# Relating Swedish traffic activity data to ARTEMIS traffic situations

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***Abstract***

*ARTEMIS is an EU model for the calculation of traffic emissions on national and regional level. The model includes 276 traffic situations, i.e. combinations of road and traffic conditions, with associated emission factors for different vehicle categories. This paper reports on a methodology for deriving the necessary traffic input data for the application of the model on a national level in Sweden. Procedures were established to distribute total vehicle mileage over: 1) urban and rural roads, 2) different road categories and 3) different traffic flow conditions, and to translate the results to the traffic situations defined in ARTEMIS. The basis for the work was: 1) two national road databases, 2) traffic simulations (SIMAIR) for test regions, 3) a GIS layer with polygons defining built-up areas and 4) ranking curves for the yearly distribution of Average Daily Traffic, ADT. Overall results for the Swedish case are presented.*

## Introduction

ARTEMIS (Assessment and Reliability of Transport Emission Models and Inventory Systems) is a EU model for the calculation of traffic emissions on national and regional level. It was established in 2005 as the result of the EU's 5th Framework Programme. At the end of 2004 a joint research project was started (including IVL, AVL MTC, VTI and LTH at Lund University) aimed at implementing ARTEMIS in Sweden and using it for the reporting to the UNCCC (United Nations Convention on Climate Change) in 2004, (Sjödin et al., 2006). ARTEMIS is an emission factor model based on detailed descriptions of vehicle and road categories and traffic conditions. The model includes 276 traffic situations (TS), based on a combination of road class and traffic flow conditions, see Table 1.

When modelling emissions it is naturally important to use reliable data. This article describes a methodology used to distribute the total Swedish vehicle mileage for the years 1990 to 2004 between the TS in Table 1.

## 1 - Methods

The aim was to distribute national Swedish data concerning vehicle mileage between the traffic situations in the ARTEMIS model. The method of distribution and the data used are described. Calculations were performed for the years 1990, 1995, 1998, 2000 and 2004.

### 1.1 - Data Used

Firstly, a road database was required in which each road is associated with information about: 1) traffic flow and length, to compute the vehicle mileage, 2) road function and 3) speed limit. In Sweden, roads are owned and maintained by the state, municipalities or privately. For the state roads there is a complete and accurate GIS road database called VDB. This database is updated once a year by the Swedish Road Administration, SRA. For the municipal and private roads there is a complete digital map called the National Road Database (NVDB) in which function and speed limits are included, but the traffic flow is not given. On the basis of the vehicle mileage for the state road network, the SRA estimates the total vehicle mileage in Sweden using the Vehicle Mileage model (VM model). This model contains total mileage for each year since 1990, and is produced by The Swedish Institute for Transport and Communications Analysis (SIKA) and the Swedish National Road and Transport Research Institute (VTI) (SIKA and VTI, 2005). To estimate the traffic flow for the municipal and private roads the traffic demand model SAMPERS and the traffic model EMME/2 were used for four test regions that were chosen to represent the distribution over road types for municipal and private roads for the whole of Sweden. Traffic was simulated on a detailed and classified road network according to NVDB To differentiate the vehicle mileage on urban and rural roads, polygons defining built-up areas were used. These polygons define the borders of built-up areas ranging from small villages to large cities Sweden, and are updated every five years.

### 1.2 - Distribution of national vehicle mileage - overview

The identification of vehicle mileage with the TS in the ARTEMIS model is based on a top-down model. The total vehicle mileage was separated into the three road administration categories using the VM model. The proportion of vehicle mileage on urban and rural roads was calculated for each road administration category. The urban vehicle mileage was then divided into three classes based on the number of inhabitants. The last step before matching the Swedish road categories with the ARTEMIS traffic TS was to adjust the relation between the average daily traffic (ADT) and traffic volumes in ARTEMIS's four classes for traffic conditions, via considerations concerning the speed-flow curve for different types of roads.

### 1.4 - The state, municipal and private road networks

Information on the distribution of vehicle mileage for the years considered was obtained from the SIKA and VTI and converted using the VM model. The vehicle mileage on state roads in the VM model is based on 80 measuring points on these roads (Björketun et al., 2005). The total vehicle mileage was found to increase from 64 310 to 74 599 million km between the years 1990 and 2004. The proportion on state roads increased from 65.8% to 67.7% while there was a corresponding decrease on municipal roads, from 30.2% to 28.4%. The private roads were estimated to have a constant share of 4% of the total vehicle mileage during the period studied.

