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Consolidated Resolution on Road Traffic (R.E.1): Multidisciplinary crash investigation (MDCI)

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Multidisciplinary crash investigation (MDCI)

Submitted by the Government of Sweden

This document aims at amending Consolidated Resolution on Road Traffic to include multidisciplinary crash investigations.

General principles and approaches for Multidisciplinary Crash Investigation (MDCI)

I. Background

1. In 2010 approximately 1.24 million people were killed in road traffic crashes and between 20 and 50 millions suffered non-fatal injuries. There is an obvious risk that these figures will increase substantially without strengthened efforts and new initiatives, especially if the increasing traffic in the developing countries is taken into account.

2. To be able to take effective countermeasures it is of utmost importance not only to rely on statistical figures and analyses but also on a deeper understanding of the underlying and contributing factors of the road safety problems.

3. One common approach to road safety is mainly based on a premise where individual road users are solely responsible when crashes occur. This view has been enabled by, and is in turn constitutive of, findings claiming that human error is the cause of approximately 70-95per cent of road crashes.

4. An important contribution to these findings is that accident investigations historically have followed a model based on the assumption that ”human error” caused the mishap. Accident investigations have focused on the personnel closest to the mishap in order to find the “root cause” of the accident. That has lead to the incorrect conclusion that improving road user behaviour is the only effective road safety strategy and hence remedies has primarily been sought in persuading road users to adopt error-free behaviour. Such remedies often consist of legislation, information, education and police surveillance.

5. There is however a growing awareness among traffic safety professionals that a multidimensional systems approach is required today to effectively address road safety issues. Instead of focusing on one element of traffic safety in isolation (engineering, enforcement or education), there is a need to build bridges and relationships between all the elements that influence road safety, and to understand how the various elements affect each other at all times. The systems approach focuses on the relationships and dependencies between the various individual elements of the traffic system and the organisational levels which influence those relationships.

6. For that reason there is also a need to engage different competences in the work of investigating road traffic accidents in order to look at them from different systemic angles.

II. Human error

7. Human error is often defined as unwanted or inappropriate actions leading to an undesired outcome. Broadly, human error models can be categorised as either person models focusing on the errors made at an individual operator level (e.g. driver) or system models focusing on the interaction between wider systemic failures and errors made by individual operators.

A. The person approach

8. The person approach focuses upon the errors that operators make when operating in the system. Such errors are seen to emerge from psychological factors in individuals such

as aberrant mental processes, including forgetfulness, inattention, poor motivation, carelessness, negligence and recklessness.

9. Error management based on the person approach is focusing on countermeasures aiming at reducing variability in human behaviour through e.g. legislation, enforcement training, education and information campaigns.

B. The systems approach

10. System approach models treat human error as a systems failure, rather than solely an individual operator´s failure. These models consider the presence of system wide latent conditions and their role in shaping the context in which operators make errors. Unlike the person approach, human error is no longer seen as the primary cause of accidents. Instead it is treated as a consequence of latent failures created by decisions and actions at all levels in a system (e.g. government, local authorities, organisations/companies and their different management levels). In principle at least, the systems perspective approach is now the dominant approach in most safety critical domains where it is often denoted Human Factors or MTO (Man, Technology and Organisation).

11. Current road safety approach in large parts of the world is based on “Vision Zero” or “Safe System Approach”, two expressions of an identical policy which is built on a systems perspective approach.

C. Accident investigation in relation to human error approaches

12. It must be understood that the outcome of an accident investigation and hence the precondition of MDCI to become an effective tool for road safety work is very much depending on the approach to human error. The approach fundamentally forms the basis for the investigation and analysis and hence constitutes which data should be collected. Another important precondition is that those conducting the collection and analysis of accident data and information are competent and understand these working conditions.

III. The purpose of accident investigation

A. General

13. There is a large number of accident investigation methods described in the literature. All of them are dependent on the purpose of the accident investigation but also on the approach to human error as described above. It is therefore necessary to clearly stipulate these preconditions to be able to choose the “right” investigation method. The methods will not further be elaborated in this paper.

B. Different purposes

14. A road traffic accident investigation may have different purposes:

- Identify and describe the course of events (what, where, when);
- Identify the direct causes/contributing factors of the
- accident and its consequences (why);
- Identify risk reducing measures to prevent future, comparable

- accidents or their consequences (learning);
- Investigate and evaluate the basis for potential criminal
- prosecution (blame);
- Evaluate the question of guilt in order to assess the liability for compensation (pay).

15. It is important to note that there is a quite widely spread belief, at least in the legal domain, that the investigations carried out in order to investigate and evaluate the basis for potential criminal prosecution also will increase safety by finding the guilty party who violated the legislation in an accident. Contemporary human factors research though clearly shows that this is very seldom the case. It may affect intentional violations but have marginal or no effects on unintentional human errors and mistakes. It must therefore be emphasized that human error should not be the conclusion of an accident investigation. Instead it should be the starting point since human error is the effect or symptom of deeper, latent conditions in a system.

