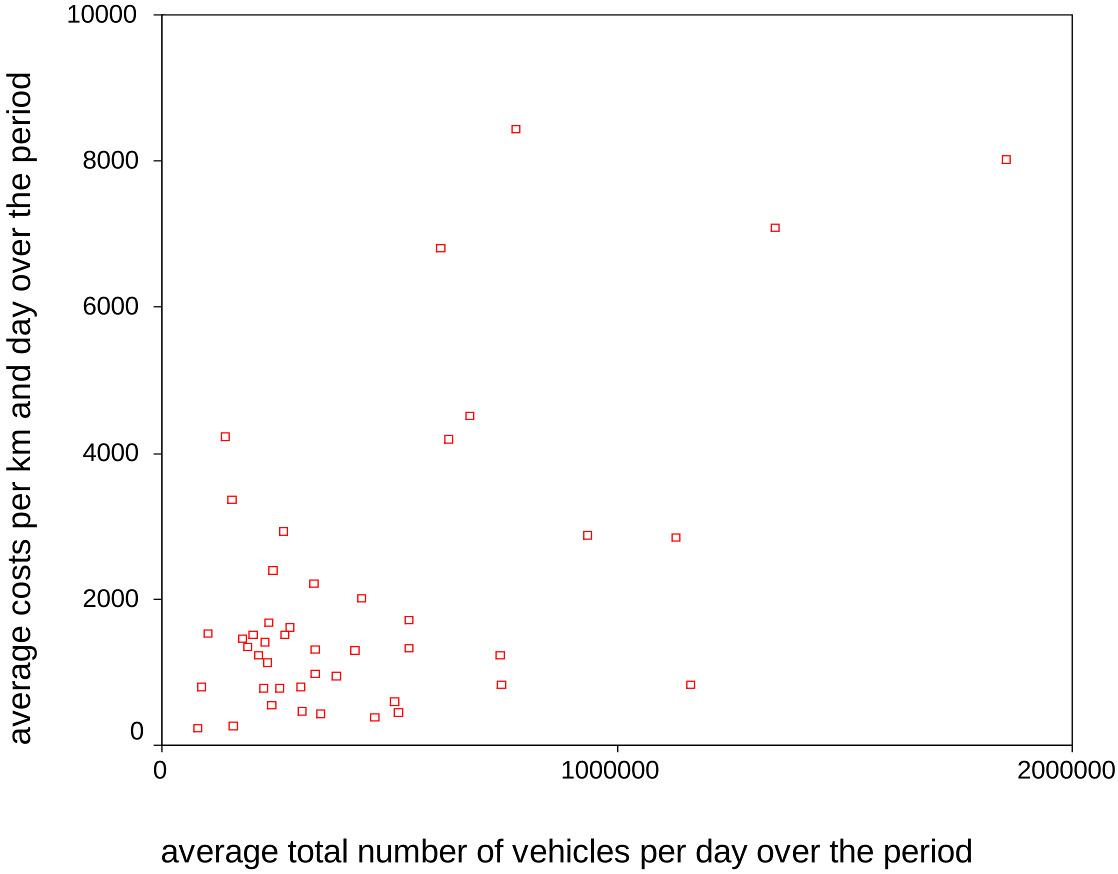
Given the fact that the spent expenditures for maintenance and renewal of one year not only depends of the traffic of that year but also of the previous years, a useful analysis is a longwise view per time. That means that the cost and the traffic of a time period are added per section. The period should be as long as an average renewal circle.

Therefore for every of the 46 motorway sections the cost data and the traffic over the years 1987 to 2004 of the data set described in chapter 3.3 where added to one value for costs and one value for the specific traffic information.

That means the number of cases is reduced and only 46 cases are available for the regression analysis.

