Incident Warning Systems: The Analysis of Traffic Behaviour

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R-95-63

HOPES

Horizontal Project for the Evaluation of Safety

DRIVE II Project V2002
Internal report
Work package 31
Activity 31.4

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Deliverable type: P
Submission date: February 1995

Commission of the European Communities - R&D programme Telematics Systems in the Area of Transport (DRIVE II)

Printed at SWOV Institute for Road Safety Research,
P.o. box 170, 2260 AD Leidschendam, The Netherlands.

Report documentation

Number:	R-95-63
Title:	Incident Warning Systems: The Analysis of Traffic Behaviour
Author(s):	J.E. Lindeijer, S. Oppe & J.G. Arnoldus
Research manager:	F.C.M. Wegman
Project number SWOV:	69.771
Client:	The research reported herein was conducted under the European Community DRIVE Programme.
Keywords:	accident prevention, warining, incident detection, motorway, accident, driver information, telecommunication, data processing, accident rate, behaviour, road user.
Contents of the project:	Part of the DRIVE II project HOPES is a traffic safety evaluation study regarding three Incident Warning Systems: PORTICO, EURO-TRIANGLE and MELYSSA. An analysis of the traffic process with and without the system installed gives information about the strong and weak points of the systems.
Number of pages:	56
Price:	f 22,50
Published by:	SWOV, Leidschendam, 1995

SWOV Institute for Road Safety Research

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FOREWORD

The research reported herein was conducted under the European Community DRIVE Programme. The project is being carried out by a consortium comprising: Institute for Transport Studies, University of Leeds; Department of Traffic Planning and Engineering, University of Lund; Swedish National Road Administration; Fachgebiet Verkehrsplanung und Verkehrswesen, Technische Universität München; Traffic Research Centre, University of Groningen; Transport Research Laboratory; Centro SStudi Sui Sistemi Transporto; FACTUM; Department of Transport and Logistics, Chalmers University of Technology; Department of Civil and Environmental Engineering, University College Cork, Technical Research Centre of Finland; Institute for Road Safety Research SWOV; Institute for Traffic Safety, TÜV Rheinland; INRETS BRON; INRETS DERA; and Swedish Road and Traffic Research Institute. The opinions, findings and conclusions expressed in this report are those of the authors alone and do not necessarily reflect those of the EC or of any organization involved in the project.

1. INTRODUCTION

Part of the DRIVE II project HOPES is a traffic safety evaluation study regarding Incident Warning Systems. Three systems are selected from DRIVE II projects:

- the PORTICO system, at the A1 motorway near Lisbon and at the IP5, a mountain road also in Portugal;
- the EURO-TRIANGLE system at the Antwerp motorway ring road;
- the MELYSSA system, at the A6 motorway near Lyon.

Although these systems are considerably different in local circumstances as well as in the concept of the system, they are all aiming at the improvement of safety by warning the drivers for incidents that happen. It is assumed that the warned drivers will adept their behaviour sufficiently, to decrease the amount of potential risk.

The effectiveness of such a warning system can finally only be proved, by showing that the number of accidents is less with the system on, and not higher with the system off. Such an evaluation is difficult to carry out at small scale implementations. Accident records should be collected over a number of years to prove statistically significant effects. Circumstances will change as well over the years, making it difficult to interpret changes in accident numbers. Furthermore, it does not say how an expected effect is achieved or why is not achieved. A careful analysis of the traffic process with and without the system installed, will give more information about the strong and weak points of such systems. A major question then is, whether road users do change their behaviour, in order to reduce the risk, and how, where, when and under what conditions they change it.

It is not easy to define safe road user behaviour. In different countries, differences in life styles are reflected in traffic behaviour. What is regarded "risky behaviour" in one country is accepted as normal traffic behaviour in another country. To our Western eyes, traffic behaviour of the massive amounts of bicyclists as well as cars, trucks and buses in Beijng look rather chaotic. Still, the amount of road fatalities per year is rather low. But also in Europe there are large differences in driving styles and road use, that make a comparison of risk difficult.

Incident Warning Systems aim at warning road users for special events, in order to let them adapt their behaviour to reduce the potential danger. There is general agreement about the types of events the driver should be warned for if they happen. However, one of the ambitions of warning systems is to prevent traffic from getting into a state with an increased probability of such an event to occur.
Apart from events that are not caused by human drivers themselves, such as black ice, or a punched tyre, there are also incidents that result directly from the behaviour triggered by the traffic process itself, e.g. in case of congestion lanes that are blocked. In unstable traffic situations many accidents are evoked by the characteristics of the traffic flows. Manoeuvres of other road users, such as overtaking, braking or reacting with an evasive action become less predictable, especially if the number of road users involved increases.

Till now, the characteristics of traffic streams are hardly ever studied in detail to describe the aspects of risk. Incident detection systems as developed, e.g. within the DRIVE project, concentrate on situations that already ran out of hand. Such systems detect accidents that took place or traffic streams that came to a stop. These situations are rather easy to detect, because they can be identified directly. This is not the case with *potential danger*.
In general, traffic flow research is not focused on incidents. It describes flows in terms of general stream characteristics (average speed or headway, speed distributions etc.).
One of the fundamental characteristics of traffic flows that does not get attention in classic traffic flow theory, is the interaction between individual road users. Conflict techniques on the other hand

detect interactions between road users with imminent danger, but these techniques isolate the events, and do not relate them to the characteristics of the traffic stream.

2. METHODOLOGY OF THE BEHAVIOURAL STUDY

2.1. Aim of the study

The major aim of the study is to define and use behavioural indicators that measure changes in the behaviour of road users as well as the risk of an accident with regard to the functioning of a incident detection and warning system.
A second aim of this study is to bridge the gap between traffic flow theory and risk detection, in order to predict the likelihood of incidents to occur, and to indicate possible improvements of (pre-)incident detection systems and incident warning messages. For both aims behaviour is defined in terms of (interactive) traffic flow characteristics.
To do this, one should first find out what characteristics of the traffic flows are potentially dangerous. One argument against this approach is, that danger is the result of human error and cannot be measured from the traffic characteristics. This position, however, is hardly tenable. Although the human error may be in the end the final cause for a particular accident, the characteristics of the traffic flows are the major conditions for human errors to be evoked. Especially, in traffic flows that become more and more unstable, the probability of incidents and accidents will increase rapidly.

A first step to be made, is trying to understand which traffic conditions are potentially dangerous. Although this knowledge is essential for guiding traffic streams, such studies are hardly ever carried out, because of their complex nature. Furthermore, these studies are traditionally made by human observers, which makes the research expensive. New techniques are available to develop semi-automated recording systems for this purpose.

2.2. Working procedure

A traffic safety evaluation has been carried out at the two systems in Portugal at the A1 motorway near Lisbon and the one in Belgium, at the motorway ring road in Antwerp.
The study was designed as a before-after study. The major aim was to put the safety evaluation of the warning systems in a wider perspective. This means that the study regards all aspects of the so-called safety pyramid. With this concept it is assumed that accidents show only the top of the ice-berg, and that a complete study should also take near-accidents, conflicting behaviour or other forms of risky behaviour into account, against the background of normal traffic behaviour. A complete description of the design of the study is found in .... ****
Here we will report the methodology and outcomes of the behavioural study.

2.3. Definitions of interactive traffic behaviour with potential risk involved

The following concepts are distinguished:

- Disturbance: a traffic situation in which one of the drivers does not adapt his behaviour adequately, putting him or herself or other road users in danger, or behaves otherwise unexpectedly, e.g. by violating the traffic rules, with or without interrupting the normal traffic process.
- Potential risk: a traffic situation in which one or more road users have such limited possibilities for manoeuvring, that in case of a disturbance or unexpected manoeuvre, an accident can hardly or not be avoided by one or more of the traffic participants involved.
- Evasive action: observable manoeuvre (e.g., braking or changing lanes) carried out by a road user to decrease or remove the potential risk caused by a disturbance.
- Risky disturbance: the following characteristics are used to score a disturbance as risky:
    - short headway;
    - number of manoeuvres necessary to decrease risk;
    - complexity; number of participants and/or lanes occupied by participants involved.

2.4. Operational definitions of disturbances or categories used to score potential risk

After examining a large number of traffic events for the experimental sites, the following disturbances were selected as traffic situations with a certain degree of potential risk:

Incorrect traffic behaviour, by violating the traffic rules:

- Overtaking-to-the-right and moving back to the left.
- Overtaking-to-the-right and staying in the right lane, except in case of an exiting lane on the left (Euro-Triangle).
- Pushing: i.e. keeping a short headway, while driving at high speed (primarily in the left lane).
- Diffuse behaviour: e.g., driving at two lanes or indicating to go to the left and not going or going to the right.

Risky, but otherwise correct behaviour:

- Cutting off to the left/right.
- Not giving way: not allowing other road users to merge at the convergence of two lanes (Euro-Triangle).
- Cutting in at the shoulder or acceleration lane.
- Approaching a car in front with high speed (although the left lane or all lanes are fully occupied) and braking severely.

2.5. Background for scoring from the video screen

- Scoring of a disturbance (with/without reaction(s)) is restricted to the first 150 meters on the video screen; interpretation of the different reactions/manoeuvres is not a problem in this area.
- Reactions further on (like braking or overtaking) are only used for judging the risk of a disturbance that is scored within the range of 150 metres.
- In case of uncertainty (screening and/or scoring), the observer puts a question mark on the coding form. Afterwards another observer will screen and score the same situation. In case of different interpretations screening and scoring are discussed to come to an agreement.
- Screening and scoring are carried out by trained observers.

