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# SWITZERLAND - NATIONAL REPORT

# STRATEGIC DIRECTION SESSION TSC

# SAFETY OF THE ROAD TRAFFIC SYSTEMS

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# SUMMARY

The research package "Safety of the road traffic systems and its civil engineering structures" presented in this National Report has the aim to provide the basis for decision-making and methods for the attention of the road management administrations, which allow them to apply precisely and functionally restricted financial resources to accomplish the required safety standard across the entire road traffic system and to maintain it.

The research package is structured in specific projects and by a synthesis report developing the following topics:

- Methodological basis for comparative risk assessment
- Term of the network risk with particular regard towards civil engineering structures
- Effectiveness and efficiency of intervention strategies
- Scenarios of risk developments
- Validation of the method by a test region

The National Report is concentrated upon the roads systems. The research package deals as well with further specific issues as:
- Considerations about law's implication
- Structures inventory of the procedure for the structural safety of existing bridges and other structures
- Safety on construction sites

All the cited working documents are costless at disposal on the website www.astra.admin.ch

The working process has permitted a large concertation among several different administration offices with the result of common procedures and the sharing of specific knowledge. This represents a considerable added value.

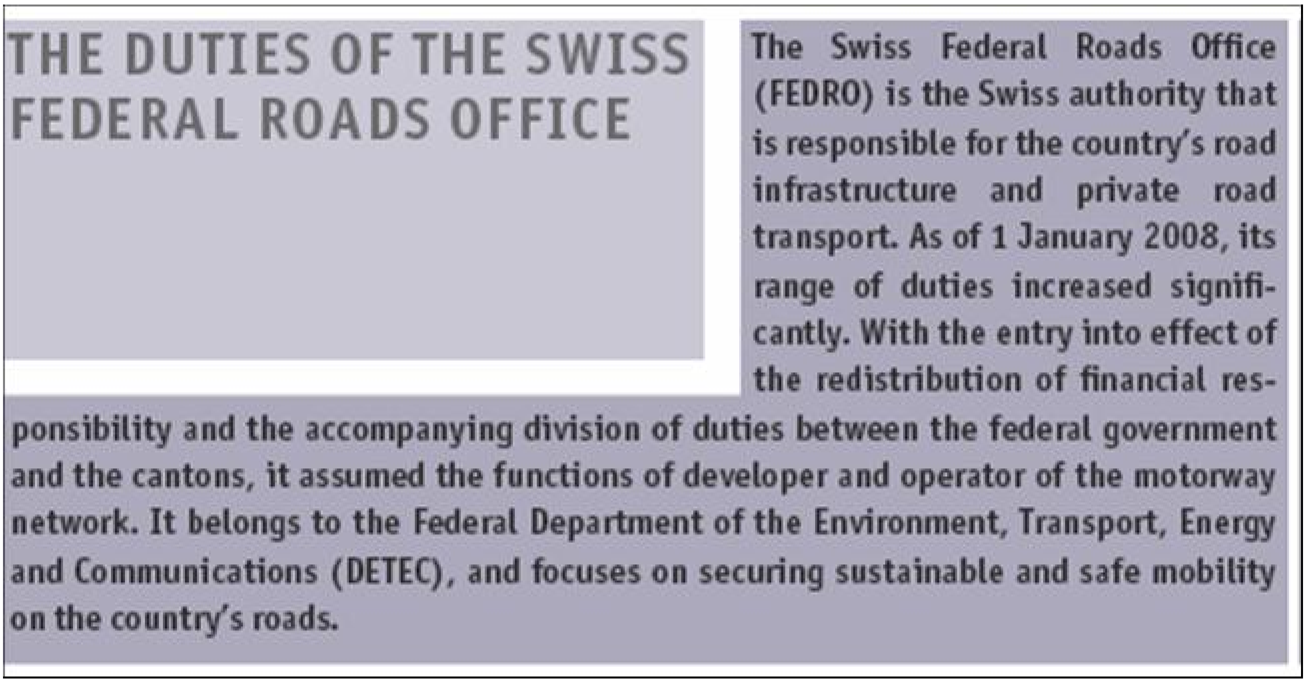
The methodology for the comparative risk assessment proposed is suitable for the application in the different safety areas. It allows for a consistent treatment and for the comparability of miscellaneous risks. New options are provided for the risk based approach, this particularly for the evaluation of the net risk. It represents a valid tool to develop furthermore the risk management system. However this methodology may lead to a considerable expenditure and it can only be implemented into practice if the legal prerequisites exist and the legal practice accepts the approach.

## 1. INDEX

## 2. INDEX OF THE TABLES

# 1. SWISS CONTEXT

The present National Report "Safety of the Road Traffic Systems and its Civil Engineering Structures" emphasizes the issues of the risk management and is proposing as introduction a review of the Swiss context.



**THE DUTIES OF THE SWISS FEDERAL ROADS OFFICE**

The Swiss Federal Roads Office (FEDRO) is the Swiss authority that is responsible for the country's road infrastructure and private road transport. As of 1 January 2008, its range of duties increased significantly. With the entry into effect of the redistribution of financial responsibility and the accompanying division of duties between the federal government and the cantons, it assumed the functions of developer and operator of the motorway network. It belongs to the Federal Department of the Environment, Transport, Energy and Communications (DETEC), and focuses on securing sustainable and safe mobility on the country's roads.

Table 1 – The duties of the Swiss Federal Roads Office

The duties of the Swiss Federal Roads Office are as follows:

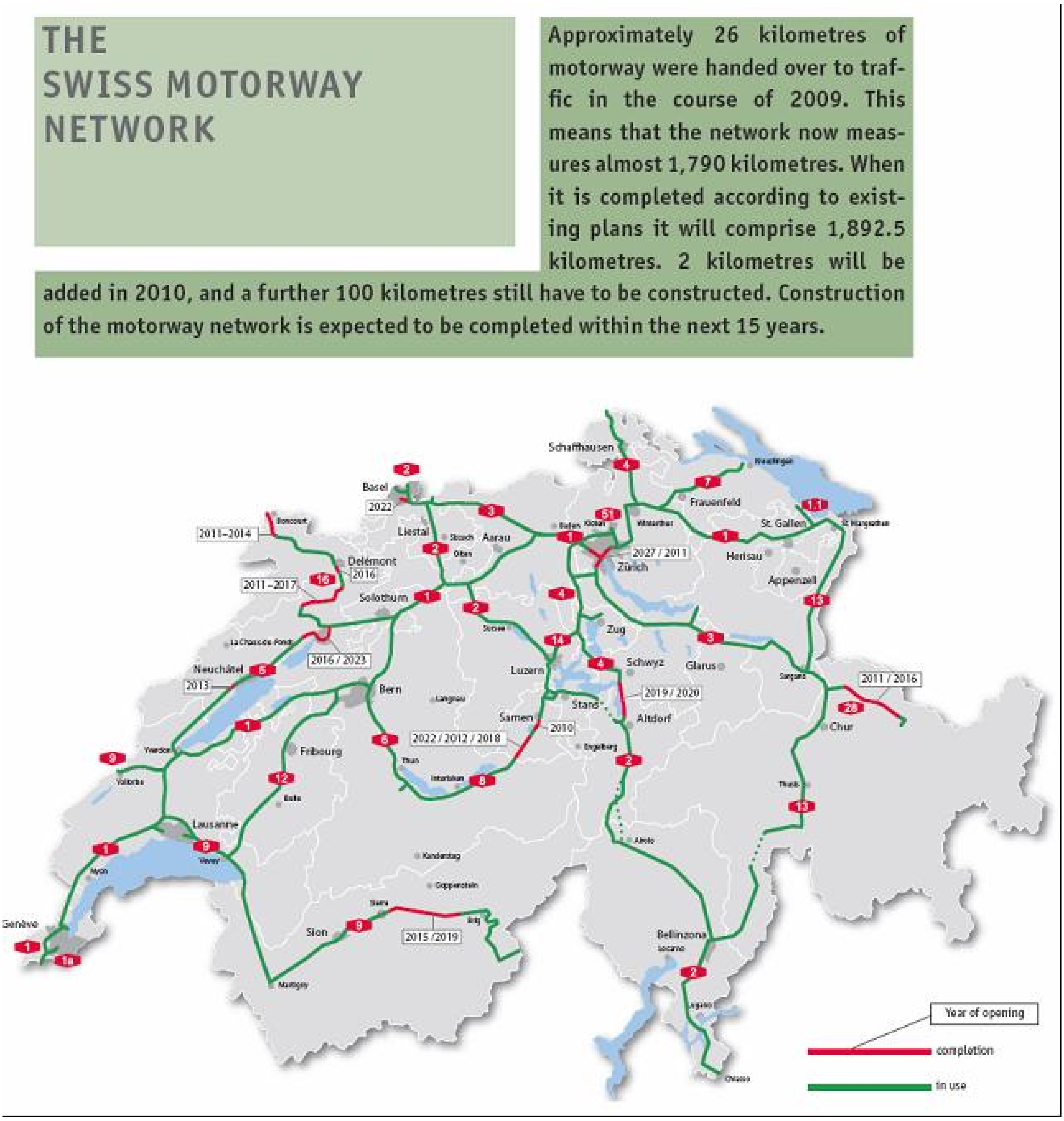
a) To complete a safe, efficient and economical motorway network and preserve its substance over the long term.
b) To secure the functionality of our country's motorways and their integration into the Pan-European network.
c) To guarantee safe and secure access for road users and vehicles.
d) To enhance the degree of safety on our roads for all users and vehicles.
e) To reduce the burden on the environment attributable to road traffic.