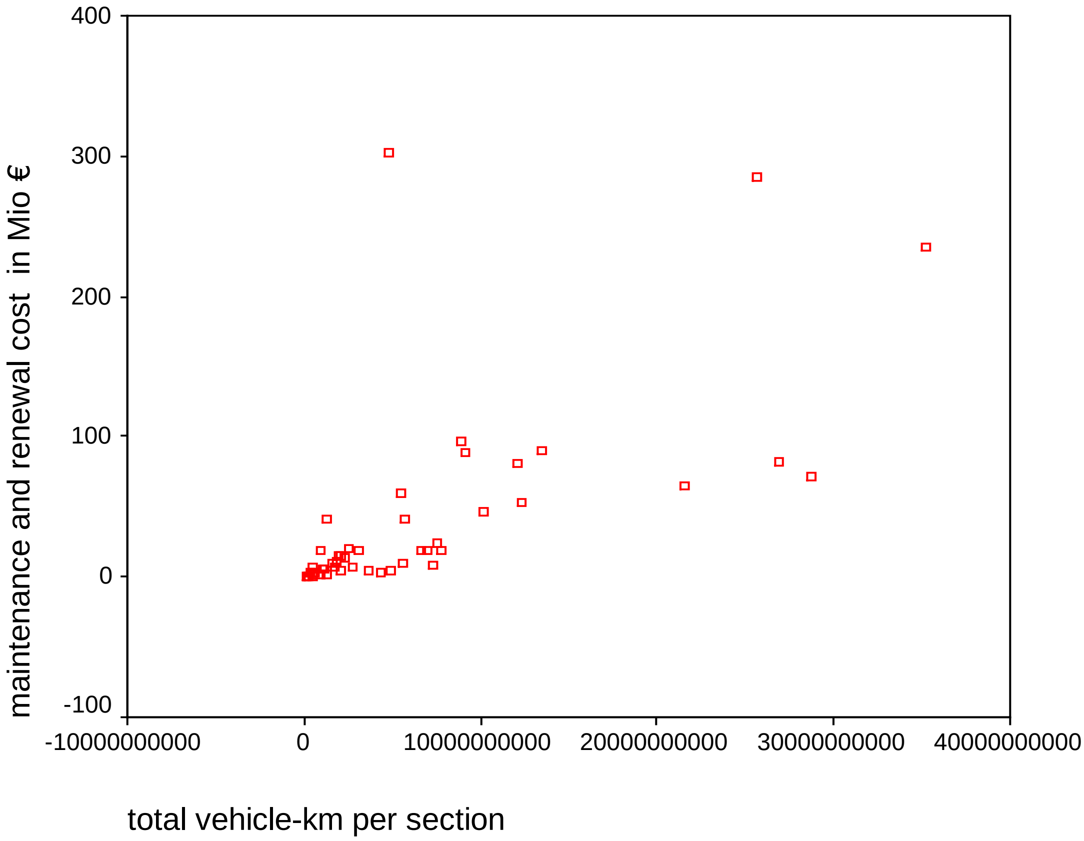
The following chart shows the average costs per km and the total number of vehicles per motorway section for this longwise aggregation view over the time.

Figure 2: (renewal and maintenance) costs per km and average total number of vehicles per motorway section



The next chart shows the information per section (costs per section and total vkm per section) over the time period.

Figure 3: (renewal and maintenance) costs per km and average total number of vehicles per motorway section



Both figures show a better picture than Figure 1 but in both pictures runaways can be seen that can "destroy" the regression analysis.

Nevertheless first trials with this data set have been started using at first different linear functions based on the general functional form of equation (1).

These tests with the complete data set of the longwise view per time brought one functional form with plausible marginal costs for cars and trucks.

(2) $C = a_0 + a_1 * V_{car} + a_2 * V_{truck} + a_4 * V_{ton} + a_4 * V_{axle}$

with:

C	= maintenance and renewal costs
V_{car}	= traffic volume of cars
V_{truck}	= traffic volume of trucks (and buses) ≥ 3,5 t GVW
V_{ton}	= number of gross tons of trucks (and buses) ≥ 3,5 t GVW
V_{axle}	= number of axle load equivalents of trucks (and buses) ≥ 3,5 t GVW

The problem of this result is that the T-values are much to low and the coefficient of the axle load equivalents is negative. A main reason for this is the high correlation between traffic volume, gross tons and axle load equivalents. The reason for that is the synthetic calculation of the gross tons and the axle load equivalents based on the traffic volume and information on proportions to the traffic volume.