2.6. Scoring the complexity of a disturbance

When a disturbance is screened the following items are scored:

- Risk classification of each disturbance with categories high and low risk. The scoring depends on a subjective judgement of the observer.
- Type of disturbance: the scoring code gives direct information whether the disturbance demands for reaction of others or not.
  Standard manoeuvres (according to the rules) will not be scored as disturbances. But these are scored, if carried out when all lanes are occupied and/or other road users are hindered (e.g., passing is blocked). To get an indication of the recurrence of this kind of disturbances, we decided to score those situations also and judged them risky or not.
- Number and type of manoeuvres; each manoeuvre will be scored by its lane, and include the manoeuvre causing the disturbance together with those to neutralize the disturbance, such as:
  - braking;
  - overtaking to the left/right;
  - cutting in to the right/left.
- Number of vehicles involved per lane, distinguished into two classes:
  - motorcycle/car/van;
  - lorry.

For an example of the coding form, see Appendix I.

2.7. Reliability

Screening and scoring are based on subjective interpretations of what happens in the traffic stream. To test the consistency and consensus of the scoring, three observers screened and scored the same video tape. Afterwards the results were compared. Differences were discussed to reach a satisfactory level of consensus. The reliability of screening and scoring during the whole period is controlled by taking samples (one tape per location is screened and scored completely by two observers).

3. THE PORTICO INCIDENT WARNING SYSTEM

3.1. General background

The warning system used in PORTICO is a flashing light system, with lights mounted on poles along the road. It only gives a general warning sign to the driver; it does not tell him about what he is warned (e.g., a road blocking, or a parked car) and also not what he has to do (e.g. , to reduce his speed or to keep distance).
The automatic incident detection would be based on common loop detector data, such as speeds, to detect stopping cars etc. or congestion. The system could also be manually controlled; e.g. after warnings from road users or the police about incidents or bad weather conditions, such as fog.

The aim of this study is to evaluate the safety effects of this flashing light warning system on traffic behaviour, given the system the way it is operating, and to compare the results with other systems.
The study was planned as a before and after study on the A1 motorway and the IP5 mountain road, using video and loop detector data of one week before and one week after instalment. The after study at the A1 could not be carried out, because the system instalment had been delayed.

The first before study was carried out at the experimental section on the A1 motorway (apr. 3 km long).
In November 1993 a meeting was held at JAE headquarters in Lisbon to discuss the preparation of the evaluation plan in detail, and to decide about the cooperation between the HOPES and the PORTICO project. HOPES took care of the measurements and was assisted by PORTICO.
According to this plan, the first loop detector was placed 200 metres before the start of the experimental section, in order to measure the traffic parameters before the experimental area.
The video camera's were placed near the beginning and the end of the experimental section. The position of the first video camera was at the beginning, at location 6.510. It was installed at a 5 metre pole, just inside a guard rail, as close as possible to the road. The video camera is partly masked by trees at the background.
The second video camera position was at the upwards slope of the hill at point 5.390. There are trees again that hide the camera.
Two pairs of loop detectors were installed at the position of camera two, to measure speed as well as changes in speed, headway etc. at 20 and 40 metres from the video camera.

To study general adaptive behaviour, mean speeds and head-ways, as well as speed and head-way distributions are collected at the experimental zone using loop detector data.
To study behavioural interactions and adaptive and conflict behaviour, speed differences and differences in headway, lane changing and breaking data is collected. In this case video and loop detector data is used to describe behaviour.

The study was meant to answer the following questions:

1. Does driver behaviour change at the location where the warning is displayed, and if it does, how does it change?
2. Does driver behaviour change between the location of warning and the location of the incident, and if it does, how does it change?
3. Does driver behaviour change at the location of the incident, and if it does, how does it change?
4. Does the existence of the warning system change driver behaviour at times without warnings, and if it does, how does it change?

3.2. Results

3.2.1. Reliability of the behavioural scores
During the before period at November 1993, video and loop-detector data is collected. The following reliability on screening and scoring of the disturbances from video was reached:

- The analysis of two video tapes by separate observers, showed that 90% consensus was found for the screening of disturbances.
- An exception had to be made for manoeuvres scored as "pushing". Here approximately 50% consensus was found. After discussion, pushing situations were reanalysed and restricted to headways of less than five metres. After this correction also approximately 90% consensus was reached on the screening of "pushing" disturbances.
- Agreement on the screening of disturbances with high risk was nearly 100%.
- Approximately 75% consensus was reached on scoring the number of vehicles involved and on the number and types of manoeuvres.

3.2.2. Scoring problems
All video data (camera nr. 1 and 2: 84 hours) are screened and scored, except the first period of approximately 10 minutes each day; the interpretation of the traffic behaviour was too difficult, because of the dark. During sunny hours it was difficult to read the video time. Sometimes this was even impossible. In those cases the exact time, necessary to link the video data to the loop-detector data, was estimated. Sunlight also hampered the interpretation of braking behaviour occasionally.

Because the task of the observers to interpret the behaviour was sometimes rather complex, situations could be scored incorrectly or inconsistently. For instance, a car entering the video screen is driving on the right lane and the manoeuvre could be scored either as "overtaking-to-the-right" or as "passing to the right"; for the analysis it is important to distinguish between these situations, and also between situations where there is a free versus blocked lane on the right side during the manoeuvre. The manoeuvres are scored as indicated in Figure 3.1, 3.2 and 3.3. In these figures, the vertical line represents the beginning of the video picture.
Another kind of uncertainty regards pushing behaviour that might be caused by a car overtaking-to-the-left, just before entering the video screen in front of a car that drives already on the left lane, or a car that was already driving in the right lane (see Figure 3.4 and 3.5); if two cars are driving on the left lane and there is enough room on the middle lane to give free passage to the car from behind, only pushing behaviour will be scored (see Figure 3.5); if there is no room on the middle lane, pushing together with overtaking-to-the-left are scored (Figure 3.4).
Discussions about these kinds of uncertainties resulted in the scoring categories distinguished above.

Figure 3.1: type of disturbance: overtaking-to-the-right; type of manoeuvre: overtaking-to-the-right.

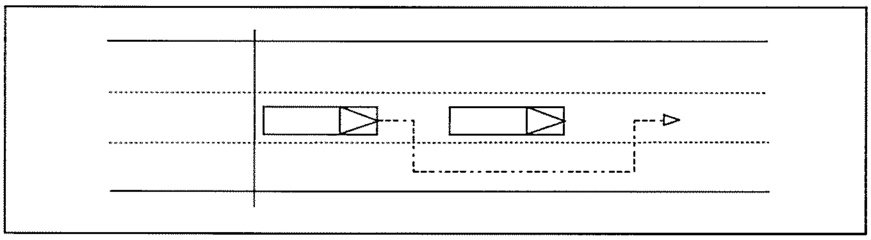


Figure 3.2: type of disturbance: overtaking-to-the-right; type of manoeuvre: overtaking-to-the-right.

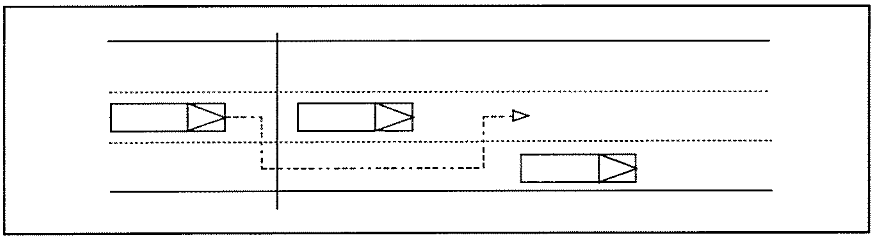


Figure 3.3: type of disturbance: overtaking-to-the-right; type of manoeuvre: passing-to-the-right.

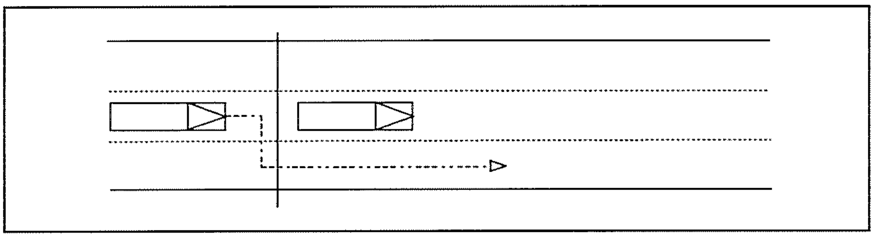


Figure 3.4: type of disturbance: pushing; types of manoeuvre: pushing and overtaking to the left.

