INTACT Final Report:

Methodology Development for Advanced Accident Investigations - INTACT
Version 1.0

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SUMMARY

Road traffic accidents continue to be an important health issue for society, both in terms of personal injury and cost. It is of great importance to reduce the number of all accidents and in particular reduce the number of fatalities and personal injuries. There is a need to understand the causes of road traffic accidents and personal injuries to be able to suggest proper and effective counter-measures. Investigations of road traffic accidents and storage of the results in databases provide one way to increase our knowledge.

In-depth databases exist both internationally and in Europe. In Sweden, investigations of road crashes have been undertaken by the vehicle industry, the Swedish Road Administration, hospitals and universities for many years. The existing official databases the organisations have access to do not fulfil the demands for technology development, especially for vehicle active safety systems and understanding pre-crash conditions. Research aInMeDe at increasing road safety has a high demand on information derived from real-world traffic accident data. A need for increased knowledge about injury outcome and the long term consequences of injures was also identified.

In 2007 an initiative from vehicle manufacturers, safety system suppliers, the Swedish Road Administration and universities in Sweden took off. It was run as a three-year research project called INTACT (Investigation Network and Traffic Accident Collection Techniques), and had three purposes: to develop an investigation network; to develop and evaluate an advanced methodology to collect data and analyse real-world traffic accidents and store the information in a database; and to prepare INTACT for an initiative on a European level.

In 2007 sampling criteria and a set of variables as a minimum base for the accident investigations were defined. An inventory of activities and methods was used for the development of the INTACT methodology and a pilot study was performed. In 2008 methods for retrieving the data from accidents were tested and further developed in real-world on-scene and retrospective investigations. In 2009 the methodology was fine-tuned and tested in real-world on-scene investigations and the INTACT database system was finalized. A total number of 123 accidents including pilot cases and special investigations have been investigated and 110 accidents, those investigated according to a consistent methodology in phases 1 and 2, have been entered into the database.

An investigation process covering all phases of a crash and all parts of the road system has been developed. The INTACT accident investigation process consists of two parts, data collection and case analysis, and both are supported by protocols and routines. Data collection consists of accident site investigation, vehicle inspections, driver interviews and retrieval of medical records. Case analysis consists of pre-crash analysis, injury mechanism analysis, reconstructions and long term injury follow-up. A database for storage of data and an on-line manual were developed.

ABBREVIATIONS

CCIS	Co-operative Crash Injury Study
CIREN	Injury Research and Engineering Network
Delta V	Velocity Change during an Impact
DBMS	Database Management System
DREAM	Driver Reliability Error and Analysis Method
DSDM	Dynamic Systems Development Method
EDR	Event Data Recorder
EES	Energy Equivalent Speed
FICA	Factors Influencing the Causation of Accidents and incidents
GIDAS	German In-Depth Accident Study
HVE	Human-Vehicle-Environment Simulation Software for simulating vehicle accidents
INTACT	Investigation Network and Traffic Accident Collection Techniques
NASS-CDS	National Automotive Sampling System – Crashworthiness Data System
NVDB	Nationell VägDataBas (the Swedish national road database)
OTS	On-The-Spot
STEP	Sequentially TInMeDe Events Plotting
STRADA	Swedish TRaffic Accident Data Acquisition
TIKK	Clickable Traffic Information Maps
XML	Extensible Markup Language

DEFINITIONS

Accident investigation

Acquisition of factual information regarding an accident (note: can include on-scene elements, elements recorded retrospectively, or both of these) [ISO 12353–1:2002]. In INTACT it includes both "data collection" and "case analysis".

Accident notification

A message from the emergency service (SOS-alarm) is sent to the on-scene team when an accident occurred (according to the sampling criteria).

Accident scene

The area of a traffic accident before the vehicles and people involved have left [ISO 12353–1:2002].

Accident site

The geographic location of the accident scene (note: the accident site may be given as exact coordinates or in a less detailed way) [ISO 12353–1:2002].

Accident Phases

A traffic accident can be divided into three phases:

Pre-crash phase

The pre-crash phase starts when the trip begins and ends when contact with a collision object or a roll-over occur. Relevant background factors beyond those in the pre-crash phase are included in the INTACT pre-crash analysis.

In-crash phase

The in-crash phase starts when contact with a collision object or a roll-over occurs and ends at final rest position.

Post-crash phase

The post-crash phase starts at final rest position and ends when the road user rescue is finalised (drop-off at hospital). Long term injury follow-up is included in the INTACT post-crash analysis.

The three phases can differ between the different road users in the same accident.

Case analysis

The analysis of available data and computation or coding of new data after completion of data collection by the case group.

Case group

A multidisciplinary group of investigators collecting and analysing data about a specific accident.

Case

A case is a separate accident that has been chosen for accident investigation. A case is opened the moment an accident is being chosen for investigation. Each accident investigation is treated as a case.

Case leader

A case leader is the investigator responsible for and in charge of a case.

Data analysis

Aggregated analysis of finalised cases.

Data collection

Collection of objective data either on-scene or retrospectively or retrieval of data from other sources (including subjective information, such as interviews).

Element

Vehicles and vulnerable road users are referred to as elements in INTACT. An element can be a car, heavy truck, bus, pedestrian or other vehicle (bicycle, MC, moped, tram etc.)

Investigator

A person with expert knowledge in one or more areas of accident investigation

On-scene (accident) investigation

Accident investigation conducted at the accident scene with the purpose of collecting on-scene information before physical evidence (e.g. the vehicles involved) has been removed [ISO 12353–1:2002].

On-scene team

A team of investigators who are members of a case group, ready to respond to an accident notification and perform on-scene investigations.

Operations manager

Person in charge of the running of the project

Published case

When a case has enough data (according to defined criterion) to be viewed by others than the case group.

Retrospective (accident) investigation

A complete accident investigation conducted retrospectively, i.e. no on-scene investigation is conducted.

Retrospective inspection

When an on-scene accident investigation has been conducted, retrospective inspections of vehicles is conducted.

Retrospective team

A team of investigators who are members of a case group performing retrospective investigations.

Sampling criteria

Principals of evaluation of scope and coverage of an accident investigation referring to different aspects [ISO 12353–1:2002].

Task

A task is a piece of work in the investigation process. All tasks are assigned to an investigator role.

Team organizer

Person in charge of the investigators, monitors progress and assigns case leaders.

Variable

A piece of information relating to an item in an accident investigation that can have different values, either discreet values (e.g. “car body style” can have the possible values of “Sedan”, “Hatchback/wagon”, “Sports”, “Convertible”, “Derivative”, “Off-road/SUV”, “MPV/Minibus”, “Pick-up” and “Van”) or continuous values (e.g. lane width that has values increasing from 0 meters).

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1 INTRODUCTION

Road traffic accidents today are a big problem, both in terms of personal injury and in terms of cost. The WHO World Report on Road Traffic Injury Prevention (Peden et al., 2004) estimates that 1.2 million people die and up to 50 million people are injured every year. In Europe, 34,000 people died due to road accidents in 2009. In Sweden, the Vision Zero target for 2020 is a maximum of 220 fatalities. Therefore, it is of great importance to reduce the number of fatalities, injuries and accidents. To do this, there is a need to understand the underlying mechanism to accidents and injuries to be able to suggest proper and effective counter-measures. Investigations of road traffic accidents and storage of the results in databases provide one way to identify these mechanisms.

1.1 Background to INTACT

A number of in-depth databases exist around the world. One of the longest running and largest in-depth activities has been active since the 1970s, the NASS-CDS (National Automotive Sampling System - Crashworthiness Data System) [1] in the USA. Data collected in NASS-CDS are used to investigate injury mechanisms to identify potential improvements in vehicle design. More recently, CIREN (Crash Injury Research and Engineering Network) started which includes fewer cases but has more depth, focusing on improving the prevention, treatment and rehabilitation of car crash victims [2]. In Europe, there are some well established national in-depth accident databases existing in e.g. Germany (GIDAS), France, Finland and the UK (CCIS and OTS).

In Sweden, investigations of road crashes have been undertaken by the vehicle industry, the Swedish Road Administration, hospitals and universities for many years. Naturally, the organisations have focused the investigations on areas where safety measures could be foreseen and implemented. So far, these organisations usually have made the investigations separately and without much formal cooperation between each other in cases where two or more of the organisations were involved. They may have focused on specific accident factors and used investigation routines which are unique for each organisation. Multiple investigations, made by different organisations in parallel, inevitably create redundancies and different ways of data interpretation. Persons involved in accidents also may choose not to take part in more than one investigation. This may limit the extent to which an accident can be investigated with regard to accident phases and involved elements.

It was recognised that the existing official databases which the organisations participating in INTACT had access to did not fulfil the demands for technology development, especially for active safety systems in vehicles and in understanding the pre-crash conditions. Current and future research aiming at increasing road safety with regard to active and passive safety of vehicles, safety of the road environment and human behaviour in specific road traffic situations have a high demand on information that is derived from real-world traffic accident data. A need for more knowledge about injury outcome and the long term consequences of these injures were also identified.

Therefore, a national initiative from vehicle manufacturers, safety system suppliers, the road administration and universities in Sweden took off in 2007. The initiative was formally run as a project with the acronym INTACT (Investigation Network and Traffic Accident Collection Techniques), and had a three-year project plan. Eight organisations were involved in the project which built upon an active interaction between the partners representing academy, society/authority and industry.

The following organisations were represented in INTACT:

- Chalmers University of Technology and Gothenburg University from academy
- Swedish Road Administration[1] from society/authority
- Autoliv, Saab Automobile, Scania, Volvo Cars and Volvo Trucks and Busses from industry.

The project was financed by the industry partners and the research program IVSS (Intelligent Vehicle Safety Systems) with a total amount of 33 MSEK.

Six out of the eight partners in INTACT already had an infrastructure for accident investigations. Saab Automobile, Scania, Volvo Cars and Volvo Trucks investigate crashes where vehicles from their brands are involved. The Swedish Road Administration investigates all fatal crashes in Sweden and Chalmers University of Technology is involved in several national and European studies where accidents are investigated. The Traffic Injury Register at the Department of Orthopaedics, Sahlgrenska University Hospital, has been involved in different studies on injury mechanisms and accident consequences together with several INTACT partners. As all these organisations are acting in the greater Gothenburg area, there was a substantial need to harmonise methods and streamline the investigations. It was recognised in the partnership that a holistic view of accidents investigations was important to fulfil all needs.

1.2 Purpose and Aims

1.2.1 Purpose of the Project

The Swedish national initiative for advanced crash investigations, INTACT, had three purposes.

The first purpose was to develop a national investigation network, i.e. a network of partners active in the field of accident investigations and traffic safety who contribute to and benefit from the project.

The second purpose was to develop and evaluate an advanced methodology to collect data and analyse real-world traffic accidents and store the information in a database.

[1] The Swedish Road Administration and the Swedish Rail Administration were amalgamated on 1 April 2010 to form the Swedish Transport Administration. The new name is used in this report.

The third purpose was to prepare INTACT for an initiative on a European level, where INTACT can be one of the nodes for contributing to a European in-depth accident database.

1.2.2 Aims of the Project

The INTACT project had three main aims.

The first aim was to develop a national investigation network and an investigation methodology focusing on all phases of a crash (pre-crash, in-crash and post-crash) as well as all parts of the road transport system (road user, vehicle and road environment). The objectives were

1. To define sampling criteria for accident investigations and set up a sampling plan to fulfil these
2. Define data variables to be collected or retrieved through computation or analysis
3. Develop operational routines and theoretical methods for collection of high quality data and for case analysis
4. Documentation of the final methodology
5. Investigate 100-300 real-world accidents to evaluate the developed methods

The second aim was to develop a system and create a database with data from real-world traffic accidents. These data should be a complement to STRADA and the two databases combined should provide the diversity and depth needed to get a basis for prioritising measures, a deeper understanding of factors causing accident and injury, develop safety systems, get the possibility to evaluate safety measures and be a foundation for influencing legislation. The objectives were

6. Develop a software tool for storage and analysis of data
7. To electronically store data from the investigated real-world accidents in a database

The third aim was to prepare INTACT for an initiative on a European level where INTACT can be one of the nodes for contributing to a European in-depth accident database. In line with this, it was decided that the methods, as far as possible, should not be constrained to national limitations and all documentation from the project should be in English.

2 DEVELOPMENT OF METHODOLOGY

2.1 Overview of the INTACT Project

The INTACT project was divided into three phases which each lasted one year.

2.1.1 Phase 1, 2007

During the first phase of the project, the partners shared their expertise in behavioural science, medicine, biomechanics, vehicle design, and road design to agree on sampling criteria and a set of variables as a minimum base for the accident investigations. An inventory of previous and running activities and methods in-house, nationally and internationally, was used for the development of the INTACT methodology. The work packages started in the first phase were:

1. Sampling criteria
2. Variables and definitions
3. Pre-crash method (data collection and analysis)
4. Routines and protocols for data collection and analysis (in-crash and post-crash)
5. Accident investigation team requirements
6. Technical tools for data collection
7. Database requirements
8. Data collection (pilot)
9. Review phase I
10. Legal issues

2.1.2 Phase 2, 2008

Methods for retrieving the data from the accidents were tested in real-world investigations during the second year of the project. There are two major investigation methods for traffic accidents; on-scene and retrospective investigations and both methods were evaluated.

An on-scene investigation is defined as *Accident investigation conducted at the accident scene with the purpose of collecting on-scene information before physical evidence (e.g. the vehicles involved) has been removed [ISO 12353–1:2002].* The purpose of an on-scene investigation method is to collect physical evidence before it has been removed which means that the investigation team departs directly after notification to an accident scene when the accident occurs.

In a retrospective investigation, the accident scene is not inspected directly when the accident has occurred and the vehicles involved are usually removed from the scene. Instead, data collection at the accident site is performed post hoc. This allows the sampling time to be outside ordinary working hours. There are also retrospective elements in an on-scene investigation such as vehicle inspections.

A lot of effort was put into the development of a web based manual, in order to have a uniform way of working among the partners. In the web based manual editions can be made online and changes will take effect immediately. The manual include all routines and variable definitions developed for data collection and case analysis. Major efforts were also put into the development of the INTACT system for storage and analysis of data.

The work packages started in the second phase were:

11. Investigation manual
12. Training
13. Database development
14. Review phase 2

2.1.3 Phase 3, 2009

In the last year of the project most of the effort was put into fine-tuning the methods developed during phase I & II and test them in real-world accident investigations and to finalize the INTACT database system. Except the work packages already open, the ones defined in phase III were:

15. Project continuation and national expansion
16. Analysis of the collected data
17. Evaluation and final report

2.2 Investigation Method, On-scene and Retrospective

Both on-scene and retrospective accident investigations were evaluated in the different phases of INTACT (Table 1).

Table 1. Investigation methods evaluated in the different data collection periods of INTACT.

Period	Dates	Investigation type
Pilot	071001 – 071031	On-scene/retrospective
1	080310 – 080404	Retrospective
	080407 – 080430	On-scene
2	080602 – 080804	On-scene
	080602 – 080804	Retrospective
3	080915 – 081205	On-scene
4	090302 – 090626	On-scene
5	090810 – 091016	On-scene
6	090101 – 091031	Retrospective, Heavy truck
7	091123 – 091206	On-scene, Night

After the first two periods in phase 2, it was decided to use on-scene investigations only as the percentage of dismissed cases was much larger for retrospective investigations than on-scene investigations and the quality of collected data was higher in on-scene investigations. There was no significant difference in time consumption between retrospective and on-scene investigations.

Retrospective investigations were reintroduced for period 6. The purpose was to increase the number of severe accidents involving heavy trucks. A deviation from the decided sampling criteria and accident investigation method was made. For two months, accidents with heavy trucks were investigated retrospectively. The choice of accidents was flexible, but no lane change accidents involving trucks were included and the accidents were decided upon a case to case basis.

On-scene accident investigations during night time were carried out during two weeks in period 7. The study was performed in cooperation with a rescue service station within the INTACT sampling region. Only one investigator manned the shifts as the number of accidents occurring at night was deemed to be low. The safety issues related to being one investigator on-scene were solved by cooperating with the rescue services.

2.3 Sampling Criteria

Work package 1 included the development of sampling criteria for the INTACT project. The sampling criteria were then used to set up a sampling plan.

When setting up an accident investigation activity such as INTACT, an important task is to define a purpose with the investigations. The purpose of the INTACT investigations was to form a basis for safety measures reducing:

- the number of accidents with a passenger car, LGV and HGV or bus involved with personal injury
- the severity of injuries in accidents
- the consequence of sustained injuries in accidents

The first task was to set up a way of notification to determine how INTACT will receive information about road traffic accidents that occur. The notification chosen in the INTACT project was to receive alarms from the SOS Alarm, the emergency call operator in Sweden. The alarms were received through e-mails and short messages service via mobile phones.

The purpose of the sampling criteria was to determine what kind of accidents would be investigated in the INTACT, based on the purpose of the project. The process of defining sampling criteria was iterative where the participating organisations in INTACT defined their needs to fulfil the purpose of INTACT. Since INTACT partners included vehicle industry, authority and universities, these organisations provided different input on sampling criteria.

The process started by each partner filling in their desired levels in a matrix with selected parameters that could influence the sampling criteria. The resulting matrix was discussed, which led to a decision of the sampling criteria. The following parameters were included in the process:

- Accident type (oncoming traffic, crossings, single etc.): All organisations agreed on collecting data for all accident types.

- Collision type (frontal, side, rear end etc.): All organisations agreed on collecting data for all collision types.
- Collision object (vulnerable road users, tree, other vehicle etc.): All organisations agreed on collecting data for all collision objects.
- Driver categories (age, gender etc.): All organisations agreed on collecting data for all driver categories.
- Geographical area: One suggestion was to collect accidents within either 30 or 60 minutes travel time by car from Gothenburg (Figure 1). However, as all police and rescue services operate within municipalities, the easiest way was to use the same geographical limits. The next suggestion was to collect within Gothenburg city and the six surrounding municipalities and within Trollhättan city and the six surrounding municipalities (Figure 2) to be able to sample in two different traffic environments and types of accidents, since single vehicle accidents and rear end collisions differ between the areas according to national statistics. The final decision, based on available resources, was to collect accidents within Gothenburg city and the six surrounding municipalities.
- Motor vehicle: If there are too few accidents in each category of vehicles, it is unlikely that any safety measures for that specific vehicle category can be suggested as the sample size is too small. It was therefore discussed to exclude accidents which did not include cars, trucks or busses. Arguments against excluding e.g. single vehicle accidents with motorcycles were that these accidents often are severe and behaviour is an important factor and possible safety measure were beyond the scope of INTACT, e.g. legal options. The final decision was made based on the argument that the organisations in the project wished to use the accidents in the database to develop safety measures.
- Model year of vehicles: Some of the organisations wished to collect accidents with only newer vehicles and therefore exposure data was collected to ensure that no other criteria such as age of driver would change if a limitation of the model year was set. The final decision was that vehicles of all model years would be included.
- Time of day: Everyone agreed that accident data should include all times around the clock. This is an important factor when striving for representativity.

Figure 1. Gothenburg with approximately 30 and 60 minutes travel time respectively.

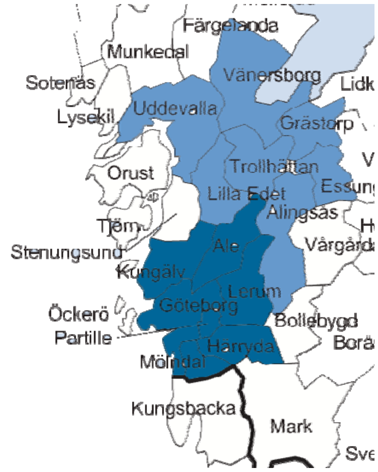

Figure 2. Gothenburg and six surrounding municipalities are shown in dark blue.

- Personal injury: The severity of injury set as a criterion was brought up for discussion. As the aim of the project was to collect accidents with at least one person injured, it was desirable to only receive alarms for accidents with injuries. The best way to achieve that was to collect all accidents where an ambulance was called to the scene for assumed injury.
- Representativity: To decide whether the collected material would be representative or not, it was first decided how the project interprets representativity. The INTACT definition of representativity was that a sample can be representative according to its criteria and does not have to be representative according to all accidents. Using accident statistics from police reports, it was shown that the data collected in Gothenburg with surroundings can only be representative for that area and not for any other part of Sweden or Europe, e.g. due to the number of habitants per area and differences in road types.

The final sampling criteria were:

- **Motor vehicle**: Accidents where at least one of the following vehicle types is involved
  - Car (all categories)
  - Light truck (≤3500 kg)
  - Heavy truck (>3500 kg)
  - Bus (all categories)
- **Personal injury**: An ambulance is called to the scene due to an assumed personal injury.
- **Accident time**: All times of the day will be equally considered.

Table 2. Investigation periods in INTACT with accident shift hours.

Period	Dates	Shift hours when accidents were sampled and investigated
Pilot	071001 – 071031	All times
1	080310 – 080404	All times
	080407 – 080430	06-12 or 12-18
2	080602 – 080804	06-12 or 12-18
	080602 – 080804	18-06
3	080915 – 081205	06-13 or 13-20
4	090302 – 090626	07-13 or 13-19
5	090810 – 091016	07-13 or 13-19
6	090101 – 091031	00-24
7	091123 – 091206	20-07

A sampling plan was set up to fulfil the sampling criteria and strive towards representativity within these chosen sampling criteria. The shifts for accident investigations were planned in a specific time interval considering all times of the day equally. Due to personnel resources, night and weekend accidents were not sampled equally but daytime accidents were (Table 2).