Nevertheless (looking at the plausible results for marginal costs - cars: 0,0009 €, trucks: 0,0315 €) the data set as well as the functional form can be used as a starting point for further trials.

The different applied independent variables and the correlation analysis between all independent variables showed that the use of vehicle-km (per vehicle type) respective AADT (per vehicle type) is okay, only.

The next trials concentrated on two main things:

- Analysing the runaways and drop them out if necessary.
- Testing linear and log-linear functions
    - for the "per km-view" (average costs per km and day and AADT) and
    - for the "per section-view" (total costs per section and vehicle-km per section)

To avoid using estimated cost values the data set for the longwise aggregation view over the time was recalculated using only the years 1987 until 2000 and ignoring the values for 2001 to 2004 (as forecast estimates).

4.1.2.1 Runaway Analysis

In a first step five sections could be identified as runaways:

- All four sections of the motorway A1 have very high costs. This is due to refurbishment of the whole A1 that started in the nineties and will last until the end of this decade.
- The motorway A13 which has much higher maintenance costs per km than the other sections.

Without these sections two different three dimensional charts showing the costs and the traffic of cars and the traffic of trucks are interesting to analyse for further runaways:

Figure 4: (renewal and maintenance) costs per km, average number of cars per motorway section, average number of trucks per motorway section