Due to the completeness of the information in the VDB, it was possible to recalculate the total vehicle mileage for state roads. The traffic flow in VDB is given as ADT based on the number of vehicles or on pairs of axles during a specific year. To calculate the total vehicle mileage for a certain year this ADT was enumerated by index, to represent the intended year. The index shows how the set of traffic has increased or decreased since the year it was measured (Johansson et al., 2002; Holmgren, 2004). When all links were enumerated to the intended years, the total vehicle mileage on state roads could be calculated from a bottom-up approach and compared with the top-down values in the VM model. There was a small difference between the two methods. In this study the enumeration method was used for all distributions.

### 1.5 - Distribution of vehicle mileage on urban and rural roads

By using the polygons describing each built-up area, all roads could be defined as either urban or rural. Roads with their centre inside a polygon were defined as urban, and vice versa. The definition of a built-up area is: "a group of buildings normally not more than 200 metres apart, and a minimum of 200 inhabitants" (SCB, 2005). For the state road network obtained from the VDB this polygon overlay method was used for all the years of interest. The results showed an increase in vehicle mileage on state rural roads from 78.3% to 81.8% between 1990 and 2004. Due to the lack of traffic flow data on the municipal and private road network, four test regions with simulated traffic data were used to distribute mileage between urban and rural areas. The four regions studied were three counties (Stockholm, Uppsala and Östergötland County) and one municipality (the municipality of Halmstad). The same overlay method was used for these areas as for the state road network. For the municipal road network the results showed that 88.9% of the vehicle mileage was driven on urban roads, the corresponding proportion on the private road network was 25.2%. The total distribution over urban and rural roads for the different road administration categories is given in Table 2.

### 1.6 - Distribution of vehicle mileage between different urban areas

Urban vehicle mileage as well as the distribution over road classes and traffic conditions is likely to be related to the size of the city. The next step in the distribution model was thus to find a method of calculating the vehicle mileage for cities with different populations. One hypothesis is that the number of TS as well as the proportion of vehicle mileage per TS varies depending on the city size i.e. its population. Due to the fact that national data for the municipal and private road network are not complete, the polygons describing the built-up areas in the four test regions were used. The 207 areas were classified into three groups based on the number of inhabitants; villages and small towns (200-49 999 inhabitants), towns and small cities (50-199 999) and large cities (>200 000) in accordance with classifications made by Vilhelmson (2000).

An equation for the vehicle mileage within a city as a function of the number of inhabitants was obtained through regression analysis, see Equation 1. The R2 value for the equation was 0.9971 including Stockholm and 0.9501 excluding Stockholm. Equation 1 was applied to distribute the urban traffic over different kinds of built-up areas, see Table 3.

Vehicle mileage = 3975.81 * Number of inhabitants Equation 1.

### 1.6 - Functionality, speed limit and traffic condition classifications

ARTEMIS includes in total 69 road categories (including functionality and speed limit), see Table 1. Each road category is divided into four classes of traffic conditions, "level of service", giving altogether 276 TS. The prevalence of road categories as well as their shares of total vehicle mileage varies between countries and conditions in Sweden had to be matched to those in ARTEMIS. The classifications in the two Swedish road databases (VDB and NVDB) utilised were translated into the classifications in ARTEMIS. Keys between the Swedish classification systems and ARTEMIS road categories were based on road hierarchy (national, primary, secondary, etc.), function and design (motorway, dual carriageways, single-lane roads etc.) and the prevailing speed limits. In total 33 of the ARTEMIS road categories were identified in Sweden.

To distribute the vehicle mileage on different roads over different traffic conditions, ranking curves for the yearly distribution of ADT divided on light and heavy vehicles, based on measurements of the distribution of traffic flow over the hours of a year for different road types (Björketun et al 2005, Jensen 1997), were utilised. Calculations of traffic flow and vehicle mileage at different hours (using ranking curves) for different links were performed for all state road links. These calculations were also performed for the municipal and private road links in the test regions of the county of Östergötland, the municipality of Halmstad and the Stockholm area (for which new traffic simulations were performed to represent traffic flow in large cities). Urban and rural roads have different ranking curves and thus separate procedures were used. The result, traffic flow per lane per hour at different rang classes, was related to volume-delay functions according to Figure 2, and preliminarily classified into traffic conditions 1-3. For, 4, stop & go see below.

