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Statistical and Methodological Foundations of the GIDAS Accident Survey System

Abstract

In Germany, in-depth accident investigations are carried out in the Hannover area since 1973. In 1999 a second region was added with surveys in Dresden and the surrounding area. Internationally, the acronym GIDAS (German In-Depth Accident Study) is commonly used for these surveys. Compared to many other countries, the sample sizes of the GIDAS surveys are much larger. The goal is to collect 1.000 accidents involving personal injuries per year and region.

Data collection takes place by using a sampling procedure, which can be interpreted as a two-stage process with time intervals as primary units and accidents as secondary units. An important question is, to what extend these samples are representative for the target population from which they are drawn. Analyses show, for example, that accidents with persons killed or seriously injured are overrepresented in the samples compared to accidents with slightly injured persons. This means, that these data are subject to biases due to uncontrolled variation of sample inclusion probability. Therefore, appropriate weighting and expansion methods have to be applied in order to adjust or correct for these biases.

The contribution describes the statistical and methodological principles underlying the GIDAS surveys with respect to sampling procedure, data collection and expansion. In addition, some suggestions regarding potential improvements of study design are made from a methodological point of view.

Introduction

In-depth accident investigations represent an important basis for empirical traffic safety research. At national and international level various analyses and comparisons are carried out on the basis of “in-depth data”. These data play a decisive role for example within the validation of EuroNCAP results on secondary safety of individual passenger car models. Consequently, statistically sound methods of data analysis and population parameter estimation are of high importance.

In Germany, in-depth accident investigations are carried out in the Hannover area since 1973. In 1999 a second region was added with surveys in Dresden and the surrounding area. Internationally, the acronym GIDAS (German In-Depth Accident Study) is commonly used for these surveys. Compared to many other countries, the sample sizes of the GIDAS surveys are much larger. Moreover, data collection takes place by using a sampling procedure, which can be interpreted as a two-stage process with time intervals as primary units and accidents as secondary units.

The contribution describes the statistical and methodological principles of the GIDAS survey system with respect to sampling procedure, data collection and expansion. By the end of last year IVT finished a research project on behalf of BASt which was dealing with examining and adjusting the previous weighting and expansion methods for the two regional accident investigations, using data from the years 2000 and 2001 [1].

Finally, some suggestions regarding potential improvements of study design are made from a methodological point of view.

The Project GIDAS: In-Depth Investigation on Scene in the Hannover and Dresden Areas

Investigation methodology

One of the main characteristics of in-depth accident investigations is that the research team arrives on scene and starts collecting the accident data immediately after having been alarmed by the police, rescue services, or fire department headquarters (“on scene” and “in time”). Apart from the acquisition of accident data on site (gathering information, taking pictures, etc.), the process of data collection also covers additional phases like the interrogation of witnesses or the collection of data at different places (e.g. hospitals, scrap yards). Basically, in-depth data can also be collected exclusively in retrospect by ex post examination of

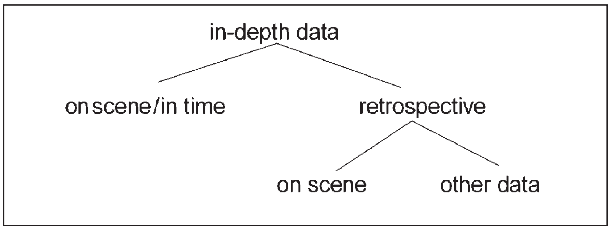

Figure 1: Categorisation of in-depth data on road traffic accidents

the spot of accident ("on scene") or by gathering relevant data solely at other places.

Accident investigation in the Hannover and Dresden areas takes place daily during two six-hour time intervals (so-called shifts) following a 2-week cycle. During the first week data collection is carried out from 12:00 a.m. to 06:00 a.m. and from 12:00 p.m. to 06:00 p.m. and within the second week those accidents are documented that occur during the other two intervals. So, the premise for the acquisition of accident data is that the accident occurs within the respective time interval and within the demarcated investigation area. In any case, however, only accidents involving personal injury are taken into consideration.