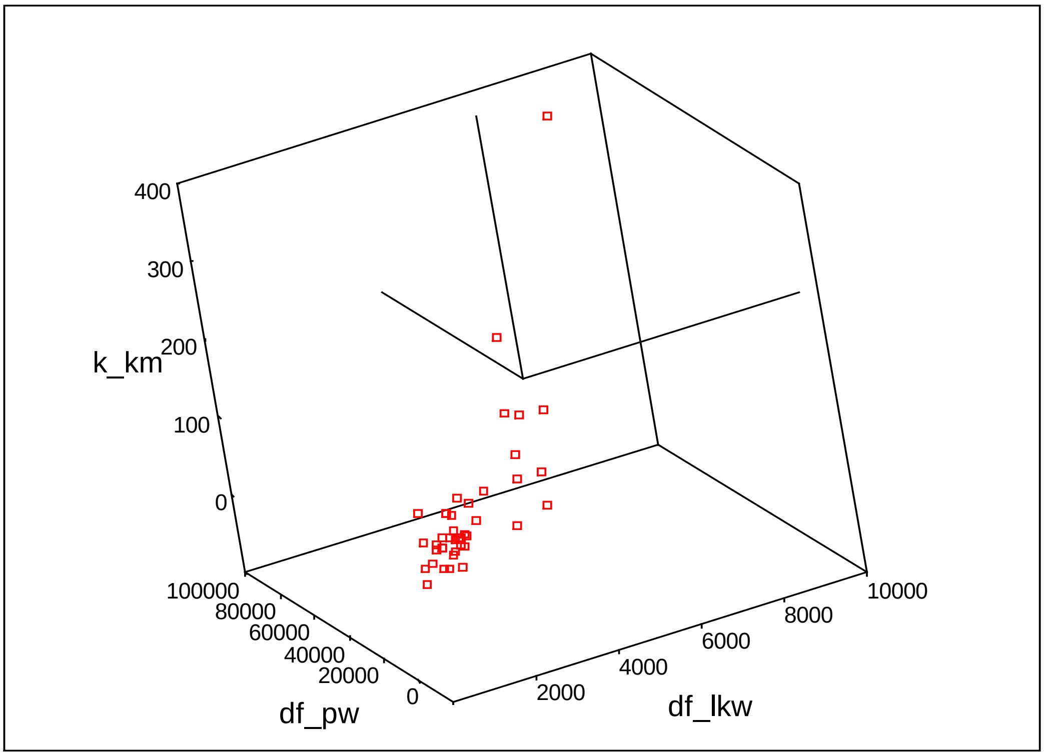
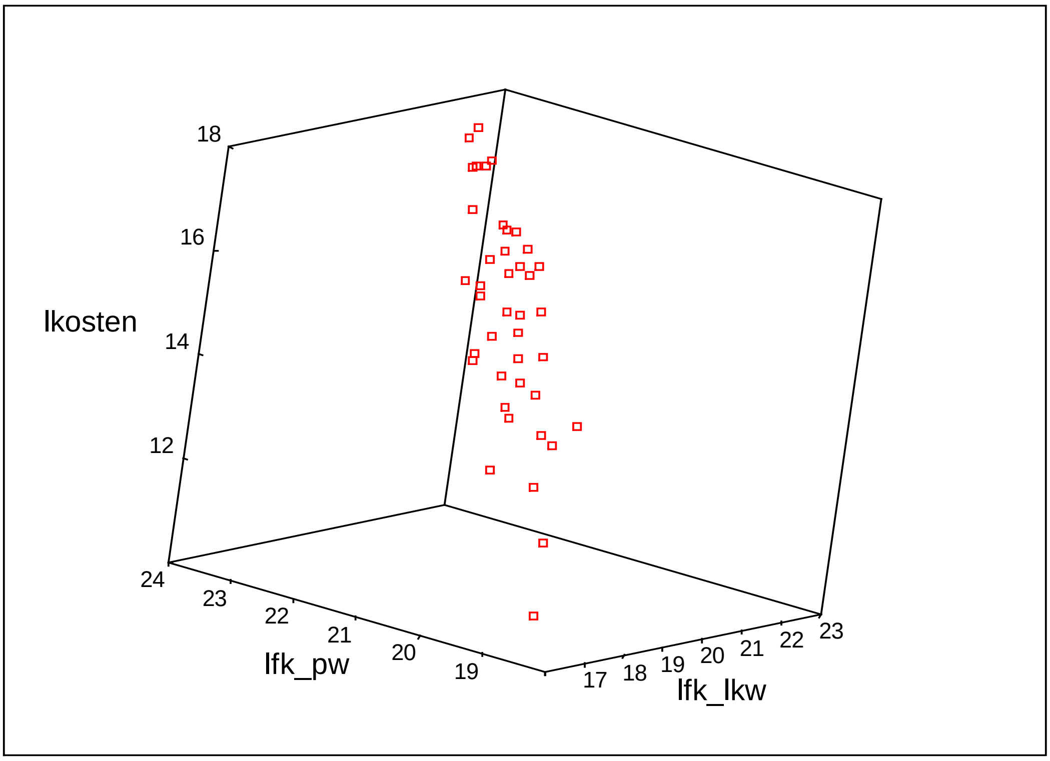


Figure 5: ln of (renewal and maintenance) costs per section, ln of vehicle-km of cars per motorway section, ln of vehicle-km of trucks per motorway section



Analysing both figures (with the help of different views) three more sections could be identified as runaways.

So the final used data set has 38 data points.

4.1.2.2 Description of the final used data

The following table describes the basic statistics of the final used data (longwise aggregation view over the time from 1987 to 2000 without runaways).

Table 4: Descriptive statistic of the most important variables

Variable	N	Minimum	Maximum	Mean	Standard diviation
maintenance and renewal costs in €	38	51.230	44.431.780	9.475.434	12.180.382
vehicle-km cars	38	106.327.258	17.897.466.759	3.537.734.743	4.453.389.220
vehicle-km trucks and busses	38	12.019.804	2.904.730.259	474.493.500	634.789.154
vehicle-km total	38	118.347.063	20.802.197.018	4.012.228.243	5.074.485.649
average maintenance and renewal costs per km per day in €	38	5	361	51	62
average annual daily traffic of cars	38	3.733	89.833	20.311	18.621
average annual daily traffic of trucks and busses	38	734	8.389	2.421	1.634

The correlation between the traffic volume of the two vehicle types is another relevant data test.