16. From a strict safety perspective an accident investigation should be a fact finding activity to learn from the experience of the accident, not an exercise designed to allocate blame or liability. The emphasis in conducting investigations should be on identifying the underlying causes in a chain of events leading to an accident, the lessons to be learned, and ways to prevent and mitigate similar accidents or injuries in the future. Hence accident investigation should be used to gather information and data to be able to analyse accidents so that the human and system contributions can be identified. The findings are then used to develop measures to ensure that similar accidents do not occur again or that the consequences of them are mitigated or reduced.

IV. The purpose of MDCI

17. Multidisciplinary Crash Investigation (MDCI) should be used for identifying the direct causes and especially the contributing or underlying factors of the accident and its consequences from a systems approach in order to get enough knowledge for implementing effective risk reducing countermeasures to prevent future accidents or their consequences.

18. It cannot be stressed enough that the objective of MDCI is to prevent accidents or their consequences – not to apportion blame or liability.

19. For that reason a very clear boundary between MDCI:s and investigations to distribute legal responsibility must be created. If not, there is a great risk that the information flow to the investigators will be seriously hampered if the involved parties suspect that the information will be used for liability matters.

20. It must also be stressed that MDCI is not another or different tool for collecting statistical data about the magnitude of a road safety problem and its prevalence in time and space. Such data is of course valuable for many reasons, e.g. identifying and prioritizing problem areas, but will seldom give any detailed information about the contributing and underlying factors which is necessary to understand why the accidents and injuries occur.

21. Instead it is a valuable tool to get a deeper understanding of the underlying accident and injury mechanisms of a limited number of accidents, e.g. a certain type of accidents.

V. The framework of MDCI

A. General approach

22. It is important to establish the fact that MDCI is not a detailed accident investigation method. First and foremost it is a general approach to accident investigation based on a systems perspective on accidents and human error which is described above. Hence there is no detailed operational manual for carrying out the investigation. The purpose here is to give some important guidelines and examples of what to think of when establishing and conducting MDCI:s.

23. The most paramount question that MDCI should answer is why an accident occurred and also, which is important to stress, why the consequences became serious. The question why must be asked several times, not only on the human level, but also on the technical (e.g. vehicles and infrastructure) and organisational (e.g. organisations responsible for the building and maintenance of infrastructure, professional transport companies and authorities) levels in order to identify latent conditions and contributing factors to the accident and its consequences. It is of utmost importance to understand these conditions and factors in detail in order to be able to learn from them and consequently take effective countermeasures with a systems approach. It is not enough if the conclusion of the investigation is that the accident occurred because the road user did not follow the rules. Instead it must conclude why the road user did not follow the rules and why the consequences became serious. It is first then effective countermeasures can be taken. A brief example:

24. A professional driver is driving his truck 70 km/h. The driver falls asleep and drives off the road. The truck hits a rigid lamppost and the driver is killed. Following questions could be asked:

25. Why did the truck drive off the road? Because the driver fell asleep (many accident investigations end here).

26. Why did the driver fall asleep? Because he had volunteered to take an extra shift outside the permitted driving hours even though he was very tired (he needed the money).

27. Why was the driver able to take the extra shift? Because the employer did not have a management system or similar to prevent the driver from driving outside the permitted driving hours.

28. Why didn´t the employer have a safety management system? Because the legislation does not provide that and hence there is no authority supervision.

29. Another answer to the question “why did the driver fall asleep?” could be that the truck was not equipped with a driver alert system. From this answer further questions could be asked which may result in answers showing that vehicle manufacturers do not find economical or other reasons for marketing such devices and politicians or authorities who are not willing to pass laws or regulations stipulating that the manufacturers must install such systems in their vehicles.

30. Why was a rigid lamppost placed in close proximity to the road? Because the regulations governing the design of the road permitted such design.

31. Why did the regulations permit such design? Because the road authorities do not have a systematic way of investigating accidents e.g. as a part of a safety management system.

32. Why do the road authorities not need a safety management system? Because politicians are unwilling to pass a law which may increase societal costs.

33. What can be learned from this accident is that important contributing, indirect or underlying causes can be found on other levels of the system which imply countermeasures other than ones directed towards the direct causes connected to the actual situation and the road user. Informing, educating or punishing drivers will not solve the underlying system problems of rigid lampposts in close proximity to roads, employers not taking responsibility for safety of their drivers and politicians not willing to pass laws.

B. Basic preconditions for MDCI

34. It is of utmost importance to secure information about occurred accidents. This is particularly important if information and data are going to be gathered on the scene of the accident. Such information can be achieved from the police, emergency services, alarm centres etc. and should be secured by legislation, formal agreements etc.