Within the shifts, the first reported accident involving personal injury is recorded by the team and subsequently all other accidents. Due to the fact that data acquisition on scene takes about one hour per accident, overlapping of accidents is possible. In this case, the most current accident after reestablishment of the operational readiness of the team is registered.

Each research team consists of two technicians, a physician and a co-ordinator and has two vehicles at its disposal. While the technician's vehicle remains at the scene of accident, the physician's vehicle, if necessary, accompanies injured persons to the hospital.

The goal is to collect 1.000 accidents involving personal injuries per year and region. For each accident hundreds of variables are recorded covering data on accident situation (for example traffic regulation), involved vehicles and persons, as well as information on vehicle deformation and injury patterns. Moreover, an accident reconstruction takes place.

GIDAS survey plan from a sampling point of view

Target population and Ample

Concerning the sampling procedure, the target population of the GIDAS sample consists of all police-recorded accidents involving personal injuries which occur in the Hannover and Dresden areas. Accidents which are reported neither to police nor to the rescue services do, strictly speaking, not belong to the target population, since they are not included in the official accident statistics and, therefore, cannot be considered in the expansion factor.

The sampling units – that means the accidents – can be seen as "events" occurring in time and space. For this reason, at the beginning of the survey period there is no list containing all elements of the target population which could serve as a sampling frame. Moreover, neither the annual sample size nor the size of the target population is known in advance.

Selection of time clusters as primary units

Since the 1st of August 1984 the "in-depth investigations on scene" in the Hannover area have been carried out according to a sampling plan developed by HAUTZINGER [2] in the context of a research project on behalf of BASt. This sampling plan corresponds to a two-stage selection procedure. The first stage is to randomly select time intervals as primary units. Here, the primary units correspond to time clusters of accidents. Due to organisational reasons, for each calendar week two basic types of survey intervals exist.

Type A: where data collection is carried out daily between 12:00 a.m. and 06:00 a.m. and between 12:00 p.m. and 06:00 p.m.

Type B: where all accidents are documented which occur between 06:00 a.m. and 12:00 p.m. and between 06:00 p.m. and 12:00 a.m.

Over the year, the time clusters according to the two basic types are selected alternately, that means, first week type A, second week type B, third week Type A, fourth week type B and so on. Thus, the selection of primary units can be regarded as a systematic sample with sampling interval 2:

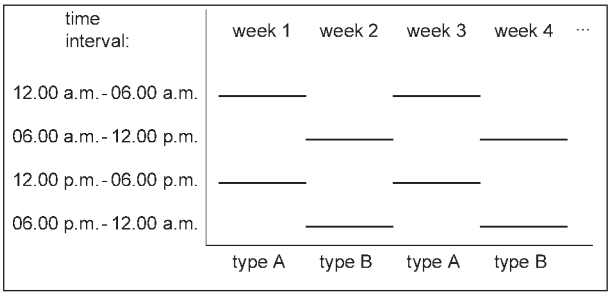

Figure 2: Systematic selection of time intervals

Due to this procedure all parts of the year are equally covered by the sample. So, with respect to the selection of primary units, this systematic sampling is even superior to simple random sampling of time intervals.

Assuming perfect preconditions, this means that within each selected time interval all police-recorded accidents are reported to the investigation team and all reported accidents are documented by the team, this selection of time intervals would be absolutely sufficient. But these ideal preconditions are not given in practice: on the one hand not all police-recorded accidents are reported to the research team and on the other hand not every reported accident can be documented by the team. Therefore, a sampling procedure at the second stage, this means for the selection of accidents within the selected time intervals, is needed.

Selection of accidents as secondary units

With regard to selection at the second stage, special emphasis has to be given to the documentation of as many accidents as possible. For this reason the first reported accident of a selected time cluster has to be documented and after that all other reported accidents as far as the team is ready for operation. In the case of overlapping of accidents, the most current accident after reestablishment of the operational readiness is documented.

From a statistical point of view, inclusion in the sample depends on the results of two subsequent random experiments. On the basis of a first random experiment it is determined whether or not a police-recorded accident is reported to the survey team. In case of an incoming report a second random experiment determines whether or not an accident will be registered by the team. The accident will be documented either if at the corresponding point in time the team is ready for operation or if the reported accident is the most recent reported accident after reestablishment of operational readiness of the team.

