TESTING THE SAFETY LEVEL

Structured control of whether existing and planned streets and roads
meet a package of safety requirements

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Abstract

The safest links in a road network are motorways and local streets with traffic calming. Most of the accidents occur on the rest, the larger part, of the network. So for safety reasons motorised traffic should be encouraged to use motorways and should be discouraged to use local streets. However, much traffic will (therefore) use the intermediate roads, which have high accidents figures. These intermediate roads mostly serve for distribution (to and from areas) and at the same time for local access. It is very difficult to separate the two traffic functions in such a way that these roads can still be important links in the road network while being sufficiently safe too. How can proposals for adapting these types of roads be evaluated regarding the safety consequences? Estimation of these consequences should me made possible in all stages of the life cycle of a road of street (planning, design, construction, redesign, and reconstruction). A first sort of estimation, of a qualitative nature, is given by a Road Safety Audit; it gives an expert judgement. The estimation or test becomes more objectified when a proposal is evaluated according to a set of safety requirements. These requirements aim at preventing different accident types, e.g. preventing accidents with opposing vehicles is expressed by the requirement that opposing directions should be separated physically. Tests with these sort of requirements are currently being performed in the Netherlands. The experiences were compared to outcomes of Road Safety Audits.

1. Introduction

It is generally accepted that a journey should be made smoothly and safely. It is less clear how smoothly and how safely, and at what price. At the national level we produce some clarity by fixing goals and targets about the how and the price, but at the regional and local level there is less clarity. At the level of road networks we 'calculate' using traffic models what the flow, accessibility, and safety are. This is, however, much more difficult at the level of road sections and crossroads. At that level, it is sufficient for the road designer to transfer the goals and targets from the higher levels for a concrete road section or crossroads. A well nigh impossible task? As far as the contents are concerned, there are indeed many unanswered questions for every design. In practice it always comes down to yet another design that has a strongly traditional character and in which goals, wishes, and preconditions of various natures are combined. It is possible to arrive at traffic engineering designs that, already during the design phase, provide a better sight on the extent in which a contribution is made to flow, accessibility, and safety?
If the answer is yes, the designer can make a better balance between flow, accessibility, and safety (FAS). At the same time, the designer can balance against FAS, effects of external wishes and goals not necessarily aimed at FAS.
If the answer is no, for the road section or crossroads involved, there are perhaps relevant, general points of contact such as at the route level.
For both 'yes' and 'no' there is greater clarity, for the designer and for others, about the choices and balances in a design. And that is necessary because the designer makes choices, often implicitly, during the creative process that designing just is. However, participants, joint deciders, and those responsible must be able to find out what the choices were; all inputs and outputs of the design must, during all design phases, be clear. Preferably that should be quantitative information. This information must provide sufficient sight of the consequences of the design to be carried out, for all relevant safety aspects.

2. Sustainably-safe road network

In the Netherlands since 1992, we have the concept 'sustainably-safe traffic' (Koornstra et al., 1992). The main goal of a sustainably-safe road transport system is that only a fraction of the current, annual number of road accident casualties will remain. Just what such a system must look like has, during the past few years been worked on. One of these is the result of a national working group of experts who have drawn up draft requirements for categorising roads on a sustainably-safe basis (CROW, 1997).

It is of great importance for a sustainably-safe traffic system that, for each of the different road categories, road users know what behaviour is required of them and they may expect from other road users. This acquired pattern should be supported by optimising the recognition of the road categories.
The three main concepts in a sustainably-safe traffic system are:
- functionality,
- homogeneity,
- recognition/predictability.

The *functionality* of the traffic system is important to ensure that the actual use of the roads is conform the intended use. This has been worked out by dividing the road network into three categories: through roads, distributor roads, and (residential) access roads. Each road or street may only have óne function; for example, a distributor road may not have any direct dwelling access.
The *homogeneity* is intended to avoid large speed, direction, and mass differences by separating traffic types and, if that is not possible or desirable, by making motorised traffic drive slowly.
The third principle is that of the *predictability* of traffic situations. The design of the road and its surroundings should promote the recognition, and therefore the predictability, of the

possible occurring traffic situations. Undesirable traffic situations can, therefore, be acknowledged and avoided in good time.