C. Access to data sources

35. Further the access to different information and data sources related to the accident which are important for the analysis must be secured. Examples of such information and data are driver´s licence data, vehicle data, infrastructure data (technical data about the road and its surroundings), injury data (hospital data, autopsy reports etc.), rescue data, organisational information (e.g. information about road safety work of the road authorities and buyers and sellers of transports) etc. It is important to establish a long-term accessibility through legislation, formal agreements etc. and not only to rely on personal contacts. When it comes to MDCI there may also be a need for establishing new sources. This depends on which information or data that is needed.

D. Legal aspects

36. The legal framework in a country may hinder the accessibility to important information for the accomplishment of MDCI. The legislation can be very complex and differ a lot from country to country. Hence it is impossible to give any detailed criteria or advice how to deal with these issues. On a very general level however a piece of advice is the importance of dealing with issues of secrecy and personal privacy. Experiences can nevertheless be found in the operational descriptions from Sweden in annex I.

VI Conducting MDCI

A. Investigation method

37. As mentioned above the outcome of an accident investigation and hence the prerequisite of MDCI to become an effective tool for road safety work is very much depending on the approach to human error. For that reason the investigation method used for MDCI must be based on the systems approach to human error.

38. There are several specific methods described in the literature which are based on such an approach. Some examples are:

- MTO Analysis (Man, Technology and Organisation)

- AcciMap
- STAMP
- FRAM (Functional Resonance Accident Method)
- AEB (Accident Analysis and Barrier Function Method)
- TRIPOD-BETA

39. None of these investigation methods are solely developed for road traffic accident investigations. But in some cases, e.g. the MTO Analysis, they could quite easily be adapted and used for MDCI. The details of the different methods and their usability for MDCI will not be further elaborated.

40. It must also be concluded that the investigation method is not the paramount issue when investigating an accident. Instead it is to apply a systems approach.

B. Collection of data and information

41. The operational work to gather data and information and practical tools for that work is rather basic and not specific to MDCI. The preconditions in the form of a systems approach, the specific investigation method used and the accident or accident type of interest very much governs which information and data that are of interest. As mentioned above it is though important to guarantee access to the data and information sources.

42. Generally a rather large amount of information and data are needed to cover the different levels of the road transport system in which the accidents occur. Hence it is impossible to present a list of detailed information and data which should be gathered to answer all questions for all types of accidents when applying a systems perspective approach. For this reason MDCI is not an effective tool for the analysis of e.g. all accidents in a country. The most effective way to use MDCI is probably for thematic analysis of certain accident types which have been indicated by statistical or quantitative analyses.

43. An information source which should not be forgotten is testimonies from people (e.g. involved persons, witnesses and experts) collected by interviews or by hearings. Such information is often important in order to be able to answer the question why on different levels of the system.

44. Further the choice and collection of data and information needs to be as unbiased and as objective as possible. Otherwise there is a risk that the assumptions about the nature of accidents guide the investigation resulting in that it finds what it looks for.

VII. Analysis

A. Composition of analysis group

45. As mentioned earlier MDCI is based on a systems approach to human error. This means that there is a need for a multidisciplinary group or team to carry out the accident analysis in order to understand the complex interactions among the components of the transport system leading to accidents and injuries. As a basic requirement the group should consist of at least the following expert competences:

- vehicle mechanics (dynamics and crash properties),
- road design and traffic engineering,

- human factors (HF) and behavioural science,
- medicine (injury mechanisms),
- accident investigation method

46. The members of the analysis group should also have very good knowledge and understanding of the systems approach to human error. They must of course also be as independent and objective as possible.

47. The group may also call on other experts depending on the analysis.

B. Reconstruction and analysis of the accident and its consequences

48. To be able to analyse why an accident occurred and/or why the injuries arose it is important to understand what happened. Such reconstruction of an accident must be based on factual findings. There are different practical tools for the reconstruction of vehicle paths etc. on the operational level. But it is almost even more important to reconstruct what happened or rather what did not happen on an organisational level (e.g. road authorities, vehicle manufacturers and sellers and buyers of commercial transports). This must also be reconstructed. Further it is important, if possible, to reconstruct the situation which surrounded or framed the assessments and actions of the road users to be able to understand why the road user acted the way he or she did.

C. Formulation of findings and recommendations

49. The analysis group has a responsibility to base their findings and recommendations logically on factual data and information. Findings and recommendations must never be based on speculations. If the group form hypotheses which are not covered by the data material they must consider gathering complementary data and information.

50. The findings and recommendations must further be based on a systems approach to human error. They should therefore be based on the analysis of what happened and especially why it happened, both from an accident and injury perspective, on different levels of the system. It means that they principally should be aimed at system countermeasures which have a documented safety effect on accident or injury reduction. Countermeasures aimed directly at the road user in order to correct his or her behaviour should however only be proposed if there is clear proof that they will have a long term safety effect. In most cases their behaviour and errors are only a symptom of systemic problems that other road users also may be vulnerable to. The underlying, latent system factors which shape the behaviour or contribute to the injury outcome will still remain in the system. It must also be noted that countermeasures on a higher level in a complex, dynamic system often are more stable or resistant to different pathways to accidents.