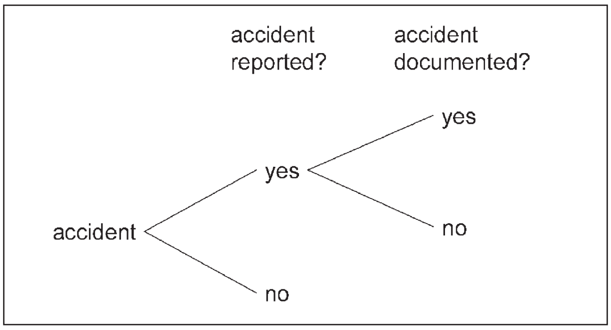

Figure 3: Selection of accidents

An important question is, to what extent these samples are representative for the target population from which they are drawn. Representative means, that the obtained results can be generalised from the sample to the population which normally consists of all injury accidents in the study region. Even if the in-depth study is based on a well specified random sampling scheme the empirical data actually collected might be biased. Analyses of GIDAS data show, for example, that accidents with persons killed or seriously injured are overrepresented in the sample compared to accidents with slightly injured persons. For in-depth studies which, unlike GIDAS, are not built upon a proper sampling plan, the biases due to uncontrolled variation of sample inclusion probability might be even more severe. In several European in-depth studies purposive rather than random selection of accidents takes place.

Selection probabilities

If we assume for the moment that accident severity is the only determining factor for the reporting or non-reporting of an accident, the reporting rates shown in the first column of Table 1 are obtained.

In contrast to accidents with slightly injured persons, accidents with seriously injured persons or persons killed are significantly more frequently reported to the investigation team. Of course, a reporting rate of 100 percent within each category would be ideal.

The next column shows, to which extent the reported accidents are actually documented. The percentages vary between 85 and 96 percent; the ideal case would be given if these rates were identical.

	percentage reported	percentage documented	selection probability (%)
accident with slightly injured persons	34.3	84.5	29.0
accident with seriously injured persons	66.3	88.4	58.6
accident with persons killed	75.0	96.3	72.2

Table 1: Selection probabilities (Hannover area, year 2000) [3]

The third column finally shows the resulting selection probabilities. While an accident with slightly injured persons is selected with a probability of about 30%, the inclusion probability for an accident with persons killed amounts to more than 70%.

These analyses show that the raw GIDAS sample is subject to biases due to uncontrolled variation of sample inclusion probability – at least with respect to accident severity. Due to small sample sizes or imperfect data collection procedures, in-depth traffic accident data are often susceptible to a lack of representativeness with respect to the underlying target population. Taking this into account, an appropriate weighting procedure is needed for in-depth data in order to remove these biases as far as possible. The variables to be used for this weighting process must, of course, be available in the official accident data files and should be correlated highly with as many as possible “true” in-depth accident characteristics. By adjusting the sample joint distribution of certain structural variables (e.g. road type and accident outcome severity) to the corresponding distribution in the population of all accidents as recorded in national statistics, the accuracy of estimates referring to the true in-depth variables (e.g. collision speed) can be improved.

Weighting and Expansion

Previous weighting procedure

At present, the GIDAS weighting procedure is based on the characteristics

- severity of accident (accident with slightly injured persons, with seriously injured persons, with persons killed),
- locality of accident (within built-up areas, outside built-up areas) and
- time interval of accident occurrence (12:00 a.m. –06:00 a.m./06:00 a.m.–12:00 p.m./12:00 p.m. –06:00 p.m./06:00 p.m.–12:00 a.m.).

The weighting procedure consists of an adjustment of the three-dimensional sample contingency table to the corresponding table for the target population from official accident statistics.

Alternative weighting methods

Within a project on expanding GIDAS data to the regional and national level IVT developed and tested alternative methods for the expansion of the Hannover sample to the Hannover area and to Germany, for the expansion of the Dresden sample to the Dresden area and to Germany, and for the expansion of the pooled sample (Hannover plus Dresden) to Germany.