It is not possible from traffic flow data alone to determine whether a flow between free flow (a) and congested (b), in Figure 2, is a case of demand exceeding capacity (stop & go) or if it is a lower flow (heavy). Thus it is not possible to quantify the vehicle mileage under stop & go conditions. To overcome this, two assumptions were made: stop & go would only occur on road links that had reached their capacity, c; and for these roads it was assumed that stop & go constituted a fixed share of the preliminary estimated vehicle mileage in the traffic condition "heavy". By studying flow over the day for individual congested roads, see Figure 3, it was seen that a local decrease in flow sometimes occurred within a congested period (i.e. when flow is near the capacity). This period was assumed to be a stop & go period. Thus, for links reaching their capacity the vehicle mileage under 'stop & go' conditions was estimated to be 14% of the vehicle mileage that had initially been assigned to 'heavy'. The vehicle mileage under level "heavy" conditions was decreased correspondingly on those roads. Vehicle mileage was finally summed over all road classes and traffic conditions and translated into ARTEMIS TS.

## 2 - Traffic situations in Sweden in 2004

Concerning the different road administration categories the largest share of vehicle mileage, 53.0%, was driven on state roads in rural areas. The second largest share, 26.0%, was driven on municipal roads in urban areas, and the third on state roads in urban areas, 13.8%, see Figure 4. In total 59.2% of vehicle mileage was driven in rural areas (of which 14.6% on motorways and 44.5% not on motorways) and 40.8% in urban areas (of which 4.0% was on motorways and 36.9% not on motorways). Before this study the rural share of vehicle mileage in Sweden had been assumed to be 65% (Ringhagen, 1987).

The result of the distribution of the total vehicle mileage over road categories and traffic conditions on urban and rural roads in Sweden showed that 85 of ARTEMIS 276 TS were found in Sweden in 2004, 45 in rural areas and 40 in urban areas. They consisted of 33 road categories, most of them never exceeding the traffic conditions free flow (1) and heavy traffic (2). In fact, as much as 94.4% of the vehicle mileage in Sweden is performed under free flow conditions; 3.4% in heavy traffic, 2.1 % in congested traffic and as little as 0.05% under stop & go conditions. Stop & go traffic occurred only in the largest cities (>200 000 inhabitants). The ten most common TS in Sweden are presented in Table 4.

## 3 - Conclusions and further research

This paper presents a procedure for relating national Swedish data concerning vehicle mileage with the TS in the ARTEMIS model. Eighty-five of ARTEMIS's 276 TS were identified in Sweden in 2004. The study presents new figures concerning the distribution over urban and rural roads in Sweden i.e. 41% and 59%, respectively. Furthermore, a model for estimating the distribution of urban traffic in cities of different sizes is presented. This methodology will be developed and refined in further research when more simulated traffic data are available. New results concerning the distribution of the vehicle mileage in Sweden over traffic conditions are presented. Validation of the assumptions and methods to estimate the share of vehicle mileage at "stop & go" conditions are areas for further research. The translation between Swedish road categories and ARTEMIS categories was mainly based on the description of road hierarchy, function and design, and speed limit. In further research the driving cycles associated with the various TS in ARTEMIS will be compared with data on real traffic driving patterns for the corresponding Swedish road categories.

**Acknowledgements**

We would like to thank Håkan Johansson, SRA, for his help, and EMFO for financing the project.

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Table 1: Principle for division into traffic situations (Keller et al., 2005; Andre et al., 2006)