VIII. Learning from MDCI – Implementation of findings and recommendations

51. As mentioned earlier the point of MDCI is to learn from failure. But one of the most difficult challenges is to spread the lessons learned and get the recommendations implemented in reality and followed up by different stakeholders and organisations in the road transport system. It is not enough to write reports and spread them quite widely to these stakeholders and hope that they will get the message and consequently act according to the recommendations. The learning must in some way be integrated or internalized in a

systematic way in an organisation. This means that there has to be some kind of learning culture in the organisation and preferably learning also should be an integral part of a quality assurance system or safety management system (e.g. the newly established ISO 39001, a management system standard for road traffic safety).

52. Probably the most effective way of learning from MDCI is if an organization (e.g. a road authority responsible for designing, building and maintaining road infrastructure) carries out own MDCI:s as a part of a safety management system.

53. In the railway area in Europe, legislation stipulates that infrastructure providers and railway companies must have a safety management system of which the investigation of accidents and incidents is an integral part.

54. It could be considered to impose such legislation for important stakeholders also in the road transport system.

55. In several countries there are specific accident investigation authorities which objectively investigate accidents in different areas of society. These authorities often issue recommendations which at least other public authorities must implement and follow up.

56. Another less legal way to learn from MDCI is to gather different stakeholders, both private and public, to discuss the analysis and findings of a certain accident or type of accidents and how they can contribute to different countermeasures within their field of formal or informal responsibility.

Appendix I

I. MDCI – Sweden

1. In Sweden MDCI is called In-depth studies (reference to this name will appear in the text) and have been conducted by the Swedish Transport Administration (STA, formerly the Swedish Road Administration), on all fatal road traffic accidents in Sweden since 1997. The main focus of the In-depth studies is to increase insight how to prevent fatalities in the road transport system.

2. All analyses are based upon the possibilities for the designers and professional users of the system to create a safe road transport system. The basic idea is that there must have been a flaw in the system causing the fatality if a fatal injury has occurred. A flaw in the system is deemed as a deviation from a safe road transport system. Such a deviation could be:

- A circumstance where a condition considered a precondition for safety is not fulfilled, e.g. not using a seat belt, hence being thrown out of the vehicle and sustaining fatal injuries. The reason for the specific deviation in the system needs to be handled to increase safety. In this case the deviation not using a seat belt shows a system that allows use without complete safety which indicates that a measure needs to be taken to prevent further similar system failures.
- A circumstance where all preconditions for safety are fulfilled in the system, e.g. a belted and sober driver who are keeping the speed limit in a safe car on a safe road, but still sustains fatal injuries. It is then obvious that the system is not as safe as considered and that the preconditions must be revised.

3. Deviations from the preconditions for the safe system design that cause fatalities can be found when analyzing a single accident or multiple accidents of a similar type. The collected data and information may therefore be analysed both on an individual (single accident) and aggregated (multiple accidents of a similar type) level to find these deviations causing fatalities. By implementing recommendations from the In-depth studies the preconditions for what is considered a safe road transport system design is altered and pushed to a higher level of safety.

4. This paper will hereafter after follow the structure presented in the framework for MDCI and consist of six sections, where each section includes:

- A general part, in “normal font”, that show the basic routines and work conducted regarding In-depth studies in Sweden;
- A part with examples, in “italic font”, that show how MDCI was used in four specific cases:
  - where case 1 and 2 show how MDCI can be a part of an organizations quality management system; and
  - case 3 and 4 show how MDCI can be a successful tool for encouraging stakeholders to act.

5. The following cases will be used:

Case 1 – Concrete pillar within the deformation zone of a crash barrier

6. A young woman loses control of her vehicle after overtaking another car on a highway, causing it to skid into the median barrier. As she tries to recover control over the car it skids over the driving lanes into the side barrier. The car crashes into and penetrates the side barrier and hits a concrete pillar behind the barrier. The woman sustained severe injuries and died 2 weeks later.

Case 2 – Barrier failure

7. A vehicle collides with the median barrier, causing the barrier to be pushed down and run over. One of the barrier pillars hooks on to the vehicle´s undercarriage and makes it airborne for a short period of time, during which the roof of the car collides with a lamp post and the driver is thrown out of the car. The driver is subsequently killed due to being crushed between the car and the barrier. Shortly thereafter the car comes to a hold against a section of the median barrier away from the initial collision.

Case 3 – Airbag did not inflate

8. A vehicle run off the road in high speed and moves some 50 meters in the road side area before colliding with a stone wall. In the collision the driver is thrown forward and up towards the roof at the same time as the front end of the vehicle is pushed inwards towards the driver. The driver is killed immediately due to the injuries sustained in the impact.