To achieve these goals, FEDRO performs the following main functions:

a) It prepares decisions for a coherent policy in the areas of road transport (including goods transport by road) and traffic safety at the national and international levels, and subsequently implements them. This encompasses the following areas of action:
- Construction, maintenance and operation of the country's motorways.
- Enforcement of the provisions governing the use of the portion of oil tax that has been earmarked for road traffic.
- Specification of requirements on vehicles and road users, behaviour in road traffic, footpaths, cycle paths and historical routes (human-powered mobility).

b) It is the highest authority for the supervision of roads of national importance.
c) It deals with complaints to the Federal Council against local traffic measures.

The strategic theme "Safety of the Road System" represents a major challenge for a national motorway network characterized as follows:



THE SWISS MOTORWAY NETWORK

Approximately 26 kilometres of motorway were handed over to traffic in the course of 2009. This means that the network now measures almost 1,790 kilometres. When it is completed according to existing plans it will comprise 1,892.5 kilometres. 2 kilometres will be added in 2010, and a further 100 kilometres still have to be constructed. Construction of the motorway network is expected to be completed within the next 15 years.

Table 2 – The Swiss Motorway Network

As of the end of 2009 a total of 1,789.1 kilometres of motorway were in operation

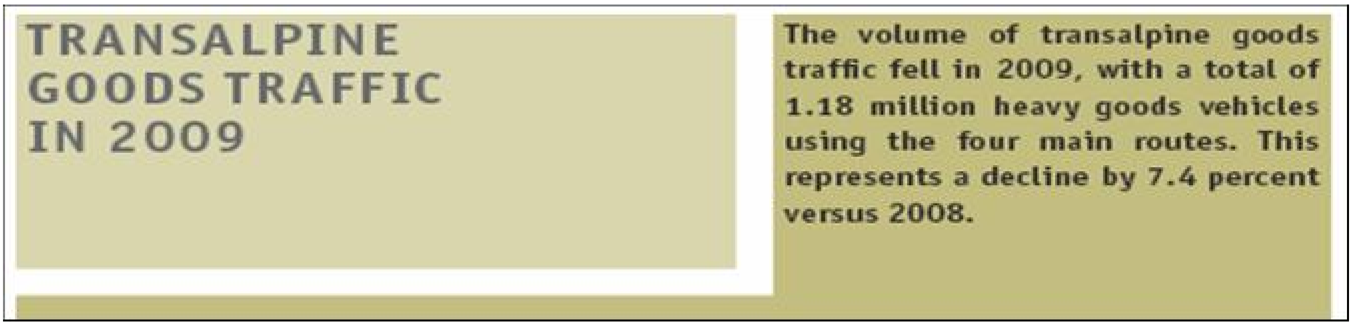
| | |
|---|---|
| 7-lane stretches | 1.2 km |
| 6-lane stretches | 80.7 km |
| 4-lane stretches | 1324.3 km |
| 3-lane stretches | 1.9 km |
| 2-lane stretches | 269.5 km |
| Mixed stretches | 111.5 km |

This corresponds to 94.5 percent of the planned network

Traffic volume on Swiss motorways in 2009:
In 2009, the automatic traffic counting stations operated by the Swiss Federal Roads Office recorded an average daily traffic volume on Switzerland's motorway network of

almost 7 million motor vehicles. The network of automatic traffic counting stations now covers 175 stretches of motorway, and last year 157 of these delivered a full set of data.

The transalpine goods traffic, concerning the safety of roads traffic, always deserves a particular attention.



## TRANSALPINE GOODS TRAFFIC IN 2009

The volume of transalpine goods traffic fell in 2009, with a total of 1.18 million heavy goods vehicles using the four main routes. This represents a decline by 7.4 percent versus 2008.