| Area | Road type | Speed limit (km/h) | Traffic flow conditions |
|---|---|---|---|
| Urban | Motorway - National (Through Traffic) | 80, 90, 100, 110, 120, 130 | 4 levels of service |
| | Motorway - City | 60, 70, 80, 90, 100, 110 | 4 levels of service |
| | Main Trunk Road - National | 70, 80, 90, 100, 110 | 4 levels of service |
| | Trunk Road - City | 50, 60, 70, 80, 90 | 4 levels of service |
| | Distributor - DistrictConnection | 50, 60, 70, 80 | 4 levels of service |
| | Local Collector | 50, 60 | 4 levels of service |
| | Access - Residential | 30, 40, 50 | 4 levels of service |
| Rural | Motorway | 80, 90, 100, 110, 120, 130, >130 | 4 levels of service |
| | Semi motorway (2+1 lanes, variable) | 90, 110 | 4 levels of service |
| | Trunk Road | 60, 70, 80, 90, 100, 110 | 4 levels of service |
| | Distributor-DistrictConnection | 50, 60, 70, 80, 90, 100 | 4 levels of service |
| | Distributor-DistrictConnection (withCurves) | 50, 60, 70, 80, 90, 100 | 4 levels of service |
| | LocalCollector | 50, 60, 70, 80 | 4 levels of service |
| | Local Collector (with Curves) | 50, 60, 70, 80 | 4 levels of service |
| | Access-Residential | 30, 40, 50 | 4 levels of service |

Table 2: The distribution of vehicle mileage for urban and rural roads in Sweden during 2004

| | Urban | Rural | Total |
|---|---|---|---|
| **State roads** | 15 % | 53 % | 68 % |
| **Municipal roads** | 25 % | 3 % | 28 % |
| **Private roads** | 1 % | 3 % | 4 % |
| **Total** | 41 % | 59% | 100 % |

Table 3: The vehicle mileage in 2004, distributed over the three types of built-up areas

| Type of built-up area | State roads | Municipal & private roads |
|---|---|---|
| **Villages & small towns (200 – 49 999 inh.)** | 58.9% | 58.1% |
| **Towns and small cities (50 000 – 199 999 inh.)** | 12.5% | 16.5% |
| **Large cities (> 200 000 inh.)** | 28.6% | 25.4% |
| **Total** | 100% | 100% |

Table 4: The ten most common TS in Sweden in 2004, and their share of the total vehicle mileage

| Description of traffic situation | Vehicle mileage |
|---|---|
| Rural / Distributor-District connection / Speed limit: 90 km/h / Free flow | 21.3% |
| Rural / Distributor-District connection / Speed limit: 70 km/h / Free flow | 11.1% |
| Rural / Motorway / Speed limit: 110 km/h / Free flow | 10.7% |
| Urban / Local collector / Speed limit: 50 km/h / Free flow | 9.7% |
| Urban / Access-Residential / Speed limit: 50 km/h / Free flow | 6.6% |
| Urban / Distributor-District connection / Speed limit: 70 km/h / Free flow | 5.9% |
| Rural / Local collector / Speed limit: 70 km/h / Free flow | 5.7% |
| Urban / Distributor-District connection / Speed limit: 50 km/h / Free flow | 4.8% |
| Urban / Access-Residential / Speed limit: 30 km/h / Free flow | 2.2% |
| Rural / Trunk road / Speed limit: 110 km/h / Free flow | 2.0% |
| **Total** | **79.9%** |

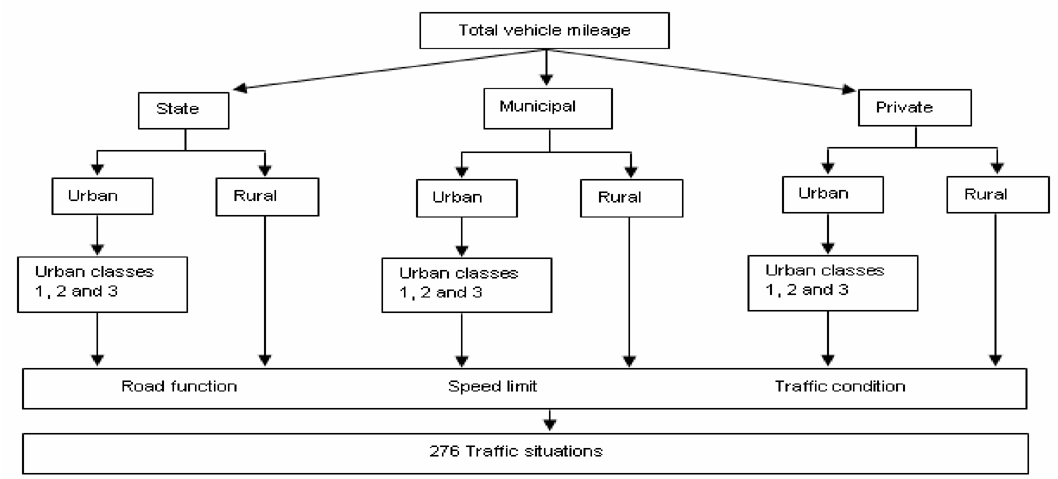
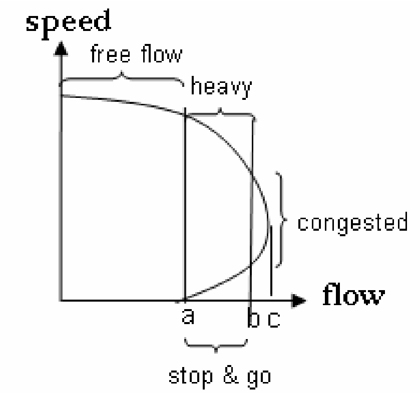