During the pilot, three investigators performed the on-scene investigations. After the pilot, it was decided to only have two investigators for on-scene investigations. Even though there is time pressure to collect all information before the accident is cleared up, two investigators was deemed sufficient.

2.4 Variables and Definitions

Work package 2 included the development of variable lists. The development of variable lists was through an iterative process (Figure 3). Except for the purpose of accident investigations, the variable lists are the basis for all further development of data collection methods and case analysis. Variable lists from previous and running accident collection activities in-house and from other traffic safety-related projects were collected and a first selection was made. For the INTACT project, four variable lists were compiled: accident, road user, vehicle and road variable lists.

Additions to and exclusions from these first variable lists were based on the input from the partners in the project and the purpose of INTACT. Each variable and its possible values were defined and during the investigation periods (Table 1) it was found that some of the variables needed further explanations and updates.

Figure 3 Methodology development process for variables, routines and protocols.

2.5 Development of the INTACT Methodology

To distinguish between factual information and data interpretation it was decided in the beginning of the project to divide an accident investigation into two parts, data collection and case analysis. Data collection was defined as *collection of objective data either on-scene or retrospectively or retrieval of data from other sources (including subjective information, such as interviews)*. Case analysis was defined as *the analysis of available data and computation or coding of new data after completion of data collection by the case group.*

Both data collection and case analysis methods have been developed through an iterative process (Figure 3). The methods used were tested in real-world accident investigations in the investigation periods (Tables 1 and 2). The overall INTACT process, described in chapter 3, includes both new and well-recognised methods.

2.6 Accident Investigations – Data Collection

2.6.1 Accident Scene Inspection

The data to be collected at the accident scene were decided based on the four variable lists. Protocols were developed to support investigators during data collection. The first protocols were designed based on the variable lists for the first trial period. After the trial period, the protocols were re-designed based on the feedback from investigators.

The process of re-designing the protocols after each period continued in periods 1 through 4 (see Table 1) until the protocols were finalized. The re-designing consisted both of changes to the layout to improve usability and changes to the number of protocols. In period 3 two on-scene protocols were used, one for each investigator. A more detailed way of measuring the accident scene which included a choice of X/Y measuring and triangulation was added after period 3 for use in period 4. After period 4 only small changes were made and in period 5 the final protocols were used.

The tools used for data collection at the accident scene were defined before the pilot period and continued in use during periods 1 to 7. The tools were measuring wheel, measuring tape, spirit level, road temperature measuring device and digital camera. To standardize how photos were taken a photo routine was developed. In period 4 chalks were introduced to mark traces on the road and equipment to measure road friction was added.

2.6.2 Interviews with Involved Road Users

In traffic accident investigations, there is a general need to get in touch with the drivers to get their opinion about what happened. Some questions cannot be answered in any other way and for many questions this is by far the easiest way to get an answer. This goes not only for pre-crash related information but also for in-crash and post-crash related information as well. In INTACT however, the need for an interview routine has mainly come from the pre-crash methodology work [3], therefore the methodology selected for pre-crash analysis very much influenced the making of an interview guide.

As described in chapter 3.1.1 below, the method DREAM was chosen for pre-crash analysis. DREAM does not determine the way information should be gathered, but its pre-defined factors certainly have a strong influence on the investigation method.

DREAM had earlier been used in the FICA (Factors Influencing the Causation of Accidents and Incidents) projects [4] and the SafetyNet project [12]. Several INTACT partners collaborated in investigating pre-crash factors and developing the method in FICA. An interview guide existed from those projects, and the recommendation from the INTACT pre-crash working group was to use that guide and modify it for INTACT use. However, the FICA projects had a much narrower scope than INTACT, mainly focusing on investigating accident causing factors in the pre-crash phase, so this interview guide needed modification to fit the INTACT project. The variable lists and the requirements given by the DREAM method were used to modify the FICA interview guide for INTACT.

A group of investigators specializing in interviewing was put together to develop the interview guide for INTACT. The interviewer group developed the guide iteratively, i.e. repeating the procedure of trying out the guide, gathering feed-back and making changes. The guide was used in real-world INTACT cases during the development process and most feed-back came from the interviewer group itself. Both practical issues (e.g. format, numbering, space for comments in the form) and issues about the contents (e.g. which questions to include, order of questions, introduction) were considered as input for changes. Some questions in the INTACT interview guide were later moved to the questionnaire used for long-term injury follow-up, e.g. questions concerning the length and weight of the person. A specific section concerning truck-car lane change accidents was created to give a more detailed description of that accident type. Different layouts for the guide were also evaluated.

In non-fatal accidents, the first interview is made by the case leader, or sometimes by another member of the case investigation team. If information indicates a possible fatal accident outcome, according to "the road user routine", a specially trained counsellor from the Sahlgrenska Academy makes the first interview with involved road users.

2.6.3 Vehicle Inspection

Detailed information about the involved vehicles is an essential part of the accident analysis. It is important to have access to information about the vehicles to compare the outcome in different accidents and to draw conclusions about accident causes as well as injury mechanisms and possible countermeasures, The variables should reflect the need for information of all the different areas such as vehicle specification data, deformation patterns and impact direction, presence and activation of driver assistance or safety systems etc.

Detailed information about vehicles must be collected, defined and structured in such a way that adequate case studies can be performed. The collected vehicle information should allow for further calculation, such as reconstructions of accidents.

When defining the INTACT methodology/routine for how to perform the vehicle inspections, the description above has been a guiding principle. Protocols and variable lists used by accident investigation teams at AB Volvo, Saab Automobile and

Volvo Cars were used as a starting point. Analyses of external protocols from other organizations, projects e.g. EU PENDANT and public authorities have also contributed to the final result of the used protocols.

It became evident during the project that it was difficult to obtain reliable information about what types of safety systems a vehicle was equipped with. Especially active safety systems were difficult to identify since they mainly consist of electronic components and software. Different sources of information were tested as a complement to inspections, such as Audatex [5], Autograph [6], PC-Crash [7] and Bilfakta [8], but none of these products offered the desired information. When accidents involving Saab, Scania or Volvo trucks and cars are investigated, the necessary information can be obtained from the respective organisation, but for all other brands the project had to rely on information from the national motor-vehicle register [10] (which is very limited) and information obtained from the vehicle inspection and/or other sources such as the driver, the owner's manual or workshops.

Car and Light Truck Inspection

The complete inspection of a car or a light truck consists of a wide range of variables which are all explained and defined in the digital manual. Below, some impact measurement variables are further explained.

A set of variables are collected for each impact to a vehicle. In the early stages this was limited to the three largest impacts but that constraint was later discarded. The variables collected for each impact define the forces, deformations and intrusions to the vehicle.

One of the variables collected is a modified version of the CDC code (Collision Deformation Classification, SAE J224 [16]). INTACT uses an extension in digit four of the original code which was first used by the PENDANT project, i.e. digit four is divided into 4 and 4e. This enables a more precise horizontal definition of the impact. The CDC used in INTACT is numbered 1, 2, 3, 4, 4e, 5, 6, 7 instead of 1-8 to achieve commonality with the most widely used CDC code outside of the project (the original SAE J224 CDC code only has 7 digits; the addition here is the digit 4e).

To obtain a more detailed description of the damage and to enable energy-based reconstructions, a crush profile is measured for each impact, e.g. location, length of deformation and crush depth in six different positions, known as the C1-C6 measurements developed by NHTSA and used in e.g. NASS-CDS. The values can be used to estimate the delta V (a vector describing the change in size and direction of the velocity of a vehicle) and/or EES (Energy Equivalent Speed) by computer programs such as AI Damage [20].

In frontal and rear collisions, a method based on load paths was developed from the study conducted by Lindquist [5]. The Lindquist method was based on fatal crashes and the method allowed demolishing the vehicles. Therefore, some adjustments had to be made to the Lindquist method to make it applicable to INTACT, where not only fatal crashes are investigated and no demolishing of the vehicles is allowed.

In side impacts it was desired to code intrusion into the passenger compartment but it was found to be very difficult. Instead a method based on exterior measurements was developed. The measurements are executed along the passenger compartment, from A-pillar and backwards and at different height from sill up to the side roof rail.

Instead of entering exact values when measuring deformation variables, it was concluded to be sufficient to use deformation depth intervals for example 1) None or minor deformation (0-2 cm), 2) Small deformation (3-10 cm), 3) Moderate deformation (11-20 cm) and 4) Major deformation (>20 cm). The first option was later divided into two, either None (for undamaged parts) or None or minor (where damage is very little or uncertain).

Two training sessions have been included in the project. The purpose of these was to improve the investigations as well as the investigation protocols. The training sessions included basic knowledge about cars, how to secure the vehicle and the work site, how to carry out vehicle inspections and how to fill out the vehicle inspection protocols

Truck and Bus Inspection

The truck inspection protocol was based on a protocol used by Volvo Trucks. After removing all Volvo specific questions from this protocol and expansion of some chapters, e.g. wheels and airbags, the protocol was used in the INTACT project. Several additions were made based on the car protocol to have as much similarity as possible between the different protocols. More effort was put on distinct variables and they are explained below.

A special Truck Deformation Classification (TDC) was developed. It was based on the CDC used in the car protocol (originally from PENDANT, see above). The code consists of 8 digits numbered as the INTACT CDC used for cars. The TDC allows for coding of both conventional and cab-over-engine trucks. Instead of entering the exact value of how much the pillars were deformed, it was concluded to be detailed enough and easier to use deformation intervals as in the car inspection protocols.

The level of detail in the protocol is generally higher for the actual truck/tractor than for connected trailers. There are variables in the protocol specifying the location of centre of gravity of the truck and the trailer, and the loading retention. These variables are valuable to analyse the stability of the combination and the impact thereof in e.g. a rollover accident. However, these variables turned out to be quite difficult to specify and consequently difficult for the investigators to code.

Since there was no equivalent bus protocol to start from, the truck protocol was used as the base for the bus protocol. Some questions were added and others removed and the alternatives altered to correspond to bus conditions. The bus protocol was finished later than the truck protocol so in the beginning of phase 2, the truck protocol was used also for bus inspections since no specific bus protocol was available. Some variables turned out to be difficult to define in such a way that all possible bus models were covered. One example is the number of pillars and windows and consequently the damage on them. It was also concluded to be too difficult and time consuming to code all passengers so it was decided to only code for injured passengers. A special

Bus Deformation Classification (BDC) was developed, with the same principle as the Truck Deformation Classification (TDC).

The truck and bus inspection routines and protocols were reviewed after phase 2 of the project and some points in need of clarification were identified. To improve the protocols based on the phase 2 review and to secure that the coding of vehicle data is not investigator-dependant, a special training session was performed which involved using the protocols on staged accidents. Based on the result of the training session, the bus and truck protocol were updated with respect to clarity, understanding and inter-investigator coding.

2.6.4 Long Term Injury Follow-Up

Information on why and how traffic accidents occur and their consequences can be gathered from individuals involved in the accidents. In INTACT there was the objective to collect the medical records and develop a routine for long term injury follow-up.

The injury follow-up procedure used in INTACT was based on that used by the Traffic Injury Register on behalf of the Traffic and Public Transport Administration in Gothenburg, for estimation of the medical costs for injuries sustained in traffic accidents in Gothenburg during the early 1990-ies. The procedure was complemented and adapted according to the main objectives of the INTACT project.

The procedure used by the Traffic Injury Register includes questionnaires sent to road users involved in traffic accidents and are sent after specified time intervals. The same set-up was used in INTACT. The questionnaires used in INTACT also included the pre-status of the road users, such as medical histories, diagnoses, and medications which might be of importance for the accident cause. Involved road users were asked in the interviews if they wanted to participate in the long term injury follow-up. When consent was obtained, the Traffic Injury Register was informed and sent the first questionnaire, which included a consent form to obtain information from other sources, such as medical records and ambulance reports, in order to obtain maximum reliability. The information retrieved from other sources included circumstances and actions during rescue, ambulance transport and medical care, which may have had an influence on the final outcome (such as post-crash position and posture, ejection, extrication, stabilization, and other measures at the accident scene and during ambulance transport) and the victim's physiological status after the accident (blood pressure, respiratory rate, and level of consciousness; so called vital parameters).

The type of injury and the injury severity for each specific injury were coded according to the AIS-system (2005). The effect of multiple injuries was graded according to the Injury Severity Score (ISS).

2.7 Accident Investigations - Case Analysis

Data from interviews, site of accident, road characteristics, involved vehicles, and injuries are put together in order to describe plausible causes of the accident, estimate the travel speed, define factors related to injury-causing events for individual subjects, such as vehicle trajectory, impact velocity, impact points, impact directions, injury causing parts, and injury mechanisms.

2.7.1 Accident Summary – Course of Events

It was noted in the data collection part of the method that there is a need to describe the most likely course of events, i.e. a description of the accident. This was proven important for several reasons but the main reason was that it is very difficult for another investigator to get introduced to a case if there is no information about the course of events. There are several ways to do this and in INTACT a written summary, the STEP method (see Event Sequence Analysis) and a scaled sketch (see Accident Reconstruction) were tested.

It was noted during the test periods that the amount of information in the written accident summaries varied a lot between different investigators. Therefore, a guideline was created to ensure that written summaries contained the same basic information and were written in a similar way.

2.7.2 Accident Causation Analysis

To determine the methodology for investigating the pre-crash phase in the accidents, a special working group was put together. The aim of the pre-crash group was to investigate what different pre-crash methods that exist today and see how good they work in order to find risk factors in different traffic situations. The group was also supposed to define variables that the chosen method requires and give recommendations on how to collect the data.

Each method investigated was initially evaluated by one of the group members and then it was discussed within the group. The evaluation and the discussion were based on the guiding principles for choice of method that were formulated in the beginning of the work [3]. In summary the guiding principles were:

- It is required that the method can handle case analysis, preferably also aggregated analyses.
- The method should have theoretically described accident model.
- The method should have a clear description/documentation of the analysis.
- It is required that the analysis does not end with defining guilty participants.
- It is required that the method covers contributing factors rather than accident causes.
- It is required that the method can have several levels at the same time and that it can handle several different contributing factors and not just a single causation chain.
- It is required that the variables are clearly described to increase the reliability.
- It is desirable that variable values like time, position, and action, and the driver’s apprehension of these things are analysed in the method.
- There should be a clear connection between the results of the analysis and possibilities to find countermeasures.
- It is desirable that the method is/can be implemented in a database.
- It is desirable that the results of the analysis can be searchable in a database.

The pre-crash group recommended that a modified version of the analysis tool DREAM (Driving Reliability and Error Analysis Method) [11] should be used in INTACT to map out accident causation.

DREAM (Driver Reliability and Error Analysis Method) is a specialized version of CREAM (Cognitive Reliability and Error Analysis Method, [13]), which was developed for accident analysis within working environments and complex technology domains (e.g. power plants, air traffic control). The earlier version of DREAM [14] was developed within the FICA (Factors Influencing the Causation of Accident and Incidents) projects to fit the traffic accident domain.

DREAM is based on an accident model describing different failures in a traffic system, which can be both blunt end failures latent in the system and sharp end failures. The failures can be related to vehicle factors (e.g. worn out tires), human factors (e.g. distraction) and environmental factors (e.g. fog and snow). Since DREAM consists of pre-defined variables, aggregated analyses can be made. However, there is no defined way on exactly how to do the aggregation. One way can be to aggregate on accident classification, another can be on specific factors (e.g. aggregate the accidents containing 'observation missed').

The INTACT pre-crash group determined that the main advantages of DREAM were the pre-defined variables, which makes it possible to aggregate analyses, the deep analysis of the behaviours of the drivers before the crash, the possibility to analyze several link chains of causes at the same time, and the clearly described analysis method. The disadvantage of weak definitions of some variables has been eliminated with the version DREAM 3.0 [11], which was developed in a parallel project during phase 2 of INTACT and used in phase 3.

2.7.3 Event Sequence Analysis

The pre-crash working group also suggested using STEP (Sequentially TInMeDe Events Plotting) as a part of the analysis, in addition to DREAM, to give a good overview of the accident and cover all three accident phases (pre-crash, in-crash, and post-crash). However, STEP is a tool to describe *what* happened rather than *why* it happened.

The STEP analysis is based on multi-linear event sequences that describe several activities that take place at the same time. The event sequence is described in a worksheet along a time scale which tells how events relate to each other in terms of time. Each actor has a row in the worksheet. An actor is a person or an item (animal, vehicle, object etc) that has influenced the accident process. An event is one actor performing one action. Each event is described in a box in the matrix. Actions can be physical and observable or mental. Arrows between the boxes illustrates the flow, i.e. how the events influence each other in the accident process. The arrows may be placed between events for the same actor or between different actors. The scope of the investigation goes from the action that deviated from the planned process to the last harmful event in the incident or accident. The analysis is checked by means of different tests.

STEP proved to be too vague when applied to INTACT cases, which resulted in various results from the analyses, confusion about the way an analysis should be conducted and general scepticism about the method. This led to the creation of a set of rules to be used in INTACT STEP analyses. These were tried out during an investigation period and later on compared with cases where a thorough narrative summary was included to decide whether STEP should be used in INTACT case analyses. The final decision was that STEP should not be included in INTACT case analyses and it was replaced by a thorough summary.

2.7.4 Accident Reconstruction

In general the term *accident reconstruction* is applied to different methods of accident analysis. Within the INTACT project, *accident reconstruction* means that physical evidence of vehicle damage and vehicle and/or person trajectories are used to derive quantitative parameters, e.g. energy equivalent speed (EES) or change of velocity (ΔV) during the impact, to describe the severity of impact and the pre-, in-, and post-crash kinematics of vehicles and persons involved in an accident.

In the mid of INTACT phase 2, it was suggested that all accidents would be considered for reconstruction but based on the amount of available data a further selection should be made. The suggestion was implemented in the second half of INTACT phase 2. An evaluation phase was planned in the beginning of INTACT phase 3 and included a summary on how many cases and which types of accidents were reconstructed and how much time was spent on this. Further, the evaluation included why accidents could not be reconstructed.

To organise the method development for accident reconstruction four tasks were defined

- Status after phase 2, review of accidents investigated so far regarding their suitability for reconstruction
- Methodology for improved data collection, improving data collection by training and methodology development
- Methodology for reconstruction, how reconstructions would be performed
- Choice of reconstruction method
- Use of reconstruction tools

Status after Phase 2

The review of the cases collected in INTACT phase 2 showed that a quantitative reconstruction was most likely not possible for most of them. The following issues were identified:

- The scene sketches were not drawn to scale, most of them without but some with more or less detailed measurements of the road and road marks.
- Vehicle and/or person end position and potential collision points (identified by e.g. splinter fields) were not identified in all scene sketches.
- Complete road measurements were rarely available and as scaled road maps were only available in one of seven municipalities, important scene information was missing.

- Satellite photos had been used for the description of vehicle trajectories, but as some of them did not show an orthogonal view, they could not be used for reconstruction purposes.

The accident investigation teams were not yet specifically trained in which kind of on-scene measurements were necessary to conduct a reconstruction.

Methodology for Improved Data Collection

From the end of phase 2 to the beginning of phase 3 the following training courses containing both theoretical and practical parts were conducted.

Photo documentation, which introduced the investigators to the camera models used in the investigations and practical usage of the updated photo routine aInMeDe at improving the way photos were taken.

Accident sketch, this was the first training for accident sketch drawing in the INTACT project, the method for taking the measurements at the accident scene was also included. The training comprised information about traces at the scene, different measuring methodologies (x-y-coordinate system, path-coordinate system and triangulation) and sketch drawing. In the first investigation period of phase 3 (see Table 1, period 4), sketches were drawn by hand but in the subsequent period (see Table 1, period 5) the sketches were drawn using “SmartSketch 4.0” [14], a basic 2D CAD program, which allows the usage of infrastructure and vehicle specific symbols and various layer settings.

Road investigation, besides road layout measurements, the documentation of the road environment was also expanded upon and included measuring embankment not only at the place where vehicle left the road, classification and measurements of road side barriers and radius calculation of road sections.

Vehicle investigation focused e.g. on the CDC coding according to the SAE J224 [16] and the deformation measurements according to the NASS-CDS procedures. Both classification schemata are important for impact evaluation and calculation of the damage-based energy dissipation.

Methodology for Reconstruction

In a first step the accident scenario was divided into events for each vehicle. To enable a consistent coding, all events with a temporal length are only considered in their initiation. With this simplification, events are "time points" in a subsequent order. Twenty event types were identified, such as skidding initiation, cross median line and contacts and impacts.

The accident reconstructions were conducted with specific focus on the impact(s) and general pre-impact information (e.g. pre-brake velocity and approach angle). The sequences were not coded with a time stamp (e.g. time to/after first impact) as the pre-crash information is mostly limited to a few parameters.

Selection of Reconstruction Method

Accident reconstruction within the term of definition (see above) can be conducted in different ways. The reconstruction methods can generally be classified as momentum calculation, force calculation and damage calculation. Information required for momentum or force calculation is generally provided by on-scene accident data collection. Damage-based calculation is only applied to retrospective in-depth studies, where specific information like vehicle rest position or collision point is not available.

It was decided in the mid of INTACT phase 2 that only on-scene investigations would be conducted in the remaining data collection periods. Therefore, the reconstruction variables were defined according to on-scene data collection and reconstruction with use of momentum and force calculation. For further information see Appendix A.