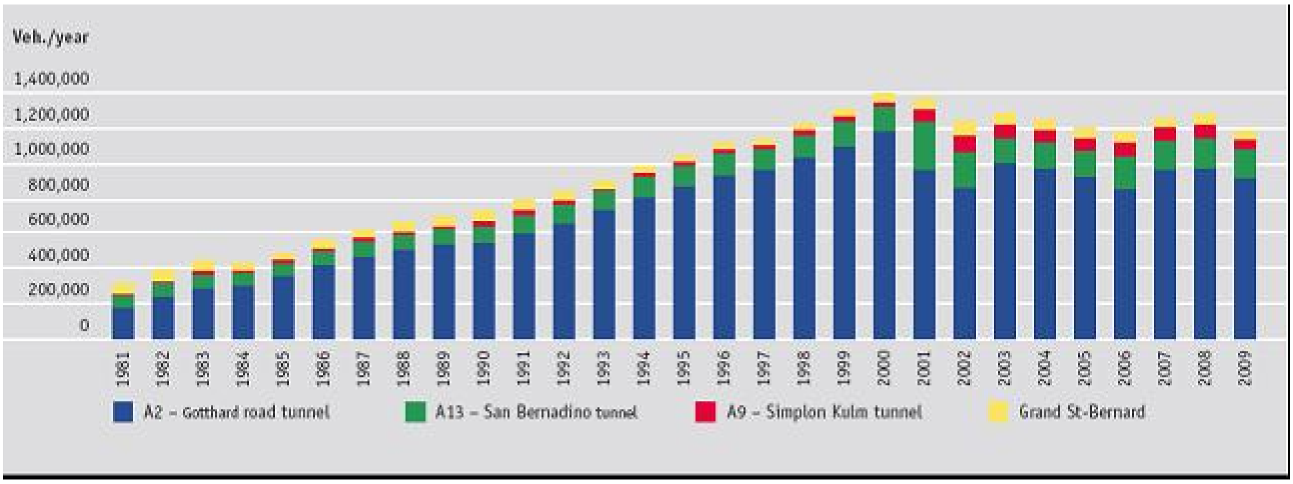
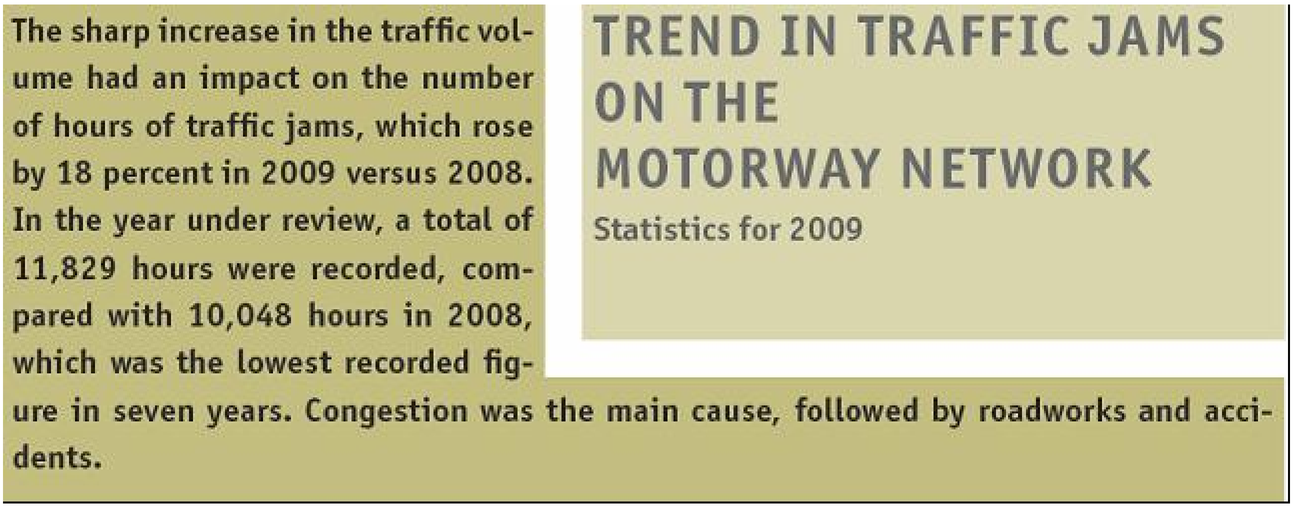


Table 3 - Transalpine goods traffic, 1981-2009: number of heavy goods vehicles per annum , shown by transalpine route

The topic of traffic congestion plays an important role for an optimal monitoring of the motorway network system



## TREND IN TRAFFIC JAMS ON THE MOTORWAY NETWORK

Statistics for 2009

The sharp increase in the traffic volume had an impact on the number of hours of traffic jams, which rose by 18 percent in 2009 versus 2008. In the year under review, a total of 11,829 hours were recorded, compared with 10,048 hours in 2008, which was the lowest recorded figure in seven years. Congestion was the main cause, followed by roadworks and accidents.

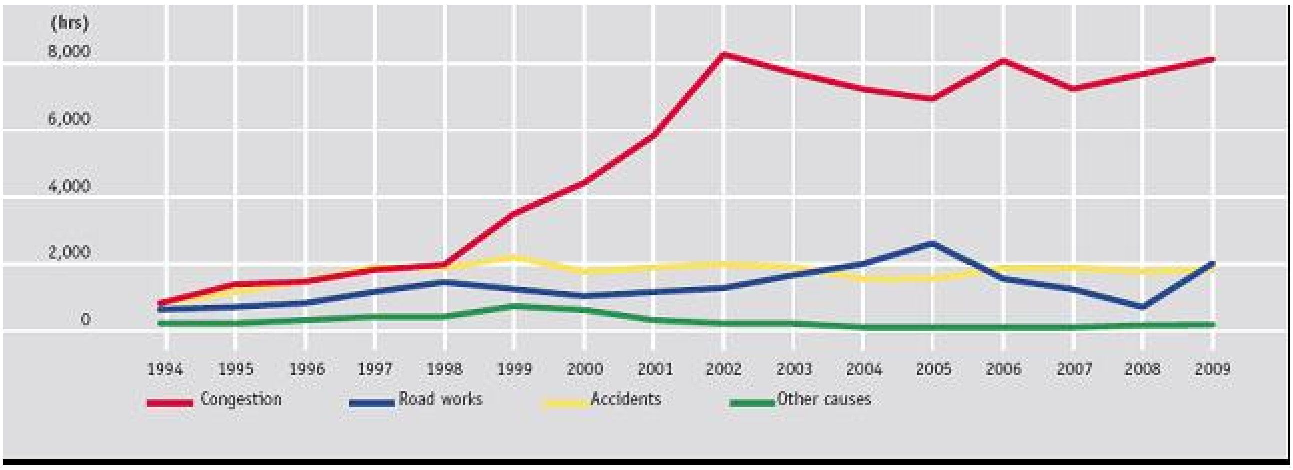


Table 4 – Trend in traffic jams on the motorway network 1994-2009 (in hours)

These few highlights of the traffic situation in Switzerland emphasize the importance of the topic "Safety of the Road Traffic Systems". In order to tackle with these many challenges and with the purpose of disposing of a valid risk management, the Federal Roads Office (FEDRO) has launched the following research package.

## 2. SAFETY OF THE ROAD TRAFFIC SYSTEMS AND ITS CIVIL ENGINEERING STRUCTURES

The research package, *Safety of the road traffic systems and its civil engineering structures,* was initiated by the Working Group for Bridge Research (WGB) in the range of the research in the roads sector and financed by the Federal Roads Office (FEDRO). It provides a relevant contribution to the main research topic *Safety of roads and traffic* of the research strategy in the roads sector 2008-2011.

The aim of the research package is to provide the basis for decision-making and methods for the attention of the road management administrations, which allow them to apply precisely and functionally restricted financial resources to accomplish the required safety standard across the entire road traffic system and to maintain it. This requires methods to evaluate risks of the different safety areas like traffic situation, natural hazards, hazardous incidents etc. and to make them comparable among each other and to determine efficient measures for risk mitigation.

The research package deals with the methodology for risk evaluation and for optimisation of measures on the overall road system at the superordinate level and validates these approaches for the subarea of civil engineering structures. Furthermore it deals with the legal issues as a requirement for the application of the risk based approach. The research package is structured in specific projects and by a synthesis report developing the following topics:

- Methodological basis for comparative risk assessment
- Term of the network risk with particular regard towards civil engineering structures
- Effectiveness and efficiency of intervention strategies
- Scenarios of risk developments
- Validation of the method by a test region

The National Report is concentrated upon the roads systems. The research package deals as well with further specific issues as:

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## 2.1 Methodological basis for comparative risk assessment (specific project)

### 2.1.1 Problem and objectives of the project

The Swiss roadway system, facilitating private and public traffic within and across the borders of Switzerland plays a key role for the success of the Swiss society and moreover contributes importantly to the interconnectivity, mainly the north-south interconnectivity, in Europe.

The benefit achieved from the Swiss roadway system may be related to the functionality it provides for society; e.g. measured in terms of connectivity, availability, reliability and safety. As responsible for the further development and maintenance of the Swiss roadway system it is a key focus to maximize this functionality.