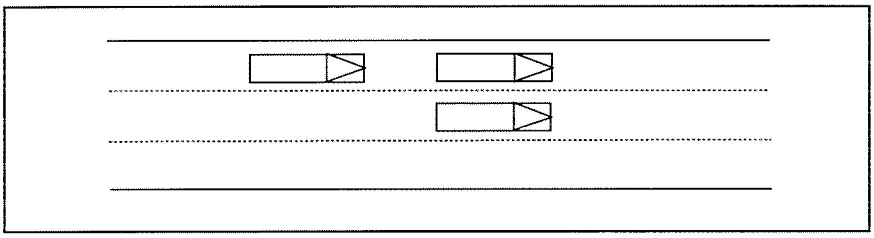
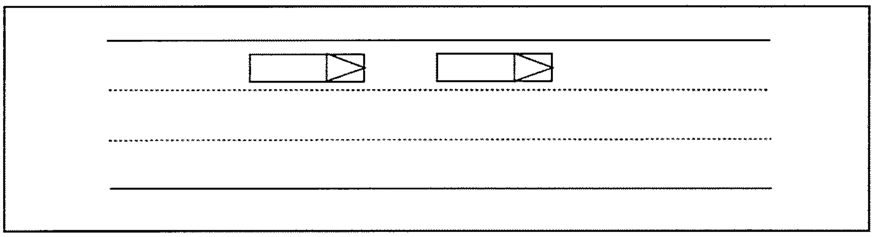


Figure 3.5: type of disturbance: pushing; type of manoeuvre: pushing



3.2.3. Disturbances with high and low risk

In all the presented tables, the disturbances will be sub-divided into the following types:

- risky (high or low), but otherwise correct behaviour; non-violating;
- incorrect behaviour according to the traffic rules, with higher or lower risk.

From Table 3.1 it can be seen that 423 disturbances are scored. Furthermore, that the percentages of disturbances with high risk, vary considerably between the two cameras. For the low risk scores these percentages are more similar. This variation will partly be due to the smaller number of scores with high risk, which makes these numbers more liable to random fluctuations. Consequently, the results of both cameras will be combined in further tables.

From Table 3.1 it can be concluded that the (column) percentage of disturbances with a traffic violation is lower for the high risk column than for the low risk column: 78% against 86%. It should be noted that passing to the right is not strictly forbidden in Portugal. The 129 overtaking-to-the-right manoeuvres do include 42 of these situations, of which only 3 had a high risk score. If we exclude these cases, the column percentages become a bit more equal: 78% against 84%. The absolute number, of scores with a high risk, however, is much higher for the group of disturbances with a traffic violation than for the group without one (88 against 25). The conclusion therefore must be that the majority of disturbances with high risk are caused by not obeying the formal rules.

Table 3.1. Percentages of disturbances for camera 1 and 2, divided in type of disturbance and risk.

type of disturbance	high risk			low risk		
	cam.1	cam.2	1+2	cam. 1	cam. 2	1+2
non-violat. behaviour	30	17	22	12	16	14
violating behaviour:	70	83	78	88	84	86
overt. right	25	17	21	34	35	34
pushing	38	45	42	45	40	43
other viol.	7	21	15	9	9	9
percentage	100	100	100	100	100	100
number	61	54	115	190	118	308

From Table 3.2 it follows that most of the disturbances, scored as violating the rules, are caused either by overtaking (or passing) to the right (36%) or by pushing behaviour (51%).
27% of all pushing and 18% of all overtaking-to-the-right scores are scored with "high risk". Probably short headways are the main reason for scoring "pushing" more often in the category "high risk" as compared to overtaking-to-the-right. Within the high risk scores for the group with a violation, the proportion of pushing scores is 55% and overtaking-to-the-right 26%.

As mentioned before, it is expected that, given a disturbance, other participants will (or must) react to neutralize the disturbance. Contrary to this expectation, most of the cases with a violation are without reactions of other participants (72%). Within this category, the most important types are overtaking-to-the-right (45%) and pushing (45%).
Within the category "reaction", the proportion of pushing is 67% and overtaking-to-the-right 15%.

Table 3.2: Number of disturbances by type, with high or low risk and with or without a reaction of other participants (PORTICO: camera 1 and 2).

	reaction				no reaction				total	
type of behaviour	high risk		low risk		high risk		low risk			
	#	%	#	%	#	%	#	%	#	%
without violation	19	4	24	6	6	1	20	5	69	16
overtaking to right	10	2	5	1	13	3	101	24	129	30
pushing	18	4	48	11	30	7	85	20	182	43
other violation	8	2	10	2	9	2	17	4	45	11
total	55	13	87	20	58	14	223	53	423	100

The amount of reactions of others to neutralize a risky disturbance is 33%, of which 39% is scored with high risk and 61% with low risk. From the scores without a reaction of others still 21% were scored with high risk. In other words, the judgement of observers to score situation risky or not does not depend only on the presence or absence of a reaction from other participants.

From the disturbances with a reaction, overtaking-to-the-right is more often judged as highly risky (67%, or 10 out of 15) than pushing is (27%, or 18 out of 66). Contrary to this, within the category of no reaction of others, only 11% (13 out of 114) of all the overtaking-to-the-right scores are judged highly risky, while there is no difference for pushing (26%, or 30 out of 116).

A log-linear analysis showed a highly significant interaction between this presence or absence of a reaction of other drivers, the level of risk for these manoeuvres and these types of manoeuvres. The (standard normal) z-score is 3.68. Apart from this second order interaction, no relations were found between the risk score and the types of manoeuvres or reactions.

A possible explanation is, that contrary to the overtaking-to-the-right situations, most of the pushing drivers use short headways to inform the driver in front that he wants to pass. A reaction is therefore not needed, other than a lane change. On the other hand, an overtaking-to-the-right manoeuvre is only effective if the lane on the right side is not occupied. If it is, problems may occur. This will be further analyzed in § 3.5.6.1.

3.2.4. Relation between occupancy and disturbances

Occupancy of a road is expected to determine the degree of complexity of a certain type of disturbance. Therefore, presence of all relevant participants involved in a disturbance are scored, each addressed to its lane.

For practical reasons, we do not represent the number of cars in each lane, but indicate only whether the lane was occupied or not.

Relations between occupancy per lane and types of behaviour are presented in Table 3.3.

Table 3.3: Disturbances by type, risk and lane occupation for camera 1 and 2.

disturb.	non-viol.		overtaking		pushing		other viol.		total
risk/ occup:	high	low	high	low	high	low	high	low	
l	-	1	-	4	2	15	-	-	22
m	-	-	-	-	2	2	-	1	5
r	-	-	-	-	-	-	-	3	3
l+m	8	11	8	15	17	38	5	6	108
l+r	1	3	-	1	7	9	-	-	21
m+r	2	6	-	15	-	4	1	4	32
l+m+r	16	21	15	71	20	65	11	13	232
total	27	42	23	106	48	133	17	27	423

For otherwise correct behaviour the distribution shows that even this behaviour can create situations with high risk, when the left and middle lane or all lanes are occupied.

Most of the disturbances concerning violations with high risk happen if the left and middle lane are occupied (34%) and if all lanes are occupied (52%). In case of low risk, the percentage for the left and middle lane is 22%, and for all lanes occupied is 56%.
As expected, the percentage of situations scored with high risk is related to the degree of lane occupation.

3.2.5. Lorries involved in disturbance
Next, we expect that the presence of one or more lorries will be a main cause for disturbances, because of the average speed differences between lorries and cars.
In 45% of the disturbances at least one lorry was scored (in 193 cases out of the total 425). One third of these cases got a high risk score (see Table 3.4). Therefore, in more than 50% of all the 121 high risk scores, at least one lorry was involved.

Table 3.4: The number and type of disturbances with lorries involved, subdivided with regard to lane occupation and risk.

	one lorry involved			more lorries involved			total
lane occupation	one	two	all	one	two	all	
risk/type:							
high risk:							
non-viol.	0	3	8	0	2	8	21
overt-to-right	0	1	6	0	0	2	9
pushing	0	5	9	0	2	4	20
other	0	1	7	0	0	4	12
sub-total	0	10	31	0	4	18	63
low risk:							
non-viol.	0	2	7	0	5	7	21
overt-to-right	0	5	32	0	0	2	39
pushing	0	9	30	0	3	15	57
other	1	1	4	2	0	5	13
subtotal	1	17	73	2	8	29	130
total	1	27	103	2	12	47	192

3.2.6 Manoeuvres

As seen before, most of the disturbances are caused by overtaking or passing to the right and/or pushing. To relate risk scores to traffic flow characteristics, it is important to know on which lane the drivers caused this kind of disturbance. This is shown in Table 3.5.

Table 3.5. Type of disturbance caused by overtaking/passing to the right or by pushing, per lane.

type of lane	overtaking	pushing	total
right lane	63	-	63
middle lane	45	19	64
left lane	21	162	183
total	129	181	310

In 84% of the cases the start of an overtaking-to-the-right manoeuvre is scored on the right and middle lane. 89% of the pushing manoeuvres are scored on the left lane.

Overtaking-to-the-right manoeuvres

As mentioned in section 3.5.4., an overtaking-to-the-right manoeuvre is scored in several situations, depending on where the manoeuvre starts and/or ends and whether or not the right lane is blocked by another car.

For instance, when a car/lorry enters the video screen on the right lane, it is possible that the driver who starts his overtaking manoeuvre drove on the middle lane before entering the video screen. This kind of manoeuvre takes time to be carried out completely. This means that the start or finish of the manoeuvre may be out of sight. However, there are situations in which a driver makes an overtaking-to-the-right manoeuvre, while the right lane is blocked by another car. If he does not reduce his speed, an overtaking (or cutting in) manoeuvre to the left is needed, to avoid a conflict. Therefore, the overtaking-to-the-right manoeuvre is further analyzed, using two sub-categories. If a driver overtakes or passes another car to the right and continues his way on the right lane or turns back to the middle lane without being forced to do so, this is called "passing to the right".
If the driver turns back to the middle lane after overtaking on the right side, because the right lane is blocked by another car or lorry, this is called "right-left" (see Table 3.6).