Use of Reconstruction Tools

Hand calculations were used to estimate the initial start parameters for the reconstruction programs. The reconstructions were not conducted solely by hand calculations, as reconstruction simulation videos became an important tool to demonstrate the course of accident. The region around Gothenburg is also hilly which requires the consideration of changing slope gradients, making hand calculations time and cost consuming.

For the simulation of accidents the software PC Crash Version 8.1 [17] was used. This software represents a state of the art 3D reconstruction tool and offers a 3D simulation environment where 3D momentum and force calculations with multi-body implementation are possible. It offers a 3D simulation environment unlike e.g. Carat [18], and compared to HVE [19], 3D momentum and force calculations with multi-body implementation are possible within a single program.

The AI Damage software (Version 1996-2008, [20]) was used to verify the EES results derived from PC Crash reconstructions. AI Damage calculates the deformation energy based on the Crash3 algorithm [21] and updated vehicle stiffness data. Further, the delta velocity can be computed if the deformation energy of all collision involved parties, the coefficient of friction and the principal direction of force are known. A regular application of the software was however not possible, as often the damage measurement was not coded or coded with high uncertainties.

Momentum calculation was used for vehicle-to-vehicle impacts. In case one of the vehicles sustained a kinetic reaction due to constrain forces, e.g. swaying, pitching, yawing, force calculation was used. Force calculation was also used for all vehicle-to-object impacts. For pedestrian accidents a multi-body simulation was used within a force calculation. Reconstruction of bicyclist and motorcyclist accidents, which eventually requires both models for occupants and vehicles in combination, was not performed.

2.7.5 Injury Mechanism Analysis

An initial proposal for an injury mechanism analysis method developed. In this proposal, the injury mechanism for each injury is coded according to a modification of the method proposed in the road user routine, where the injury mechanism could be either External or Internal. The emphasis was on the external mechanism, leaving the internal mechanism secondary, but not unimportant. A group was initiated to test the coding system. A modification was made in order to describe the injury mechanism in a more discriminative and structured way, by which specific injury mechanisms could be identified, which may be used to improve injury mitigating systems in vehicles.

The modified injury mechanism description (InMeDe) was defined by a 5-position code, in which the first and last positions are letters and the second to fourth are integers. This code could be used for most of the entries in the AIS-dictionary, even if this will create some redundancies, as some of the AIS-codes already indicate the type of trauma, i.e. blunt versus penetrating trauma. The final 5-position code represents the following items:

- Type of trauma; (A – Z)
- Proximity of action (local/direct, distant/indirect); (1 – 9)
- Character (origin) of action (inertia-related or not); (1 –9)
- Joint Injury descriptor; (1 – 10)
- Type of mechanical action (at the tissue level); (A – Z)

The InMeDe injury mechanism analysis was used to analyse injury mechanisms in a number of INTACT cases. The analysis was made by representatives from the team involved in the accident investigation on scene, preferably the “case leader”, and representatives from the Sahlgrenska Academy and the Traffic Injury Register. In several cases it was not possible to code the injury mechanism, as the injury pattern or medical description was not clear enough to allow conclusions.

2.7.6 Electronically Stored Data

Data Stored in Vehicles - Event Data Recorders

The benefits of using Event data recorder (EDR) data in accident investigations were examined [22]. These regard the quality of data, effectiveness in data collection and uniqueness of accident information. Some concerns with the use of EDR data are also acknowledged, most importantly those concerning violation of privacy.

Vehicles with EDR were involved in accidents investigated by INTACT. The vehicle owners were asked for consent to use EDR data in five cases with Volvo cars involved. If the driver was not the vehicle owner, the driver was asked for consent as well. However, the consent to use the EDR data was only returned in one case. The information used came from the airbag control units and was limited to the longitudinal and lateral acceleration of the vehicle in only one event.

The legal issues surrounding ownership of data in EDR have not been fully solved. In INTACT, since the consent was only achieved in one case, EDR data were not used in INTACT. The INTACT database is however fully prepared, as far as the current legal situation and prerequisites are concerned, to include EDR data in line with the parameters included in the FMVSR563.

Information Stored by Infrastructure

The Swedish Transport Administration is responsible for road maintenance on state roads in Sweden and employs some road infrastructure that stores data relating to road conditions and traffic electronically. The Road Weather Information System

(RWIS) consists of about 760 measuring stations and stores data about weather and road conditions. Some measuring stations have cameras but there is no recording. Adapted information is available to the public on-line.

The Swedish Transport Administration is also responsible for the operation of automatic speed cameras (ATK) that store data about speed of passing vehicles and traffic flow. Data from ATK are however not available to the public for legal reasons.

Tachograph

Tachographs are used in Heavy Goods Vehicles to store information about speed and driving hours of the vehicle/driver. Both analogue and digital tachographs are in use today. However, in Sweden only the Police are allowed to extract information from tachographs. This information was therefore unavailable and data from tachographs were not used in INTACT.

2.8 INTACT Database System

During phase 1 of INTACT the project came in contact with Umeå University, Ladok Division where work with developing a database for storing data from road accidents was undertaken. It was decided to cooperate between the two projects in developing the requirements for a system rather than to develop two different systems in Sweden. A working group was started that included investigators, analysts and system developers which addressed the issues of software architecture and input, storage and extraction of data.

2.8.1 System (Database) Requirements

The development of the system requirements has been perfomed by first describing the process of data collection and case analysis in detail. Experts in different parts of the accident investigation process took an active part in the development of the INTACT system requirements and monitored and reviewed the suggested functions and interfaces of the system. The choice of method for system development, DSDM (Dynamic Systems Development Method) puts a lot of emphasis on end-user-participation in the requirements process to make sure that the system meets the expectations and demands of the people who are going to use the system, a factor which is critical for the system implementation phase.

The INTACT System requirements document was a compilation of documents, each describing a certain part or a general requirement of the system.

The first part of the requirements document contained written descriptions of functions and technological solutions for the INTACT system. It contained the description of the complete accident investigation process and overall fundamental requirements of the system. It was divided into the following documents.

- Detailed description of the business process, i.e. the complete process of investigating an accident. This was the complete process, which further on in the requirement documentation is divided into several sub-processes which are described under Use cases.

- General system requirements, i.e. requirements which are considered to be common to all parts of the system.
- Description of the Software Architecture and Design.
- Roll based rights describing the different roles within the system and the rights of each role. There are several roles with different level of access to the contents and functions of the system.
- General input flowcharts which describe the process of entering data into the system. In some parts of the system there was a need for more detailed description of the input process, and in these cases, a separate flowchart was provided within the process/interface description.
- GUI – Graphical User Interface, a general description of the user interface, which is the working environment for the users of the system, both for entering and extracting data.

A lot of effort was put into data and software availability during work with the system architecture section. Pros and cons between web based systems and local clients were a major subject, but also the question of using proprietary or open source solutions for the system was discussed.

The second part of the requirements document contained visual representations (mock-ups) or in some cases written descriptions of the different parts of the user interface, to provide end-users and developers with a common view of what the user interface should look like, and how it should work.

The second part of the INTACT System Requirements was the part containing the Use cases. A *Use case* is a detailed description of how a certain task within the INTACT system is performed. Every use case consists of two parts, where one part was a written description of the use case and its purpose and the second part was a visual representation of how the user interface should be built. Relations to variable lists, other use cases and separate documents pertaining to the specific use case were also included in the written description.

In the second part of the use cases a lot of focus was put into designing a user-friendly, intuitive and quick user interface for both the investigators who enter data into the system, and for the analysts who use data from the system to perform analyses and perform research. The different use cases were:

- Login & permissions
- Administration
- Input Accident data
- Input Road data
- Input Vehicle data Car
- Input Vehicle data Truck
- Input Vehicle data Bus
- Input Other Vehicle
- Input Road User and Injury data
- Handle images and upload files

- Input DREAM analysis
- Input Reconstruction analysis
- Input Road User Injury analysis
- Show and print case summary
- General Search
- Export cases

2.8.2 System (Database) Development

A purchase of the system development was undertaken when the database requirements were finalised. The system development started in the end of phase 2 of the project. To allow for easier input of variables and their values into the database, a major work was undertaken to convert the variables lists to XML (Extensible Markup Language) format and adding all the rules for each variable. Some small adjustments to the system requirements were performed during the development of the system. However, the largest change from the initial requirement was to change the DBMS (Database Management System) from MySQL to PostgreSQL.

3 FINAL PROCESS AND METHODOLOGY

3.1 The INTACT Investigation Process

The final INTACT accident investigation process is shown in Figure 4. An INTACT accident investigation consists of two parts (Figure 5). The data collection and case analysis are supported by protocols and routines.

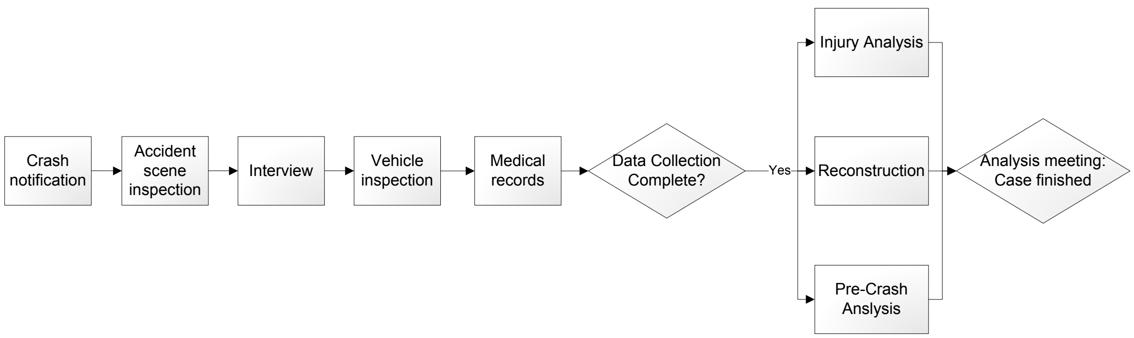

Figure 4. The INTACT accident investigation process.

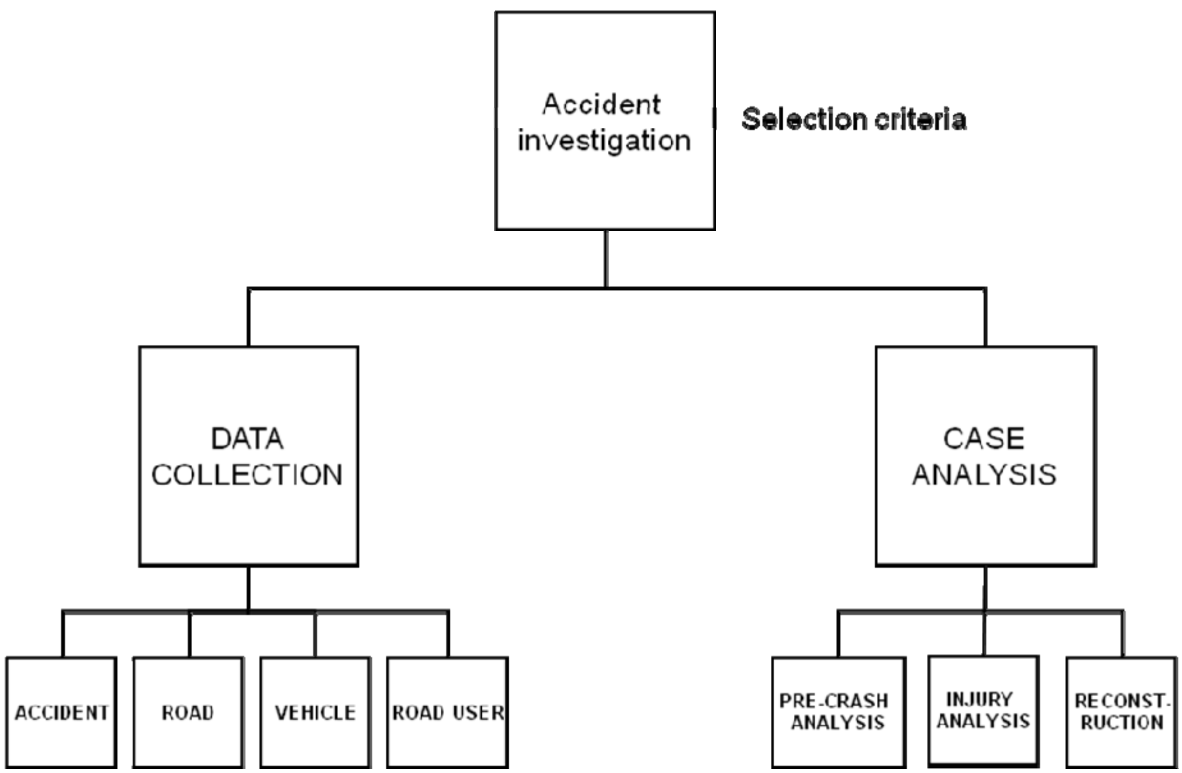

Figure 5. The two parts of an INTACT accident investigation.

3.1.1 Routines

Routines are used to support investigators during different parts of an investigation and as an aid to standardizing how vehicle inspections, photos and sketches are made. There are seven routines:

- **Safety on road**: the purpose of this routine is to make sure that an accident scene inspection or a vehicle inspection is carried out as safely as possible. It includes instructions on behaviour at an accident scene, personal protective gear, where to park the INTACT car, where to put out safety tents, required training for investigators and special instructions for third persons accompanying a team to an accident or vehicle inspection. All investigators have to read and understand this routine.
- **Photo routine**: this routine describes how photos should be taken, both at an accident site and on vehicle inspections. The accident site part includes instructions on how photos should be taken of the accident scene, traces and marks, run-in and run-out paths. The vehicle part describes a standardized way of taking external and internal photos of cars, trucks and busses and photos of deformations and impact marks. The photo routine also describes photo management, including how to remove identifying features from photos.
- **Road routine**: this routine describes how the accident sketch should be made and what should be included in a sketch for a number of different accident scenarios.
- **Vehicle routine**: this routine describes how a vehicle inspection should be performed, from initial contact with workshop, safety precautions, preparations, external and internal documentation and photo management at the office.
- **Crisis management routine**: this routine describes how crisis management for the investigators should be carried out if needed.
- **Road user routine**: this routine describes five different processes that describe how contact with road users in accidents should be established for collecting background data, information about pre-crash behaviour and the necessary information to establish injury mechanisms and follow-up questionnaires for injured road users.
- **Analysis meeting routine**: this routine describes an agenda for an analysis meeting so that all analysis meetings include the same points for discussion.

Routines for the analysis process are generally difficult to make, as the process itself is depending on the accident scenario, the interview records and further collected and coded data. It is necessary that the persons working with reconstruction, DREAM or injury analysis have an in-depth expert knowledge in these areas of work. A routine cannot replace long term experience and knowledge.

3.1.2 Protocols

All data collection is supported by protocols used at the accident scene, on vehicle inspections and in the office. The final investigation method included ten protocols, two of which are used for data collection at the accident scene, three are used at vehicle inspections and five are used at the office:

- The **on-scene sketch-road protocol** is adapted to be used in the field. It is used by one of the investigators at the accident site and consists of three parts:
  - A sketch part where a sketch of the accident site is made and scene measurements noted. These measurements are e.g. positions of skid marks, vehicle rest positions, impact points and their positions in relation to a reference point and reference line.
  - A collision object part where geometric data about collision objects such as barriers, roadside objects and fixed objects is collected.
  - A road part where data about the road itself are collected. This part contains geometric information such as road width and curve radius, road surface conditions and data about the roadside. The protocol contains two copies of this part making it possible for the investigator to collect data on two roads in e.g. an accident in an intersection.
- The **on-scene accident-vehicle protocol** is used at the accident scene to collect general data about the accident such as times, course of events, weather and rescue services. It is also used to collect basic data on the vehicles such as vehicle type, registration number, location of towed away vehicles and contact information for road users involved in the accident.
- There are **three vehicle inspection protocols** adapted for cars, trucks and busses respectively. These are used at vehicle inspections to collect data about involved vehicles such as deformations, external and internal impacts, safety systems and vehicle type information. Deformations are coded using a modified version of the standard SAE J224 [16], Collision Deformation Classification.
- The **road protocol** is filled out at the office. It consists of four parts:
  - An introduction with case number and general data about road investigators, date, position of site and accident site type.
  - Two identical road parts, sufficient for two roads, consisting of the following parts:
    - Geometric data about the road, these are taken from the on-scene accident-sketch protocol.
    - Road and lane information, e.g. speed limits, road markings and widths, and vulnerable road user facilities.
    - Office variables, these are data collected at the office and include traffic density, measured mean speed, road administrator, EuroRAP classification, speed limits etc. The data are taken from databases maintained by the Swedish Transport Administration, either the NVDB (the National Road Database) or the TIKK (Clickable Traffic Information Maps).
    - Roadside information, this is taken from the on-scene accident-sketch protocol and includes information about slopes, ditches, barriers and objects in the roadside.
  - Collision objects, this is taken from the on-scene accident-sketch protocol and includes information about all objects that have been hit by one or several vehicles involved in the accident.

The road protocol does not contain the accident scene sketch which is made separately.

- The **interview guide** is used during interviews with road users, primarily drivers, and is available in a Swedish and an English version. It is used to collect data about pre-crash behaviour, driver experience and drivers' subjective views of the accident site etc. The interview guide is in the form of a structured interview where direct questions are asked.
- The **road user child protocol** is used to collect data about child restraint systems such as make and model and how it was used.
- The **accident protocol** contains general data about the accident such as course of events, injuries, alcohol and drug involvement and accident type. It also includes a simple sketch.
- The **reconstruction protocol** contains the variables derived from accident reconstruction. Relevant previously recorded information like the crush measurement/location and the CDC code are copied from the vehicle protocols and updated after the reconstruction results are available. The first part of the protocol shows general accident information, the second part describes the impacts per vehicle. A third part deals with the description of rollovers and the fourth part offers detailed variables for the coding of pedestrian-to-vehicle contacts in case of a pedestrian accident.

3.1.3 Variables

All variables are defined in an on-line manual (INTACT wiki) available on-line to the project partners (see Chapter 5).

3.1.4 The INTACT Accident Investigation Process

An INTACT accident investigation is only started if an accident occurs during shift hours when an investigation team is on-call and the accident fulfils the INTACT sampling criteria.

Data Collection

An accident investigation starts with a crash notification from the SOS Alarm. The sampling criteria are:

- Geography: the accident must have occurred in Göteborg, Mölndal, Partille, Härryda, Lerum, Ale and Kungälv municipalities.
- Vehicle types: a car, bus or truck must be involved.
- Personal injuries: an ambulance must have been called to the scene

If these criteria are fulfilled, a two-man INTACT investigation team is dispatched to the accident scene in the INTACT car. When the team reaches the accident scene, the team performs an accident scene inspection. If the accident scene cannot be reached, is unsafe, is empty upon arrival or cannot be found, the accident is dismissed and the team returns to the office.

The accident scene inspection is supported by the safety on road routine and the photo routine and data collection is performed using the on-scene sketch-road protocol and the on-scene accident-vehicle protocol. In the two-man investigation team, each investigator, called investigator X and Y, has a number of specific tasks at the accident scene. One of the investigators is also the case leader and has overall responsibility for an accident investigation, including final data entry into the database.

Investigator X uses the on-scene accident-vehicle protocol and performs these tasks:

- Talks to police, rescue services, persons involved in the accident and witnesses
- Enters course of events, contact information and general accident information into the on-scene accident-vehicle protocol
- Enters vehicle data into the on-scene accident-vehicle protocol
- Supports investigator Y

Investigator Y uses the on-scene sketch-road protocol, measuring equipment and a camera to perform these tasks:

- Takes photos of the vehicle rest position(s), collision point(s)/collision object(s) and run in and run out traces
- Marks vehicle rest position(s), collision point(s) and vehicle/object traces and take photos of all marked areas
- Draws a hand sketch of the accident site, vehicle paths and end positions etc.
- Evaluates all non-permanent sight restrictions
- Conducts all on-road and off-road measurements
- Fills out the remaining road protocol

When the accident scene inspection is finished, the team returns to the office where the accident is given a case number. During investigation periods 1-7, dismissed accidents were also given a case number if a team was dispatched to an accident, this will not be the case when the database system is in place.

The road protocol is filled out at the office. If no contact information has been obtained at the accident scene, contact information for the vehicle owners is collected. Information about the vehicles involved is collected from the National Vehicle Registry.

A sketch of the accident site is made using the data collected at the accident site. How the sketch is conducted is described in the road routine. The sketch is drawn in the software SmartSketch 4.0 [14] and is in scale. It is used as input to the accident reconstruction and as a visual summary of the course of events.

The drivers of the involved vehicles are interviewed by phone using the INTACT interview guide by specially trained interviewers. The road user routine is used to determine when a road user can be contacted, depending on the age of the road user and the outcome of the accident. If permission to inspect the vehicle was not obtained at the accident scene, the driver (or owner) is asked for permission to inspect the vehicle during the interview. Pedestrians are interviewed using only parts of the interview guide; however these interviews are mainly used as witness statements to establish the course of events and the movement of the pedestrian. Road users are also asked if they want to participate in a long-term follow-up of injuries using questionnaires (see long term injury follow-up below).

If permission is granted, all vehicles involved in an accident (car, truck or bus) are inspected. The vehicle inspection is supported by the vehicle routine and photo routine and one of three vehicle inspection protocols is used, depending on the type of vehicle. The vehicle inspection is performed where the vehicle is located, either at a workshop or a junk yard. For slightly damaged vehicles, inspection is performed where it suites the owner.