However, it is important to recognize that the roadway network also poses risks to the society in basically three different and interrelated ways, namely

- risks to the users of the network
- risks to third parties, i.e. the general population through e.g. major accidents on the roadway network
- indirect risks to the general population through occupation of economical resources which could have been used for other risk reducing activities in other societal sectors

In 2004, the Federal Department of Finance developed the foundations for a risk management within the federal government. The aim of the new risk policy of the federal government in particular is to increase the efficiency in the performance of the departments and administrative units. The Federal Roads Office (FEDRO) and the cantonal as well as the local road administrations have to manage very diverse risks in their domain of responsibility.

In practice these risks are generally managed in so-called safety areas, in accordance with their cause: i.e. risks from traffic accidents, from the road infrastructure components, from natural hazards, etc. Between the various safety areas and sometimes even within, different and diverging methods for the assessment of risk are practiced. The methods not only differ in the approaches for risk analysis, but also in their assessment and the strategies on how to deal with them. Due to these differences, between and within the safety areas, the risks cannot easily be aggregated at a higher level, and thus cannot be integrally compared. Within FEDRO and the underlying road administrations there is thus a great need to establish a methodology and practice for integral and comparative risk assessment.

In order to ensure the maximum benefit of the project, with a view to both methodical and practical aspects, the following requirements for the methodology were identified:

- Applicability of risk methodology to the different safety areas
- Conformity with codes and practice
- Consistency in the representation of knowledge (experience and data)
- Applicability for the support of decisions on strategic and operational levels.

### 2.1.2. Procedure

The aim of the development of a general methodology for risk based decision making is to support decision making for the improvement of the safety level on the Swiss roadway network. It is clear that this problem complex contains many specific aspects and necessitates detailed considerations on a case by case basis. However, there are also some quite general characteristics which are worth noticing because they constitute a main part of the daily business in the safety management of the Swiss roadway network. In the following we outline these characteristic decision problems in short:

At the level of strategic management decision support is required in regard to:
- What is a sufficient level of safety for the Swiss roadway network and which are the principles for deciding on where and when to improve this level?
- How large budgets should be allocated to cover losses due to accidents and events of natural hazards?
- To what activities should investments be allocated differentiated in regard to e.g. improvement of roadway surfaces, traffic regulation, construction of protection structures, and improvement of the safety of existing infrastructural facilities?
- To which geographical regions should financial resources be allocated in order to achieve the highest efficiency of overall investments and in order to maintain a just and uniform level of safety throughout the entire roadway network?
- What are the temporal changes which can be expected in regard to the development of risks, what do they depend on and how may they be monitored?
- How can and should risk management be communicated to ensure efficiency in the strategic political decision making process?

At the level of operational management decision support is required in regard to:
- Which are the risks associated with existing objects and segments on the roadway network and how may the risks effectively be reduced?
- Which are the risks associated with planned activities on the roadway network and how may the risks effectively be reduced?
- How do individual accidents and events of natural hazards affect the performance of the roadway network as a system and how can the associated risks effectively be reduced?
- Which are the effective means and procedures to take in reducing consequences in the case of an accident or the event of a natural hazard?

### 2.1.3. Project results

For this project, the different areas of responsibility of FEDRO have been merged into five safety areas, namely:
- traffic accidents
- natural hazards
- structural safety
- occupational safety
- incidents involving hazardous materials.

The project focuses on the before mentioned five safety areas. Other safety areas such as political, legal and economic risks are not directly the subject of the research project. However, the knowledge gained and the developed methodology is transferable and applicable to other areas within the FEDRO and the underlying road administrations.

In a preliminary analysis, the safety areas were examined in regard to their most common methods and instruments for dealing with risks, and their similarities were pointed out. The analysis includes the nature of the assessed risks, the procedural steps of the methodology, the type of required information, as well as the approaches to the evaluation and selection of risk reducing measures. As a synthesis of this preliminary analysis, a general process of risk assessment (a methodological basis) was drawn up, being applicable to all the safety areas

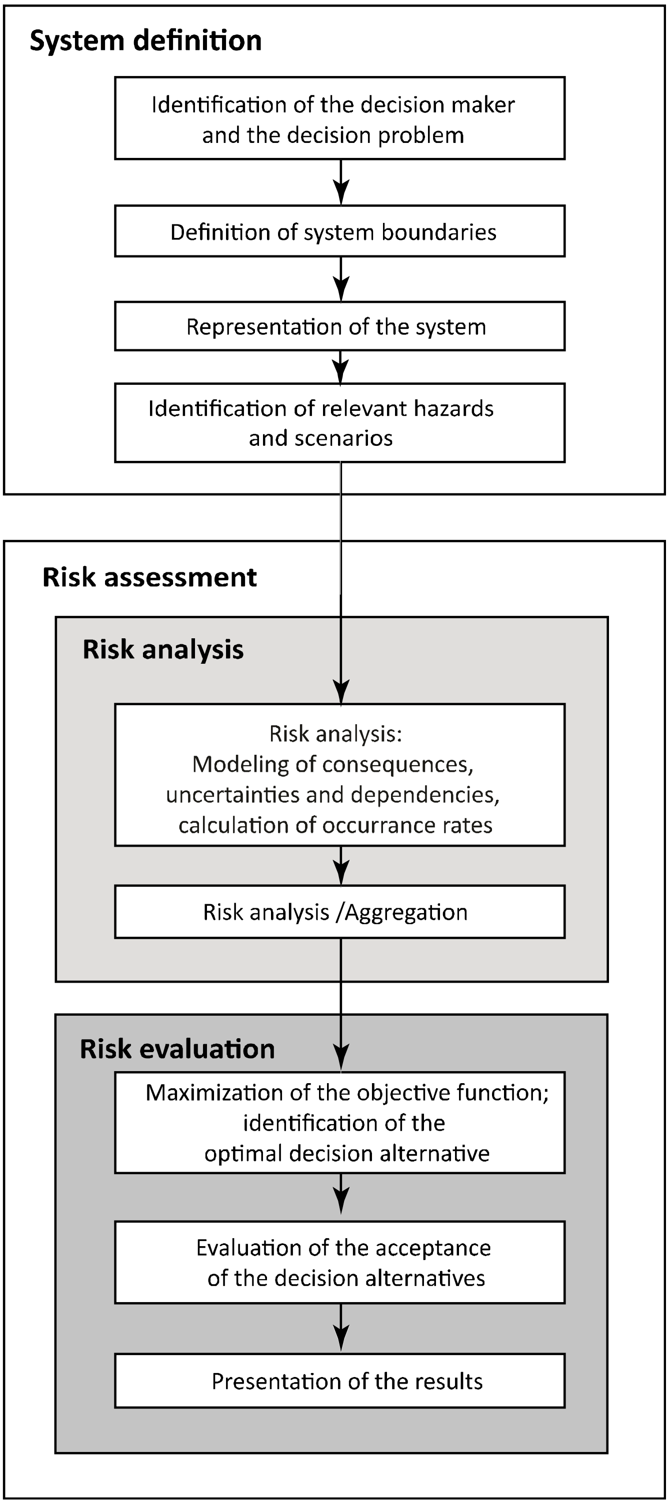

Table 5 – General process of risk assessment

This methodological basis has to be seen as the standard for a complete risk assessment. For some of the methods used in practice, this standard should be seen as an extension, but a necessary extension for reasons of consistency and completeness. The general process of risk assessment is the basis for the formulation of additional requirements, which in each procedural step are formulated to ensure comparability of results and to guarantee that they can be aggregated.