Figure 1. An overview of the distribution of vehicle mileages in the top-down model.




| Road speed limit | Capacity (c in figure veh./lane*h) | Condition 1 "Free flow" (a in figure) | Condition 2 "Heavy" (a-b) | Condition 3 "Congested" (b in figure) |
|---|---|---|---|---|
| **90+** | 2000 | <1300 | 1300-1700 | ≥ 1700 |
| **70** | 1550 | <600 | 600-1300 | ≥ 1300 |
| **50-** | 1150 | <600 | 600-900 | ≥ 900 |

Figure 2. Principles for classifying different flows (vehicles/lane*hour) on roads links with different speed limits as ARTEMIS traffic conditions 1-3. Limits for different traffic conditions were extracted from TU71 volume delay functions (Matstoms, 2004).

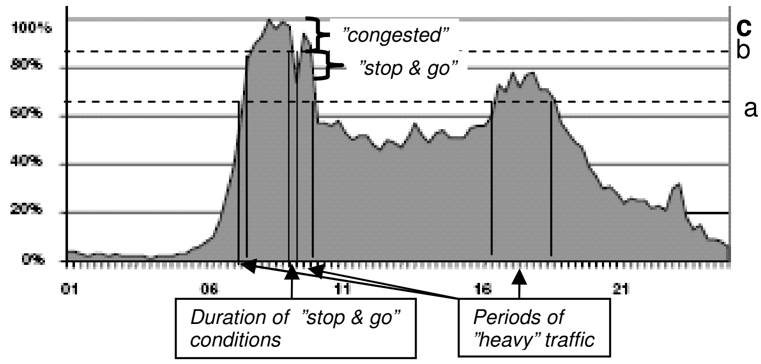



Figure 3 Principle for quantification of stop & go conditions on congested roads. a, b and c refer to Figure 2.

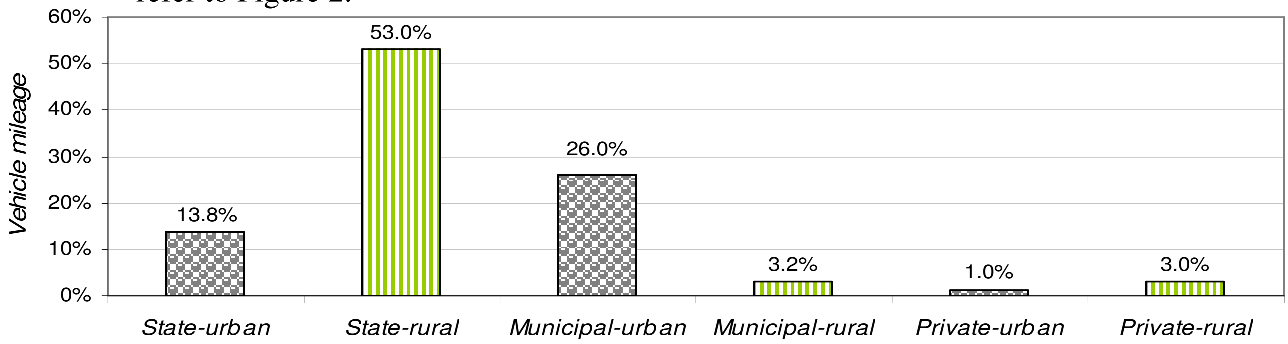



Figure 4 Distribution of vehicle mileage in Sweden on urban and rural roads for different road administrations for the year 2004.