Case 4 – Stakeholder cooperation

9. A truck-driver turns right in an intersection located in an urban area. The truck-driver hits and knocks a bicyclist over. Subsequently, the bicyclist is run over by the truck. Due to repeated accidents between bicyclists and trucks with a similar pattern, the STA invited a number of stakeholders to participate in a joint process to find effective measures. The joint process was divided into three meetings:

(a) Meeting #1 was focused on informing the participating stakeholders on the issue by introducing the facts derived from the In-depth studies.

(b) Meeting #2 was a follow-up meeting on meeting #1. The stakeholders have had a chance to reflect on the stated facts and were encouraged to introduce and discuss possible measures.

(c) Meeting #3. During the final meeting the stakeholders would state their intentions to take measures within their area of responsibility in relation to the information gained during meeting #1 and #2.

10. The method of working is called “OLA” (which is a Swedish abbreviation for Objective findings-Solutions-Intentions) and was introduced in 2006 to invite more stakeholders to take part in the road safety work. The method is based on facts derived from the In-depth studies. Findings by the analysis group are introduced to the stakeholders. They on their part form a group that analyse what measures can be implemented to prevent the chain-of-events leading to the fatal outcomes of the accidents.

II. Access to information sources of accident occurrence

11. The In-depth studies rely on two major information sources to get knowledge of the occurrence of a fatal accident; regional traffic control centres and the police.

12. Regional traffic control centres act in cooperation with the emergency service centre in the same region and notifies accident investigators by sending a pre-set text message to the accident investigators mobile phone.

13. Not every fatality is determined at the accident site, nor do all fatalities occur at the accident site. For that reason there is a need for a second central information channel (the police) to STA. Information from the police about road traffic fatalities is routinely sent to the STA by fax as soon as possible after the fatality is known. The information is a standard document that is filled in by the police after every road traffic accident (regardless if there are fatal, serious or slight injuries).

14. Both information channels are secured through signed agreements between the police and the STA as well as regional traffic control centres and the STA.

Case 1 – Concrete pillar within the deformation zone of a barrier

15. The first indication came directly from the police a couple of hours after the accident. Through his contacts within the police force the officer was able to contact the STA accident investigator and could report a suspicion that the side barrier had not worked as it was supposed to (as the car had been able to deflect the barrier and to such extent that it crashed into a concrete pillar in close proximity to the barrier). When the female driver died two weeks later the police sent the information about the accident in accordance with the agreement between the STA and the police.

Case 2 – Barrier failure

16. The police sent the information about the accident in accordance with the agreement between the STA and the police.

Case 3 – Airbag did not inflate

17. The police sent the information about the accident in accordance with the agreement between the STA and the police.

Case 4 – Stakeholder cooperation

18. After each accident, the police sent the information about the accident in accordance to the agreement between the STA and the police. Accident investigators quickly identified the accidents between trucks and bicyclists as an issue to address in an OLA-process where it was introduced.

19. The STA and the accident investigator then acted as an information source when the stakeholders were assembled.

III. Access to data sources and collection of data and information

20. The accident investigator routinely collects data from:

- The police: As a first step an initial report is sent with information about the accident site and the vehicle(s) involved in the accident are located. At a later stage the police investigation is sent to the STA. Data is transferred between the police and the STA through an agreement between the two authorities. STA accident investigators also keep in contact with the police through the entire investigation;
- The National Board of Forensic Medicine: For legal reasons, an autopsy is generally performed on each person killed in a road traffic accident. In the vast

majority of cases, a forensic toxicology test is performed for the same reason. The autopsy and forensic toxicology test is included in the police investigation. The STA has also established direct contact to allow a direct exchange of information between the two authorities;

- The accident site: The accident investigator collects data on the crash site after the rescue operation is finished. Normally the investigator collects crash site data within 5 days of the accident. During the examination of the accident site the investigator collects data about parameters that are regarded as important to the accident investigation. However a set certain of parameters must always be collected;
- The Swedish Transport Agency: This authority has overall responsibility for registers of vehicles and driving licenses in Sweden. The accident investigators has direct access to and can collect data and information directly from a database kept by the agency;
- The vehicle: The accident investigator collects data about the vehicle. During an examination of a vehicle the investigator collects data that is considered important to the accident investigation. However a set certain of parameters must always be collected;
- The Swedish Transport Administration: Information needed about roads is supplied through personal contacts and databases within the organization. The contacts may also be involved in the analysis group at a later stage;
- The rescue service: The rescue service has access to primary information about the rescue operation and photos of the accident site. Mainly, the investigator collects this data through direct contacts with the rescue service.

21. Other data sources are possible to use depending on relevance and if cooperation in the specific case is possible. Examples of such data sources are:

- The manufacturer of the specific vehicle involved in the accident;
- The road authority (if not the STA) in the form of a municipality or privately owned road open for public traffic.