Table 3.6. Number of overtaking-to-the-right manoeuvres, subdivided in passing to the right and right-left manoeuvres, per lane.

manoeuvre	passing	right-left	total
right lane	54	10	64
middle lane	36	10	46
left lane**	10	7	17
total	100	27	127*

* Two manoeuvres were too complicated to score, because drivers reacted on all lanes to neutralize the disturbance.
** "right-left" means: after overtaking-to-the-right, back to the same lane.

According to Table 3.2, an overtaking-to-the-right manoeuvre is twenty three times scored with high risk. All these situations are of the type "right-left". The presence of other traffic on the lane used for overtaking often creates a potential risk. This explains why in that table 67% of overtaking-to-the-right manoeuvres with a reaction of others is scored with high risk, and only 13% of the manoeuvres without a reaction got this risk score.

Pushing manoeuvres
The correct way to overtake a car in front is to do it on the left side. Some drivers "pushes", to inform a driver in front on the same lane that he wants to pass. If there is not enough room for the driver in front to change lanes, or if he has to slow down, this pushing behaviour might create a situation with potential risk. Therefore, pushing manoeuvres will be sub-divided into the following categories (see Table 3.7):

- Free way: no other cars are involved; a lane change is possible for the driver in front.
- Overtaking-left: the driver in front is already overtaking a car on the left side.
- Overtaking-right: the driver who starts the pushing manoeuvre, overtakes the car in front on the right side.
- Reaction-others: the driver in front or another driver is reacting to the pushing manoeuvre, or for another reason.

Table 3.7. The number of pushing manoeuvres per lane, sub-divided into four categories.

manoeuvre	left lane	middle lane	total
free way	116	16	132
overtaking-left	15	3	18
overtaking-right	4	-	4
reaction others	23	2	25
total	158	21	179*

* 3 manoeuvres were too complicated to score.

Table 3.7 shows that pushing manoeuvres often are used to inform the driver in front that he wants to pass (74%). Only eighteen times (10%, on both lanes together) it concerns a situation in which the driver in front could not respond, because the adjacent lane was occupied.
Still 42% of the pushing manoeuvres are scored with high risk.

3.2.7. Summary and conclusions
Disturbances are scored if a driver violates a traffic rule in the presence of other road-users, or makes a manoeuvre which as such is correct, but is risky given the traffic situation.
Observers, when scoring the level of risk of a disturbance, take the following issues are taken into account:
- short headways;
- number of manoeuvres or actions (braking or lane change) of road-users involved in the disturbance to reduce the level of risk;
- the complexity of the situation; i.e. the occupancy per lane of road-users involved.

72% of the 425 disturbances, caused by a violation of the traffic rules (356) or by a manoeuvre at the wrong moment (69), got a low risk score.
Although the number of manoeuvres at the wrong moment is rather small, 41% of those situations got a high risk score.
Most of the disturbances, due to a violation to the traffic rules, are caused either by an overtaking-to-the-right manoeuvre (36%) or by pushing (51%).
The following differences were found between disturbances, caused by an overtaking-to-the-right manoeuvre or by pushing.
- Most of the overtaking-to-the-right manoeuvres are caused by speed differences at the middle lane. Drivers decided not to reduce their speed and to wait for an opportunity to overtaking correctly, but to overtake the car in front at the right side. In 25% of these situations the right lane is blocked, and an abrupt braking or cutting-off-to-the-left manoeuvre is needed to avoid a collision.
- Most of the pushing manoeuvres are connected to the left lane. In more than 70% of all the pushing situations no other cars were involved. Most of the pushing manoeuvres on the left and middle lane are situations in which the pushing driver wants to make clear to the driver in front that he wants to pass.
- A pushing manoeuvre in the left lane creates more often a situation in which other participants react to the manoeuvre.

3.3. Comparison of conflict score and behavioural observations

A comparison between the outcomes of the behavioural study carried out at SWOV and the conflict study made by the TU-LUND shows the following results for the data of camera 1 + 2:

- LUND scored 61 conflicts; SWOV scored 423 disturbances, of which 115 got a high risk score.
- LUND scored two times a conflict where SWOV did not. After reanalysing SWOV considered these events also as a disturbance.
- Two times a (complicated) disturbance was scored by LUND as two separate conflicts and one in even five separate conflicts.
- LUND and SWOV scored 35 times the same situation, SWOV as a disturbance and LUND as a conflict;
- LUND scored 26 times a conflict, where SWOV did not. Eight of these regard a situation in the early morning, where SWOV considered it too dark to make a proper interpretation. The other events were judged by SWOV to be normal adaptive behaviour. For instance, in cases where a car approaches another car on the middle lane, and the driver brakes and waits for a safe opportunity to overtake to the left (for more details, see Appendix II).

It was expected that most of the situations scored by both teams would get a high risk score from SWOV. Actually, 29% of the conflicts were scored by SWOV with low risk (see Table 3.8). Half of the events scored by LUND were disturbances caused by traffic violations. The SWOV risk scores did not differ between this group and the non-violation disturbances.

It could be argued that not only disturbances as scored by SWOV, but also conflicts scored by LUND often regard situations with high speed differences and restricted manoeuvring space for road-users. High speed differences are to be expected at the left lane primarily, while manoeuvring space is strongly related to lane occupancy. Therefore, both disturbances and conflicts are divided with regard to lane occupancy (see Table 3.9). Only two conflicts are scored with only one lane occupied (one in the left lane and one in the middle lane).

Table 3.8: Events scored by both LUND and SWOV, subdivided into types of disturbance and risk score.

risk	high risk		low risk		total
events/ teams	SWOV	LUND + SWOV	SWOV	LUND + SWOV	
non-violation	15	13	37	4	69
overt. to right	19	6	102	2	129
pushing	48	2	129	3	182
other viol.	14	4	26	1	45
total	96	25	294	10	425

In 63% of the cases in Table 3.9 that are scored by LUND, all lanes were occupied, and in 26% of the cases only the left and middle lane. These proportions are similar to the proportions of the events scored by SWOV only, being 55% and 25% respectively. The other combinations of lanes were seldom scored by LUND and more often by SWOV.

Table 3.9 All LUND and SWOV scores, subdivided in type of disturbance and number of lanes occupied.

# of lanes occupied	one lane		left+middle		rest two lanes		all lanes		total
team / behaviour	L*	S	L	S	L	S	L	S	
high risk:									
non-violating	-	-	2	6	1	2	10	7	28
violation	-	4	3	27	1	7	8	43	93
low risk:									
non-violating	-	1	1	10	-	9	3	17	41
violation	2	23	3	56	-	33	1	145	263
total	2	28	9	99	2	51	22	212	425

* L= Lund+SWOV; S=SWOV only

3.4. Risk scores and traffic stream characteristics

The analysis of the loop-detector data and the development of computer programs for the link between a special analysis of the loop-detector data on a car-by-car basis, are reported elsewhere. The last analysis in a separate internal HOPES report, prepared by SWOV.
This chapter will describe the relation between the behavioural observations and the outcomes of the special SWOV-analysis of the loop-detector data.

3.4.1. Detection of disturbance on the basis of loop-detector data

On the experimental section at the position of camera 2, two pairs of loop-detectors were installed, 20 metres apart. Data from both loop-detectors were available. Speed and headway of a passing vehicle may differ between both sets of loops, making it possible to compute accelerations or decelerations.

In order to compare video observations with loop-detector data a number of steps are necessary. The first step is to synchronise the video and loop-detector recordings. To do this, characteristic traffic patterns observed on video are related to the loop-detector data. To do this, the VERSIM programme developed by SWOV was used. This computer programme visualises a set of loop-data for time slices, the duration of which can be selected, for all lanes simultaneously. It generates configurations of cars and lorries on the road on a time base or using distances. For each car or lorry, pictured as a small or large box on the road, the speed or headway can be pictured as well (see Appendix IV). Loop-data from November 22 through November 26 are compared with the corresponding video data recorded between approximately 8 a.m. and 11 a.m.

After synchronising loop-recordings and video recordings, the following steps were carried out:

1. The video picture of the first disturbance with a high risk score for a particular period was frozen and compared to the loop-data at the corresponding time.
2. After identification, the time at which the car causing the disturbance passes the first loop is called the start time.
3. The loop-data configuration was then printed for each disturbance.
4. This procedure was repeated for the second pair of loops.

It should be noted that the loop-detector configuration was based on the crossing time of the loop-detector for each vehicle that was part of the relevant configuration. The loop-data correspond to the same position on the road for each vehicle, but differ in time; the video data however, correspond to the same moment in time, but at different positions on the road. The comparable loop-detector configuration was generated under the assumption that the car kept his speed over the (small) time slice covered by the video picture.

While carrying out these steps, a number of problems had to be solved:
- Although video and loop detector times were synchronized, sudden differences (of some seconds to one minute) were found in the loop detector files.
- For 10 disturbances no traffic pattern comparable with the first pattern could be found on the second loop, because of error in the loop-data file or cars missed by the loop-detectors. In those cases only one computer pattern is available for interpretation.
- Finally, for each of the 51 disturbances with high risk one or two corresponding loop-configurations could be found.

The extra information on speed (differences), headway, acceleration or deceleration are used to check the video scoring of these disturbances.

3.4.2. Scoring disturbances for loop-detector data
The next questions were:
- Is it possible after the identification of a certain type of disturbance scored by observers, to recognize and/or interpret this event directly from the loop-detector configurations with data on speed and headway?
- Could the loop-detector data be used to improve the classification and/or the scoring of risk of a disturbance?