If data collection is complete, the case analysis begins. The case analysis consists of a pre-crash analysis, injury mechanism analysis and accident reconstruction. In the following sections a short overview of the applied analysis process is given.

Pre-Crash Analysis

The pre-crash analysis consists of a DREAM analysis. The coding of a DREAM [11] chart is made using collected data. Data for the DREAM analysis come from various sources, mainly interviews with drivers and, if needed, rescue leaders, passengers, witnesses and police as well as data from e.g. accident scene and vehicle inspections. No strict recommendation has been made at this point that data need to be collected on-scene. However, this is the case for INTACT cases.

Injury Mechanism Analysis

Injury mechanism analysis is performed by representatives from the team involved in the accident investigation on scene, preferably the case leader, and representatives from the Sahlgrenska Academy and the Traffic Injury Register. The injury mechanism for each injury is coded according to the modified injury mechanism description (InMeDe). This is defined by a 5-position code, in which the first and last positions are letters and the second to fourth are integers. The 5-position code represents the following items:

- Type of trauma (A – Z)
- Proximity of action (local/direct, distant/indirect) (1 – 9)
- Character (origin) of action (inertia-related or not) (1 –9)
- Joint Injury descriptor (1 – 10, used for joint injuries only)
- Type of mechanical action (A – Z, used to describe the injury at the “tissue level” or the “microscopic” level, which may be possible only in specific cases)

The codes are described in detail in Appendix B.

Accident Reconstruction

The available data (accident sketch, vehicle/personal data, driver statements) have to be checked, to decide if a reconstruction within “acceptable” tolerances is feasible. The term acceptable depends on the estimation of the reconstruction expert. When the data is checked, a 3D environment model is designed in PC Crash. The reconstruction expert makes a decision for the reconstruction methodology, e.g.

momentum or force calculation. If the reconstruction is sufficiently accurate, the PC Crash protocol variables are transformed into INTACT variables. Tools were developed in the INTACT project to ease this data transformation. It has to be noted that PC Crash cannot protocol an impact between a vehicle and the ground structure or a vehicle and a multi-body model. Alternative methods for variable coding have to be used, e.g. immediate pre- and post-crash data comparison. The reconstruction expert has to check and possibly revise the coded impact information based on vehicle investigations in agreement with the vehicle investigator. Finally a video from the accident simulation is generated and added to the digital file records.

When these parts are completed, the case leader is responsible for calling the case group to an analysis meeting where the accident is discussed. When the analysis meeting is conducted and the case is updated accordingly, the case is finished.

Long Term Injury Follow-Up

The Traffic Injury Register at Sahlgrenska is notified by the case leaders which occupants are willing to participate in the long term injury follow-up after they have agreed to do so in the interview. The interviewer asks for contact information to all occupants in the vehicle. A first questionnaire, information about the study and a consent form for access to medical records are sent 1 month after the accident by the Traffic Injury Register. A reminder is sent if the questionnaire is not returned within 4-6 weeks. Further injury follow-up questionnaires are sent 6, 12 and 36 months after the accident if the previous follow-up stated that they still experienced psychological or physical inconvenience from the injuries.

4 INTACT DATABASE SYSTEM

The INTACT system is based on the database requirements described in chapter 3.8.1. The system has been developed as a secure web-based application for storage and analysis of accident data. The system programming has been made in cooperation with a contracted software consultant company.

The system architecture consists of three conceptual layers; each one responsible for certain defined tasks. These layers are the web layer, the business layer and the database layer (see Figure 6). Dependencies are only allowed downward in the layer stack, i.e. the web layer may have dependencies on the business layer, but not the other way around. All communication with the database must pass through the database layer.

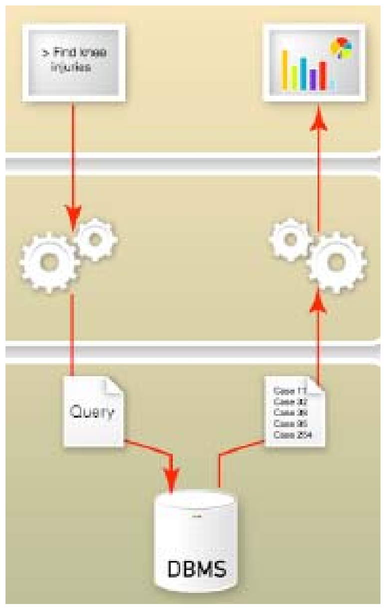

Figure 6. INTACT system architecture, from top it is the web layer which includes the user interface, in the middle the business layer which handle the communication between the web layer and the database layer and finally the database management system (DBMS).

The web layer handles presentation and validation of data input and export. The layer consists of web pages embedding Adobe Flash technology. The web pages are the user interface and enable a rich interaction to the end-user. The business layer handles the communication between the web-layer and the database layer which handles all communication with the PostgreSQL database where the data is finally stored.

The system can be reached via the Internet for authorized users according to specific role base rights. The data input is divided into data collection and case analysis folders which each include a specific number of tabs for each category of variables. The main categories are accident, road, vehicle, and road user for data collection (figure 7). For case analysis the main categories are reconstruction, DREAM, and injury analysis. It also includes tabs for folders for uploading and storing files and images and to export data.

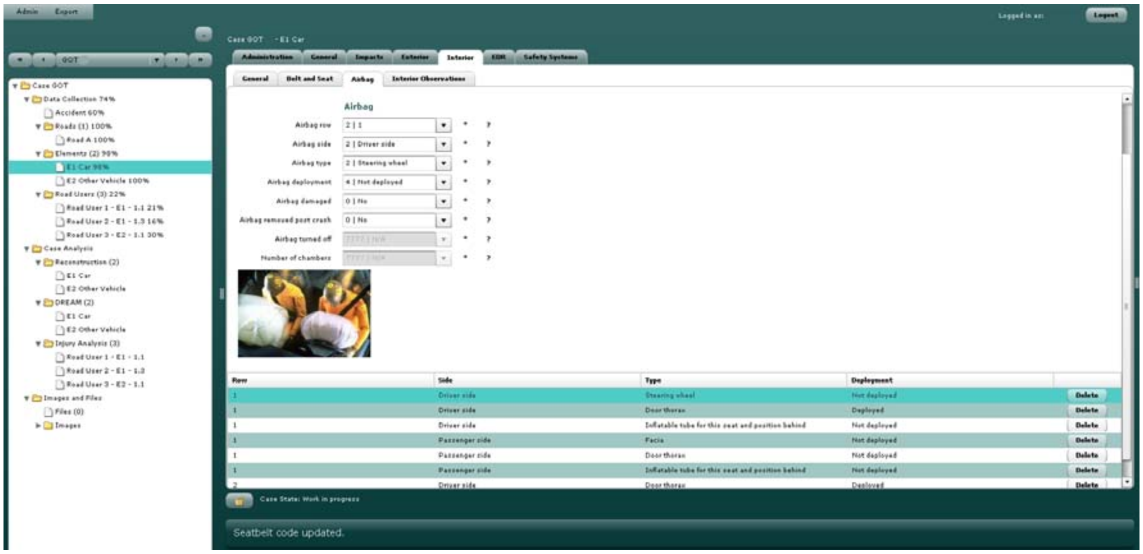

Figure 7. The INTACT system user interface, to the left there are folders including all involved actors in the crash (such as road, vehicle and road users). All tabs belonging to these actors can be viewed on the right, here the airbag tab in the interior information for passenger cars is shown.

Roads, vehicles and road users are not predefined but added into the system as data input goes along. Some variables are linked to each other and therefore several dependency rules for text values and interval rules for numeric values are included in the system. As a unique feature, the INTACT system is linked to the on-line manual (the INTACT wiki, Chapter 6). Each variable in the system is linked to the wiki codebook allowing the users, by one click, to search an explanation for a variable in both English and native language (so far English and Swedish).

As data input continues the progress of the case is updated and numbers in percent is shown both on a total level but also for each category included in the investigation. If the investigator needs to find the missing fields a case report of missing variables can be created and data input can easily be completed. When the completion rate is 100% the case is finished.

To de-identify images a tool has been built into the system where registration plates, faces etc. can be de-masked. The photos are uploaded directly from the camera to the database via the user interface. In this way the images is always stored so that all investigators can view them immediately. During the de-masking phase the investigator move the images to the folder which it belongs to (e.g. Element 1, Road A) and name them accordingly (e.g. left front, rear). The investigator also chose which images that will be included in the summary report. This step increases the work for the investigator slightly but improves the understanding of a case for other investigators and analyst dramatically.

A summary report of a case can be created which include the most important variables and images to quickly be able to understand the case. There is also a possibility to export all or selected data/images from the user interface. Both the summary report and the export are only available on finished cases.

Naturally, there are features which have been identified during the development phase which would enhance the system. These have been documented and can be implemented in a future INTACT project.

5 ON-LINE MANUAL

The on-line manual, or INTACT wiki, is available to the project partners (Figure 8). It contains protocols, routines and explanations of all variables. The on-line manual is in a wiki format.

All variable explanations contain a “short description” which is linked to the tool tips in the database system, a range of allowed values, a “long description” and, when applicable, illustrations (Figure 9). The definition also includes the database table, database variable name, the introduction date and expiration date of the variable.

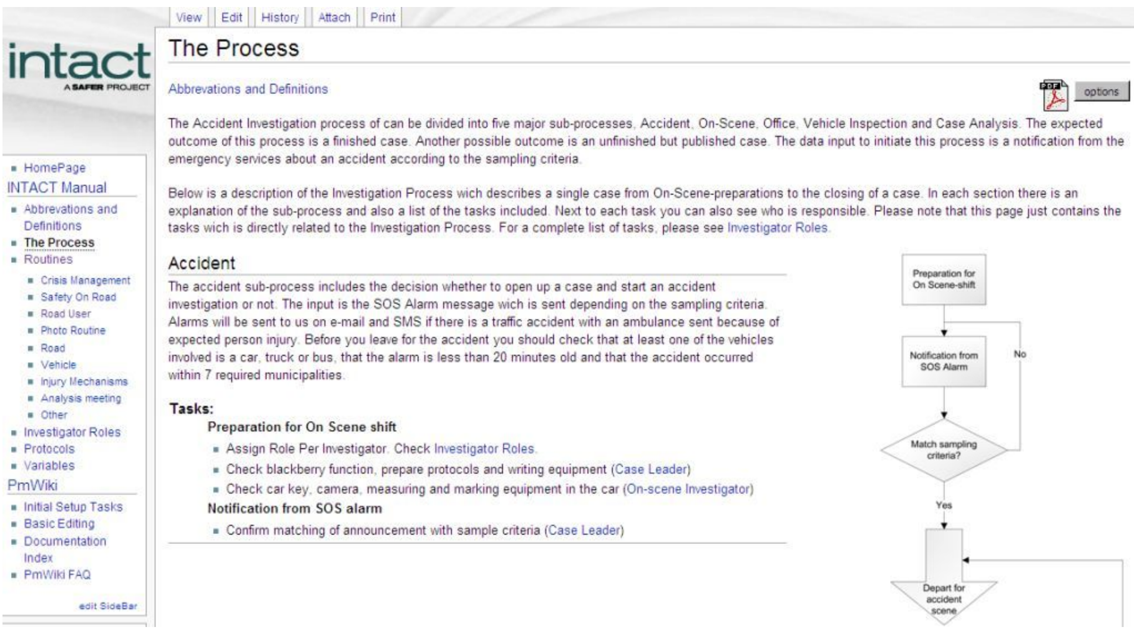

Figure 8. Part of the INTACT process in the on-line manual.

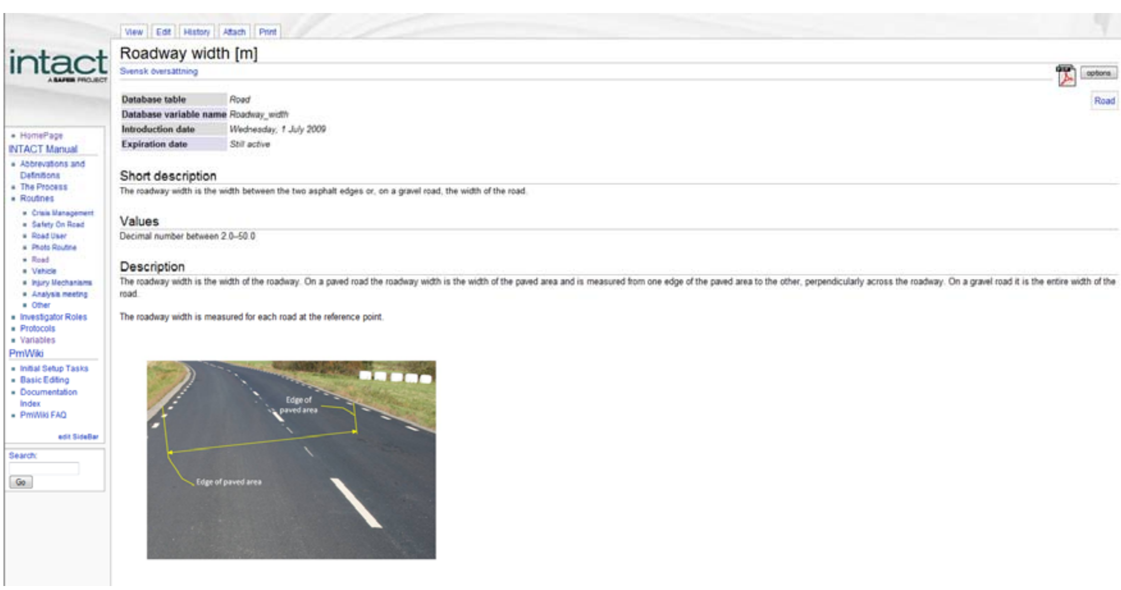

Figure 9. An example of how a variable is explained in the on-line manual.

6 OUTCOME OF ACCIDENT INVESTIGATIONS

6.1 Description of Data

The total number of accidents investigated during INTACT was 123 (see Table 3). Ten accidents were investigated in the pilot 40 accidents were investigated in phase 2 and 70 accidents were investigated in phase 3. Two accidents involving three vehicles in total were investigated in the retrospective heavy truck study, one of which was fatal (MAIS 6). One accident (fatal, MAIS 4) involving two vehicles and five occupants were investigated in the on-scene night study.

The 110 accidents in phases 2 and 3 involved 210 vehicles with 277 occupants, 167 vehicles were cars. The most common accident types were vehicles with the same direction of travel followed by vehicles running of the road (see Figure 10). In 157 vehicles the driver was alone (see Figure 11). Of the 210 drivers, 141 were male, 52 female and 17 unknown and the majority of drivers were between 31 and 40 years of age (see Figure 12). In all 210 vehicles, 68 occupants had injuries reported in STRADA hospital with a MAIS of 3 (53 had MAIS 1, 8 had MAIS 2 and 7 had MAIS 3). The injuries of 142 occupants had been graded by the police (see Figure 13).

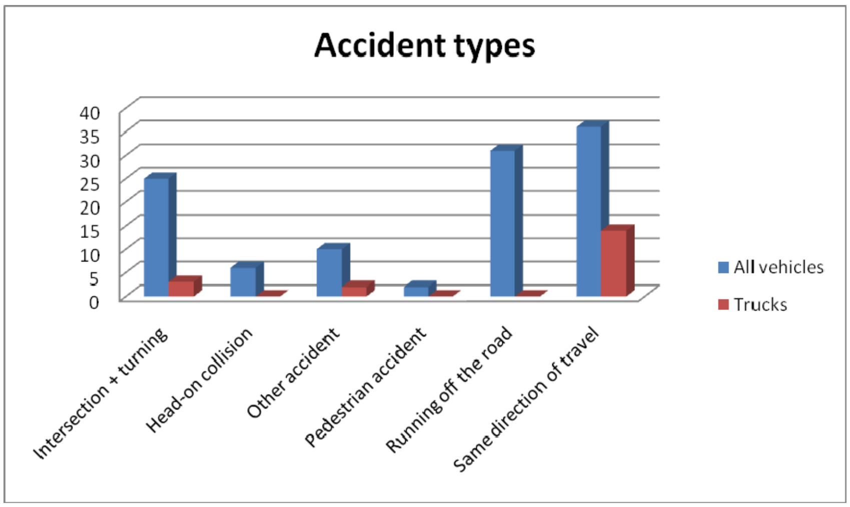

Figure 10. Distribution of accident types for all vehicles and trucks.

Table 3. Total number of investigated accidents in INTACT.

Period	Dates	Investigation type	Number of investigated accidents
Pilot	071001 – 071031	On-scene/retrospective	10
1	080310 – 080404	Retrospective	4
	080407 – 080430	On-scene	4
2	080602 – 080804	On-scene	13
	080602 – 080804	Retrospective	2
3	080915– 081205	On-scene	17
4	090302 – 090626	On-scene	43
5	090810 – 091016	On-scene	27
6	090101 – 091031	Retrospective, Heavy truck	2
7	091123 – 091206	On-scene, Night	1
Total			123

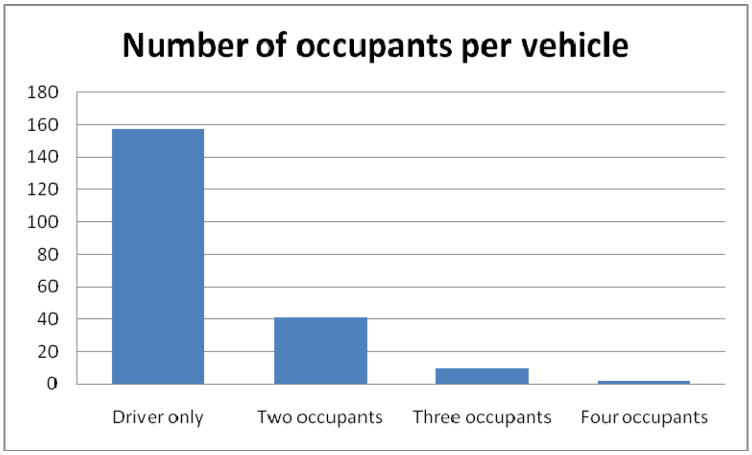

Figure 11. Number of occupants per vehicle.

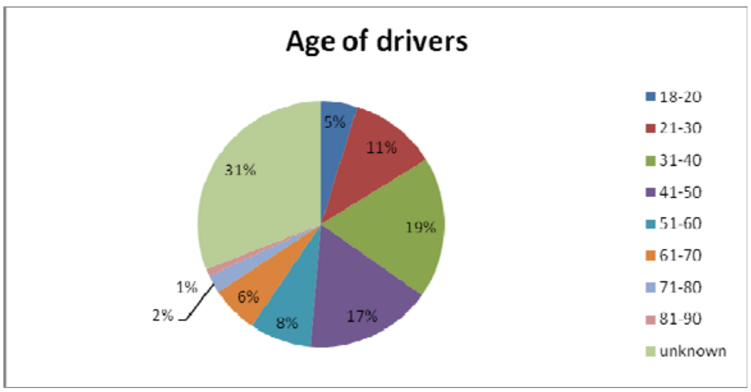

Figure 12. Distribution of age among drivers.

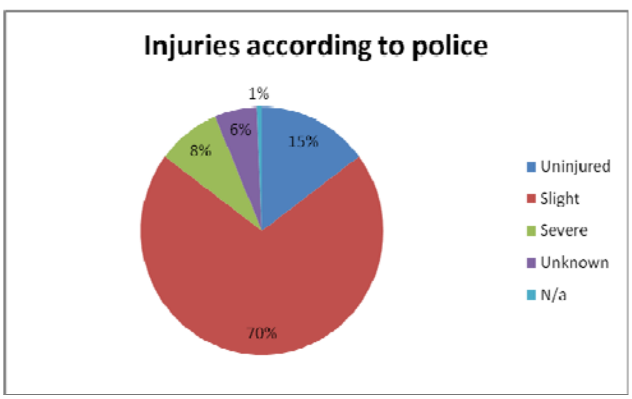

Figure 13. Injuries of occupants as graded by the police.

6.2 Process Completion

An overview of the data in terms of completion of the different process tasks described above was conducted. This section deals with the completion of accident summaries, accidents sketches and DREAM analyses.

During the investigations in phase 2, the accident summary was included in the on-scene protocol. But only in a few cases was the accident summary made in such a way that it was possible to understand what happened in the accident. Only 16 out of 40 accidents had a summary that gave an overview of the accident and these were made in the on-scene protocol, in scenarios made in power point or in a separate document. In the investigations in phase 3, the accident summary was supposed to be filled out in the accident protocol and include the most important factors like number of vehicles, trajectories, collision configuration and course of events. The accident summary was not supposed to be written until after the analysis was finished, which is why 41 of the 70 accident summaries was missing.

A DREAM analysis should be conducted for each driver/rider or pedestrian in the accident. Out of the 204 vehicles (pedestrians excluded), 177 DREAM analyses were carried out (87%). In most of the cases where a DREAM analysis was missing, no interview had been conducted.

The sketch training was not performed until late in phase 2 which could explain why only 18 sketches were present in the 40 cases (45%) out of which several of these were only hand sketches without scale. In phase 3, 18 CAD sketches and 29 hand sketches were available in the 70 cases (67%).

6.3 Response Rate on Long Term Injury Follow-Up Questionnaires

During the first half of phase 2, quite many questionnaires were sent out too late. This was because the questionnaires were not available, or the case was not reported to the Traffic Injury Register in time. As a consequence, a proposal was made to change the 1-month follow-up to a 3-months follow-up. However, it was decided to keep the 1-month follow-up, because it would probably provide more reliable data.