Table 5: Correlation of variables

	average annual daily traffic of cars	average annual daily traffic of trucks and busses
average annual daily traffic of cars	1	
average annual daily traffic of trucks and busses	0,959	1
Pearson Correlation Correlation is significant at the 0.01 level (2-tailed).		

The traffic volumes of the two vehicle types are highly correlated. Therefore a regression analysis with both vehicle types turns out to be a problem.

4.2 Final used functional forms

Due to the high correlation between the volume of vehicle types at first a regression analysis testing the dependency of the maintenance and renewal costs from the total traffic volume has been worked out.

The following equation shows the applied function:

(3) *Total Cost = f(total vehicle-km)*

This general functional form was used in the following specific way, using a log-linear model:

(4) $lnC = a_0 + a_1 * ln(vkm_{total})$

With the help of this regression model and the first derivation average marginal costs for all vehicles and a marginal cost curve for all vehicles depending on the vehicle-km per motorway section can be derived.

The aim of this case study is to produce marginal costs distinguished by vehicle classes.

To reach this aim the high correlation between the two types "cars" and "trucks and busses" is ignored and the following general function is used:

(5) $Average\ Cost_{per\ km\ and\ day} = f(AADT_{cars}, AADT_{trucks\ and\ busses})$

with the following specific form:

(6) $C = a_0 + a_1 * AADT_{cars} + a_2 * AADT_{trucks\ and\ busses}$

Equation (6) was also tested as log-linear form, but this function did not lead to useful results.

5 Model estimations and tests

5.1 Total traffic

Using equation 4 the following results could be derived:

Table 6: Model summary – total vehicle-km

Model summary			
R	R Square	Adjusted R Square	Std. Error of the Estimate
0,84	0,71	0,70	0,88
Predictor: (Constant), ln of total vehicle km of the section Dependent variable: ln of maintenance and renewal costs of the section			

Table 7: Coefficients – total vehicle-km

Coefficients					
	Unstandardized Coeffizients		Standardized Coeffizients	T	Sig.
	B	Std. Error	Beta		
(Constant)	-7,233	2,374		-3,046	0,004
ln of total vehicle km of the section	1,046	0,111	0,844	9,433	0,000
Dependend Variable: ln of maintenance and renewal costs of the section					

A good R Square and a high significance allow to use this function and to calculate marginal costs with this functional form and the finally used data.

5.2 By vehicle classes

Although the correlation test showed a high correlation between average daily traffic of vehicles up to and more than 3.5t GVW a regression analysis is tried to derive separate marginal costs for these two vehicle types.

The decision to do this has been made to avoid using allocation methods within the marginal cost calculation procedure.

By using equation 6 the following results could be derived:

Table 8: Model summary – vehicle types

Model summary			
R	R Square	Adjusted R Square	Std. Error of the Estimate
0,78	0,61	0,58	39,89
Predictor: (Constant), average annual daily traffic of trucks and busses , average annual daily traffic of cars			
Dependent variable: average maintenance and renewal costs per km per day in €			

Table 9: Coefficients – vehicle types

Coefficients					
	Unstandardized Coeffizients		Standardized Coeffizients	T	Sig.
	B	Std. Error	Beta		
(Constant)	-15,3551	13,9540		-1,1004	0,2787
average annual daily traffic of cars	0,0007	0,0012	0,2098	0,5599	0,5791
average annual daily traffic of trucks and busses	0,0217	0,0142	0,5746	1,5336	0,1341
Dependend Variable: average maintenance and renewal costs per km per day in €					

As expected (because of the given correlation) the T value and therefore also the significance of the results with this function are not really good. Nevertheless the R Square is rather high and the test brought the best results compared with other functional forms and other used data for regressions with vehicle types.

So the estimated coefficients are used to derive marginal costs by vehicle classes.

6 Results

Based on the estimated functions marginal costs can be derived by using the first derivation of the estimated functions.