There are several alternatives to carry out such weighting and expansions procedures, among them two-stage and hierarchical methods:

Two-stage procedures. As mentioned before, the in-depth investigations in the Hannover and Dresden areas are based on a two-stage sampling process. According to the principles of sampling theory, it would be most natural to use a two-stage expansion methodology. Here, in a first step the secondary units (accidents) have to be expanded to the primary units (parts of calendar weeks) and after that the expansion of the primary units takes place.

Hierarchical methods. The principle underlying hierarchical weighting procedures is also an adjustment of multi-dimensional tables to the corresponding tables from official accident statistics. However, due to restrictions with respect to the number of cases, a certain weighting variable is adjusted only within selected categories of another weighting variable.

Hierarchical weighting procedure

For example, for the regional expansion of the GIDAS data 2000 and 2001 a hierarchical weighting procedure was developed which is based on the variables

- severity of accident (accident with slightly injured persons, with seriously injured persons, with persons killed) and

- time interval of accident occurrence (as before)
- and kind of accident.

It was assumed that locality of accident is strongly correlated to accident severity and, therefore, using one of them in the weighting procedure might be sufficient. Moreover, it was hoped that considering the variable "kind of accident" in the weighting process will compensate possible biases which are due to the fact that the process of data collection takes longer for accidents with a relatively large number of road users involved, which in turn might lead to an overrepresentation of these accidents. Here, the new variable kind of accident is considered only in connection with accidents with slightly injured persons.

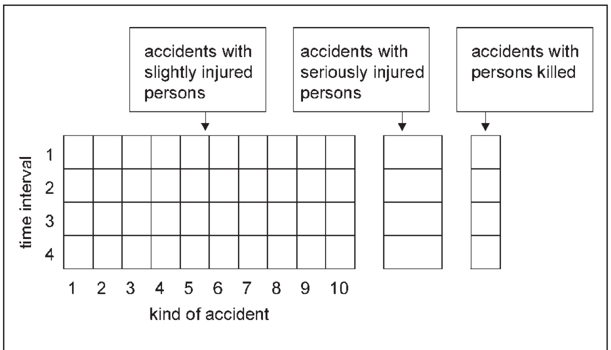

Figure 4: Hierarchical weighting scheme

The weighting procedure can be illustrated by the Figure 4.

Accidents with slightly injured persons are further subdivided by time interval and kind of accident, whereas accidents with seriously injured persons or persons killed are subdivided only by time interval.

Results: expansion of Hannover data 2000 and 2001 to the regional level

Table 2 summarises the results of a regional expansion of the Hannover data 2000 and 2001. The figures in the table represent measures of the goodness-of-fit of weighted distributions for several accident criteria resulting from different expansion methods. On the basis of data from the year 2000

variable	2000				2001			
	unweighted distr.	previous weighting method	2-stage weighting method	hierarchical method	unweighted distr.	previous weighting method	2-stage weighting method	hierarchical method
	Goodness-of-fit measure V							
severity of acc.	0,35	0,01*	0*	0*	0,29	0*	0*	0*
time interval	0,16	0,01*	0*	0,01*	0,09	0*	0*	0,02*
locality	0,07	0*	0*	0	0,13	0*	0*	0,06
kind of accident	0,32	0,28	0,26	0,03*	0,28	0,24	0,25	0,02*
number of road users involved	0,10	0,08	0,06	0,11	0,12	0,07	0,05	0,15
light conditions	0,03	0,05	0,06	0,06	0,05	0,02	0,05	0,01
road class	0,17	0,13	0,14	0,11	-	-	-	-
type of acident	0,38	0,34	0,35	0,30	-	-	-	-
influence of alcohol	0,07	0,06	0,05	0,07	0,02	0	0,03	0,02
obstacles next to carriageway	-	-	-	-	0,20	0,14	0,14	0,11
age group	0,10	0,11	0,10	0,08	-	-	-	-
gender	0,04	0,04	0,03	0,01	-	-	-	-
holding period of driving license	0,04	0,05	0,07	0,06	-	-	-	-
injury severity	0,23	0,07	0,06	0,05	-	-	-	-
transport mode	0,15	0,14	0,17	0,14	-	-	-	-
total	2,21	1,37	1,35	1,03	1,18	0,47	0,52	0,39
total without weighting var.	1,31	1,07	1,09	0,99	0,39	0,23	0,27	0,29
* weighting variable								