For the development of a comparative and integral methodology for risk assessment, necessary requirements were defined which ensure that risk assessments with varying degrees of detail and data can be compared and aggregated. For this purpose, the latest international findings on best practices in risk assessment were adapted as far as possible to the Swiss conditions. The main idea is to facilitate the aggregation of risks assessed within different safety areas with this comparative methodology and so to enable a realistic and optimal budgeting of necessary resources. The projects first outlines the basis for risk informed decision making and points to the interrelation affecting the decision making. The underlying assumptions and the core of the methodology are described.

The methodological aspects which are essential for ensuring that risk assessments are comparable and consistent are detailed in this project. Here the necessary requirements for comparability and aggregation of risks are first formulated through principles. Subsequently the principles are described in the context of risk management of roadway systems. By providing the core results of the project at three levels of detail it is aimed to enhance the readability of the report depending on the background and needs of the reader.

The project proposes a description of the necessary requirements to the definition of the system considered in the risk assessment. The system definition forms the basis for the risk assessment as a whole. This encompasses the definition of the problem and the choice of an appropriate level of detailing in the system representation. Based on the system definition the consequences that must be considered in the risk assessment are defined by the following figure:

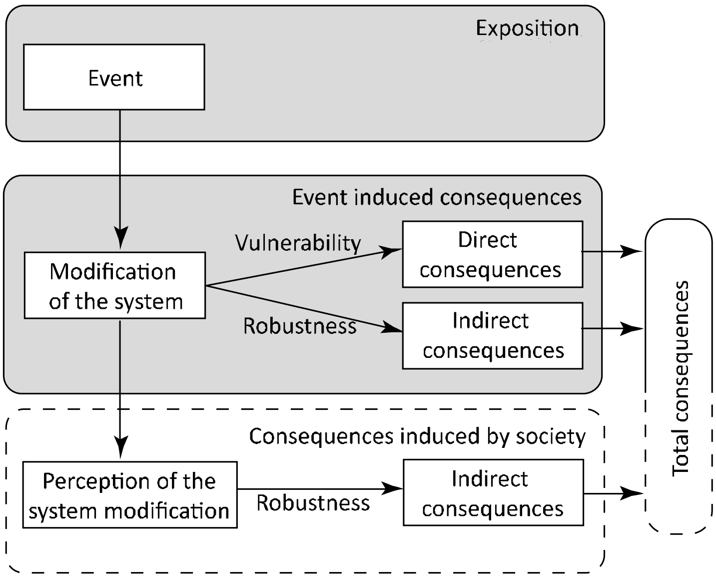

Table 6 – Evaluation of the total consequences

The representation of uncertainties concerns the representation of natural variability, lack of knowledge in general and more specifically how to treat this uncertainty in the assessment of risks. It is shown how different types of knowledge, such as observations of accident rates and the condition of a bridge can be utilized in the risk assessment and thereby improves the basis for decision making. The representation and treatment of uncertainties furthermore forms the basis for the consistent aggregation of risks which is most usually required to support strategic risk management decisions.

The project provides the requirements relating to the assessment of the efficiency of risk reducing measures. It treats the basis for assessing the societal conformity of life safety risk management and thus on how to decide in what activities and how much should be invested. Finally it provides directions on the adequate and relevant representation of risk assessment results to support risk informed decision making at both operational and strategic level.
The project is rounded off by addressing the fulfillment of the project objectives, i.e. to what degree the results of the project fulfill the project aims. It is finally evaluated if and how improvements of present best practices and knowledge are needed.

### 2.1.4. Outlook and implementation

The methodology which has been developed represents a common methodological basis over the considered safety areas, and specifies the necessary requirements for compatibility and comparability. The methods used previously within the different safety areas may, however, can still be applied provided that the necessary requirements are met. The methodological approach presented is designed to support and improve decision making so that an efficient and socially acceptable allocation of limited resources is facilitated. With the proposed approaches, risk assessments over the relevant safety areas can be conducted integrally in a manner facilitating for their consistent comparison and aggregation. The requirements for already collected data and results arise from the requirements set out in the guiding principles. The methodology has a great potential for improving the risk management in both the operational as well as in the strategic management of FEDRO.

Furthermore, the developed methodical framework underlines the significance of risk communication as a means for the management of risks on the roadway system. Until now, however, details are missing how risk communication in practice could and should be carried out. This topic is certainly an interesting problem, but it is far beyond the scope of the project presented here and should be analyzed separately.

A final issue concerns organizational risk. Whereas organizational risks are mentioned and in principle also accommodated for in the described methodical framework, general recommendations on how these risks can be modeled are still missing. During the implementation of the described risk assessment methodology in the organization of FEDRO, this issue will surely have to be considered in more detail.

## 2.2. Term of the network risk with particular regard towards structures (specific project)

### 2.2.1. Term of the network risk

The failure of a road segment within the road network due to an event (failure event) is associated with consequences on the road segment itself as well as on the surrounding road network. The consequences followed by the failure event may affect people, the environment and/or economical values.

For example one may consider the case of a large fire in a highway tunnel that causes personal (death, injured persons) as well as infrastructure damages (repair costs). These correspond to direct consequences of the failure event. The obstruction of the highway during days or weeks for the repair requires the diversion of the traffic to the surrounding road network. In general it means longer routes compared to the closed down highway and indirect consequences arise such as for example an increase of accidents, time delays, operational costs etc. The two types of consequences - direct due to the failure event and indirect due the close down of the tunnel roadway - form together what is deemed as the network risks of the considered highway segment respectively of the considered object.

The investigation of the network risks includes failures or restrictions of the capacity caused by events. It includes exposures on the considered objects, functional failures or failures caused by traffic accidents. Characteristic is the sudden, unexpected occurrence. As it is evident from the concept definition, the focus is on events that entail a certain failure duration. Short operational interruptions, up to a few hours, as for example in the case of normal traffic accidents, are not considered. As a limit for the minimum failure duration, which leads to considerable traffic rearrangements, a failure of the road segment for at least one day is postulated. As a result of this postulation restrictions due to a traffic congestion or limited capacity of the road segment are not considered.

### 2.2.2. System definition

In the system definition the boundaries and general conditions have to be specified and the basic functionality of the system also to be defined. In particular the system definition is concerned with the modeling of the road network and the traffic affected by the failure of a road segment. This road network is referred in the following as the "relevant sub-network". The application of a traffic model is necessary for the estimation of the relevant sub-network.

### 2.2.3. Risk analysis

The risk analysis consists of the following elements:

- Identification of the hazards and events that result on a closure of the road segment of more than a day duration.
- Evaluation of the frequency and failure duration due to the events: the expected number of failure days per year is considered and it is specified as the failure risk. The failure risk is required for the evaluation of the risk in the relevant sub-network.
- Evaluation of the risk of the failure event: consideration is made of the risks arising in the considered road segment through the failure event (human injuries, economical losses (asset values) and environmental damages). Those risks may in principle be designated as direct risks.

- Evaluation of the risk in the relevant sub-network: consideration is made of the risks in the relevant sub-network – that includes the considered road segment – that arise from the failure event. The risks are associated to the considered road segment. Those risks may in principle be designated as indirect risks. Risks associated with the relevant sub-network and resulting by the traffic rearrangement during the failure of the considered segment are mainly risks due to traffic accidents (human and property damages) as well as consequences such as time delays, operational expenditure and environmental interference.

The network risk of a segment is expressed through the sum of the risk due to the failure event and the risk in the relevant sub-network.