6.1 Marginal costs - total traffic

The estimated equation 4 has the following form:

(7) $lnC = -7.233 + 1.046*ln(vkm_{total})$

(8) $C = e^{1,046*ln(vkmtotal)-7,233} = 0.000722 * vkm_{total}^{1.046}$

The first derivation gives:

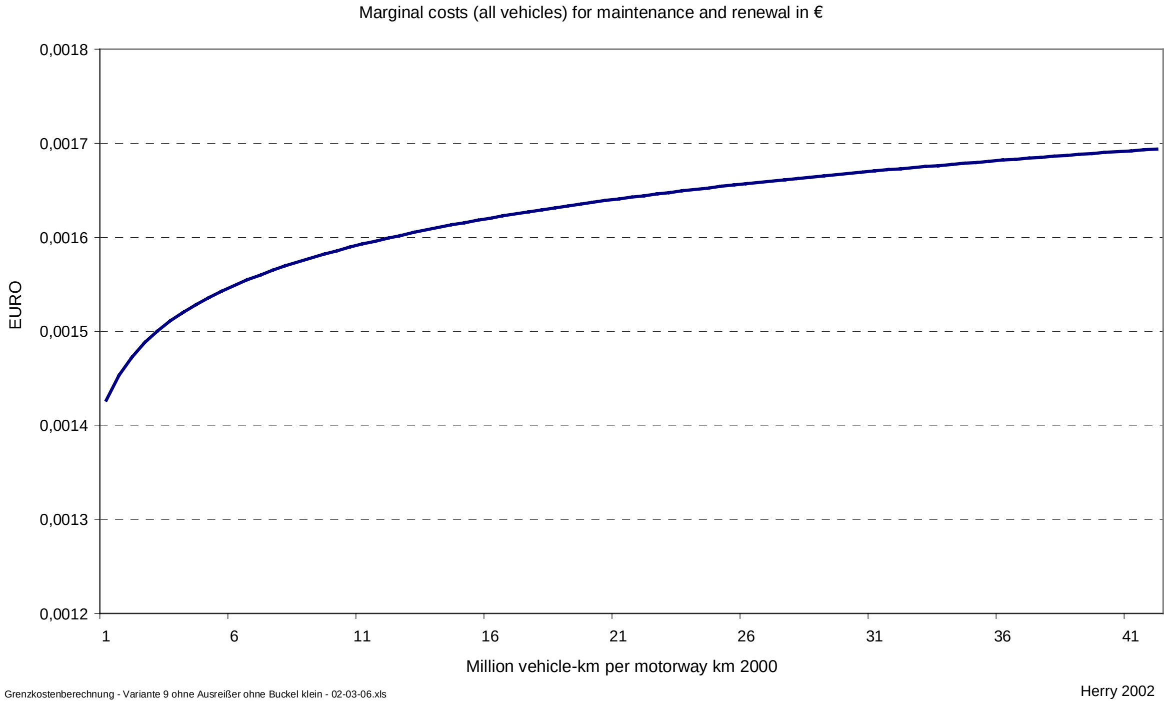
(9) $C' = 0.000756 * vkm_{total}^{0.046}$

The vehicle-km dependent marginal costs are the following:

Table 10: Marginal costs of maintenance and renewal per total vehicle-km per motorway-km

Million vehicle-km per motorway-km	Marginal costs(all vehicles) of maintenance and renewal in €
1	0,00143
6	0,00155
11	0,00159
16	0,00162
21	0,00164
26	0,00166
31	0,00167
36	0,00168
41	0,00169

Figure 6: Marginal costs of maintenance and renewal per total vehicle-km per motorway-km



By integrating the marginal cost curve between the lowest and the highest value of vehicle-km per motorway km the average marginal costs can be calculated:

Average marginal costs (all vehicles) of maintenance and renewal: **0,0016 €**

6.2 Marginal Costs per vehicle type

The estimated equation 6 has the following form:

(10) $C = -15{,}3551 + 0{,}0007 * AADT_{cars} + 0{,}0217 * AADT_{trucks\ and\ busses}$

The partial derivation of C by $AADT_{cars}$ gives:

(11) $C_{cars}' = 0.0007$

The partial derivation of C by $AADT_{trucks\ and\ busses}$ gives:

(11) $C_{trucks\ and\ busses}' = 0.0217$

Due to the linear function the marginal costs are constant.