To answer the question the following steps are carried out:
- Knowing a type of disturbance (for instance: pushing), speed and headway data were used to check the interpretation of the disturbance scored from video.
- If a disturbance could not be recognized or in case of uncertainty, the corresponding video picture was compared. For the 10 cases with only a configuration from one pair of loops available it was difficult to interpret the pattern in terms of a disturbance.
- If the definition or detection was not possible, because the type of disturbance was undefined, or if the speed and/or headway could not be read, or the type of vehicle was incorrect, it was also necessary to turn to the video picture for a correct interpretation.

The VERSIM programme gave unreliable vehicle data of two kinds:
1. The loop-data contained lorries (primarily on the left lane), the computed speed of which were too high to be realistic.
2. The computed length of some vehicles was less than 3 metres. This is also not realistic.

Twenty times a "lorry" was situated on the left lane with high speed. After verifying the video picture the lorry on the left lane turned out to be two cars with very short headway (18 times), one time a car with trailer and one time a car on the left lane giving way to a car from behind (short headway). In other words, scoring such imaginary lorries automatically as "pushing" cars, turns out to be incorrect only two times.
When a car changes lanes while crossing the loop detectors the computer program can not interpret the kind of vehicle (lorry or car). Therefore, such a vehicle is recorded unreliably too and presented by the VERSIM programmes as a "black" car. This problem differs from the one above because lane specification is ambiguous. This complicates the comparison between the pattern scored in the disturbance and the printing pattern (number of type of vehicles, each addressed to its lane).

Speed measurements of a vehicle between the first and second pair of loops often differed one to three km/h. It was not clear, whether such a difference must be interpreted as the start of an acceleration or deceleration or as measurement imprecision. Some margin had to be selected. After comparing the loop-detector configurations with the video pictures, for six out of the original 51 disturbances a correction was carried out. Two disturbances were scored as normal adaptive behaviour and therefore removed from the list. For four disturbances the high risk score was changed in a low risk score.
Therefore, finally 45 disturbances with high risk remained. A detailed description of these events is given in Appendix III. An example of an interpretation cycle is given below. The corresponding loop-detector configurations are given in Appendix IV.

3.4.3. Example of an interpretation cycle, using video and loop-data
To illustrate the procedure used to compare the loop-data and the scores from video, we will give an example of such an interpretation cycle for one disturbance. Details are given in Appendix III, file name: 32602, time: 0.11.29.

From the video picture the disturbance, that was also scored by LUND as a conflict, was scored as follows:

- Type of disturbance: pushing.
- High risk score, with reaction of others.
- Complex situation: two cars on the left lane, one car and one lorry on the right lane.
- Three manoeuvres:
  - on the left lane: pushing and braking;
  - on the right lane: overtaking to the left.

The computer pattern shows the following situation:

- A "lorry" on the left lane (speed 143 km/h; headway 34.7). One car in front (speed 138 km/h; no car in front of this one) and two cars from behind (speed 141 km/h and 132 km/h respectively).
- Two cars on the middle lane. The car in front (speed 136; no car in front of that one) was marked as unreliable of the second type; car from behind (speed 118; headway 67.7);
- One car on the right lane (speed 110 km/h; no car in front).

After screening the video picture, the following differences between items of the disturbance and the computer presentations are found:

- The "lorry" on the left lane turns out to be two cars. So, scoring the "lorry" as a "pushing" manoeuvre between two cars is correct.
- The manoeuvre on the left lane scored as braking is probably based on a direction signal to the right and should not be a braking manoeuvre, given the small speed differences. The car (marked as unreliable on the middle lane) actually changes lanes from left to middle, while crossing the loop detectors. This explains the existence of one of the two cars on the middle lane (on the VERSIM printout) and none at the pattern of the disturbance. According to the observer the second car on the middle lane (on the printout) is not involved in the disturbance and therefore not scored as part of the disturbance.
- Two cars are scored by the observer on the right lane (car and lorry). The car overtakes the lorry to the left. The printout shows only one car with no car in front (according to the definition of the computer program). The difference between the speed at the first printout (108 km/h) and at the second (110 km/h) gives an indication that the car is accelerating. However, the difference between the two values is small.

- Verifying the video picture, it turns out that the car on the right lane wants to overtake the lorry in front and indicates a lane change. At first, the manoeuvre is not carried out because the middle lane is blocked by an oncoming car. Therefore, the driver brakes (this is not scored by the observer and interpreted as normal adaptive behaviour). A bit later, the manoeuvre is carried out and scored by the observer.

From this comparison it can be seen that the additional data from the loop-detectors can be used to check and correct the video scoring. On the other hand it shows that a proper interpretation on the basis of traffic stream characteristics from one or two loops only is not always possible. In simple situations, regarding close following and pushing or approaching with high speed with or without manoeuvring space for that car or the one in front, most of the critical events can be already detected. Further investigations, preferably on the basis of image processing or data from several loops, are necessary to improve the automatic detection of risky traffic disturbances and conflicts.

4. EUROTRIANGLE PROJECT

4.1. Aim of the study

The original objective of our planned evaluation study for the EUROTRIANGLE project, was a before and after study of a VMS-system consisting of several (pictogram) gantries, to be installed at the end of 1993 or the beginning of 1994. In the before period there were already one alphanumeric gantry and three pictogram gantries available. It was the intention to measure the effect of the existing system in the before period and to compare its effectiveness with the extended system in the after period.

4.2. Field work and preparations

4.2.1. Field work preperations

Contrary to the PORTICO project, data collection in the EURO-TRIANGLE project (video and loop detector) was carried out by the EURO-TRIANGLE consortium itself. Loop detector data were directly generated on a one minute basis from CCATS-cameras, using image processing techniques. Video recordings were made using the police cameras, installed for monitoring.

At the same location on the E17 in Antwerp, the influence of two kinds of warning systems on driver behaviour were investigated of the systems already in use. The pictogram gantries were installed more than two years ago and controlled automatically, the alphanumeric gantry, installed at the first of september 1993 is manually controlled. The before study was planned to be a "system-on" versus "system-off" type. In the after period a comparison was planned between the additional system and the previously existing system.
Because the instalment of the extended system, planned for the end of 1993 or the beginning of 1994 was not realised in 1994, no after study was possible.
Detailed preparations were made for this evaluation study by HOPES representatives and representatives from the EURO-TRIANGLE project, including the Road-administration, the Police and technicians in a series of meetings.

At the last meeting, two days before the fieldwork started, the following final arrangements were made:

- The Rijkswacht officers at the control room were instructed to make recordings of the functioning of the system, using a log-book that was specially prepared for the registration of the events of interest for the evaluation, such as the messages given at the respective gantries and the time of these messages.
- TRAFICON was contracted to deliver the loop data of all the CCAT cameras (nr. 1 to 15) on the E17, in the direction of the Kennedy tunnel on a one minute basis.
- VIGITEC was contracted to take care of the recordings for four specially selected police cameras. They fixed the four cameras during the fieldwork.
- Police camera nr. 11 was not operational. Therefore, rerouting effects could not be evaluated. Traffic was counted on the exiting lane, using camera 14, to give an indication of possible rerouting.

During the experiment a number of practical problems appeared, one of which caused a delay of one day in the video recordings. More serious was the fact that the log-files could not be found at the end of the experimental period. Therefore, all information about the onset and offset of messages on the system was lost. The system-on versus system-off comparison was therefore not possible.

4.2.2. Field work

The fieldwork took place from May 16 through May 22 in 1994. As already mentioned, video recordings on Monday the 16th were lost.

On the remaining working days, video data was collected for four cameras: from 6.15 a.m. until 7.15 a.m. in the morning (before congestion time) and from 11.00 a.m. until 12.00 a.m.
On Saturday and Sunday this data was collected from 16.00 until 18.00 p.m. (busy traffic).
Video tapes and loop-detector data were available in the beginning of June and send to the various partners in the evaluation study.
The period from 6.15 hrs to 7.15 hrs was selected on the basis of previous information on traffic flows. The period after 7.15 hrs was always a period of congestion. Behavioural observations were regarded the most meaningful in free flow conditions, but that the transition from free flow to congestion should also be covered. In practice, it turned out that in the experimental week the amount of traffic was considerable lower than expected, probably because that week was a special week in Belgium. Therefore, there was less congestion as usual and traffic did not come to a stop before the entrance of the tunnel.

4.3. Results

4.3.1. Classification of disturbances and the adaptation of the scoring procedure
In order to examine the possibility of using the PORTICO screening documents and definitions to screen and score disturbances in the EUROTRIANGLE project, a test case was carried out, using one video tape for each camera. For each camera data from one quarter of an hour of observation was used for screening and scoring. During this test period, the following problems were noticed and/or adaptations made:

- For camera 14 and 2, the scoring forms were extended to score disturbances on four lanes instead of three.
- Exiting to the left was added for camera 14.
- Violation of traffic rules will be extended with the following manoeuvres:
  - not giving way (camera 4 and 2);
  - use of the exiting lane to change lanes (camera 14);
  - crossing the uninterrupted road marking (camera 7 and 4).
- Contrary to the PORTICO video data, a lot of lorries uses the right and middle lane. Combined with the camera position this means that we miss a lot of traffic situations on the left lane and/or exiting lane (camera nr. 14), because vision is blocked for that area. Furthermore, "pushing" behaviour is difficult to interpret in these situations.
- The interference of (sun)light makes it difficult to screen and score disturbances.
- Before entering the Kennedy tunnel nearly all traffic brakes (anticipatory braking, not caused by a disturbance); this was interpreted as normal adaptive behaviour when entering the tunnel (camera 4 and 2).
- During congestion the average speed goes down. A large number of cars are braking (all cameras). The scoring of risk for these situations is difficult. Additional information on TTC and/or estimation of headway is needed. When everybody keeps his/her lane these situations are also interpreted as normal adaptive behaviour, and therefore not scored. Additional loop-data was not available on a car-by-car basis. Such data could have been very valuable in these situations.