The delay, however, continued throughout the whole project. In most cases, the delay was because the interviewers were unable to contact subjects involved in the accidents. This included injured persons who had been transported from the scene by ambulance and less severely injured persons who had left the accident scene. In a few cases subjects did not want to take part in the study at all or it was not possible to contact them.

There were 110 accidents investigated in phases 2 and 3 with 292 involved subjects. Of these, 209 (72%) were reported to the Traffic Injury Register, and they all received information and the first questionnaire with the 1 month follow-up. Of the 209 subjects, 10 were reported to the Traffic Injury Register within 30 days, 120 within 31-60 days, 52 within 61-90 days and 25 within 91-120 days. The remaining 2 subjects were reported 140 and 153 days after the accident respectively.

The response rate was 43% after the first questionnaire expedition and a further 13% replied after two expeditions (56% in all). Reminders for the first questionnaire were sent to 118 of the 209 subjects (56%).

Forty-six (46%) of the 116 subjects who responded to the fist questionnaire reported residual problems at the first follow-up, and 65 subjects reported no problems. For the remaining 5 subjects, the reply was unclear.

The response rate after 6 months for the 46 subjects who reported problems at the first follow-up was 94% and 16 of these had residual problems at that time and at least 13 of them also had problems after one year. The response rate after one year was 81%.

Telephone contacts were not made regularly for non-respondents, as previously decided by the project group. In three cases, however, telephone contacts were made. In the first case, no answers were given on the accident circumstances, because a similar questionnaire had been sent from Volvo accident investigation group but the subject gave INTACT permission to use the results of the Volvo questionnaire. In the second case, serious psychological consequences were suspected from the answers in the questionnaire, and telephone contact was successfully made in order to check if further medical help was needed. The third case involved persons who were severely injured in an accident. Because the first questionnaire and the reminder were sent too late for the first follow-up, they did not return the questionnaires. As follow-up data were judged to be very important, a late contact was made, and both accepted to join the study. This rendered very important information about the injuries and possible injury mechanisms.

The quality of the data reported in the questionnaires was generally good, and the descriptions of the residual problems were quite clear. In some cases (5 - 10%) some of the questions were not replied to, probably because residual problems did not exist for the item.

The Traffic Injury Register did not note difficulties in any case during contacts with involved road users.

6.4 Fill Out Rate of Variables

The fill out rate of variables is strongly connected to the used protocols and as the protocols were updated continuously the evaluation presented below should take this into account.

The number of inspected vehicles coded into the database is 133 of the 181 vehicles involved in the coded accidents. Forty vehicles are for different reasons not inspected. In the database there are 9 vehicles created were still nothing is coded.

The database has also been checked for variables with high percentage unknown coded. For some of the variables it's also noted a high number of Not Applicable (N/A) but this is only included in this report in specific cases. Only the parts belonging to accident collection (and not accident analysis) were included in this review.

Accident variables with high number of unknown are:

- Number of Ambulances (58/110)
- Number of Ambulance Helicopters (21/110)
- Temperature (48/110)

Number of Ambulances and Number of Helicopters are often unknown since the team arrive when ambulance already might have left the accident scene. Coding "Temperature" can retrospectively be retrieved at www.temperatur.nu.

For the road variables there are quite a few with high numbers of unknown:

- Average annual daily traffic (13/122)
- AADT level of confidence (13/122)
- Average annual daily traffic for trucks (13/122)
- AADT level of confidence for trucks (13/122)
- Measured in year (13/122)
- Average speed on road for car, day (13/122)
- Traffic flow when measured, day (13/122)
- Average speed on road for cars, night (13/122)
- Traffic flow when measured, night (13/122)
- Period when measured, start (13/122)
- Period when measured, end (13/122)
- Curve radius (47/122)
- Roadway width (43/122)
- Road gradient (48/122)
- Road friction coefficient (63/105(active lanes))
- Road surface temperature (39/105)
- Microscopic road surface conditions (42/105, 44 N/A and the rest are not filled out at all)
- Traffic flow at accident time (61/122)
- Traffic at accident time, level of confidence (61/122)
- Truck traffic at accident time (61/122)
- Truck traffic at accident time, level of confidence (61/122)
- Speed at accident time (61/122)
- Barrier working width (6/23, the other 17 are not filled out at all)

The eleven traffic variables "Average annual traffic" to "Period when measured, end" are unknown in 11% of the roads. These variables are often difficult to code since there is in most cases no measure station exactly where the accident has happened and after a review it was noticed that different investigators choose different adjacent measure stations while some investigators coded unknown instead if they are unsure of which one to chose.

The reason for the high numbers of unknown in "Curve radius", "Roadway width", "Road gradient", "Road friction coefficient" and "Road surface temperature" is most likely due to safety reasons while the investigator has to enter the road to be able to measure any of them. There is also no good instrument for measuring the "Road friction coefficient".

"Microscopic road surface condition" is unknown in 42 of the 105 lanes, not applicable in 44 of the lanes and not coded in the rest of the lanes. No definition or values of this variable are available in the manual.

The five "Traffic at accident time" variables "Traffic flow at accident time" to "Speed at accident time" are often unknown while measurement of the road in question is not made at the time for the accident. This information were only filled out in eight of the 122 created roads in database.

"Barrier working width" is coded as unknown in six of the 23 cases including impact with a barrier. The other 17 cases are not coded at all. This is probably due to lack of information in the manual.

For the vehicle variables there are quite a few unknown coded in the database. One thing to have in mind for the vehicles is that some of the vehicles are not inspected for different reasons and therefore have a bigger number of unknown variables. Normally, quite a lot of information can still be coded if it is noticed on-scene or on photos but most deformation measurements must be coded unknown. If a complete inspection has not been carried out there is sometimes a confusion between unknown and N/A, for further investigations this difference should be explained in more detail in the manual.

- Bus – weight at accident time (3/4)
- Car – frontal compatibility height (27/181)
- Car – sill height (88/181)
- Car – front bumper height (68/181)
- Car – rear bumper height (99/181)
- Car – axle distance (48/181)
- Car – axle distance difference left (24/181)
- Car – axle distance difference right (24/181)
- Car – year and month of manufacture (62/181)
- Car – impact C1-C6 (49/173)
- Car – impact, distance from centre of gravity (92/173)
- Truck – year and month of manufacture (12/23)
- Truck – platform height (9/23)
- Truck – chassis frame ground clearance (10/23)
- Truck trailer – chassis frame ground clearance (4/6)
- Wheel – manufacturing date (210/412)

Three out of the four busses in the database are coded as inspection completed but one of these is only inspected on scene. "Bus – weight at accident time" is unknown in three out of four cases (and N/A in the fourth case) with a bus involved in an accident. This is probably due to the bus drivers do not seem to know this rather than that a complete inspection is missing.

A complete inspection is missing in 40 out of the 181 cars. Except for these 40 cases, sill/bumper heights of the car are often unknown because it is not always noted in the vehicle inspection protocol. For example, variables measured in the front of the car are only filled out if the vehicle has been involved in a frontal impact.

The variable “Car axle distance” should be measured on a similar undamaged car according to the description. This is often unnecessary since the information is available in books or on the internet but it requires some work to find it. “Car – axle distance difference left and right” were until phase 3 placed in an illogic place in the inspection protocol therefore these variables were often forgotten.

Both car and truck “year and month of manufacture” have high numbers of unknown since this information is only available in the vehicle specification of newer vehicles.

Measurement C1 to C6 of car impact is missing in 86 of the 173 coded impacts and is unknown in 49 of these. This is in most cases since a full inspection for some reason (like that the reparation work has already started) could not be performed or that the impact is too small or has not involved any structure and the inspectors judged that a measurement would be too complicated to do and interpret. Most of the other missing C1 to C6 coding is due to problems with these variables in the database at the time for coding of the cases.

“Car – impact, distance from centre of gravity” is unknown since this variable has never been present in the inspection protocols.

For the 19 coded trucks in the database the inspections are completed for eight cases and not completed for ten cases. Truck platform height and truck and trailer chassis frame ground clearance are in almost all of the unknown cases due to no complete inspection of the truck or inspection only made on-scene.

Unknown manufacturing date of the wheels is in 54 of the 210 cases because no inspection has been made. In most of the other cases the manufacturing date of the wheels on one side of the vehicle are known while this information often is only present on one side of the tire.

6.5 Quality of Variables

The quality of data for each variable in the road protocol was high. The consensus among investigators is that the accuracy of measured variables is good and that the correct and applicable variables have been measured for each accident. However, a specific analysis of the accuracy and validity of all data in the road protocols has not been conducted as this would be unpractical and would call for a re-visit of each accident site.

The quality of injury data obtained from medical records was acceptable. However, in some cases (estimated at 10-20%), the description of the injuries did not allow for detailed coding according to the AIS-system.

The quality of the data reported in the injury follow-up questionnaires was generally good, and the descriptions of the residual problems were quite clear, with few exceptions.

6.6 Representativity of Collected Data

The INTACT data sample aims for representativity for Sweden. The representativity was checked in three steps using accidents in STRADA (also see Appendix C).

In the first step the INTACT accidents were compared to police reported accidents in the same municipalities and time shifts, which excluded night hours and weekends. In a second step the INTACT sample was compared to all accidents in the corresponding municipalities. In the third step a comparison to the whole STRADA dataset was made. As the data collection methodology in INTACT was continuously changed in 2008, only INTACT accidents from 2009 were included. Police reported accidents in STRADA up to September 2010 were used.

Data from INTACT and STRADA were compared in three steps:

1. STRADA accidents from 2009 in the municipalities Göteborg, Lerum, Partille, Härryda, Ale, Kungälv, and Möndal, limited to accidents occurring between 6:00h to 18:59h, Monday to Friday. The time and weekday limitation does not represent the INTACT sample plan in detail, but it is estimated as appropriate for the generic analysis.
2. STRADA accidents that happened in 2009 in the municipalities Göteborg, Lerum, Partille, Härryda, Ale, Kungälv, and Möndal.
3. STRADA accidents that happened in 2009.

The accident severity reported by the police, accident type and accident location were compared.

6.6.1 Outcome of step 1

The total number of police reported accidents in STRADA was 779. The accident severity of these was slight in 712 accidents (91%), severe in 57 accidents (7%) and fatal in 7 accidents (about 1%). For the remaining accidents the injury severity is either unknown or no injury.

The total number of INTACT accidents where a police grading of severity was available was 43. The accident severity of these was slight in 39 accidents (91%), severe in 3 accidents (7%) and unknown in 1 accident (2%). There were no fatal accidents in the INTACT sample.

The accident types of police reported accidents in STRADA were 230 following vehicle accidents (30%), 139 bicycle or moped accidents(18%), 126 single vehicle accidents (16%) and 91 pedestrian accidents (12%). The accident types of INTACT accidents were 12 following vehicle accidents (28%), no bicycle or moped accidents and 13 single vehicle accidents (30%). Pedestrian accidents were strongly underrepresented and bicycle or moped accidents were not represented.

Sixty-one percent of the accidents in STRADA occured in urban areas compared to 55% in INTACT.

The INTACT data represent the accident severity and accident location of the STRADA data well if limited to the sampling area and sampling times. There are differences in the accident types. Single vehicle accidents or oncoming vehicle collisions are overrepresented, pedestrian accidents are underrepresented and accidents with bicyclists/mopeds are missing in the INTACT data.

6.6.2 Outcome of step 2

The total number of police reported accidents in STRADA increased to 1274, which means that about 40% of all accidents in the seven municipalities happen on the weekend or weekdays between 19:00 and 5:59 hours. There was an increase in severe and fatal accidents. The accident severity was slight in 1134 accidents (89%), severe in 111 accidents (9%) and fatal in 17 accidents (1,3%). The rest were unknown. The accident types were 230 following vehicle accidents (30%), 139 bicycle or moped accidents (18%), 126 single vehicle accidents (16%) and 91 pedestrian accidents (12%). Sixty percent of the accidents (N=763) occurred in urban areas.

Forty percent of the accidents in the sample area happened out of the scheduled time shifts. As the percentage of severe and fatal accidents increased, it can be concluded that accidents at late evening/night time and/or weekends have a higher risk for more severe injury outcome. The percentage of single vehicle accidents increased strongly.

6.6.3 Outcome of step 3

The total number of police reported accidents in STRADA increased to 16744 accidents. The accident severity was slight in 13708 accidents (82%), severe in 2504 accidents (15%) and fatal in 377 accidents (about 2%).

There were 2383 following vehicle accidents (14%), 2652 bicycle or moped accidents (16%), 5470 single vehicle accidents (33%) and 1333 pedestrian accidents (8%). Dominating accident types are single vehicle accidents (33%, N=5470), accidents with cycle/moped (16%, N=2652) and following vehicle accidents (14%, N=2383). Pedestrian accidents cover nearly 8 percent (N=1333) of all accidents. Forty-eight percent of the accidents (N=8095) occurred in urban areas, 45% in rural areas and the remaining accidents are coded unknown.

When all accidents from 2009 are considered, the percentage of severe and fatal accident compared to the sample region nearly doubles. The single vehicle accidents sum up to one-third of all STRADA accidents. In line with this accident type change the accidents occurred in both, urban and rural area, nearly equally distributed.

6.6.4 Discussion on the Representativity of Collected Data

Although the distribution of accident severity seems to be highly representative, there is a huge difference in the distribution of accident types. Accidents where it takes longer time to clear up the accident site (e.g. single vehicle accidents) are overrepresented, whereas accidents with vulnerable road users (VRU, i.e. pedestrians and two-wheelers), which accounts for very fast medical treatment, are underrepresented. This could be also connected to the accident site, because single vehicle accidents most often occur in rural areas and accidents with VRU in urban areas. For both interpretations fast arrival and access to the accident site is important.

The accidents at night time and/or weekend have a higher injury outcome, which is also represented in the accident type. It is further expected that accidents at night time or on the weekends have additional contribution factors to accident causation and may cover a different driver population.

The comparison between the sampling area around Göteborg and Sweden in total showed, that the sample region is not representative at all with regard to injury outcome, accident type or accident location. On a first view e.g. the single vehicle accident occurrence in percentages seems to be in line with the Swedish national statistics, but this is more a result of an overrepresentation of this accident type in the seven municipalities according to accident site access limitation together with an underrepresentation compared to Sweden.

7 ANALYSIS OF DATA

About 30% of the INTACT accidents are not coded by the police in STRADA. The explanation for this is given by the sampling criteria in INTACT, that an ambulance must have been called to the scene, which allow the recording of accidents without personal injury. In STRADA property damage accidents are not coded.

7.1 Specific Analysis Topics

All partners involved in INTACT have access to the developed methods and the collected data. A small selection of specific analysis topics are presented below to get an understanding of the possibilities of the data.

7.1.1 Injury Analysis

The road user category and the counterpart for 83 road users reported to the Traffic Injury Register until October 2009 are shown in Table 4. The vast majority (94%) of these subjects were injured as car occupants. The counterpart was a car in 61% of the cases.

In general, about half of the subjects who answered the questionnaire had no injuries at all (23%), or minimal injuries that needed minor or no medical treatment. Only 7% of the subjects who answered had an ISS greater than 8 (i.e. MAIS = 2). The ISS-distribution for 83 subjects, whose injuries have been coded until October 2009, is shown in Table 5. Two elderly car occupants are included, who died within a few days after a frontal collision with another car. The injuries in these fatal cases were analyzed only to a limited extent, because the accident scene investigation and car inspections were not sufficient.

Table 4: Road user category and counterpart in 83 road users reported to the Traffic Injury Registry

	Counterpart								
Road user category	**Single**	**MC**	**Car**	**Truck**	**Bus**	**Tram**	**Animal**	**Total**	**%**
Pedestrian	0	0	1	0	0	0	0	1	1,2
In car	19	1	47	6	3	0	2	78	94,0
In truck	0	0	1	0	0	1	0	2	2,4
In bus	0	0	2	0	0	0	0	2	2,4
Total	19	1	51	6	3	1	2	83	100
Total %	22,9	1,2	61,4	7,2	3,6	1,2	2,4	100,0	

The injured body regions and the AIS-grades are shown in Table 6. Neck injuries were most common (28%), most of them resulting from rear-end impacts.

The types of injury and the AIS-grades are shown in Table 7. Contusion was the most common type of injury, followed by distortion/dislocation (in almost all cases sprains, usually to the neck).

Table 5: Injury severity of 83 road users

ISS distribution	Number	ISS	%	Cumulative %
ISS 1-8	19	0	22,9	22,9
	38	1	45,8	68,7
	12	2	14,5	83,1
	5	3	6,0	89,2
	1	5	1,2	90,4
	2	6	2,4	92,8
ISS >8	1	9	1,2	94,0
	2	14	2,4	96,4
	1	22	1,2	97,6
Fatal	1	33	1,2	98,8
Fatal	1	35	1,2	100,0
Total	83		100,0	

Table 6: Injuries to body region of 83 injured road users

Body region	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	Total	%
Head/Face	21	4	2	1	3	31	17,8
Neck	39	5	5			49	28,2
Upper extremity	28	3				31	17,8
Upper trunk	12	8	4			24	13,8
Lower trunk	10	2	1			13	7,5
Lower extremity	25		1			26	14,9
Total	135	22	13	1	3	174	100,0

Follow-up and residual problems

Of 100 injured road users involved in accidents before September 2009, 80 returned the first questionnaire. Of these, 50 had acute problems, and 12 had not. In 18 cases the existence of acute problems was uncertain. Of the 50 subjects with acute problems, 42 reported medical treatment, of which 33 were treated at emergency hospitals and 9 at primary health care units, while 8 did not seek medical care.

The time between the accident and the first follow-up could be calculated for 55 injured road users. The mean follow-up time was 79 days (range 18 – 254 days). Only two road users, who were injured in a severe accident, had a response time over six months.

Table 7: Type of injuries of 83 injured road users

Type of injury	AIS 1	AIS 2	AIS 3	AIS4	AIS 5	Total	%
Wound	20					20	11,5
Contusion	57					57	32,8
Distortion/dislocation	51		2			53	30,5
Fracture	1	13	8			22	12,6
Organ injury	3	8	2	1	3	17	9,8
Other injury	3	1	1			5	2,9
Total	135	22	13	1	3	174	100,0

Table 8: Residual physical problems at 1st follow-up

Body region	Priority 1	Priority 2	Priority 3	Priority 4	Priority 5	Total	%
Head/Face	3	1				4	2,3
Neck	16	5	1			22	12,6
Upper extremity	13	9		1		23	13,2
Upper trunk	2	1	1			4	2,3
Lower trunk	5	3	1			9	5,2
Lower extremity	3	5	3		1	12	6,9
Total	42	24	6	1	1	74	42,5

At the time of this review, 30 November 2009, 31 subjects had reported 74 residual physical problems at the first follow-up. About half of them reported problems of minor or moderate degree. The body regions with residual physical problems and the priorities of the problems (1 = worst) are shown in Table 8.

At the first follow-up, 31 subjects reported residual general problems of various kinds. In 25 cases they also reported physical problems. Physical problems without general problems were reported in 6 cases, and general problems without physical problems were reported in 6 cases. In 5 cases more than 5 kinds of general problems were reported.

A thorough analysis of residual physical problems, caused by primarily undiagnosed injuries, has not yet been made. Such problems were suspected in several cases (perhaps in 10-20% of the subjects). However, in some of these, pain or dysfunction in body parts, adjacent to diagnosed injuries, may have been caused by referred pain, and a specific medical examination is needed for a reliable judgement.

Residual general problems (including psychological problems) were reported in about 60% of the cases at the first follow-up, as previously mentioned. In most of these cases, the primary injury was a neck sprain, often resulting from a rear-end impact, and thus the rate of residual general problems was not at all proportional to the primary injury severity. The occurrence, type, and extent of residual psychosocial problems have not yet been analysed, as these also include loss of working capacity, need of personal assistance, etc, during a longer follow-up.

In four cases a medical condition attributed to the accident. In one, a cardiac disease was discovered and treated in a young man. In the others, loss of consciousness or epilepsy attributed to the accident.

7.1.2 Psychosocial Factors

A representative from the Sahlgrenska Academy examined the answers given to the interviewer at the first contact after the accident. A trial was made to estimate how well the questions were answered to (completed) from the guide according to the following definitions.

- not complete
- quite complete

- very complete

A trial was also made to evaluate to what extent factors could be identified from the interview, which may have contributed to the occurrence of the accidents in 45 cases. Such factors are violations of traffic rules, impulsiveness, unfamiliarity, stress, distraction, worries, tiredness, hunger, use of cell phone, etc. The influences from each of these items, when noted, were graded as follows.

- not probable
- possible
- probable

Preliminary Results of the Psychosocial Factor Analysis

At the present time (1 December 2009), 45 interviews, made with road users involved in consecutive accidents from March – October 2009, have been reviewed. Seven investigators conducted these interviews. Of the 45 interviews, 42 were possible to evaluate. Three were not evaluated, because the person performing this review conducted these interviews. Three of the interviews were graded as not complete, 36 as quite complete, and three as very complete.

Usually, more than one factor was judged to have influenced the occurrence of the accident, most often combinations of distraction (12), stress (10), low attention (8), and worries (6). Cell phone use was admitted in 2 cases.

Differences between genders regarding willingness to take part in the interview were not investigated. Nor were possible influences of posttraumatic stress. Difficulties in language were noted in a few cases.