3 Requirements package belonging to the three principles

So-called functional requirements have been set up for each principle by the earlier mentioned national working group (CROW, 1997).

Functionality

- Realisation of as many as possible connected residential areas
- Minimum part of the journey along unsafe roads
- Journeys as short as possible
- Shortest and safest route should coincide

Sustainably-safe makes functionality requirements that especially are intended so that an individual road user chooses a route that is safe, also for others. So a journey may not cross a residential area. Driving along for too long on an unsafe road is also not desirable. A large residential area is safe for internal traffic; one prevents too many crossings-over of the surrounding through roads. An area that is too large leads to too much internal traffic; one that is too small leads to too many crossings-over the surrounding through roads.

Recognition and predictability

- Avoid searching behaviour
- Make road categories recognizable
- Limit and uniform the number of traffic solutions

The homogeneity requirements aim at orderly traffic surroundings: unification of measures, road signs and signposting. In Sustainably-safe, the limitation of the number of road categories produces the largest contribution to the recognition. This assumes that the differences between the categories are large, and within each category are small.

Homogeneity

- Avoid conflicts with oncoming traffic
- Avoid conflicts with crossing and crossing-over traffic
- Separate vehicle types
- Reduce speed at potential conflict points
- Avoid obstacles along the carriageway

The homogeneity requirements are mainly the result of accident analyses. Many accidents could be prevented by making certain conflicts impossible and separating different vehicle types. Accident severity decreases considerably with lower speeds and obstacle-free zones.

These twelve requirements cannot be directly linked to traffic features and traffic infrastructure elements. Designers can only use these requirements if there is a clear relation with design variables, traffic situations, and design elements. And the other way round; someone who wants to test a design of an existing situation must be able to 'translate' the situations occurring and elements into the sustainably-safe requirements. A so-called Sustainably-Safe Indicator supports the designer or road authority by processing the input data and carrying out the test.

Goal of the Sustainably-Safe Indicator

This is an instrument with which the designer or road authority can determine whether planned or existing traffic infrastructural provisions meet the above-mentioned sustainably-safe requirements.

4 Design of the Sustainably-Safe Indicator

Application in different design phases and in existing situations
The Sustainably-Safe Indicator has been developed to test all the requirements mentioned. The testing of the requirements can take place during various design phases:

1. after making the road network plan
2. after overall working out of plan parts
3. after detailed working out
4. some time after opening
5. before maintenance and reconstruction

Application of the Sustainably-Safe Indicator is also possible for existing roads and streets (here called 'phase 0').

Design variables per Sustainably-Safe requirement
Two sorts of design variables are distinguished: the one sort are the traffic and travel variables, and the other sort are the traffic infrastructure variables. In the first planning phase, there will be too little known about the actual traffic and travel variables; models can provide an indication of them. In the fourth and fifth phases and in existing situations, the actual traffic and travel variables can be observed. Sufficient is known in all phases about the traffic infrastructure. The chosen design variables per sustainably-safe requirement are given in tables 1 and 2.

Indicators
The Indicators show which variables and features are important for the testing of the sustainably-safe requirements. The indicators per requirement are given in table 3.

Measuring and observation methods
The Sustainably-Safe Indicator needs much data concerning variables, Indicators, and features. This data is obtainable with existing measuring and observation methods. A summary is given in tables 1 and 2.

Operation procedure and data needed
Much data is needed as input for the Sustainably-Safe Indicator. Depending on the phase involved, we work as follows:

- Desk research (results of model studies, phase 1; design drawings, phase 2/3)
- Measurements (dimensions, place on the road, phase 4/5)
- Inspections (state of the road surroundings, phase 4/5/0)
- Observations (traffic and travelling, phase 4/5/0)

When using the Sustainably-Safe Indicator, various data is necessary of which we (may) assume that the road authority has. During the application, it can become apparent that other or adapted data is essential. We recommend, if practically possible, to control beforehand the presence, sort, and type of the necessary data. The following data sorts per phase are important:

- Research data (traffic model, phase 1)
- Plans (section studies, design drawings, all phases)
- Measurement data (speeds, road lengths, volumes, phase 1/2/4/5/0)
- Observation data (surveys, registration number studies, phase 1/2/4/5/0)

The necessary data is specified in tables 1 and 2.