Table 2: Goodness-of-fit of weighted distributions for several accident criteria resulting from different expansion methods (regional expansion of Hannover data 2000 and 2001)

analyses have also been carried out at the level of road users involved. The goodness-of-fit measure V is based on chi-square ($V = \sqrt{\chi^2 / n}$); the lower the value, the better the fit of the distribution compared to the one from official accident statistics.

The table shows that appropriate expansion and weighting procedures can substantially improve the accuracy of data from in-depth investigations (for example road class or injury severity). However we did not succeed in finding a weighting scheme where it was possible to simultaneously improve the accuracy of all variables under consideration. In connection with the two-stage expansion method it was found that the theoretical advantages of this method compared to the simple weighting procedure are relatively small, especially, if one takes into account the complexity of the calculation process necessary to obtain the corresponding expansion factors.

Of course, the main objective of expanding in-depth data to the target population is to expand variables which are not included in the official accident statistics (e.g. AIS, EES, etc.). Here, variables which are contained both in the sample and in the official statistics have been analysed in order to check the goodness-of-fit of the weighted sample distributions.

Potential Improvements of Study Design

The results of the expansion show that even with alternative, mostly hierarchical weighting procedures it is not possible to adjust all variables for which the distributions from official accident statistics are known with sufficient accuracy to the basic population. So it can be expected that the same occurs when expanding true in-depth variables like collision speed, for example. As a consequence, at least for research topics of particular importance it is recommended to develop an individual, i.e. variable-specific weighting scheme for the respective accident characteristic under investigation.

Usually, accident characteristics which are recorded by police are also collected by the in-depth investigation team. However, it might well be that these two different measurements do not yield the same results, e.g. if police assigns an accident to another kind of accident than the research team does. It is important to say that in any case the police recorded data (standard traffic accident reports) of the accidents in the sample have to be used for expansion purposes. Even if the data from the in-depth investigation team are more precise it would not be correct to base the weighting factors on them, because in this case some of the accidents in the sample would be assigned to the wrong stratum (according to the target population).

With respect to expansion it is therefore inevitable to add the complete catalogue of variables of the standard traffic accident report to each documented accident. However, partially the problem exists that there are some discrepancies between the standard traffic accident report filled in by police and the official database, which are due to plausibility checks and data adjustment. Thus, here also the problem appears that according to the standard traffic accident report some accidents are assigned to another stratum than according to the official database. From a methodological point of view it would be favourable if the standard traffic accident reports in the Hannover and Dresden area would be supplemented by the GIDAS case number as far as the accident has been documented by the GIDAS team. This would make it possible to merge the in-depth data with the police-recorded data by case number of accident.

Finally, there are several possibilities to improve the current sampling and data collection procedure in order to obtain representative results. For example, in time intervals with high accident intensity one could work with two teams in parallel in order to be able to collect all accidents reported within the shift. In this case the sampling procedure would be closer to a one-stage cluster sampling which from a methodological point of view has some advantages compared to the present two-stage procedure.

Alternatively at least the fatal accidents could be completely collected in retrospect. I.e., fatal accidents which are not reported to the team or could not be documented during the shift would as far as possible be collected retrospectively. This could even be extended to accidents which do not occur during the selected time intervals.

Lastly, it is advisable to co-ordinate the surveys in the Hannover and Dresden area regarding the teams' operation intervals. I.e., that the two daily shifts should not run in parallel. Rather, if the Hannover team covers the shifts 12:00 a.m. to 06:00 a.m. to 12:00 p.m. and 06:00 p.m. the Dresden team should cover the shifts 06:00 a.m. to 12:00 p.m. and 06:00 p.m. to 12:00 a.m. so that across the two areas all four types of selection intervals occur with the same frequency in each week of the year. This procedure would particularly be favourable with respect to the national expansion of GIDAS data.

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