7.1.3 Injury Outcome in Intersection Crashes involving Modern Volvo Cars

Reducing the number of and injuries sustained in intersection crashes is important, and one of the factors influencing the injury outcome is the speed of the vehicles involved. The intrusion into a vehicle impacted in the side depends e.g. on the speed of the impacting vehicle, the weights of the vehicles, the vehicle structure and the presence of side-protection systems such as side airbags and inflatable curtains.

The INTACT database contains a number of intersection crashes. The purpose of this analysis was to investigate injury outcome as a function of collision speed in intersection crashes for frontal and side collisions and compare crashes with and without a line of sight. The requirements for an accident to be included in the analysis were that it included at least one Volvo car in production of model year 2000 and that it was an intersection crash. The INTACT database was reviewed to find suitable accidents.

Six accidents with seven Volvo cars fulfilled the requirements to be included into the analysis, where one is a u-turn and one takes place at a driveway. All vehicles had deformation measurements, CDC-coding and C1-C6 measurements. It gives a good picture of the deformation patterns together with photos. However, AIS-coding of the injuries was only found in one case. Four accidents that occurred in 2009 had been reconstructed; however objective data about collision speed or objective data on line of sight were not available. Therefore the injury outcome as a function of vehicle speed could not be determined as there are too few cases where the required data are available.

However, the content of the database corresponds to what is needed for answering the question. In the future, with more cases and more data available, this question can be further studied.

7.1.4 Accident Causation Patterns and Familiarity with Accident Site

A comparison of DREAM analyses was performed to find out if there was a difference in causation patterns depending on the driver's familiarity with the accident site.

The first research question was how familiar with the accident site are the drivers. The specific question "How often do you drive on this road?" is included in the interview guide. The answers from the interview question were grouped in four groups:

- Often (at least every month)
- Sometimes (a few times a year)
- Only few times (1-10 times before)
- Never before

A review of answers to the specific question in the interview guide was performed. Of the 210 drivers, 63% often drove at the accident site (see Figure 14). Only 5% were unfamiliar with the road. No conclusions can be drawn from these numbers without having access to exposure data describing how much of the traffic during daytime hours is driven on familiar roads.

The second research question was if there are any specific patterns in the accident causation charts depending on whether the driver is familiar with the road or not.

The DREAM analyses for the four groups (i.e. each group represented one answer to the specific question in the interview guide) were compared.

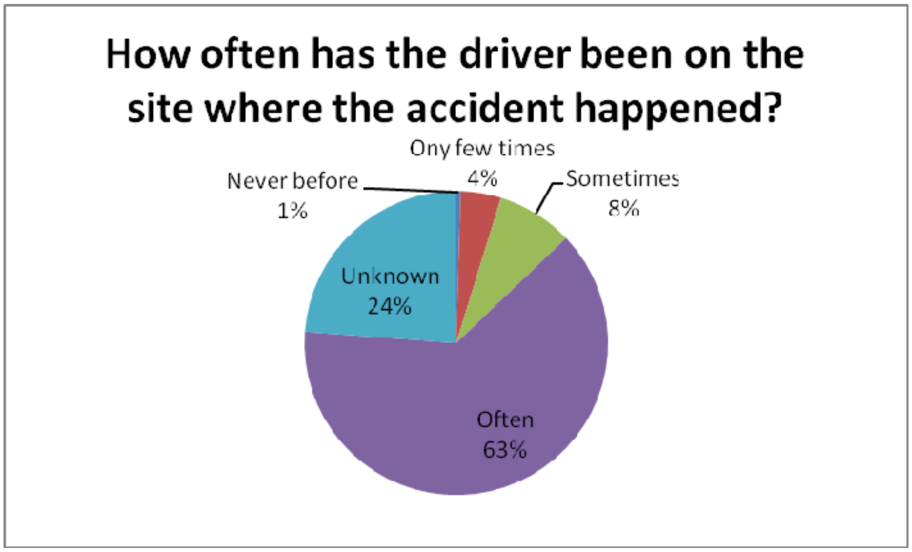

Figure 14. Driver familiarity with accident site.

The genotypes F6 Insufficient skills/knowledge, F6.1 Insufficient geographical knowledge/experience, L1 Insufficient guidance, M2 Inadequate transmission from road environment and Q1 Inadequate information design were looked for. The comments were studied and cases not relevant to this question were removed. In twelve DREAM analyses, one of the factors for the accident was that the driver was not familiar with the road. The result of one DREAM analysis showed the opposite, that the driver was expecting a stable road environment. Even though most accidents occur on familiar roads it seems, according to the DREAM analyzes, that a strong contributing factor to the accident is in 6% due to uncertainty of the road environment.

The third research question was if non driving-related inattention as a contributing factor has any connection with if the driver was familiar with the road or not.

All DREAM analyses including E2.3 Non driving-related distracters inside vehicle, E2.4 Non driving-related distracters outside vehicle and E2.5 Thoughts/Daydreaming were studied. In 17 of the DREAM analyses was one or more of these genotypes found. Sixteen of these drivers were familiar with the road they were driving on, 15 drove there often and one sometimes. The last one was unknown because the interview was not complete. The result compared to the familiarity of the road in all intact cases can be seen in Figure 15. Even though the number of cases is too small to give any significant results, a trend can be seen that when a driver is familiar with the road he/she is more likely to relax and focus less on the driving task.

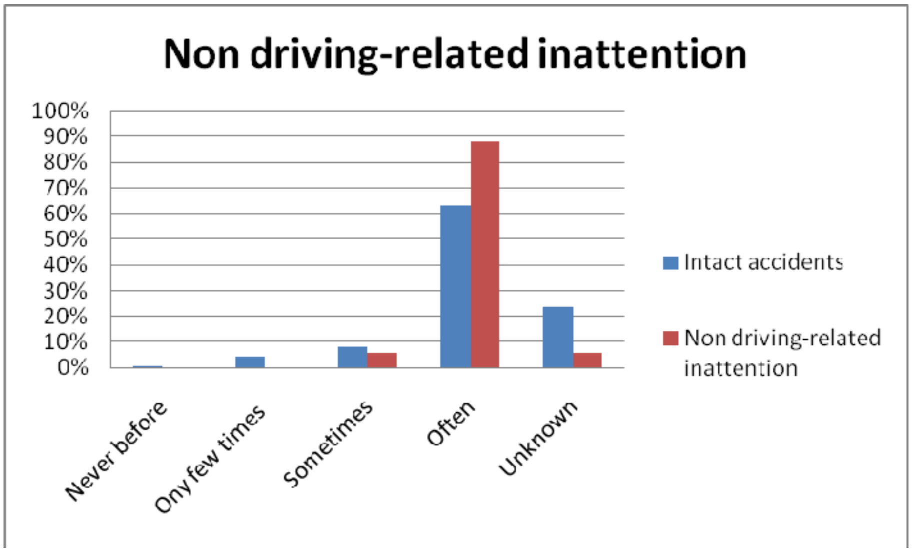

Figure 15. How often the driver used to drive on the road where the accident happened when one of the causes was non driving-related inattention.

The fourth research question was what the main purpose of the trip was. This specific question is included in the interview guide.

The answers from the interview question were grouped in three groups:

- To or from work
- In work (both commercial drivers and other business trips)
- Free time

A review of answers to the specific question in the interview guide was performed. Most of the investigated accidents (34%) occurred on trips related to leisure or other purposes not related to work or school (see Figure 16), 24% occurred on the way to or from work and 19% during trips included in work. When comparing these numbers to numbers from a national statistics study [27], it is mainly the number of accidents during work that differs. This is most probably due to INTACT's collecting hours that have mainly been during daytime and the national statistics cover 24 hours a day. But the numbers could also indicate that more accidents than reported in the statistics is work related.

The fifth research question was if this could have anything to do with stress or time pressure.

All DREAM analyses including psychological stress (E7) and time pressure (N1) were reviewed. In 16 DREAM analyses the drivers stated in the interview that they were under some form of psychological stress when the accident happened. Out of these 16, six persons were under time pressure. These data indicate that people are under more stress and time pressure in their free time than during work (Figure 17), although the numbers of cases is too small to draw any definite conclusions.

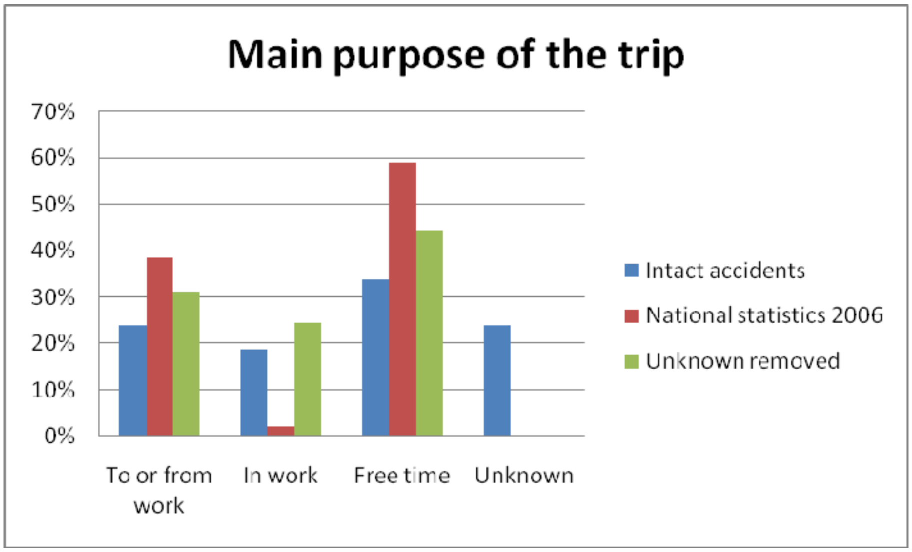

Figure 16. Main purpose of the trip.

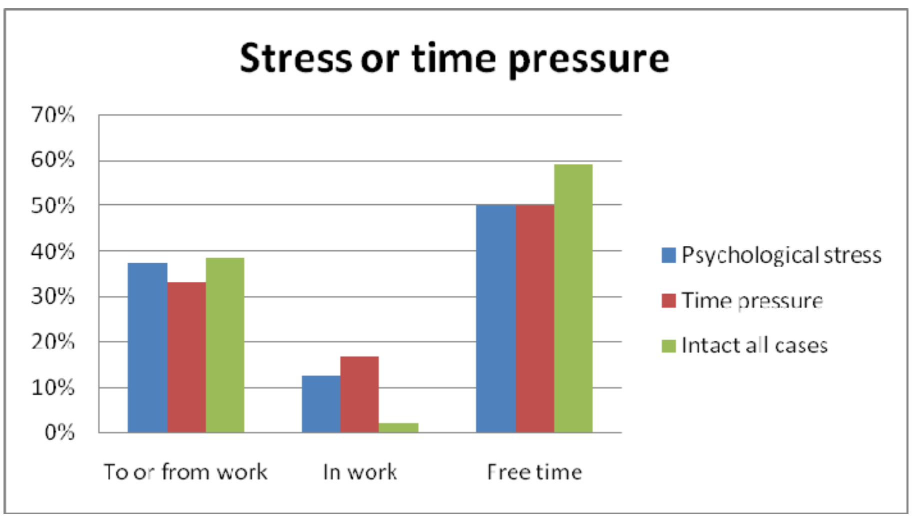

Figure 17. Main purpose of the trip in the cases were psychological stress or time pressure have been one of the contributing factor to the accident.

7.1.5 Infrastructure Related Accidents - Guardrails

Guardrails and other road infrastructure are often involved in accidents and also play an important role in increasing road traffic safety, especially reducing the number of head-on collisions. A number of accidents were investigated in INTACT that involved road infrastructure, mainly guardrails and barriers.

The INTACT database was reviewed for accidents that involved road infrastructure and occurred during 2008 and 2009. Accidents that either directly, i.e. a guardrail, barrier or signpost was impacted, or indirectly, i.e. an accident occurred where a guardrail or barrier should have been in place, involved road infrastructure were selected. The selected accidents were then reviewed together with an expert in road design from the Swedish Transport Administration, especially with respect to accidents where road infrastructure was indirectly involved. The MAIS for each accident was retrieved from STRADA.

A total of 51 accidents were found. The majority of accidents, 27, were single vehicle accidents (see Table 9). Most accidents occurred on heavily trafficked roads with a high Average Annual Daily Traffic (AADT) and the major accident type was related to lane change accidents (see Table 10).

In 35 accidents road infrastructure was directly involved. In the majority of cases (25 accidents) guardrails and barriers were impacted, in 9 accidents lamp or sign posts were impacted (see Table 11). The most common scenario was a barrier impacted in a single vehicle accident (see Table 12).

In 16 accidents road infrastructure was indirectly involved (see Table 13). The majority of these were single vehicle accidents where a barrier or guardrail would have prevented the vehicle from leaving the road and e.g. impacting objects in the roadside

Table 9. Distribution of accident types

Accident type	Number of accidents
Single vehicle accident	27
Lane change	12
Catching-up	3
Crossing paths	3
Head-on collision	3
Crossing paths-tram	*1*
Left turn across path-opposite direction (LTAP-OD)	*1*
Side swipe	*1*
Total	51

Table 10. Distribution of accident types at different AADT intervals.

Accident type	<5000	5001-10000	10001-15000	15001-20000	20001-25000	>25000	Unknown	Total
Single vehicle accident	7	1	3	5	1	6	4	27
Lane change			1			11		12
Catching-up			1			2		3
Crossing paths	1	1		1				3
Head-on collision	1			1		1		3
Crossing paths-tram			*1*					*1*
LTAP-OD						*1*		*1*
Side swipe						*1*		*1*
Total	9	2	6	7	1	22	4	51

Table 11. Impacted road infrastructure.

Impacted road infrastructure	Number of accidents
Guardrail/barrier	25
Lamp post	6
Sign post	3
Other	1
Total	35

Table 12. Impacted road infrastructure in different accident types.

Accident type	Guardrail/barrier	Lamp post	Sign post	Other	Total
Single vehicle accident	11	3	1	1	16
Lane change	9	1			10
Catching-up	3				3
Crossing paths		2			2
Crossing paths-tram			*1*		*1*
LTAP-OD			*1*		*1*
Side swipe	*1*				*1*
Head-on collision	*1*				*1*
Total	25	6	3	1	35

Table 13. Number of accidents where road infrastructure was indirectly involved.

Accident type	Number of accidents
Single vehicle accident	11
Head-on collision	2
Lane change	2
Crossing paths	1
Total	16

In 27 accidents the MAIS was found. The remaining accidents had not been reported by hospitals to STRADA, indicating that there were no injuries or the injured were not cared for at a healthcare facility reporting to STRADA. The highest MAIS was in the two fatal accidents (MAIS 4 and MAIS 6 respectively) with the most common scenario being an MAIS 1 sustained in a single vehicle accident (see Table 14).

The most common accident types were single vehicle accidents followed by lane change accidents. No particular pattern was found in the single vehicle accidents regarding road type but lane change accidents to a large extent, 11 of 12, occurred on heavily trafficked roads. This might be due to E6 passing through the INTACT sampling area and it is heavily trafficked by trucks. In 6 of the 11 accidents the median barrier was impacted, thereby preventing a head-on collision. Even though the Model for Safe Road Traffic used by the Swedish Transport Administration stipulates that roads with a speed limit above 70 km/h should have median barriers, three accidents occurred on roads with a speed limit of 70 km/h. In these cases the barrier most likely prevented a head-on collision and possibly a more severe outcome (in these three cases the MAIS was 1 in one case and unknown in the others).

The single vehicle accidents occurred on roads with different speed limits and AADT. On roads with a 70 km/h speed limit 15 accidents occurred, and in 6 cases road infrastructure was indirectly involved, i.e. there should have been guardrails or barriers at the accident site. It is unknown whether the injuries would have been less severe had a barrier been at the site; in these cases there was an MAIS 1 in one case and unknown in the others. However, 40% of single vehicle accidents occurred at sites where a guardrail or barrier should have been present.

Both fatal accidents were head-on collisions and occurred on roads without median barriers, one on a road with a 50 km/h speed limit and the other on a road with a 90 km/h speed limit. The deceased in both cases travelled in vehicles that entered the oncoming lane. A median barrier would have helped preventing both vehicles entering the oncoming lane. Even on such a small sample, INTACT has shown the importance of median barriers in reducing the number of severe or fatal accidents.

Table 14. Maximum AIS in different accident types.

Accident type	MAIS 0	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 6	Unknown	Total
Single vehicle accident	5	8		1			13	27
Lane change		6					6	12
Catching-up		1		1			1	3
Crossing paths		1					2	3
Head-on collision				1	1	1		3
Crossing paths-tram							*1*	*1*
LTAP-OD			*1*					*1*
Side swipe							*1*	*1*
Total	5	16	1	3	1	1	24	51

8 DISCUSSION

8.1 Purpose and Aims

The three purposes of INTACT were to develop an investigation network; to develop and evaluate an advanced methodology to collect data and analyse real-world traffic accidents and store the information in a database; and to prepare INTACT for an initiative on a European level, where INTACT can be one of the nodes for contributing to a European in-depth accident database.

Three aims were set to fulfil these three purposes.

The first and second aim was to develop a national investigation network and an investigation methodology focusing on all phases of a crash (pre-crash, in-crash and post-crash) as well as all parts of the road transport system (road user, vehicle and road environment). The second aim included the evaluation of the developed methodology as well as storing the information from accidents in a database. During the three years that INTACT has been active, a national investigation network has been developed to include partners from industry, academy and authority. These partners have contributed to developing an investigation methodology covering all phases of a crash and all parts of the road system. This methodology has been developed through an iterative process and trialled on real-world accidents. It contains defined sampling criteria which were used to set up a sampling plan. Relevant data variables were also defined as well as operational routines and methods for data collection and case analysis. The final methodology is presented in Chapter 4. The evaluation of the methodology was carried out through one pilot and seven data collection periods. In all 110 accidents were investigated, fulfilling the objective of evaluating the developed methodology. A software tool, i.e. a database, was developed to store data from the 110 accidents which have been electronically stored in the database. The first and second aim and its associated objectives have been achieved.

The third aim was to prepare INTACT for an initiative on a European level where INTACT can be one of the nodes for contributing to a European in-depth accident database. All documentation as well as the database is in English which makes it possible to use the developed methodology throughout Europe. The methodology as well as the INTACT (database) system has been offered to the European project DaCoTA. DaCoTA has accepted the offer and work is now underway to fine-tune the tools for European usage. The third aim has also been achieved.

The three purposes were fulfilled to a great extent. As shown in the analysis of the data (Chapter 7) the database contains the type of data suitable for prioritising measures, get a deeper understanding of factors causing accident and injury, develop safety systems, get the possibility to evaluate safety measures and be a foundation for influencing legislation. However, so far the data sample is too small to draw significant results. Knowledge from crashes involving road infrastructure, e.g. guardrails and barriers, have been used to improve guardrails and barriers.

8.2 General

The purpose of the INTACT project was to develop an effective methodology for the investigation of road traffic accidents with personal injury. According to the nature of this project, investigators from all participating organisations worked in INTACT and contributed with their knowledge, methods and processes that have been partially developed and used in their own accident data collection studies. This had both, positive and negative effects on the INTACT investigations in terms of knowledge transfer, quality, efficiency, and the ability to proper evaluate different methods.

Over the three phases of the project the number of investigators has varied from approximately five investigators working full-time to fifteen working part–time. The participation of many investigators with different backgrounds has led to the desired knowledge transfer as the investigators in turn applied the knowledge gained in INTACT in their in-house investigations. As an example, the Swedish Transport Administration has started using the INTACT road protocols and accident scene data collection methodology in its own accident investigations.

On the other hand, when many investigators with different levels of experience participate in data collection, the efficiency and quality of the investigations was affected. The time-quality efficiency was reduced by spending time in training and getting familiar with methods instead of using and further developing them. The quality of investigations was reduced, in case the definitions of variables are not precise enough, as this lead to many different interpretations. In an iterative process the variable definitions were improved based on the feedback from investigators. But since the definitions and routines updated and redefined during the project there is an inconsistency over the project runtime.

Manning an investigation team with people from different organisation also affects the definition of a representative sampling plan due to different agreements in terms of working hours. However, the final methodology has not yet been tested with a streamlined investigation team to evaluate the efficiency and quality of the investigations.

As mentioned before the objective of the INTACT project was to investigate accidents with personal injury. This selection was aimed by use of the sampling criteria “ambulance sent to the scene for possible personal injury”. However, information about personal injury is very difficult to retrieve close in time to the occurrence of an accident and it turned out that an ambulance is almost always sent to the scene of a road accident if the rescue services are notified. Results show that around 35% of the cases in INTACT are not reported by the police to STRADA. If also the data retrieved by the STRADA hospitals are included in the comparison, the percentage of accident without any injured person is 30%. In a continuation of INTACT it is recommended to redefine the present notification routine to be more accurate on the selection of accidents with personal injury.

One way to reduce the number of investigated accidents without personal injury is to investigate accidents retrospectively. This might give a better injury assessment for the accident sample but trials during phase 1 and 2 showed that it was very difficult to retrieve information about the road users, vehicles and the accident site if the team was not on-scene. In consequence, a larger number of accidents investigated retrospectively were dismissed compared to accidents investigated on-scene. Further analysis of the percentage of persons which were transported by ambulance from the scene, which are injured according to the INTACT follow-up questionnaire and to what extent the police might underreport road accidents with injuries is needed.

8.3 Data Collection

The data collection procedures in INTACT has been developed in an iterative process. The final methodology regarding data collection was very much improved in phase 3 compared to the methodology used in phases 1 and 2. However, a number of improvements can be made in a continuation of INTACT.