	Requirement, according to CROW (1997)	Indicators
1	Realisation of as many possible joined residential areas	• area and shape • number of dwellings • journey production • maximum traffic intensities • supply of daily provisions
2	Minimum part of the journey along unsafe roads	• number of category transitions per route • risk per (partial) route • crossroads distances
3	Journeys as short as possible	• length of fastest route divided by straight line distance
4	Shortest and safest route should coincide	• overlap of shortest (in time) and safest route
5	Avoid searching behaviour	• presence and locations of signposting • indication of ongoing route at choice moments • street lighting at choice moments
6	Make road categories recognizable	• presence and type of alignment marking • presence of area access roads • presence of emergency lanes • obstacle-free distances • presence of bus and tram stops • construction form of crossroads • speed limit • colour and nature of road surface • presence and transverse position of bicycle, moped, and other 'slow traffic'
7	Limit and uniform the number of traffic solutions	• number of structurally different crossroad types • number of different cross-over provisions and category transitions • number of different right-of-way regulations (per route)
8	Avoid conflicts with oncoming traffic	• degree of protection of oncoming traffic
9	Avoid conflicts with crossing and crossing-over traffic	• degree of protection of crossing and crossing-over traffic • number of possible conflict points
10	Separate vehicle types	• degree of protection of bicycle, moped, and other 'slow' traffic from motor vehicles
11	Reduce speed at potential conflict points	• degree of speed reduction per conflict point
12	Avoid obstacles along the carriageway	• presence and dimensions of profile of free space, obstacle-free zone, and plant-free zone • presence of bus and tram stops, break-down provisions and parking spaces

Table 3 *Indicators for each sustainably-safe requirement*

Data menus have been made for data input; they show if the data is correct and mutually consistent. The input takes place for every road section and crossroads within an area or along a route.