No loop-detector data is available for traffic on the exiting lane (camera 14). Therefore, we decided to make traffic counts on that lane in two categories: cars/motorcycles and lorries. The results are given in Table 4.1.

Table 4.1. Distribution of number of vehicles exiting the E17 (camera 14), subdivided in weekend and working days, time of day and vehicle type.

type of day:	week days:				week-end days:		total
time/date:	17/5	18/5	19/5	20/5	21/5	22/5	
6.15 - 7.15							
car	348	384	306	395			1433
lorry	39	36	31	38			144
11.00 - 12.00							
car	82	152	139	165			538
lorry	19	51	47	36			153
16.00 - 18.00							
car					231	225	456
lorry					5	2	7
Total	488	623	523	634	236	227	2731

As mentioned before, log-books were missing. That includes, all information about the messages given and time of the onset and offset of the messages on the alphanummeric gantry as well, was lost. Therefore, a system-on versus system-off comparison with the information given in Table 4.1., to get an indication about rerouting, is not possible.

4.3.2. Risk scoring of disturbances

As mentioned before, a new kind of manoeuvre was defined for vehicles using the exiting lane for overtaking to the left (camera 14). It is not clear whether such a manoeuvre is against the traffic rules, therefore only the number of cases this manoeuvre takes place will be scored, to see how relevant the manoeuvre is.

It was scored eleven times during peak hours (6.15 and 7.15 pm) and two times during free flow situations (between 11.00 and 12.00 pm) in the morning on working days only. In other words, only if all lanes are occupied, the exiting lane will be used sometimes as an extra lane to facilitate an overtaking-to-the-left manoeuvre.

Table 4.2 gives the risk scores for each camera. It shows that 71% of the disturbances are scored from camera 2 and 4, near the entrance of the Kennedy tunnel. The proportion of scores with high risk for the four cameras are: 21% (cam. 2), 29% (cam. 4), 25% (cam. 7) and 36% (cam. 14).

It seems that the closer traffic stream is to the entrance of the Kennedy tunnel the more disturbances are scored, but in general with a lower risk. This could be explained by the increasing congestion and the fact that drivers lower their speed at the entrance of the tunnel.

Table 4.2: number of disturbances (per camera), subdivided in risky or not

camera*)	type of disturbance	high risk	low risk	total
camera 2	non-violating	3	45	48
	overtaking to right	3	7	10
	pushing	3	30	33
	other	14	5	19
sub-total		23	87	110
camera 4	non-violating	18	12	30
	overtaking to right	3	13	16
	pushing	7	26	33
	other	3	7	10
	not giving way	7	13	20
	line crossing	-	21	21
sub-total		38	92	130
camera 7	non-violating	4	3	7
	overtaking to right	-	5	5
	pushing	3	12	15
	other	3	1	4
	line crossing	1	12	13
sub-total		11	33	44
camera 14	non-violating	6	7	13
	overtaking right	1	6	7
	pushing	3	9	12
	other	4	3	7
sub-total		14	25	39
total		86	237	323

*) For the position of each camera, see Appendix V.

Contrary to the scores with high risk for the disturbances without a traffic violation for camera 2 which amounts 6%, the proportion of scores for this category for camera 4 is very high (60%). This is due to weaving problems near camera 4 (see Appendix V). Also camera 7 and 14, these proportions are also much higher than for camera 2. It can be concluded that in general the traffic violations do not seem to result in severe problems.

4.3.3. Comparison of the Eurotriangle and Portico results

Given the differences between data of the four cameras in the Eurotriangle project, the scores for camera 2 and 4 data are added together as well as the scores for camera 7 and 14, to facilitate comparison, without too much loss of information.

A comparison of the results from Eurotriangle and Portico is only possible for the following types of disturbances:

- non-violating behaviour;
- overtaking-to-the-right;
- pushing;
- other (excluding: "not giving way" and "line crossing", i.e. crossing an uninterrupted line).

Table 4.3 shows the results.

Table 4.3: proportion of disturbances, caused by types of incorrect behaviour, sub-divided in risky and not risky scores.

project	high risk	low risk	total number
row percentage:	%	%	#
EUROTRIANGLE (2+4)			
non violation	27	73	78
overtaking right	23	77	26
pushing	15	85	66
other	59	41	29
EUROTRIANGLE(7+14)			
non violation	50	50	20
overtaking right	8	92	12
pushing	22	78	27
other	64	36	11
PORTICO			
non violation	40	60	69
overtaking right	17	83	129
pushing	26	74	181
other	40	60	44

As already expected and indicated before, the proportion of disturbances caused by non-violating behaviour for camera 2 and 4 differ the most from the outcomes of the other cameras and those of PORTICO (see Table 4.3). This supports the conclusion that at least these disturbances scored in a congested situation (Eurotriangle) should be treated in a different way than those scored under free flow conditions (Portico).

For the other types of disturbances the differences in percentages are not very large, with an exception for the overtaking-to-the-right manoeuvres, which seem to be less risky for camera 7+14 than those for the other situations. However, the total amount of overtaking-to-the-right and pushing manoeuvres, scored with high risk as well as low risk, is much higher in PORTICO than at the EURO-TRIANGLE testsite. Because the sites are different in many respects, no firm conclusions can be drawn from that fact.

5. BEFORE AND AFTER STUDY IP-5

5.1. Introduction

As reported elsewhere, it was not possible to carry out the before and after comparison for the systems on the motorway A1 in PORTICO and the motorway ring road in EURO-TRIANGLE. Therefore, a before and after study, as originally planned for the motorway systems, was carried out at the existing incident detection system on the IP-5 in Portugal. The system was similar to the one planned for the A1.
The IP-5 is a two-lane rural mountain road, with shoulders on both sides. This road connects Aveiro (harbour on the west coast) with Spain. Many lorries and busses use this road. The traffic stream in the direction of Aveiro is called: westbound traffic and in the direction of Spain: eastbound traffic.
According to the Portuguese authorities a lot of accidents happen on this road, due to high speed and overtaking manoeuvres at critical moments. To increase safety, a warning system with flashing lights is installed. This system gives warnings to the eastbound traffic at both sides of the road. This direction is called the experimental direction; the westbound direction is called the control direction.
The aim of this study is to evaluate the safety effects of this warning system on eastbound traffic, using the changes in traffic behaviour as safety criteria.

5.2. Fieldwork

The warning system at the IP-5 is planned to work with three types of alarm:

- "Overspeeding" (fast blinking lights;7 Hz blinking): from at least 5 poles ahead of the vehicle; the following criteria are used: car/van speed > 100 km/h or lorry speed > 80 km/h).
- "Obstacle-on-road" (i.e. a slowly moving vehicle, with speed < 40 km/h): slow moving wave, against traffic from the same direction, starting at least 5 poles behind the vehicle; 2 Hz blinking.
- "Overtaking-on-prohibited-section" (7 Hz blinking, in opposite direction); wave against oncoming traffic for eastbound traffic.

From the 5th until the 12th of November the power of the system was off. The system was started again just before the beginning of the field study.
Two video cameras were installed on the experimental section, which was approximately 5 km long.
Camera 1, was mounted half way at the beginning of a steep downhill curve to the right for eastbound traffic, approximately 1 km from the start of our experimental section and partly hidden by trees. Before entering this curve, overtaking is not allowed.
Camera 2 was mounted just before a straight part of the section of approximately 500 metres length and also hidden by trees. This section is gently going downhill for eastbound traffic, underneath a bridge; after a curve to the right, overtaking is possible in both directions.
Just after the bridge a test car was parked on the shoulder during 10 minutes intervals. Coming out of the curve, eastbound drivers can see the test car (appr. 150 metres ahead).
Both cameras cover westbound (oncoming traffic on the video) and eastbound traffic.

Video recordings were made in the before period (18th until 23rd of September 1994) and after period (12th until 23rd of November 1994). For both cameras data was gathered appr. 6 hours a day, three hours during the morning peak at working days and three hours during the off-peak hours, with free flow traffic. In the before period both cameras were functioning, but not always in the after period (see next section).

5.2.1. Camera problems

The following problems were noticed:

- In the after period camera 2 was stolen on the 16th of November and replaced from the following day onwards by the camera from position nr. 1. This choice was based on the

experience in the before period, where only a minor number of disturbances were located at the camera 1 position. Therefore, no data from camera position 1 is available after the 16th of November.
- In the morning of the 17th of November camera 2 broke down and had to replaced by a rental camera. Therefore, no data is available from that day as well.
- Although the team at the field reported that the system was working at the position of camera 2 during the whole after period, only three times (on the 23th of November) blinking lights could be detected on the video pictures, due to sunlight interference.

5.2.2. System problems

The following problems with the functioning of the system were noticed:
- Along the whole section a lot of poles were broken or stolen after the system was installed. For instance, 50 arrays of leds had been stolen from a total of 200 from the poles; at the position of camera 2 the first poles on the left side (westbound traffic) did not function.
- At the camera 2 position, only one type of the warning system (overspeeding) was functioning.
- After activation of the poles, the lights often keep on blinking, when they had to be switched off. Several times a day, the system had to be reset by our team in the field.
- No poles were working at the camera 1 position, due to some technical problems with the system itself. This means that drivers at this part of the section did not get any information from the system at all.
- Loop data in the before period was not available, because the computer programmes had to be rewritten at that time. Therefore, information about the number of vehicles (cars/ lorries/ motorcycles) are gathered by hand from the video data.