A methodology is effective if high quality data can be collected in a reasonable time frame. On-scene data collection is very vulnerable with regard to the time factor as the police and rescue services aim to clear up heavily trafficked roads as quickly as possible. This means that using traditional measuring equipment it is either not possible to measure an accident scene as accurately as required for a scaled sketch or doing so in dangerous conditions for the investigators. Therefore, there is a need for equipment that enables quick, safe, and accurate site measurements and sketch drawings. During the project phases neither differential GPS based measuring equipment nor partly-automated sketch drawing were tested. Another way of improving the quality of the sketch is to use digitalised maps of the area where accidents are being sampled. For Göteborg municipality, where 75% of the INTACT accidents occurred, digitalised drawings of the road network are available. These drawings have not been used and evaluated as it was shown in a number of cases that their accuracy is limited.

Vehicle inspections are an important part of accident investigations and two issues during vehicle inspections have been identified: classifying load paths and identifying active safety systems. The methods for retrieving this data and to achieve high reliability must be further enhanced.

The INTACT method for classifying load paths in frontal and rear collisions was developed from a method used in investigations on fatal accidents, which generally means more severe accidents. An assessment of how well the developed method for load path coding works for less severe accidents should be performed before a continuation of the INTACT project.

New car models entering the car fleet today are increasingly equipped with active safety systems and the identification of these systems and their activity status is very important for the assessment of their effectiveness. Currently there is no existing substantial method for identifying which vehicles are equipped with which system. It is also difficult to retrospectively determine the operating status of these systems in a vehicle involved in an accident. In a continuation of the INTACT project, ways to retrieve information about system introduction date, the affected models with serial or extra equipment, relational information on sensor fusion systems, etc. should be considered.

Interviews with involved road users were used to collect data for the pre-crash analysis. Both telephone and face-to-face interviews were trialled in the pilot, but later interviews were conducted mainly over the telephone, as it was found to be the most efficient and practical way. However, no qualitative comparison has been made between these two methods.

The interviews were conducted using the interview guide. The review of the interview guide regarding the possibility to evaluate the influence of psychosocial factors for the accident occurrence is not complete. Nevertheless, the impression is that the interview guide can be used to evaluate such factors. Also, the quality of the interviews varies. It is difficult to evaluate if a low quality stems from a sub-optimal interview technique, or if some of the possible contributing factors were not actual. In some cases, difficulties were noted when subjects, who may have been at guilt for the accident, did not want to be interviewed. This will create some bias in the evaluation. In some cases, drivers with foreign origin had difficulties with the language. This may also create bias, regarding driver licence.

Generally more efforts should be made to further develop the cooperation with e.g. the emergency and rescue services, police and national and local authorities to widen the channels of information and increase efficiency and quality of the data collection.

8.4 Case Analysis

The interviews were used as one input to the pre-crash analysis, i.e. a DREAM analysis. A DREAM analysis consists of factors, not events (apart from the phenotype), some of which are constant latent conditions such as obstructions to view or road design and cannot be related to a timeline. There is a need to validate the DREAM analysis against other data, e.g. the reconstruction results. In the accident analysis meetings, the “draft-DREAM” analysis have been subjected to change and updated after input from reconstructions. To develop this process further, the factors that can be validated should be identified in the draft-DREAM analysis so they receive special attention in the reconstruction.

The injury coding in INTACT depends on the persons involved in accidents giving consent to gather their medical records. If this consent is not given, medical records cannot be used. On-scene approval or other methods might help to increase the feedback rate and should be further investigated. The actual injury coding in the project was conducted in the STRADA module by the Traffic Injury Register. This process minimize the risk of coding errors, and automatically derives complete ICD and AIS codes (however, without localizers) as well as the ISS score. An optimal future permanent INTACT system should continue investigating the possibilities to implement the injury coding module from the STRADA system.

The routines proposed for data collection from involved road users have been useful, but some drawbacks were noted, mainly regarding the time schedule for the first follow-up questionnaire. The time schedule for the first follow-up, one month after the accident was too tight, because cases were reported too late to the Traffic Injury Register. This meant that questionnaires were sent late and only 5% of the road users answered within one month. The first follow-up could be changed to three months, as 88% replied within this time. A lower response rate from involved road users than expected was also noted. The follow-up questionnaires were complete in most of the cases, and described the residual problems to a sufficient grade.

The results of the follow-up procedures do not confirm the previous experience made by the Traffic Injury Register. The response rate was only 56% during this project. One reason may be that many subjects sustained only minor injuries or were not injured at all. Another reason may be unwillingness in people who feel guilt to disclose details, which may seem unfavourable to them from a legal/insurance point of view. In one case, no answers were given on the accident circumstances, because a similar questionnaire had been sent from Volvo accident investigation group. It seems to be of vital importance that investigations are co-ordinated in cases where two or more INTACT partners are involved in the same accident investigations. According to the previous experience made by the Traffic injury Register, a telephone contact made by the medical staff at the register would probably have increased the response rate by 10 - 20%, and would also make it possible to afford medical advice when necessary.

8.5 Electronically Stored Data

One of the pre-requisite for the INTACT project was to investigate how data stored in vehicles, e.g. in EDR equipment, could be used as a supplement and validation to other collected data. It has proven very difficult to retrieve this type of data, both for cars and for trucks. Several issues obstruct the usage of data from cars. The main issues are personal privacy and data retrieval. The data stored in the car belongs to the owner of the car and can only be used upon agreement and with the permission of the owner and driver. For trucks, the Swedish Transport Agency[2] is responsible for approving data retrieval and so far, only the police have been approved. The data retrieval is not standardised and can only be made for a number of specific brands.

To be able to use electronically stored data in the future, there is a need for standardisation, both in terms of variables and validation of stored data, in order to make results and comparisons reliable and useful in research. There is also a need for a routine to receive the car owner’s permission to use the data. The INTACT database is however fully prepared for input of EDR data.

8.6 INTACT Database System

During the development of the database system requirements, it was proposed to use handheld units for data collection. It was concluded that it is a strong desire from the project to use handheld units, but it was to difficult to develop these protocols before the database was in place. This issue was therefore placed on-hold. On-scene data collection with paper protocols is static and not linked to the information that is already collected or available in other databases. Logic and consistency of the of the collected data could be directly checked and therefore the usage of handheld units for on-scene data collection and vehicle inspections might shorten the investigation time, improve the data quality and reduce office work.

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[2] Transportstyrelsen

Another issue has been the storage of case information when the database is not in place. One example of this was problems to keep the vehicle numbering consistent in the cases and problems with overseeing what information was missing in a case. It can be concluded that clear routines of responsibilities and how to name, structure and store the documents was lacking and probably these issues could have been prevented by a good database system that could support the investigators in structuring the information.

9 CONCLUSIONS

- An investigation methodology covering all phases of a crash and all parts of the road system has been developed.
- The methods are available for authorised users via the Internet, presented in an on-line manual, the INTACT wiki. It includes the working process, routines, protocols and detailed descriptions of all variables collected and analysed.
- An investigation network has been identified and includes partners from industry, academy and authority.
- The participation of many investigators from different organisations with different backgrounds has led to the desired knowledge transfer as the investigators in turn applied the knowledge gained in INTACT in their in-house investigations.
- Part-time investigators from several organisations make it more difficult for the base team to gain continuity in the investigations and might affect the efficiency and quality in a negative way.
- A software tool, i.e. a database, has been developed to store data from road accidents.
- 110 accidents have been investigated and entered into the database.
- Approximately 35% of the accidents investigated in INTACT are not reported by the police.
- On-scene accident site inspection provided more and better data compared to retrospective accident site inspection and fewer accidents were dismissed due to lack of information.
- Classifying load paths and identifying active safety system is difficult and methods for this need to be further evaluated and developed.
- Using the interviews to evaluate the influence of psychosocial factors for accident causation was not completely assessed.
- The cooperation with e.g. the emergency and rescue services, police and national and local authorities should be improved and expanded to widen the channels of information and increase efficiency and quality of data collection.
- The possibilities of using electronically stored data (from vehicles and road environment) were investigated. A methodology for retrieving the crash pulse from specified passenger cars was developed and the database is prepared for EDR data.
- All documentation as well as the database is in English which makes it possible to easy adjust or use the developed methodology throughout Europe.
- The methods and the INTACT (database) system has been offered to and accepted by the European project DaCoTA to be used in an harmonised European in-depth accidents investigation activity.

10 RECOMMENDATIONS

- Methodology development should always be followed by an extensive training for the investigators before data collection begins.
- When a complex computer system like an accident database is developed the requirements for it need to be compiled in cooperation between professional system developers, the investigators and accident analysts.
- It is important in the case analysis phase to have more crosstalk between the DREAM analysis, injury analysis and reconstructionist to validate the final conclusions from the investigation
- Use of handheld units for data collection will allow logic and consistency of data to be directly checked. The usage of handheld units for on-scene data collection and vehicle inspections might shorten the investigation time, improve the data quality and reduce office work.
- Have clear routines of responsibilities and how to name, structure and store the documents.

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APPENDIX A: ACCIDENT RECONSTRUCTION

Backward calculations make use of the law of conservation of momentum during the impact. Constrain forces, e.g. tyre forces can be neglected for this calculation (as they are very small compared to the impact forces) and further assumptions about the lateral friction force during the impact are established. The time extension of the impact itself is infinitesimal small. The actual forces during the impact are unknown, but the integral of the forces over the time, the momentum, can be calculated with the knowledge of other parameters.

The forward calculation solves the actual kinematics equations, therefore the contact forces over small time steps are considered. Constrain forces like tyre forces due to gravity cannot be neglected. To solve the equations, information about the deflection-force relation, the stiffness, must be available. Multi-body models can be used in forward calculation models to investigate pedestrian or occupant kinematics. Theoretically also deformations can be shown by forward simulation, but as only average stiffness values depending on the force application are available (specific vehicle structure stiffness is not considered), the damage pattern is likely in huge variation to the real deformation.

To support the momentum or force calculations, additionally a damage calculation can be conducted. The damage calculation is based on vehicle horizontal deformation pattern description (2D) in conjunction with vehicle stiffness data and information about the principal direction of force. In a first step the damage calculation delivers the energy equivalent speed. When the deformation energy of all collision involved is known and they reach a common velocity at maximum compression the delta velocity of each participant can be calculated (assuming the coefficient of restitution). This type of calculation is further named deformation calculation.

With the forward and backward calculation it is possible to describe the vehicle kinematics immediate before and after the impact, in case the vehicle trajectories after the crash to the end position are known. Furthermore with knowledge of the run in trajectories also the pre-crash phase can be evaluated.

Necessary information for this kind of calculation is:

1. End position of the collision partners
2. The collision point
3. The energy dissipation between these points
4. Relative vehicle position immediate before impact (e.g. longitudinal axis)
5. Relative position of the velocity vectors immediate before the impact

If a vehicle is not skidding before an impact (slip angle is zero), the longitudinal axis and the velocity vector have the same direction.

Further assumptions about the coefficient of restitution and the lateral coefficient of friction have to be made. These parameters can be validated by consideration of the conservation of energy.

For simplification the most popular calculations methods are named further momentum and force calculation.

APPENDIX B: MODIFIED INJURY MECHANISM DESCRIPTION

The modified injury mechanism description (InMeDe) is defined by a 5-position code, in which the first and last positions are letters and the second to fourth are integers. This code could be used for most of the entries in the AIS-dictionary, even if this will create some redundancies, as some of the AIS-codes already indicate the type of trauma, i.e. blunt versus penetrating trauma.

The 5-position code represents the following items:

- Type of trauma (A – Z)
- Proximity of action (local/direct, distant/indirect) (1 – 9)
- Character (origin) of action (inertia-related or not) (1 –9)
- Joint Injury descriptor (1 – 10)
- Type of mechanical action (at the tissue level) (A – Z)

The Joint injury descriptor is used for joint injuries only. The type of mechanical action is used to describe the injury at the “tissue level” or the “microscopic” level, which may be possible only in specific cases.

The type of trauma
The type of trauma describes the type of mechanical, thermal or chemical action, which causes the injury. The values A to D in the following list represent different types of mechanical action, caused by a contact between the body and a physical structure, which are the most common types in road traffic accidents. The types E to G represent non-mechanical actions.

Blunt trauma means that a penetration into the human body is not present. Penetrating trauma is divided into superficial (limited to the surface area) and deep (not limited to the surface area). Perforating trauma is a specific type of deep penetrating trauma through a greater part of the body, where there is an entrance and an exit wound.

A: Blunt
B: Penetrating, superficial
C: Penetrating, deep
D: Perforating
E: Thermal
F: Chemical
G: Electrical
H: High pressure (explosion)
H: Combination
Z: Unknown

The proximity of action

The proximity of action describes if the injury is located at or very close to the contact surface, or at a distance from the surface.

1: Local/direct (located at the contact surface)
2: Distant/indirect (not located at the contact surface)
3: Combination of local/direct and distant/indirect
4: Other
9: Unknown

A distant/indirect injury can be caused by forces transmitted through the body by rigid or semi-rigid structures on one hand, or by inertia effects on the other. Inertia effects are further specified by the third part of the 5-position code.

Examples of the proximity of action:

- A knee contact with the dash panel in a frontal impact may cause a fracture of the patella and an injury to the hip joint, like a fracture of the acetabulum or a dislocation. The fracture of the patella should be coded local/direct. The injury to the hip joint should be coded distant/indirect.
- The B-pillar in a side impact may cause head injuries to a car occupant [i. e. a vault fracture at the impact point and two contusions of the brain; one beneath the fracture (ipsilateral) and the other on the opposite side of the brain (contralateral, “contre coup” injury)]. The event may also cause a sprain to the cervical spine, even if there is no contact between the B-pillar and the neck. The skull fracture should be coded local/direct, the ipsilateral brain contusion local/direct, the contralateral brain contusion distant/indirect, and the neck sprain distant/indirect.
- A spleen or kidney injury (laceration of the capsule and superficial tissue), caused by a direct blow against the side of the trunk where the organ is located, should be coded local/direct.
- A spleen or kidney injury (avulsion of the hilus), caused by a great retardation of the trunk of a restrained occupant in a frontal impact, should be coded distant/indirect.

The character (origin) of action

The character (origin) of action specifies if the injury occurred due to forces, transmitted from the impact area to the body parts where the injury is located by inertia effects or not. Non-inertia action is mediated by forces transmitted through structures, between the impact area and the site of injury, without a significant inertia effect (most often due to a movement of rigid or semi-rigid structures - like bones - between the impact point and the site of injury). Inertia action is mediated by a forces acting on a specific part of the body, which cause a change of velocity (acceleration) of another part of the body at a distance from the impact area, without a significant rigid mechanical coupling.

1: Non-inertia effect
2: Inertia effect
3: Combination of non-inertia and inertia effects
8: Not applicable
9: Unknown

Many injuries to visceral organs are caused by a combination of local/direct (external) forces and distant/indirect (internal) forces. Injuries caused by relative organ/body motions, due to contact action should be coded as a combination of non-inertia and inertia effect.

Examples of the character (origin) of action:

- A vehicle is hit from the left side. The driver sustains an anterior dislocation of the humeral head caused by intruding structures of the door. Non-inertia should be coded.
- The same driver sustains a cervical neck injury without a head or neck impact. Inertia should be coded.
- A spleen or kidney injury (avulsion of the hilus) is caused by a great retardation of the trunk of a restrained occupant in a frontal impact. Inertia should be coded.
- A car driver injured in a frontal impact sustains displaced rib fractures and liver lacerations, both on the upper and the lower surfaces the liver. The liver injuries on the upper surface may be caused by the rib fractures and the lacerations on the lower surface by inertia forces. The upper liver injury could be coded as a non-inertia effect and the lower injury as an inertia effect. A combination could also be coded.

The joint injury descriptor

The joint injury descriptor is used for joint injuries only. It defines the mode, by which an exaggerated or non-physiological movement of a joint causes injuries. This part of the code could preferably be used for joints in the extremities, like shoulder, elbow, finger, hip, knee, and ankle. It is not supposed to be used for joints in the vertebral column, even if this would be possible in some cases.

1: Hyperextension
2: Hyperflexion
3: Hypertranslation
4: Hypertorsion (including supination & pronation as sub-classifications)
5: Hyperadduction
6: Hyperabduction
7: Combinations of 1 – 6
8: Not applicable
9: Unknown
10: Joint injury without non-physiological movement. This code is supposed to be used for intra-articular fractures.

Examples of the joint injury descriptor:

- An unbelted occupant hits the lower leg 5 cm below the knee joint against the dash panel in a frontal impact. A rupture of the posterior crucial ligament is sustained. Hypertranslation should be coded ("Dash-board injury").
- A car occupant hits the shoulder against the B-pillar, when the car is impacted from the side. The humeral head dislocates ventrally. Hypertranslation is coded.
- A cyclist falls to the ground and tries to protect himself with a stretched arm. The elbow joint is overstretched, the ventral part of the capsule ruptures, and the Ulna dislocates in the posterior direction relative Humerus. Combination is coded (hyperextension and hypertranslation).
- A Monteggia injury (combination of Ulna fracture and dislocation of the Radial head in the elbow joint) should be coded as a hypertranslation, as the joint injury only includes the Radius. The Ulna fracture should be coded separately. The same principle should be used for the Galeazzi injury (a fracture of the Radius and a dislocation of the distal Radio-Ulnar joint).

The type of mechanical action
The type of mechanical action preferably describes the mode, by which a force acts at the tissue ("microscopic") level. Probably, this part of the code can be used only for specific injuries. In many cases, several modes are active, and if so, the most relevant type of mode should be coded. As this part of the code requires a detailed understanding of the injury process, it might be coded only for some injuries.

A: Compression
B: Tension
C: Shear
D: Bending
E: Twisting
F: Shock wave effect
G: Vacuum effect (*contre coup*)
H: Combination of mechanical actions
Y: Not applicable
Z: Unknown

Examples of the type of mechanical action:

- A contusion of the skin caused by a blunt impact without excoriation is coded as compression.
- A cut wound is coded as shear.
- An avulsion of the brachial plexus in a motorcyclist who hits the shoulder against a pole is coded as tension.
- A vertebral burst fracture is coded as compression.
- A vertebral wedge fracture is coded as bending.

- A posterior vertebral ligament rupture, without a coincident ventral ligament rupture, is coded as bending.
- An anterior dislocation of an intervertebral joint (facet joint) is coded as bending.
- A cranio-cervical separation is coded as tension.
- An excoriation is coded as shear.
- A rupture of the medial ligament of the knee in a pedestrian, who is hit by a car bumper at the lateral side of the knee precisely at the tibio-femural joint is coded as bending.
- A rupture of the medial ligament of the knee in a pedestrian who is hit by a car bumper at the lateral side of the knee at a distance from the tibio-femural joint is coded as a combination (translation & bending).
- A spiral fracture of the tibia in a person, who has rotated the body, when the foot is prevented to rotate during the injurious event, is coded as twisting.
- Shock wave effect is only applicable for injuries caused by explosions.
- Vacuum effect is only applicable for specific brain injuries.
- Degloving injuries are coded as combination.
- DAI (axone or white matter injury) in many cases is the result of angular accelerations, causing shear stresses. In that case shear is coded.

Example of coding
A typical injury in a traffic accident is a contusion or bruise caused by an impact. Using the InMeDe, this injury would be coded as A118A where

A: Blunt force trauma
1: Local/direct (located at the contact surface)
1: Non-inertia effect
8: Not applicable (not a joint injury)
A: Compression

APPENDIX C: REPRESENTATIVITY ANALYSIS

Objective

The representativity of a data sample is important, when the sample is used to describe conditions and derive effects of conditional changes for a whole population. Representativity for Sweden is a InMeDe for in case of the INTACT data sample.

In this study, the INTACT accidents were compared with police reported accidents in STRADA in the same municipalities and time shifts, which excluded night hours and weekends. In a second step the INTACT sample was compared to all accidents in the corresponding municipalities. The last step shows a comparison to the whole STRADA dataset.

Methodology

The analysis of STRADA was restricted to police-reported accidents during 2009 as the data collection methodology in INTACT was continuously changed in 2008.

The analysed variables included the accident number from the accident record, municipality information and accident date from the report record and accident type and traffic environment from the police report record. The police-reported injury severity in the person record was aggregated to an accident level, thus representing the accident severity. INTACT cases were identified by the accident number.

The STRADA coding for accident type was aggregated to the first letter, which represents the main category. The categories G (accidents not involving a car or truck) and J (accidents involving a train or tram) were excluded, as all types in G and most types in J do not fulfil the INTACT sampling criteria for vehicles (at least one passenger car or truck/bus involved).

The INTACT data were compared to STRADA data in three steps:

1. STRADA accidents that occurred in 2009 in Göteborg city, Lerum, Partille, Härryda, Ale, Kungälv, and Möndal municipalities. Further the accident time was limited from 6:00h to 18:59h, Monday to Friday. The time and weekday limitation does not represent the INTACT sample plan in detail, but it is estimated as appropriate for the generic analysis.
2. STRADA accidents that occurred in 2009 in the municipalities Göteborg, Lerum, Partille, Härryda, Ale, Kungälv, and Möndal.
3. STRADA accidents that occurred in 2009 in the whole of Sweden.

Accident severity, accident type and accident location were compared. The accident type is covered to some extent in the stepwise analysis procedure. A bias of the accident severity in a sample compared to the whole population is a natural consequence of outcome-based sampling. The comparison of type of accident and accident location provides information about the representativity of the defined sampling area. It is obvious, that the variables are not independent from each other: In rural areas we would expect higher vehicle velocities and therefore also higher injury outcome.