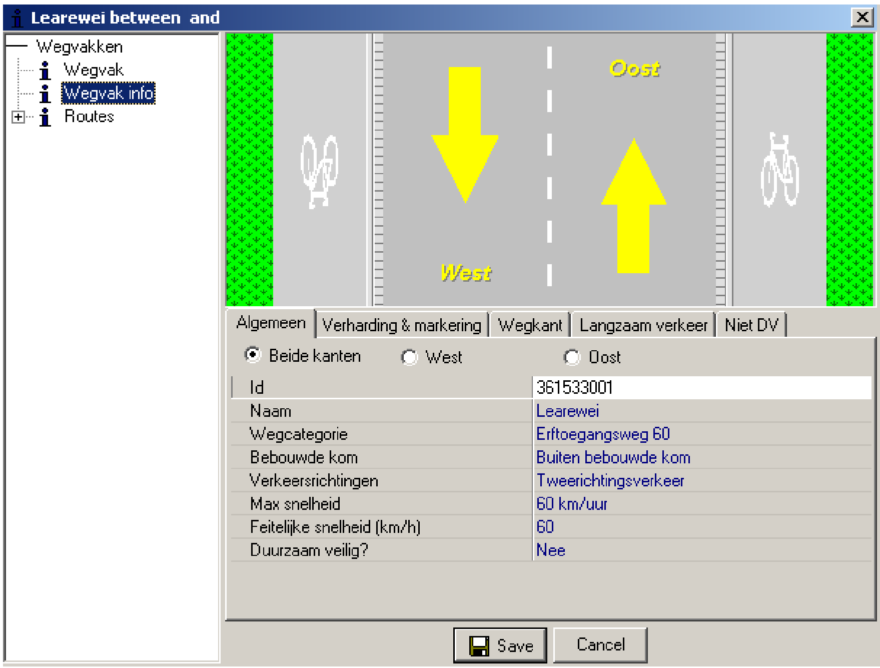

Figure 1 *Input screen for a road section*

5 Testing criteria and application

Testing criteria

On what basis can one determine the extent in which a route or an area meets the sustainably-safe requirements? All relevant variables and feature are input for each road section in the previous steps. This happens on the basis of the derived Indicators of each requirement. Whether an Indicator sufficiently fits in Sustainably-safe depends on the sustainably-safe criterion. During the past years, it has, for each road category, been determined which criteria the variables and features have to meet in a sustainably-safe traffic system (Infopunt DV, 1999; Infopunt DV, 2000, CROW, 2002a/b/c/d). These testing criteria are divergent by nature, sometimes on a metric scale, sometimes on an ordinal or nominal scale. These criteria are built into the Sustainably-Safe Indicator.

The Sustainably-Safe Indicator: determine differences between package of requirements and (carried out) design

In essence, the Sustainably-Safe Indicator compares each Indicator of a planned or existing situation with the testing criteria. So for road sections one can investigate which portion of the total road length meets the sustainably-safe criteria, and for the crossroads, which share of the crossroads meets them. This testing is specified by road category, by crossroads class (depending on which road categories and crossroads) and any selected routes.

The final result of the Sustainably-Safe Indicator consists of percentages that indicate which portion of the road length or which portion of the crossroads meet the various sustainably-safe requirements.

If a traffic provision meets the sustainably-safe criteria, and thus scores a high percentage in the Sustainably-Safe Indicator, this does not mean automatically that from now on there will be no more accidents. The sustainably-safe requirements perhaps indicate the contours for a safer road traffic but, up till now, have not been tested in their entirety.

6 The Sustainably-Safe Indicator, road safety audit, and calculation model

it should now be clear that the Sustainably-Safe Indicator is an instrument which, as far as possible, makes objective comparisons between, on the one hand, planned or existing design features and, on the other hand, externally determined criteria. Those people who are not safety experts can carry out tests with the Sustainably-Safe Indicator. Moreover, the Sustainably-Safe Indicator indicates a relation with the accident data by means of weighing heavier those requirements that have a great effect on the number of accidents.
The Sustainably-Safe Indicator is an supplement of the road safety audit (Van der Kooi ed., 1999 and PIARC, 2001) and calculation models for design purposes (FHWA, 2000). These instruments all fit in the approach according to the Road Safety Impact Assessment (Wegman et al., 1994).
Road safety audits are very dependent on 'expert knowledge' and standard checklists. They do not always indicate a relation with accidents. Calculation models are independent of experts and indicate a direct relation with accidents. The supplement that the Sustainably-Safe Indicator offers is in the systematic analysis of all portions of a design and the linking to accident data.

	Road Safety Audit	Sustainably-Safe Indicator	Calculation model
Expert judgement	yes	hardly any	hardly any
Necessary data	drawing and explanation	design data per SuSaf demand	design variables
Grip during carrying out	checklists	input menu	input menu
Quantitative statements	hardly any	many	exclusive
Linking to accident data	sometimes	via balancing of demands	quantitative relation (formula)
Reporting	audit report	S-S level per demand (in %)	optimise design variables

SuSaf' is an abbreviation for "Sustainably-Safe"

Table 4 *Agreements and differences between the Sustainably-Safe Indicator, Road Safety audit, and calculation model*

7 Conclusions and recommendations

Application of safety requirements to a designed or existing traffic provision is only possible when every portion of the provision is linked to road safety Indicators.

Data is necessary for each safety requirement: an inventory of this data is usually necessary.

The various safety requirements are not equally important for accident reduction: a balancing of requirements is desirable.

The result of the Sustainably-Safe Indicator show the difference between intended and current or planned safety levels.

The expertise of the road safety auditor determines the quality of the road safety audit. The quality of the results of the Sustainably-Safe Indicator depends on the kinking of the formulated safety requirements with all portions of the designed or existing traffic provision.