Case 1 – Concrete pillar within the deformation zone of a barrier

22. The accident investigator used all mentioned data sources. However, some data sources were more crucial to the case.

23. Information from the police arrived first which made it possible to locate and examine the vehicle. Due to the fact that the accident site was a part of a high-density highway, the accident site was restored before the accident investigator had time to examine it. The accident investigator visited the accident site at a later stage of the investigation and received important data and information from the police and the rescue service as well as persons employed by the STA to reconstruct the accident site. Information collected from the National Board of Forensic Medicine gave an important insight how the young woman had sustained the injuries that caused the fatality. In addition to the standard data collected, the accident investigator collected data and information specifically about the side barrier and road side area.

Case 2 – Barrier failure

24. The accident investigator used all mentioned data sources. However, some data sources were more crucial to the case.

25. Information from the police arrived first which made it possible to locate and examine the vehicle. While examining the vehicle, the accident investigator found that the median barrier had attached to the undercarriage of the car. Due to the fact that the accident site is a part of a highway, the accident investigator had difficulties to access the location of the accident and contacted the persons employed by the STA to reconstruct the accident site to gain the data and information needed about the accident site. At this time the accident investigator learns about the median barrier and acknowledges that it could have been a factor. Subsequently, the accident investigator contacted experts on barriers within the STA to gain further knowledge about the specific type of barrier used. The accident investigator also contacted road maintenance personnel of the STA for further information about the ground conditions.

Case 3 – Airbag did not inflate

26. The accident investigator used all mentioned data sources. However, some data sources were more crucial to the case.

27. Information from the police arrived first which made it possible to locate and examine the accident site and the vehicle. During the examination of the accident site the accident investigator learned through additional contacts with the police that the police had strong indications that the fatality was the result of a suicide. The accident investigator continued to collect data and information and examined the accident site carefully. When the accident investigator examined the vehicle he found that the airbags did not inflate during the crash. Through vehicle experts in the STA the accident investigator was able to contact the vehicle manufacturer. This lead to a joint examination with vehicle manufacturer, which enabled the accident investigator to gain further information and knowledge about the crash.

28. The autopsy later show that the airbags most likely could not have prevented the fatality in this case.

Case 4 – Stakeholder cooperation

27. In each of the fatalities caused by the specific accident type the accident investigators used all the data sources. However, some data sources were more crucial to the cases.

30. In the cases of accidents between right-turning trucks and bicyclists, police data and information were particularly important as the truck normally did not have any traces of the accident when the accident investigator is able to examine it. The witness reports taken by the police were also important to the accident investigator. The accident site and the vehicles were then examined. The autopsy normally confirmed the suspicion that the bicyclist had been run over.

31. Data and information from the accident investigation then served as the data source used for the stakeholders' cooperation group.

IV. Legal aspects

32. In Sweden, it is possible for authorities to share data and information through the principle of public access.

33. The principle entitles the general public to access official documents. Documents that are received or sent out by the Government Offices and other government agencies, e.g. letters, decisions and inquiries, usually constitute official documents.

34. The principle also grants officials and others working in central government, municipalities, agencies, etc. to have freedom of communication. This means that, with some exceptions, that the STA is enabled to cooperate with important stakeholders, as the police, the rescue service, etc. However, the communication must be done in accordance with the laws on confidentiality.

35. To be able to receive data and information about use of drugs and alcohol or other information that could be of harm to a person's integrity, the STA also has been ensured further confidentiality through a paragraph in the law on confidentiality.

V. Investigation method

36. The In-depth studies are a part of a safe system approach and use the principles of Vision Zero as a foundation for the investigation method. As mentioned in the introduction the purpose of the investigations to find flaws in the transport system causing the fatalities. Flaws are compared with a model for safe road traffic, which is defined by the principles in Vision Zero. The model describes, from a system perspective, the way a number of factors interact in order to achieve safe road traffic. The starting point of the model and the prerequisite for a safe journey is the psychological and physical conditions and limitations of the human being. The main limiting factor is human ability to withstand external violence, which can be considered given and constant. The passive safety, or injury mitigation capability of the system, is determined by the safety standard of the vehicles and the roads/streets added together. The total injury mitigation capacity of these components determines the safe speed of the system. If a higher speed is desired, the safety performance of vehicles, roads/streets and/or road user must be increased. Deficiencies in the system design must be compensated by a lower speed.

VI. Composition of the analysis group

37. The guidelines for the In-depth studies conducted by the STA state which competences that should be included in the analysis group. Competences could be retrieved both internally (within the STA) and externally (other stakeholders). Experts that always are included in the analysis group, due to the aim of the In-depth studies, are:

- An accident investigator. In most cases the investigator/investigators who conducted the investigation.
- A road safety expert. The expert represents specific knowledge of road safety issues.
- A road designer, or a similar expert with general knowledge of a technical aspects as well as its safety features and safety performance.
- A vehicle engineer, or a similar expert with general knowledge technical aspects as well as its active and passive safety features
- A behavioural scientist, or a similar expert with good knowledge about human factors.
- A physician, or a similar expert with a good knowledge about human physical conditions to sustain collision forces as well as how drugs, age, illnesses, etc affect a person´s precondition to act safely within the system boundaries.