5.2.3. Research material

The behavioural study on the A1 was based on disturbances scored from the original video tapes. For the behavioural study of the IP-5, LUND carried out a selection of all kinds of in principal relevant disturbances with a certain degree of potential risk, using our definition of a disturbance. These disturbances were collected on a compilation tape and sent to SWOV for the before and after period. SWOV used these compilation tapes, in order to reduce the total time necessary for the analysis.

As mentioned before, no suitable loop data of the before period was available. Therefore, using the original video tapes, VTT calculated by hand the following items:
- Traffic flow in the before period: number of cars/lorries and motorcycles for the experimental direction, and for the control direction.
- Number of times a vehicle "starts" an overtaking manoeuvre in the before and after period. "starts" means: at least going partly onto the opposite lane in order to pass a vehicle in the same direction. A scored overtaking manoeuvre could include situations with an actual overtaking vehicle (or perhaps more than one overtaking vehicle), as well as a situation without an actual overtaking, because the driver interrupted the manoeuvre.
- Stopping times of the test car.

This information was collected at a half hour interval bases for each day, and also combined at an aggregated level for daily video periods.

5.2.4. Definitions of interactive traffic behaviour with potential risk

After the examination of a test tape from the experimental area, it became clear that the dominant manoeuvre on this kind of road is "overtaking". Many overtakings with oncoming traffic, create traffic situations with a certain degree of potential risk.

Overtaking situations are covered by the incident warning system. Therefore, overtaking manoeuvres were the major object of study to evaluate the behavioural effects of the installed warning system on the IP-5.

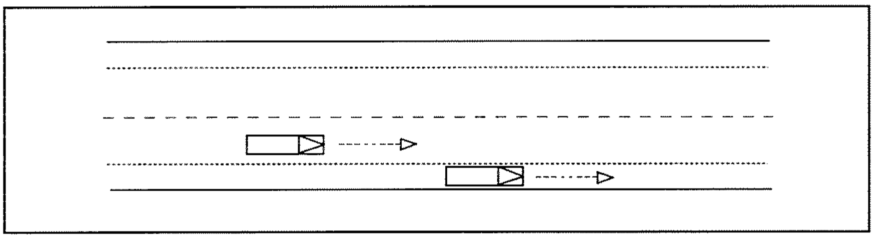
If a driver starts an overtaking manoeuvre, it seems that he or she expects (by some unwritten rule) that other road-users which are present, will swerve to the right or even to the shoulder to let him

or her pass freely. It was noticed that many times oncoming cars or cars from the same direction swerve voluntarily to the right shoulder. Especially in the up-hill direction, lorries give a free passing, by swerving to the shoulder voluntarily.
Although this kind of adaptive behaviour is not unsafe in itself, it creates often diffuse situations, if there is not much space to swerve. For instance in case of a driver, driving in the same direction as the overtaking vehicle, who wants to return to his or her lane (irrespective of the presence or absence of oncoming traffic), because a car is parked on the shoulder, or because the shoulder ends or becomes narrower in front.
Not all the participants are voluntarily swerving. In those cases they are often "forced" to give way, because the driver of the overtaking car goes on to carry out his manoeuvre.

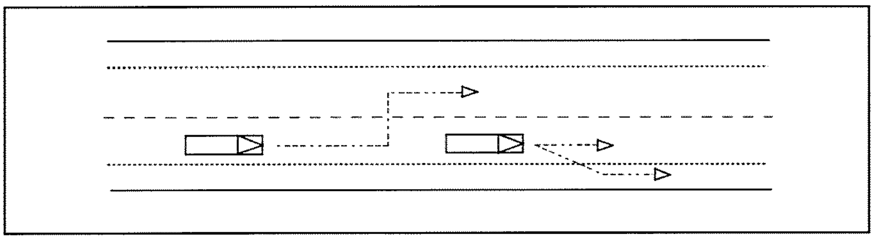
These are the reasons why it was concluded that overtaking manoeuvres had to be studied in relation with actions of drivers of oncoming traffic or driving in the same direction. Therefore, the following categories are added for scoring:
- Overtaking with oncoming traffic; with/without a test car standing on the shoulder (at the camera 2 position only).
- Overtaking without oncoming traffic; only scored if the manoeuvre could be carried out, without a necessary action from the oncoming traffic.
- Action of the driver(s), driving in the same direction: forced or voluntarily swerving to the right or shoulder.
- Action of the oncoming driver(s): forced or voluntarily swerving to the right or shoulder.
- Overtaking on prohibited section (camera 1 position), with or without oncoming traffic.

In addition to the definitions of interactive traffic behaviour with potential risk (section 2.3 and 2.6), the following concepts are added:
- Risk classification of each disturbance with categories: low, moderate and high risk. Differences between those three categories are illustrated below:

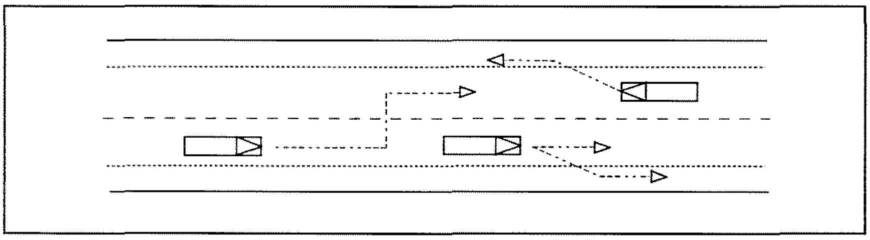
1. Free passing through: the opposite lane is not used, because the driver in front swerves voluntary to the right or shoulder; no reaction from oncoming traffic.



2. Overtaking by using the opposite lane; no reaction necessary of oncoming traffic



3. Overtaking by using the opposite lane; oncoming traffic and/or driver in front is forced to swerve to the right or shoulder



5.3. Results

The system was supposed to warn, when a driver overtakes at a prohibited section. However, this type of warning was not functioning. At camera 2, this type of violation occurs five times in the before and five times in the after period. At camera 1 this type of violation occurs 29 times in the before and 26 times in the after period.

Table 5.1: Number and types of disturbances in the before period, scored for each camera seperately, for east and west bound traffic.

Type of disturbance	camera 1		camera 2	
	system	control	system	control
1. overtaking with oncoming traffic	11	32	54	120
2. overtaking without oncoming traffic	7	11	23	29
3. pushing	-	-	1	-
4. diffuse behaviour	-	-	3	-
5. unfinished overtaking manoeuvre	2	1	13	1
6. cutting-off a curve	-	1	-	-
7. two cars overtaking at the same time	-	5	1	3
8. cutting-in manoeuvre	-	-	3	-
total	20	50	98	153

As mentioned before, camera 1 was removed and placed at the position of camera 2, because camera 2 was stolen. Therefore, further analyses will be carried out for camera 2 only.

According to our expectation, most of the disturbances are caused by an overtaking manoeuvre (Table 5.1 and 5.2: type 1, 2, 7 and 8), of which most are with oncoming traffic (type 1). For camera 2, 67% (54 out 81) of the disturbances are of that type for the experimental group and 79% (120 out of 152) for the control group. In the after period the proportion of overtakings with on-coming traffic was nearly the same for the control group (81%) and increased for the experimental group (92%), although the total number of disturbances decreased in the after period.

An explanation for the decrease in the total number of overtakings will be given later. In general, the following effects could be relevant:

- the system causes directly a reduction in the number of overtakings because the drivers are discouraged to do so;
- the system causes a reduction in high speeds and therefore reduces the need for overtaking;
- the number of overtakings is reduced because there is less traffic.

Table 5.2: Number and types of disturbances in the after period, for each camera seperately, for east and west bound traffic.

type of disturbance	camera 1		camera 2	
	system	control	system	control
1. overtaking with oncoming traffic	7	18	34	70
2. overtaking without oncoming traffic	15	-	1	16
3. pushing	-	-	-	-
4. diffuse behaviour	-	-	-	-
5. unfinished overtaking manoeuvre	-	-	2	1
6. cutting-off a curve	-	-	1	-
7. two cars overtaking at the same time	-	2	1	-
8. cutting-in manoeuvre	-	-	1	-
total	22	20	40	87

The number of overtaking actions within a disturbance, caused by an overtaking manoeuvre, can be more than one. It is often the case when a lorry gives way to traffic from behind, that three to five cars are overtaking. Therefore, a question is, whether the number of overtaking actions within a disturbance, also decreased in the after period.
From Table 5.3. it can be seen that the number of overtakings within a disturbance does not change for the control direction. The amount was 1.27 overtakings per disturbance in the before period and 1.29 in the after period. For the experimental direction these numbers are 1.43 and 1.26 respectively. Here, the number of overtakings is comparable to the control direction in the after period. Only during the before period this number is relatively high.
The marked cases in table 5.3 show that many lorries gave way to traffic from behind.

Table 5.3: Number of disturbances, caused by an overtaking manoeuvre, and the total number of overtaking manoeuvres within the disturbances for each day.