### 2.2.4. Risk assessment

The result of the risk analysis is in the form of expected consequences expressed in e.g. casualties, injured persons, money, traveled hours, traveled kilometers etc. per year. Risk assessment means to express the consequences uniformly in monetary terms and to assess risks based on risk criteria (optimization and acceptance criteria).
The risk assessment is carried out, as described in the methodology for the uniform risk assessment, by means of the following elements:

- Economic optimization: Only the consequences directly affecting the road authorities are taken into consideration.
- Societal optimization: it encloses the totality of consequences, independently of their origin, including, for instance, the assessment of environmental influences as well as time and operational costs of road users.
- Assessment of the acceptance of human risks based on marginal cost criteria.

For the network risks' assessment the focus lies primarily on the societal optimization.

### 2.2.5. Civil engineering structures

In this area methods are required with which risks associated with individual objects and groups of objects can be assessed. The large number and diversity of structures and possible influences present special challenges in respect of such methodology. Risk-based approaches, with which the specific risks of one of more objects are determined, have hardly ever been used in the field of structures to date. The safety check performed on structures is currently based on different assessment methods, assumptions regarding load effects and resistance and an inconsistent approach to dealing with uncertainties. To guarantee safety against load effects, evidence of safety is provided from which no failure risks concerning the supporting framework arise.

The risk assessment methodology for structures should both make it possible to deal with entire populations of structures and to observe individual objects. Significant requirements regarding its application to populations and individual objects are listed below. When applied to populations:

- Enable an overview and comparison of risks associated with selected structure types, influences or regions

- Compare and prioritise risks within selected structure types, influences, supporting framework components and other defined parameters

- Identify specific weaknesses of structure types (main risks within a particular structure type)
- Set priorities for and optimise effective network-wide measures for reducing risks in the whole network (being able to assess general measures)
- Determine the priority of risks associated with structures compared to other risks (make it possible to compare risks )

When applied to individual objects:
- Analyse risks associated with the individual object for all or selected influences, supporting framework components, etc.
- Assess measures and compare different measures with respect to an individual object
- Prioritise measures and rank individual objects within limited object inventories
- Assess the acceptance of risks associated with the individual object

The risk $R$ associated with structures is calculated in general form as set out below:
$R_j = \Sigma\, (h_j \cdot p_{fj} \cdot C_j)$

With the event rate $h_j$, the probability of failure $p_{fj}$ if an event occurs, the consequences $C_j$ and the index of event scenarios $j$. The summation sign stands for the risks associated with all influences, combinations of influences and consequences considered.

The risk assessment methodology for structures contains a step-by-step procedure for analysing risks. The aim of this procedure is to tailor and limit the level of analysis to the issue in question. The procedure is made up of the elements ‘Selection’, ‘Rough Analysis’ and ‘Detailed Analysis’. The result of the risk analysis is expected consequences, expressed in terms of deaths, injured people, Swiss Francs, etc. per year. During the selection process, the objects associated with risks can be filtered out of the population of a road network. The selection criteria required for this purpose are determined by experts based on their own experience. The selection results in the formation of groups of structures which need to be thoroughly examined. The rough analysis refers to a population of structures which has been limited by means of a selection process. The rough analysis provides an overview of the risks associated with this particular population. It is also possible to make a rough assessment of the measures that need to be taken.

Analysing the risk involves determining the event rate $h_j$, the probability of failure $p_{fj}$ if an event occurs and the consequences $C_j$. Determining the probability of failure of a structure and relevant supporting framework components is done with the help of a probabilistic approach, which compares the resistance of a structure or supporting framework component with the influences. In the detailed analysis, a comprehensive risk analysis is conducted on the individual object. The risks are assessed in discriminating fashion taking into consideration detailed, object-specific properties in relation to influences and the structure itself. The level of detail used for such a risk assessment leads to correspondingly great costs being incurred for the risk analysis.

The project clearly shows the area of contention between exact, detailed analysis of an individual object and application in big populations. Even if the methodology can generally be used for both issues, limits are evident both in terms of the quality of statements on the individual object and regarding cost handling in a big population. The description of the methodology at hand focuses on the level of the rough analysis. At this level, the biggest requirement is to obtain risk results in an efficient manner. The level of the detailed analysis can be based more on well-established approaches to probabilistic modelling and calculation.

It is appropriate that a committee of experienced experts provides a systematic overview of the selection criteria within the framework of a qualitative assessment process:

- Identification of risk-related weaknesses in structures
- Determination of risk-related influences

Limiting the costs, simplifying the application and the requirement to make results reproducible require simplifications, assumptions and standardisations of individual areas of the methodology In order to enable discriminating statements to be made in spite of this, it is necessary to develop risk analysis methods for decisive and severely restricted issues, this on the basis of the selection process described. Taking a rock fall protector as an example, this could include the following restricted topics: ‘rock fall on gallery’, ‘vehicle impact on pier’. As the development of appropriate user-related methods is time-consuming and yet not all issues can be addressed with it, it is sensible to proceed gradually and first apply the existing methodology, gain experience and verify it. In previous case studies, assumptions were made about numerous parameters of risk analysis. It is appropriate to systematically group assumptions which are made in various risk assessments.

### 2.3. Effectiveness and efficiency of intervention strategies (specific project)

A general method for the evaluation of risk reducing intervention strategies, with respect to their effectiveness and efficiency, has to be developed. A number of selected examples from literature on the state-of-the-art demonstrate that numerous methods are now used, such as cost-benefit analyses and simulation, but that no standardized method exists.

Building on the method developed in sub-project AGB 2005/102 the herein presented method is divided into the following stages:

- Problem definition
- Determination of the costs and benefits of intervention strategies
- Evaluation of intervention strategies.

The problem definition stage includes the formulation of the problem and the demarcation of the object of investigation. This includes identification of the hazard and the system components to be investigated, and the determination of the goals and requirements of the client. In general, the intervention strategies that are to be evaluated using the method are initially determined from experience or with help of some form of pre-analyses, and are in principle acceptable. In the determination of the costs and benefits of intervention strategies stage, the analysis properties and requirements are formulated so that the probabilities of events and their consequences can be estimated. In the evaluation of the intervention strategies stage the optimal intervention strategy is determined taking into consideration the absolute and relative conditions. The optimal intervention strategy is the one with the highest effectiveness, where the effectiveness is the difference between the benefit and costs of the intervention strategy being investigated and the reference intervention strategy.

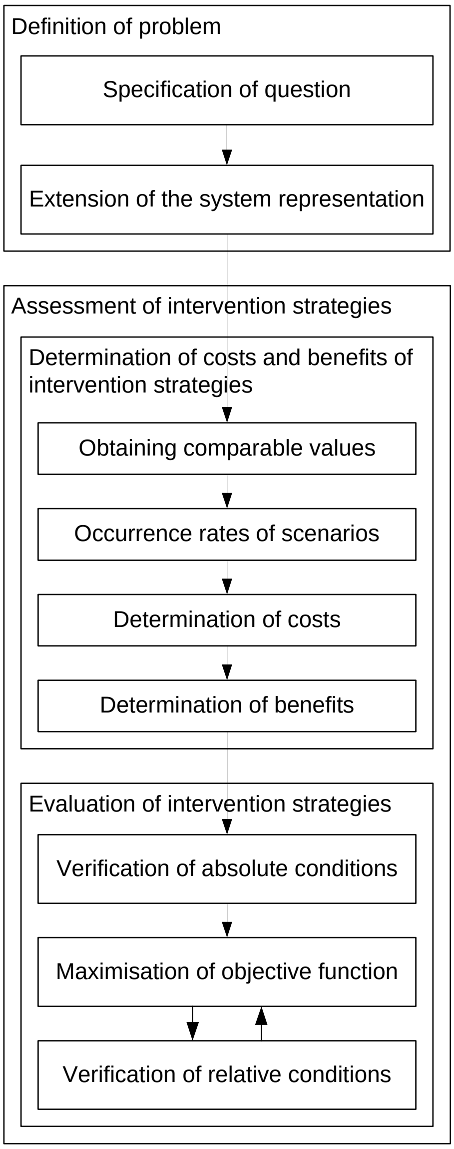

Table 7 – Summary of the method

The method is independent from the level of detail required in the analysis  and is as applicable to the evaluation of intervention strategies on individual structures asss for entire highway networks. It contains the following general steps:

Definition of the problem, including specification of the problem, determination of the possible intervention strategies, and an extension of the representation of the system already developed in the initial risk assessment. It is proposed to represent the system as an event tree composed of scenarios that may occur over the investigated time period. Each scenario is comprised of the hazard event, e.g. avalanche, the effect of the event on the structure, e.g. depth of snow, the physical change to the structure due to the effect, e.g. collapse of the structure, and the monetarisable direct and indirect consequences. Each scenario may occur more than once.