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	Requirement according to CROW (1997)	Design or help variables	Methods to set down traffic infrastructure	Necessary data (from road authority)	Phase					
					1	2	3	4	5	0
1	Realisation of as many as possible connected residential areas	Area in square metres Distances between surrounding through roads	Measurement from road map	Distances between all points where distributor roads cross each other	x	x		x	x	x
2	Minimum part of the journey along unsafe roads	Origins and destinations Route choice	Apply traffic model	Table with most frequent origins and destinations Map showing (modelled0 route choice	x	x		x	x	x
3	Journeys as short as possible									
4	Shortest and safest route should coincide									
5	Avoid searching behaviour	Design requirements per road category (Infopoint S-S, 1999 and 2000)	Control detailed design Inspection per road section/crossroads	Detailed design drawings of road sections and crossroads		x	x	x		x
6	Make road categories recognizable									
7	Limit and uniform the number of traffic solutions									
8	Avoid conflicts with oncoming traffic	Dwelling accesses / Carriageway separation / Parking / Public transport stops / Crossroads type	Control overall design Control detailed design Inspection per road section/crossroads	Overall and detailed design drawings of road sections and crossroads	x	x	x	x	x	x
9	Avoid conflicts with crossing and crossing-over traffic	Dwelling accesses / Carriageway separation / Crossing-over on road sections / Parking / Public transport stops / Crossroads type								
10	Separate vehicle types	Position of cyclists on cross section / ditto mopeds / ditto slow motorised traffic								
11	Reduce speed at potential conflict points	Dwelling accesses / Crossing-over on road sections / Speed-limiting measures / Crossroads type								
12	Avoid obstacles along the carriageway	Parking / Public transport stops / Break-down provisions / Obstacle distance / Street lighting								

Phase 0:existing situation

Table 1 Traffic infrastructure: design variables per requirement, method(s) in the Sustainably-Safe Indicator to test design variables and necessary data of road authority

	Requirement according to CROW (1997)	Design or help variables	Methods to set down traffic infrastructure	Necessary data (from road authority)	Phase					
					1	2	3	4	5	0
1	Realisation of as many as possible connected residential areas	Area in square metres Distances between surrounding through roads	Count crossers-over on distributor roads Registration number study	Share of rat run traffic Number of crossers-over on distributor roads				x	X	x
2	Minimum part of the journey along unsafe roads	Origins and destinations Route choice	Registration number study Traffic survey	Table with most frequent origins and destinations Data showing actually used routes	x	x		x	X	x
3	Journeys as short as possible									
4	Shortest and safest route should coincide									
5	Avoid searching behaviour	Design requirements per road category (Infopoint S-S, 1999 and 2000)	Observation per road section/crossroads	List with intended traffic measures (including boarding and marking)			x	x	X	x
6	Make road categories recognizable									
7	Limit and uniform the number of traffic solutions		Photo-/video study of subjects in measuring vehicle				x	x	x	X
8	Avoid conflicts with oncoming traffic	Dwelling accesses / Carriageway separation / Parking / Public transport stops / Crossroads type	Behaviour rules per road section/crossroads Observation per road section/crossroads Speed measurements (radar, loops)	List with intended traffic measures (including boarding and marking)		x	x	x	X	X
9	Avoid conflicts with crossing and crossing-over traffic	Dwelling accesses / Carriageway separation / Crossing-over on road sections / Parking / Public transport stops / Crossroads type								
10	Separate vehicle types	Position of cyclists on cross section / ditto mopeds / ditto slow motorised traffic								
11	Reduce speed at potential conflict points	Dwelling accesses / Crossing-over on road sections / Speed-limiting measures / Crossroads type								
12	Avoid obstacles along the carriageway	Parking / Public transport stops / Break-down provisions / Obstacle distance / Street lighting								

Phase 0:existing situation

Table 2 Traffic infrastructure and travel: design variables per requirement, method(s) in the Sustainably-Safe Indicator to test design variables and necessary data of road authority