The INTACT database contains accidents without personal injuries. When all INTACT cases are weighted to the national statistics by use of the accident severity, these cases get the weighting factor “zero”, as the national statistics only consist of police reported accidents with at least one injured person. This means that the cases were excluded in the statistical analysis.

A comparison between INTACT accidents with and without personal injury with regard to the accident type was not feasible due to inconsistencies in the available data file.

Results from step 1

Ninety-one percent (N=712) of the police recorded accidents in STRADA in the seven INTACT municipalities with the given time and day limitations have a slight injury outcome, seven percent (N=57) are severe and about one percent fatal (N=7) (Figure C-1). For the rest the injury severity is either unknown or no injury, despite the sampling criteria. This compares to 91 percent (N=3) of slight and seven percent (N=39) of severe accidents in INTACT (Figure C-2). A fatal accident is not expected in the INTACT database, as this would required a minimum of N=100 cases, where the actual size is at N=43 cases.

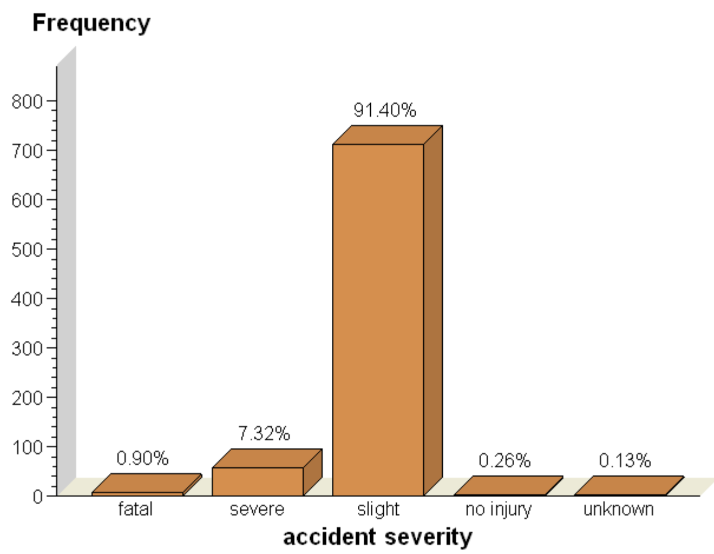

Figure C-1. Accident severity distribution in the STRADA sub-sample for 2009.

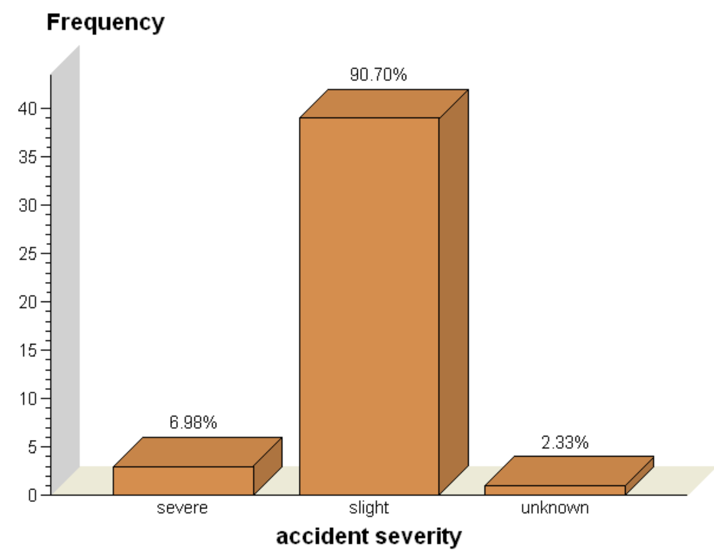

Figure C-2. Accident severity distribution in INTACT sample.

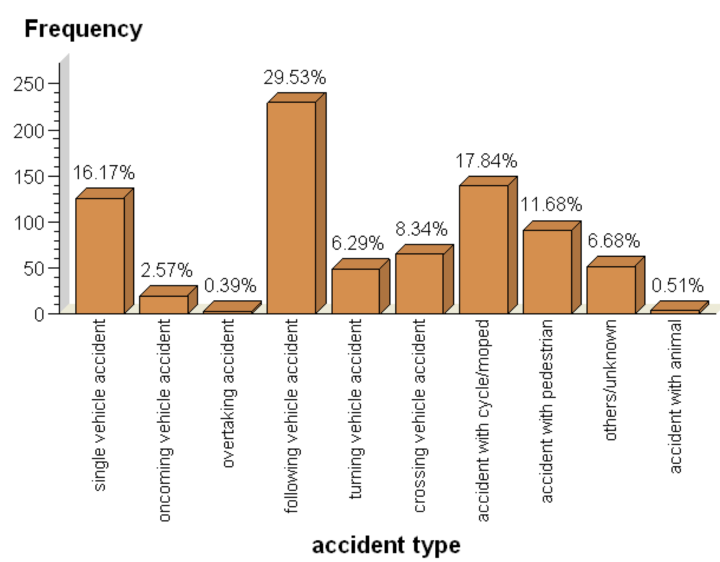

Figure C-3. Accident type distribution in STRADA sub-sample 2009.

The STRADA data sample contained 30 percent (N=230) of following vehicle accidents, 18 percent (N=139) of accidents with bicycles or mopeds and 16 percent (N=126) of single vehicle accidents (Figure C-3). Pedestrian accidents sum up to 12 percent (N=91).

However, in INTACT 30 percent (N=13) of the accident involved only a single vehicle (Figure C-4). Following vehicle accidents accounted for 28 percent (N=12) and crossing vehicle accidents for 19 percent (N=8). Pedestrian accidents are strongly underrepresented whereas accidents involving bicyclist are not present.

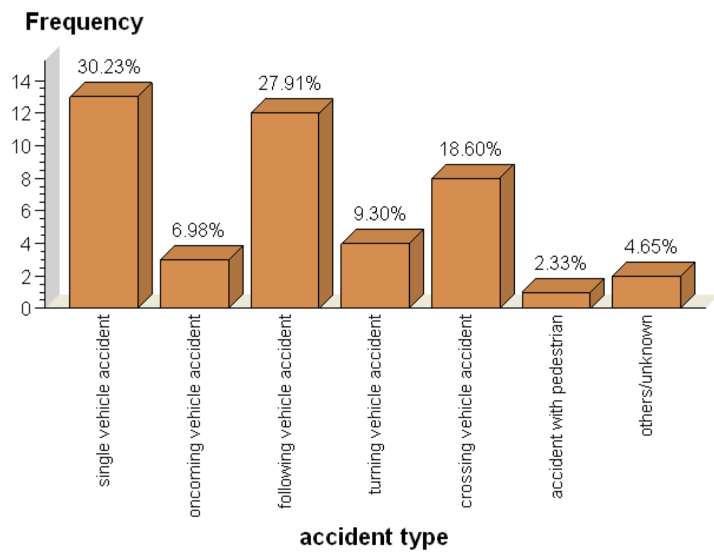

Figure C-4. Accident type distribution in INTACT sample.

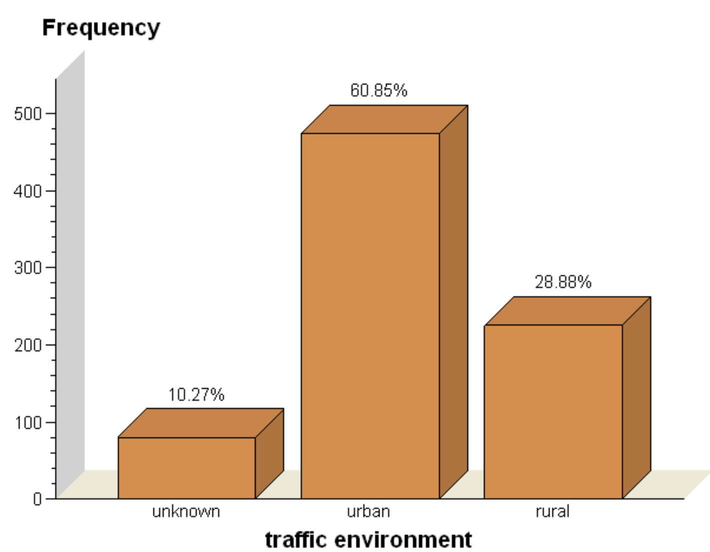

Figure C-5. Accident location distribution in STRADA sub-sample 2009.

Sixty-one percent of the accidents in STRADA (Figure C-5) occur in urban areas compared to 55 percent in INTACT (Figure C-6).

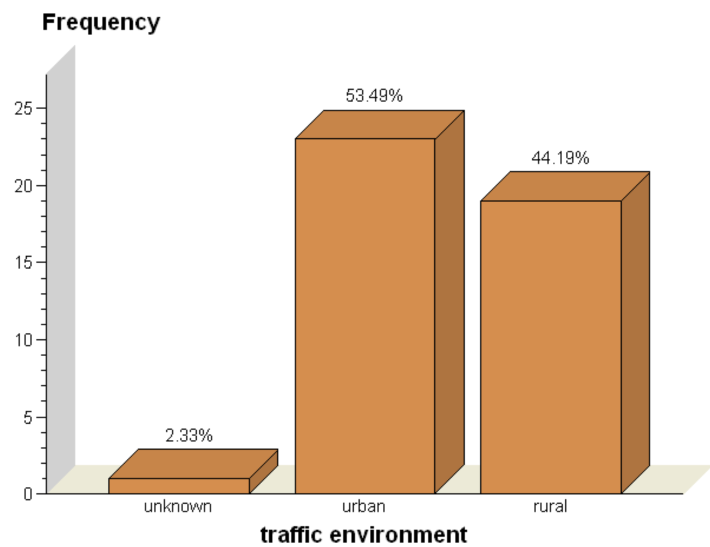

Figure C-6. Accident location distribution in INTACT sample.

Conclusions from step 1

The INTACT data represent the accident severity and accident location of the STRADA data for the same time and day span in 2009 well. Nevertheless there are differences in the accident types. Whereas single vehicle accidents or oncoming vehicle collisions are overrepresented, pedestrian accident and accidents with bicyclists/mopeds are missing/underrepresented. Especially missing accident type categories lead to the situation that weighting with regard to this variable is not possible, hence the whole dataset is biased towards specific accident types.

Results from step 2

The number of accidents in STRADA increased to N=1274, which means that about 40% of all accidents in the seven municipalities happen on the weekend or weekdays between 19:00h and 5:59h.

The accidents in STRADA covering 24 hours and seven days a week in the seven municipalities show a slight increase of severe and fatal outcome (Figure C-7). Eighty-nine percent (N=1134) of the accidents were slight, nine percent (N=111) severe and 1.3 percent (N=17) fatal.

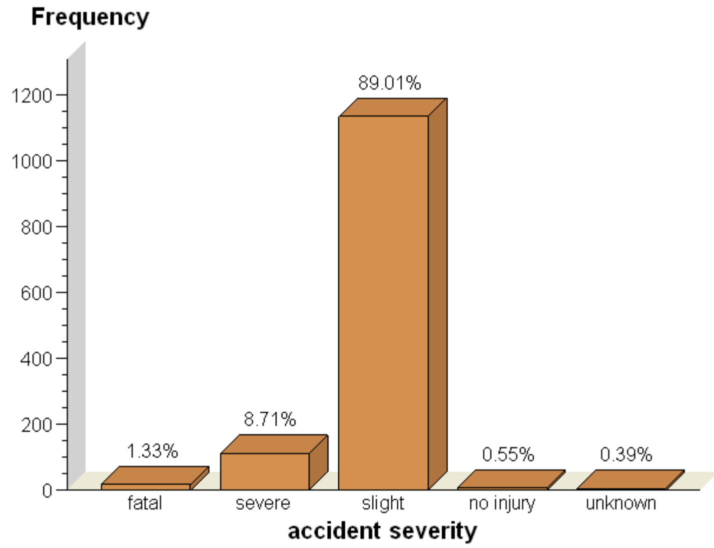

Figure C-7. Accident severity distribution in STRADA sample 2009.

Most accidents that occurred were following vehicle accidents (26%, N=328) or single vehicle accidents (24%, N=303), followed by accidents with cycle/moped (15%, N=182) and pedestrians (11%, N=142) (Figure C-8). Sixty percent of the accidents (N=763) happened in urban area (Figure C-9).

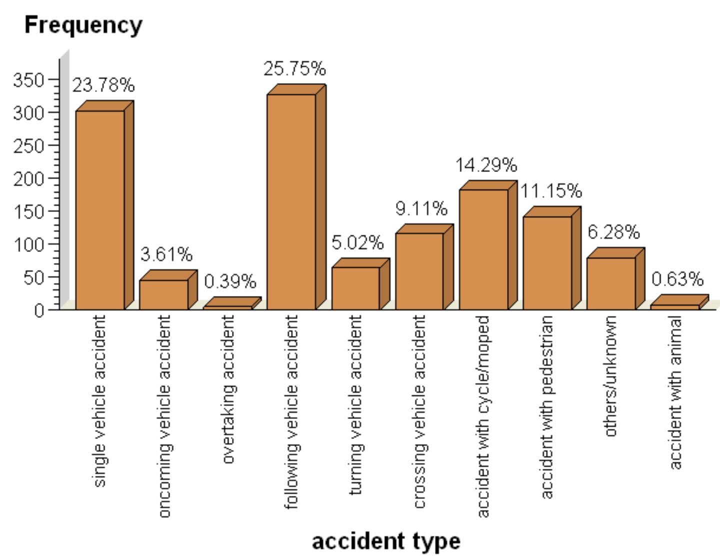

Figure C-8. Accident type distribution in STRADA sample for 2009.

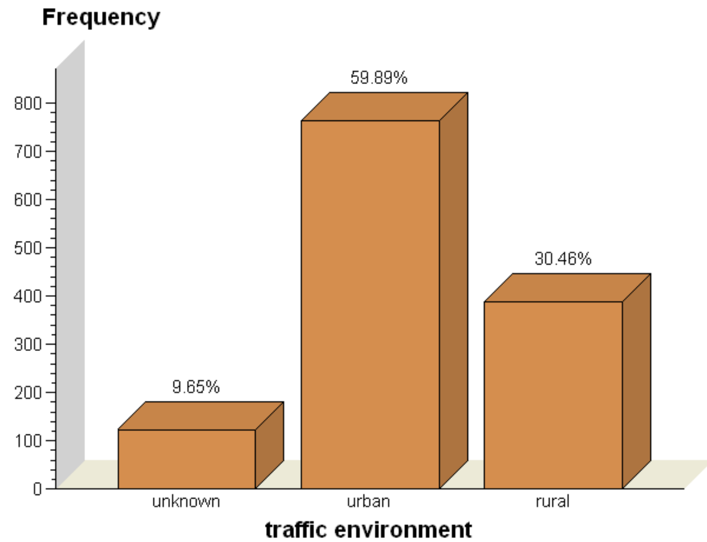

Figure C-9. Accident location distribution in STRADA sample 2009.

Conclusions from step 2

Forty percent of the accidents in the sample area happened out of the scheduled time shifts. As the percentage of severe and fatal accidents increased, it can be concluded that accidents at night time and/or weekends have a higher risk for more severe injury outcome. The percentage of single vehicle accidents increased strongly whereas the percentage of e.g. crossing vehicle accidents dropped.

Results from step 3

The STRADA data for all municipalities in 2009 include 16744 accidents. In 82 percent (N=13708) of the accident the outcome was slight, in 15 percent (N=2504) severe and for a bit more than two percent (N=377) fatal (Figure C-10). Dominating accident types are single vehicle accidents (33%, N=5470), accidents with cycle/moped (16%, N=2652) and following vehicle accidents (14%, N=2383) (Figure C-11). Pedestrian accidents cover nearly 8 percent (N=1333) of all accidents.

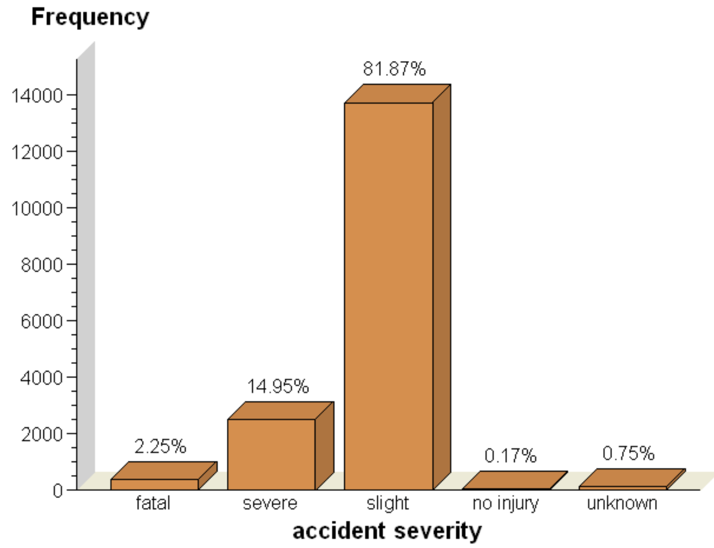

Figure C-10. Accident severity distribution in STRADA population 2009.

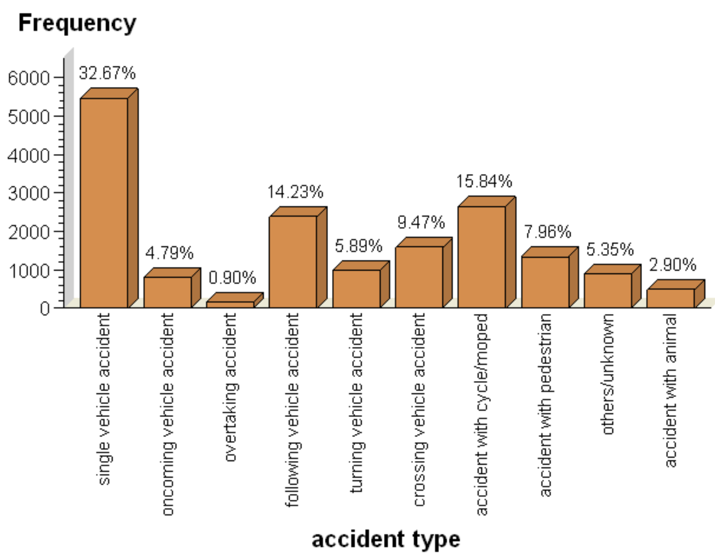

Figure C-11. Accident type distribution in STRADA population 2009.

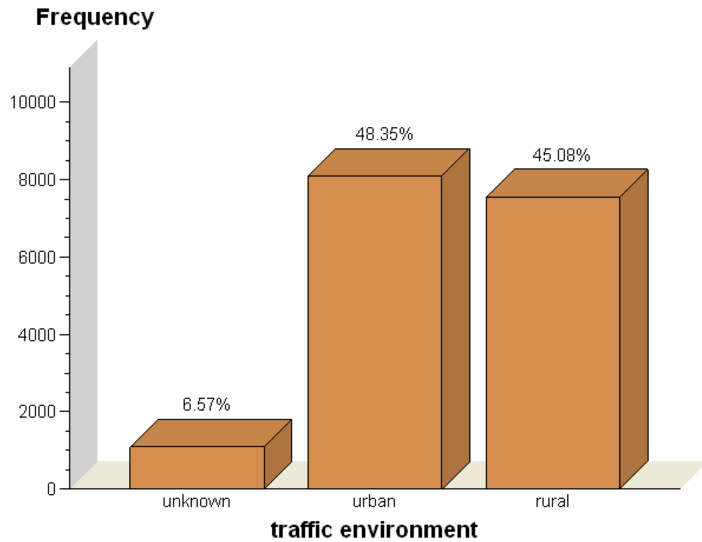

Figure C-12. Accident location distribution in STRADA population 2009.

The percentage of urban accidents is 48 percent (N=8095), similar to rural accidents (45%, N=7549) (Figure C-12). For the rest of the accidents the accident location is unknown.

Conclusions from step 3

When all accidents from 2009 are considered, the percentage of severe and fatal accident compared to the sample region nearly doubles. The single vehicle accidents sum up to one-third of all STRADA accidents. In line with this accident type change the accidents occurred in both, urban and rural area, nearly equally distributed.

Discussion

Although the distribution of accident severity seems to be highly representative, there is a huge difference in the distribution of accident types. Accident types where it takes longer time to clear up the accident site, e.g. single vehicle accidents, are overrepresented, whereas accidents with vulnerable road users, quickly cleared up, are underrepresented. This could also be connected to the accident site, because single vehicle accidents most often occur in rural areas and accidents with vulnerable road users occur in urban areas. Quick arrival and access to the accident site are important in both cases. In future accident studies, the shortcomings of late scene arrival or non-accessibility of scene itself should be minimised to ensure a representative collection of accident types.

The accidents at night time and weekends, i.e. outside of INTACT sampling hours, have a more severe injury outcome, which is also represented in the accident type. It is further expected that accidents at night time or on weekends have additional contributing factors to accident causation and may cover a different driver population. Therefore it is highly recommended that future accident studies cover 24-hours and 7-days a week in a statistically optimised sample plan.

The comparison between the sampling area around Göteborg and Sweden in total showed, that the sample region is not representative at all with regard to injury outcome, accident type or accident location. At first e.g. the single vehicle accident occurrence in percentages seems to be in line with the Swedish national statistics, but this is more a result of an overrepresentation of this accident type in the seven municipalities according to accident site access limitation together with an underrepresentation compared to Sweden.