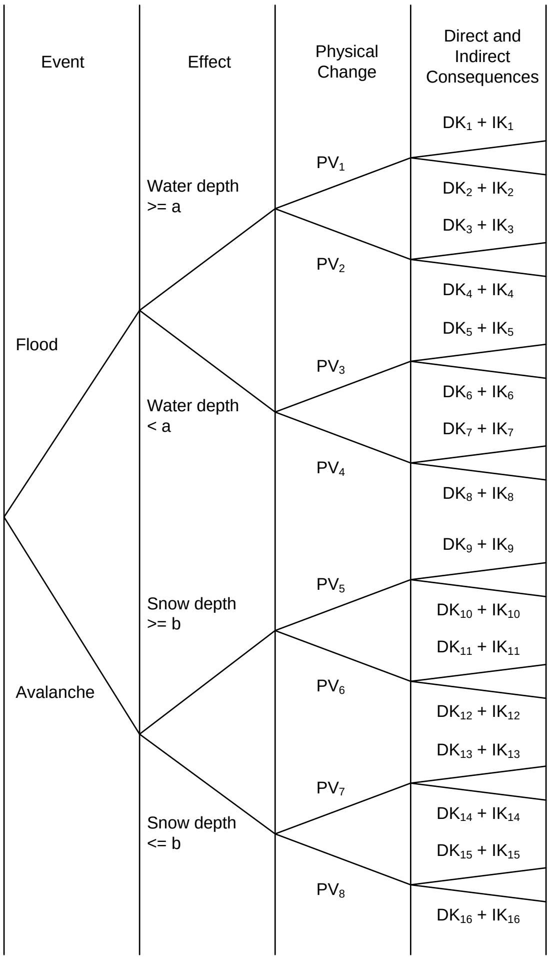

Table 8 – Partial event tree for structure problems/structure problems types

- Determination of the costs and benefits of intervention strategies, including how comparable values are to be obtained, occurrence rates of scenarios, and how costs and benefits are to be estimated.
- Evaluation of intervention strategies, including the verification of the fulfilment of any absolute conditions, the determination of the optimal intervention strategies, and the verification of the fulfilment of any relative conditions. The specific methodologies to be used to determine the optimal intervention strategies that fulfill both the absolute and relative conditions for discrete intervention strategies are given.

The developed methodology can be easily illustrated graphically. The intervention strategies are represented as points in the cost/benefit diagram. The effectiveness of the intervention strategies is presented in the upper diagram of as the vertical distance between a point representing an intervention strategy and the efficiency frontier. The intervention strategy that maximizes the effectiveness (benefit - cost) is the optimal strategy. This intervention strategy must, however, fulfil the relative conditions e. g. marginal cost criterion. The marginal cost of saving an additional human life is checked in the lower diagram. The intervention strategy fulfils the marginal cost criterion if the slopes of the straight lines connecting this intervention strategy to all remaining, more expensive, intervention strategies with higher reductions of fatality rate are flatter than the marginal cost criterion line.

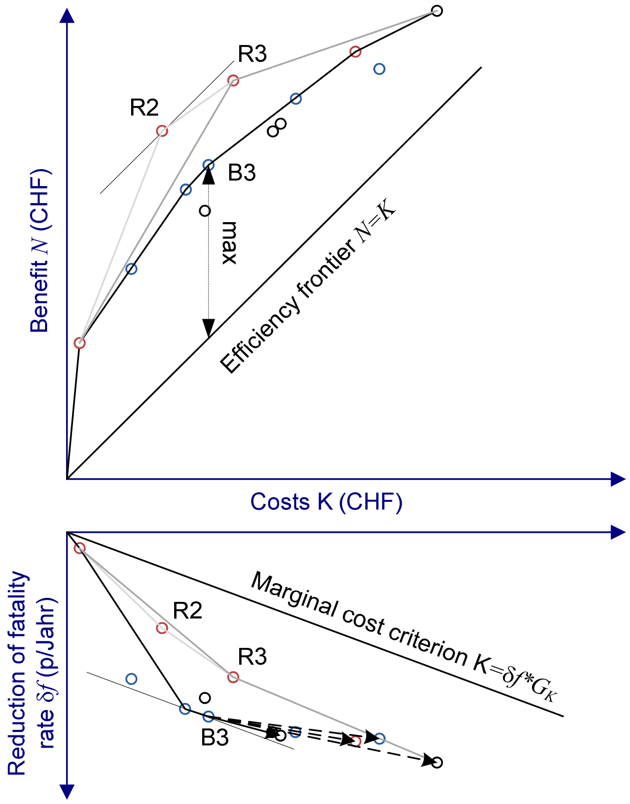

Table 9 – Determination of optimal intervention strategy

## 2.4. Scenarios of risk development (specific project)

The safety of the road as a traffic system and of its civil engineering structures is constantly being challenged by new developments. These developments can be attributed to various influences such as changes in the amount of traffic or advances in traffic and vehicle technology. All these influences have their roots in fundamental societal or natural processes, such as the economic situation or climate change. If only the current traffic situation is considered, there is a risk that the available means for rectifying existing safety deficits will be utilised incorrectly as the measures implemented will be unable to address new, unforeseen developments. A future-oriented approach should help avoid incorrect decisions. It is for this reason that scenarios that could influence future traffic system safety were developed. The process has to differentiate between evolutionary scenarios reflecting developments and trends that appear probable from today's viewpoint and visionary scenarios that indicate the scope of potential scenarios.

Megatrends, trends and scenarios are interconnected. Megatrends usually result in various trends. Some trends can be traced back to a number of megatrends, others to just a single megatrend. Some of these trends are of relevance to the safety of the road as a traffic system. It is these safety-relevant trends that provide the basis for the scenarios developed.

The evolutionary scenarios are based on foreseeable trends that have found a broad consensus in the literature. They indicate the developments that will presumably take place over the coming years. The visionary scenarios, by contrast, describe trends that are much less probable.

The evolutionary scenarios developed cover the following subject areas:

1. Increase in temperature
2. Flooding and heavy rainfall
3. Mass movements
4. Traffic-related behaviour
5. Type and quantity of hazardous goods
6. Load effect
7. Vehicle technology
8. Transport telematics
9. Operational infrastructure
10. Traffic situations
11. Criminal influences

A scenario reflecting the most probable development from today's viewpoint is developed for each area. The scope of the anticipated scenarios is staked out by two additional scenarios reflecting developments and trends that could be rated as positive or negative in relation to safety. Each scenario is also assessed with regard to its safety relevance. The various courses of action open to the road traffic authorities are then developed for each scenario.