38. Other competences may be included if needed, e.g. the police, the rescue service, pathologists, road maintenance, road regulations, etc. General competences involved in a pre-investigation analysis could also be included in the analysis group.

Case 1 – Concrete pillar within the deformation zone of a barrier

39. In addition to the expertise always included in the analysis group, an expert within the road maintenance area and a person within the unit that plans investments in the road infrastructure were included in the analysis group.

Case 2 – Barrier failure

40. In addition to the expertise always included in the analysis group, an expert within the road maintenance area was included in the analysis group.

Case 3 – Airbag did not inflate

41. In addition to the expertise always included in the analysis group, no other expertise was used. (The vehicle manufacturer's expert involved in the vehicle examination was invited but was not able to take part.)

Case 4 – Stakeholder cooperation

42. An analysis have been made following every accident investigation between a truck and a bicyclist. In addition to the expertise always included in the analysis group, expertise of some of the involved vehicle manufacturers have been used.

43. The stakeholder cooperation group have among others included; vehicle manufacturers, representatives of municipalities, the police and trucking organizations.

VII. Reconstruction and analysis of the accident and its consequences

44. All conclusions made by the analysis group must be derived from facts. The objective of the analysis group is to:

(a) Reconstruct the most probable chain of events in the pre-crash, crash and post-crash phase of the accident.

(b) Conclude which factors contributed to the fatal injury. If possible also conclude which factors contributed the accident occurrence.

(c) Suggest possible measures to "break the chain of events".

Case 1 – Concrete pillar within the deformation zone of a barrier

45. In this paper only the part of the reconstruction relevant for the findings and conclusions is included.

(a) After the initial collision the car crosses all three driving lanes (all in the same direction as the accident occurred on a highway). The car drifts into the side barrier almost head on. Behind the barrier, within the deformation zone of the specific type of barrier, a bridge pillar made of concrete is located. It is concluded that the deformation zone between the side barrier and the concrete pillar is too small which causes the car to crash head on with the pillar.

(b) The combination of the crash between the car and the side barrier at a large angle and the concrete pillar being located in the deformation zone causes the fatal injury. It

is also concluded that a similar chain of events is possible even if the collision angle with the side barrier is smaller.

(c) Possible measures are presented in "Formulation of findings and recommendations".

Case 2 – Barrier failure

46. In this paper only the part of the reconstruction relevant for the findings and conclusions is included.

- As the car crashes with the median barrier, it is pushed backwards and down because the soil is too soft to keep the barrier pillars in place. As the barrier is pushed down one of the pillars is pulled up out of the ground and connects to the undercarriage of the car. The barrier is torn from the next couple of pillars. After travelling a couple of meters with the pillar and barrier connected to the undercarriage the car is thrown into rotation when the barrier finally holds to the pillars. At this time the driver is thrown halfway outside of the car.
- When the car again crashes with the median barrier the driver is caught between them and crushed. The driver is subsequently drawn completely out of the car. It is determined that the driver had not been wearing a seat belt.
- Possible measures are presented in "Formulation of findings and recommendations".

Case 3 – Airbag did not inflate

47. In this paper only the part of the reconstruction relevant for the findings and conclusions is included.

- The vehicle has drifted off the road in a narrow angle. Thereafter it has travelled at a high speed about 50 meters in the road side area. When crashing with a stone wall the front of the vehicle is raised and the driver, who is not wearing a seat belt is thrown towards the compartment ceiling. The high speed of the vehicle allows almost the whole front end to be pushed into the compartment. After that the car is thrown back onto the road. When the deceased is retrieved from the wreck, the police finds a suicide note.
- The driver is killed immediately by the severe injuries sustained when the front end of the car is pushed into the compartment.
- The collision and subsequently the injuries are due to a suicide. However an important finding is discovered and is presented in "Formulation of findings and recommendations".

Case 4 – Stakeholder cooperation

48. In this paper only the part of the reconstruction relevant for the findings and conclusions is included. The chain of events described in case 4 is a general description of repeated events found in numerous accidents involving trucks and bicyclists. In the analysis of every accident, the analysis group concluded these specific events to be important factor which contributed to the fatality and accident occurrence. The general description formed the basis for further analysis made by the stakeholders.

(a) All fatally injured bicyclists had been close to the right hand side or just in front of the truck-driver compartment at a signalized intersection in an urban area. In all cases the driver is also unaware of the position of the bicyclist. As the light turns green both road users start their motion. The truck-driver has the intention to turn right and the bicyclist has the intention to ride their bike straight through the intersection. As the truck-

driver begins to turn right, the truck collides with the bicyclist and knocks the bicyclist over. The truck-driver is unaware of the collision and continues to turn the vehicle. The bicyclist, now lying on the ground, is run over by the truck.