Marginal costs (vehicles up to 3.5t GVW) of maintenance and renewal: **0,0007 €**
Marginal costs (vehicles more than 3.5t GVW) of maintenance and renewal: **0,0217 €**

These values are plausible although a correlation between the two independent variables is existing. The marginal costs for vehicles up to 3.5t GVW are much lower than the average marginal costs derived without splitting into vehicle types and the marginal costs of vehicles more than 3.5t GVW are higher than the average.

The **factor 31** between the marginal costs of vehicles up to 3.5t GVW and the marginal costs of vehicles more than 3.5t GVW seems to be plausible too.

7 Generalisation and transferability of results

The following results/methods are transferable or suitable for generalisation:

- It is possible to generate marginal costs of renewal and maintenance on traffic roads, especially on motorways.
- For generating results one have to have valid data on traffic and renewal and maintenance costs differentiated by years for a time period covering the renewal and maintenance life cycles, at least. The traffic data should be differentiated at least for the specific vehicles used in the marginal cost schema.
- The aggregation method of building the dataset for calculating the marginal costs: Year-wise cost data as mentioned above can have a time related structure which is not appropriate for using cost functions. In this case, an aggregation of these cost data in using sums of these costs over the time period can lead to better results.

- The values of marginal costs of 0,0007 € per v-km of maintenance and renewal for vehicles up to 3.5t GVW can be transfered to countries with at least an average traffic of approximately 30.000 vehicles (AADT) on motorways from which about 15% are heavy goods vehicles (more than 3.5t GVW).
  The same with the marginal costs of heavy goods vehicles (more than 3.5t GVW) of maintenance and renewal: 0,0217 €.
  That means this the marginal costs for HGV (with more 3.5t GVW) are about 30 times higher than the marginal costs for vehicles up to 3.5t GVW.

8 Conclusions

Following conclusions can be drawn:

- To produce cost function for constructing marginal costs of maintenance and renewal on motorways in relationship to the traffic is not easy and needs accurate data with a “minimum of variety”.
- Time series must have a “duration” of a period which covers the renewal and maintenance life cycles, at least.
- In the Austrian case the mainly used types of functions did not led to plausible results. So, only the use of quite very simple cost functions led to significant results.
- The separation of the traffic into vehicle categories must be handled very carefully (because of the need of a “basic variance” in the respective categorised datasets.
- A disaggragation of the data needed over the time did not led to plausible results because of the data distribution.
  An aggregation of these data can be used if the time period regarded covers at least the life cycle time of renewal and maintanance (for each type of construction).
- Besides the considered determinants, there are many other factors which have an influ-

ence on the results of the marginal costs, certainly. They could not be included in the analysis because of the lack of the respective data.

- The results give indication to following generalisation:
  - It is possible to generate marginal costs of renewal and maintenance on traffic roads, especially on motorways.
  - For generating results one have to have valid data on traffic and renewal and maintenance costs differentiated by years for a time period covering the renewal and maintenance life cycles, at least. The traffic data should be differentiated at least for the specific vehicles used in the marginal cost schema.
  - The aggregation method of building the dataset for calculating the marginal costs: Year-wise cost data as mentioned above can have a time related structure which is not appropriate for using cost functions. In this case, an aggregation of these cost data in using sums of these costs over the time period can lead to better results.
  - The values of marginal costs of 0,0007 € per v-km of maintenance and renewal for vehicles up to 3.5t GVW can be transfered to countries with at least an average traffic of approximately 30.000 vehicles (AADT) on motorways from which about 15% are heavy goods vehicles (more than 3.5t GVW).
  - The same with the marginal costs of heavy goods vehicles (more than 3.5t GVW) of maintenance and renewal: 0,0217 €.
  - That means this the marginal costs for HGV (with more 3.5t GVW) are about 30 times higher than the marginal costs for vehicles up to 3.5t GVW.

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