The following diagram provides an overview of the expected absolute change in risk for those scenarios that represent the most probable development from today's viewpoint:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| strong decrease | | | | | | | | 🚗 | | | |
| moderate decrease | | | | | | | 🚗<br>🌲 | 🌲 | | | |
| slight decrease | | | | | 🚗<br>🛣️<br>🌲 | | 🛣️ | | 🛣️ | | |
| neutral | 🌲 | 🚗<br>🛣️<br>🌲 | 🌲 | 🚗<br>🛣️<br>🌲 | | 🚗<br>🌲 | | | 🚗<br>🌲 | 🚗<br>🛣️<br>🌲 | |
| slight increase | 🚗<br>🛣️ | | 🚗<br>🛣️ | | | 🛣️ | | 🛣️ | | | |
| moderate increase | | | | | | | | | | | 🚗<br>🛣️<br>🌲 |
| strong increase | | | | | | | | | | | |
| probability | moderate | moderate | moderate | moderate | high | high | moderate | moderate | high | moderate | moderate |
| | 1. Increase in temperature | 2. Flooding and heavy rainfall | 3. Mass movements | 4. Traffic-related behaviour | 5. Type and quantity of hazardous goods | 6. Load effect | 7. Vehicle technology | 8. Transport telematics | 9. Operational infrastructure | 10. Traffic situations | 11. Criminal influences |

🚗 People and vehicles 🛣️ Infrastructure 🌲 Environment

Table 10 – Scenarios of "moderate" development" – anticipated absolute change in risk

The qualitative estimation of the absolute change in risk is based on the following scale: with regard to personal injury, a slight change in risk means less than one fatality per year; a moderate change, one to ten fatalities per year; and a significant change more than ten fatalities per year.

Some scenarios display significant potential with regard to improving or impairing the safety of the road as a traffic system. Developments of relevance to safety are certainly conceivable over the coming years, even though the most probable scenario of "moderate development" does not envisage any drastic change in risk. Road traffic authorities should therefore keep a special eye on these scenarios. Developments in the areas of traffic-related behaviour, vehicle technology, transport telematics, traffic situations and criminal influence are classed as developments with particularly high safety-relevant potential.

How these developments can best be countered is evident from the courses of action developed for each scenario. The scenarios reflect what are often complex, far-reaching societal and natural developments. However, the influence of the road traffic authorities is often limited.

The visionary scenarios cover both major events and gradual, far-reaching developments. Differentiated planning for emergency situations based on concrete scenarios in preparation for possible major events is certainly called for. Early detection is the first step towards adopting effective measures to counteract developments that often take many years to unfold. It is therefore important to take into consideration all significant developments and trends to observe and the scenarios to update regularly. In future, an effort will have to be made to gather more accurate data on road traffic safety and to improve that data’s accessibility. The societal aspects of far-reaching technological and, in some cases, societal developments should be fathomed with the help of specific estimations of technological consequences, as should the scope of the available options for counteracting these developments effectively and in good time.

### 2.5. Validation of the methods by a test region (specific project)

The objective of the project ‘test region’ was the test of the methodology of the comparative risk assessment in combination with different safety areas. For the first time this combination could be tested with this project and numerous findings arise from that.

Particular objects and impacts on the test region Amsteg – Göschenen (Nord-Sud Transit Road; Gothard) were treated for the test region in different safety areas (natural hazards, hazardous incident, highway structures, traffic situation, network risk). The intention of this project was not a complete analysis of the risks on the test road, but the determination of the risk values and the evaluation of measures as input for the comparative risk assessment. Due to the reduced approach in the safety areas the determined results and the proposed measures do not comply with reality and do not allow further conclusions.

For the safety areas highway structures and network risks these findings can directly be integrated in the methods which were developed in the research package. For example the already existing finding was verified that the methodology for the risk evaluation for highway structures has to be expanded in regard to the treatment of the large number of highway structures.

Within the comparative risk assessment under the methodology chosen for this project, it has been found that the comparability of risks depends considerably on a common system definition. In the project test region the coordination of a common system definition by agreements between the safety areas and the involved administration's offices was feasible. During application of the methodology of the comparative risk evaluation at strategic level within road authorities it has to be guaranteed that the results to be used base on risk evaluation with adequate system definition.

Beside the common system definition specifications with regard to contents are necessary as well. Only if common principles of evaluation, common approach at the monetary valuation of consequences, identical base data etc. are used, consistent results can be developed.

The effort for a comprehensive quantitative comparative risk assessment on the system road will prove to be very high. It will therefore hardly be realistic for example to evaluate the risk situation of the whole national road network and to define the adequate measure policy as an entity. In practice the methodology can though be used very well for selected problems of this kind, e.g. when a increased risk is expected.

However, if the principles of the proposed methodology establish themselves in every safety area of the road departments as a scope for the risk evaluation, over the years the calculated risks of various kind there will become distinguishable better and better. Then they can form a foundation to mutually balanced measure policies.

Finally we may conclude that within the project test region the practical feasibility of the methodology for the comparative risk assessment could not be assessed exhaustively, since numerous simplifications were inevitable. It is not definitely determinable, which difficulties and additional expenditures without these simplifications would arise. The feasibility considering all aspects could not be proved.

Having finished the project test region – the following measures should be taken:

- The main criterion for the comparability of risks next to the compatible system definition and the adequate assessment of the probability of occurrence and consequences is the coordinated use of approaches for the modelling of consequences. A corresponding manual with standardized approaches to enable a comparison of the determined consequences and risks should be developed.
- The general methodical principles should be applied as the standard at the comparative risk assessment in the road administration.

## 3. CONCLUSIONS

The aim of the research package "Safety of the Road Traffic Systems and its Engineering Structures" within the framework of risk management is to provide the basis for decision-making and methods to the attention of the road management administrations, which allow them to apply precisely and functionally restricted financial resources to accomplish the required safety standard across the entire road traffic system and to maintain it. This aim has been achieved by the research work and through its validation in a test region.
The following most important insights derive from the research package:

- The methodology for the comparative risk assessment proposed is based on the practice employed so far and is suitable for the application in the different safety areas. It allows for a consistent treatment and for the comparability of miscellaneous risks.

- The methodology emerges as applicable, however when applied may lead to a considerable expenditure depending on there complexity, quality and database of the examinated system.

- In certain safety areas like traffic situation used as an example good prerequisitetes exist indeed for the risk based approach (accident data, statistics etc.). Its implementation and application however is still at the beginning. Corresponding tools would have to be established yet.

- In a further group of safety areas new options are provided for the risk based approach, this particularly for the evaluation of the net risk and the risks of the asset of civil engineering structures.

- In design and conservation of civil engineering structures there is a profoundly fixed and established tradition of standards based on a safety oriented approach. In the foreseeable future today's dimensioning procedures will not be replaced by a risk based approach. The latter however may add to the traditional safety analyses in special cases and challenges, particularly for the examination of existing structures.

- The risk based approach may only be implemented into practice, if the legal prerequisites exist and the legal practice accepts the approach. Partly these prerequisites have to be created yet.

The working process has permitted a large concertation among several different administration offices with the result of common procedures and the sharing of specific knowledge. This represents a considerable added value.

The Federal Roads Office (FEDRO) has at its disposition a valid tool to develop furthermore its risk management and at the same time an instrument to increase the level of safety of the road traffic systems.

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References:

- Contracting authority:
  Federal Roads Office (FEDRO)
- General Project Management:
  Emch + Berger AG, Gartenstrasse 1, 3001 Berne (Beat Schneeberger)

All the documents regarding the research package AGB 2005/100 presented in this national report are available free of charge on the website www.astra.admin.ch