(b) The fatal injury is sustained when the bicyclist is run over.

(c) Possible measures are presented in "Findings and recommendations following the analysis".

VIII. Formulation of findings and recommendations

49. The In-depth studies aim to increase safety by addressing all parts of the transport system. Findings and recommendations may therefore be directed to all stakeholders involved in designing and operating the transport system. Within the STA, a recommendation is provided to the part of the organization that can make the adjustment needed to increase safety.

Case 1 – Concrete pillar within the deformation zone of a barrier

50. When analyzing the accident the analysis group concluded that the concrete pillar is standing within the deformation zone of the barrier. The road maintenance competence informed the analysis group that the barrier had been moved closer to the pillar to ensure more roadside surface. The analysis group was also informed that barriers had been moved in the same way along a long stretch of the highway in the region due to a specific roadside project.

51. The analysis group recommended that the highways in the region where the project had been carried out should be investigated, and subsequently, if more non-yielding objects were found a list of how and when they should be taken care of should be established.

Case 2 – Barrier failure

52. When examining the car, the STA investigator discovered that the barrier had stuck to the undercarriage of the car. To follow up the finding the STA investigator contacted the entrepreneur who was responsible for the maintenance the specific road and its installations. It was discovered that the pillars holding the median barrier were standing in soil too soft to hold the pillars when the car collided with the barrier. This caused the pillar to bend down which in turn caused the barrier to bend down as well. The analysis group concluded that if the pillars would have been installed correctly the pillars would have kept the pillars in place and the barrier would have been likely to withstand the collision. Subsequently the barrier would have worked as intended and stopped the chain of events.

53. The analysis group recommended the STA to form a strategy on how to ensure that barriers are set up in ground conditions that can support the pillars.

Case 3 – Airbag did not inflate

54. When examining the vehicle the investigator found that none of the frontal airbags had deployed. Even though the accident investigator has information that the fatality was caused by a suicidal act the STA investigator decided to investigate the airbags to ensure that there was no deviation from the required functionality. For that reason the investigator contacted the vehicle manufacturer. In the joint examination the STA investigator and the vehicle manufacturer found that the brutal impact force also disconnected the airbag system. Their findings worked as an input to the vehicle manufacturer to improve their airbag systems. The information was also important knowledge gained for the vehicle experts of the STA.

55. No recommendations were submitted by the analysis group to the vehicle manufacturer.

Case 4 – Stakeholder cooperation

56. The analysis group found that in each case the truck-driver had been unaware of the bicyclist standing on the right hand side of the truck. The analysis group concluded that this is a crucial factor to handle to prevent the fatal injuries and therefore recommended that measures to ensure the visibility of the bicyclists should be implemented to prevent the initial collision.

IX. Implementation of findings and recommendations

57. Depending on the stakeholder, the knowledge of the implementation of a recommendation varies. In general the follow up is made:

- through contacts between the STA and the stakeholder. The STA has no possibilities to force any stakeholder to act. The aim is instead to encourage stakeholders to make changes that increase safety,
- through contacts between the Accident Investigation unit and the part of the STA with a possibility to make changes that increase safety.

58. For this reason the In-depth studies can be seen as a part of safety management system which the STA uses to improve safety within their organization.

The OLA-cooperation method, which was described above and which case 4 is based on, is also a method for the implementation of findings and recommendations.

Case 1 – Concrete pillar within the deformation zone of a barrier

59. The investigation to seek out more non-yielding objects behind barriers was carried out by the STA. The investigation showed a number of objects that could jeopardize safety if a similar chain-of-events would take place in the location of the discovered object. A list of how and when the issues should be taken care of was therefore established. The STA has been working with objects on the list, systematically minimizing the injury risks through a similar chain-of-events. In most cases the STA has changed the type of barrier in the vicinity of a non-yielding object.

Case 2 – Barrier failure

60. The STA was updating its strategy for barriers at the time of the accident. The findings and recommendations from the analysis group were implemented into the new strategy for barriers. The findings also initiated a research project on the subject of ground conditions to ensure that the barrier pillars work as expected.

Case 3 – Airbag did not inflate

61. The finding served as an input to the vehicle manufacturer to improve their safety systems. The information is also valuable insight gained for the vehicle experts of the STA and spread through their work.

Case 4 – Stakeholder cooperation

62. During the stakeholder cooperation meetings the idea of “bicycle boxes” was brought up. The principle is that the stop line for motor vehicles at a signalized intersection is drawn further back from the intersection. This creates a box for bicyclists to reside in

during the time when given a red light. The box gives the truck-driver increased visibility over the bicyclists at the intersection as well as relocating the bicyclists from the dangerous area on the right hand side of the truck. This idea is subsequently systematically implemented in the urban area of Stockholm.

63. The findings also have served as an input to the truck manufacturer to improve their safety systems. Active research include radar systems (that e.g. cover the right hand side) and other measures to reduce the risk of being run over.