Date	control group		experimental group	
	disturbances	overtakings	disturbances	overtakings
Before period				
18/9/94	19	20	25	37
19/9/94	40	41	16	26*
20/9/94	26	42*	19	23
21/9/94	35	51*	8	16
22/9/94	24	31	18	22
23/9/94	9	10	5	6
Total	153	195	91	130
After period				
12/11/94	1	1	2	2
13/11/94	8	9	6	7
14/11/94	13	22*	5	5
15/11/94	16	18	5	6
16/11/94	8	12	4	8
18/11/94	16	18	6	7
22/11/94	11	17	7	8
23/11/94	14	15	3	5
Total	87	112	38	48

* = When a lorry gives way to traffic from behind, one disturbance is scored, but often three to five cars are overtaking.

In Table 5.4 a comparison is made between all the overtaking actions at the position of camera 2, and those scored in the disturbances, during the video recordings in the before and after period. The total number of overtaking actions, as well as those in the scored disturbances, decrease in the after period.

The most important question then is: will the proportion of disturbances, caused by an overtaking manoeuvre with a certain amount of potential risk, decrease as well? To answer this question, only these disturbances are further analysed.
The following three explanations for the decrease in the number of disturbances in the after period, caused by an overtaking manoeuvre, will be studied in more detail:

1. Traffic density decreased in the after period, and with it the necessity to overtake.
2. The interaction between cars and lorries is changed, due to the higher percentage of lorries in the traffic stream.

3. There is a direct effect of the system, due to the fact that drivers want to avoid high risk situations.

Table 5.4: comparison between all overtaking actions (both directions) and the amount of those actions within all the scored disturbances, in the before and after period.

type of day	videohours	all overt. events	overt. in disturb.	% overt. in disturbances
Before period (camera 2)				
sun 18/9/94	6.07	147	57	28%
mon 19/9/94	6.16	197	67	25%
tue 20/9/94	6.15	196	65	25%
wed 21/9/94	6.16	183	66	27%
thur 22/9/94	6.15	236	53	18%
fri 23/9/94	3.08	97	16	14%
Total	33.8	1056	325	24%
Events/hr		31	9.6	
After period (camera 2)				
sun 13/11/94	6	71	16	18%
mon 14/11/94	6	159	27	15%
tue 15/11/94	6	148	24	14%
wed 16/11/94	3	100	20	17%
fri 18/11/94	6	163	25	13%
tue 22/11/94	6	170	25	13%
wed 23/11/94	6	144	20	12%
Total	39	955	178	16%
Events/hr		24.5	4.6	

5.3.1. Comparison of traffic density in the before and after period.

As mentioned before, no loop data was available in the before period. Therefore the number of cars, motorcycles, lorries and busses are counted manually from the video tapes. In the after period, differences in numbers of cars and lorries were found between the loop data and manually counted numbers from the video tape. Therefore, only the number of vehicles (traffic density) from the video tapes will be used. For each day at the camera position 2 (before and after period) traffic density and number of overtaking actions are presented in Appendix VI. A summary is given in table 5.5.

Table 5.5 Comparison of the total number of cars and lorries/ busses and of the overtakings for each direction in the before and after period at the camera 2 position.

period	system direction			control direction		
	cars #	lorries #	lorries %	cars #	lorries #	lorries %
before	8,550	2,432	22.1	6,305	2,180	25.7
cars/hour	253	72		187	65	
overt./hour	17.09			14.18		
after	8,541	3,074	26.5	6,164	2,834	31.5
cars/hour	203	73		147	67	
overt./hour	12.61			11.26		

The number of lorries per hour does not differ much between the before and after period. However, the total number of cars per hour decreased considerably for both directions.
These figures give an indication that a considerable part of the decrease in overtakings will be explained by the decrease in the number of cars in the after period. If this decrease would have been linear with the number of cars, then the expected number of overtakings would have been decreased from 17.09 to 13.71 for the system direction and from 14.18 to 11.14 for the control direction. The actual numbers of overtakings per hour decreased to 12.61 and 11.26 respectively. This number is close to the expected number for the control direction. The expected decrease for the system direction from 13.71 with 12.61, leaves only a minor, non-significant effect as a result of the onset of the system (the z-score = 1.38).

5.3.2. Comparison of the amount of lorries in the before and after period
As said elsewhere, the decrease in overtaking actions can (partly) be caused by an increase in the proportion of heavy traffic in the after period, because the lower average speed of heavy traffic will influence overtaking actions of cars (see Table 5.3).
Therefore, disturbances, caused by an overtaking manoeuvre, are devided into disturbances with and without lorries involved, as shown in Table 5.6.

Table 5.6: Comparison disturbances, caused by an overtaking manoeuvre, for each direction devided in with/without lorries involved.

type of vehicle involved	control group		experimental group		Total
	before	after	before	after	
without lorries	39	18	41	16	114
with lorries	114	69	50	22	255
Total	153	87	91	38	369

A Chi-square analysis of this 2x2x2 table showed, that there only was a highly significant interaction between directions and vehicle types. The Chi-square value was 14.76, with one degree of freedom. All other first and second order interaction effects were not significant. All Chi-square values for interactions with period were smaller than 1. The significant interaction can be explained by the fact that the control direction is up-hill. Therefore, more overtakings with lorries are expected, because of the speed differences between cars and lorries.

5.3.3. The possible effect of the warning system on the degree of potential risk of disturbances, caused by an overtaking manoeuvre

We expect that a disturbance, if scored for a type 1. and type 2. situation as defined in section 5.2.4., would be classified with low risk. Table 5.7 shows the results. In the before and after period 23% resp. 33% of the disturbances were scored with moderate or high risk for the control group; nearly the same proportions were found for the experimental group.

A Chi-square analysis of the 2x2x2x2 table as given in Table 5.7, with type 1 and type 2 combined and also moderate and high risk combined, only showed a highly significant interaction between type of situation and level of risk which outcome is not surprising. The Chi-square value was 34.65, with one degree of freedom. The only interaction that was also significant was between direction and type of situation. The Chi-square value was 16.43, with one degree of freedom. The effect is due to the relatively high amount of type 1 and type 2 disturbances for the control direction.

Reasons for scoring type 1 or 2 situations, with moderate or high risk are:
- a lorry was involved;
- and/or the test car (standing on the shoulder) decreased the manoeuvring space;
- and/or a driver who was driving on the shoulder turns back to the lane, before all cars had passed.

It was further expected that most of the situations where other participants are forced to react (swerving to the right or shoulder), will be classified with moderate or high risk. Contrary to this expectation, a third of those disturbances were classified with low risk, in the before as well as in the after period and for both groups to the same amount. One of the causes for judging such a situation with low risk, turned out to be the critical distance between the overtaking car and oncoming traffic.

Table 5.7: Classification of risk scores, subdivided according to the three types of situations given in section 5.2.4 for the experimental and control group in the before and after period.

Risk score	Type of situation						Total	
	type 1.		type 2.		type 3.			
	Before	After	Before	After	Before	After	Before	After
Overtaking action in the control direction								
low	46	21	36	19	14	10	96	50
moderate	8	5	13	11	17	10	38	26
high	-	1	4	3	15*	7	19	11
total	54	27	53	33	46	27	153	87
Overtaking action in the experimental direction								
low	9	2	30	8	17	11	56	21
moderate	-	-	7	1	13	11	20	12
high	-	1	4	2	12*	2	16	5
Total	9	3	41	11	42	24	92	38

* = in these numbers one disturbance, concerns overtaking actions at the same time from both sides; this disturbance is scored twice in this table (once for each direction).

5.4. Summary and conclusions

According to traffic safety, the most important type of disturbance is the overtaking action with oncoming traffic, where drivers from both directions have to react, to avoid an accident. In many cases, the driver who overtakes is forcing other road-users to swerve to the right or shoulder.

On the IP-5 it is an unwritten rule that drivers, driving slower than cars from behind, give them free passing, by swerving (voluntarily) to the right or shoulder. Also in situations where cars from the opposite direction want to overtake, oncoming drivers voluntarily swerve to the shoulder, creating enough manoeuvring space. This behaviour at this particular spot often causes risky situations. Perhaps because of this rule, a lot of drivers expect others to swerve to the shoulder, for instance in case of oncoming traffic, or even force them to do so if necessary. Therefore, a warning system may reduce accident risk at this location.

The disturbance caused by an overtaking manoeuvre is decreased in the after period by 37% for each direction. The total amount of overtaking manoeuvres decreased as well considerably for both directions.
However, also the total amount of cars was strongly reduced in the same period, while the number of lorries was the same. This fact, together with the fact that the reduction was similar for both directions makes an interpretation of the reported reductions difficult. The expected reduction, due to the decrease in the number of cars was calculated, under the assumption that the number of overtakings is linearly related to the number of cars. The estimated reduction was similar to the observed reduction for the control direction and only slightly (not significantly) smaller than observed for the experimental direction.
There was no effect for overtaking manoeuvres with or without lorries involved.
Finally, no before and after effects were found with regard to the risk score of disturbances.

On the basis of this behavioural analysis it is therefore not possible to confirm a positive effect of the PORTICO Incident Warning System.
Given the conditions of the system during the experiment, with many failures of the system, due to vandalism or malfunctioning, this does not give conclusive evidence about the system potential.

APPENDIX I

* LOCATION: PORTICO DATE : TIME :from till CAM: PAGE:

case nr.	number rec.	video	disturbances (a) behav	(b) risk	COMPLEXITY left #pc	left #lor	middle #pc	middle #lor	right #pc	right #lor	# man.	? ? ?	MANOEUVRE L	M	R
01															
02															
03															
04															
05															
06															
07															
08															
09															
10															

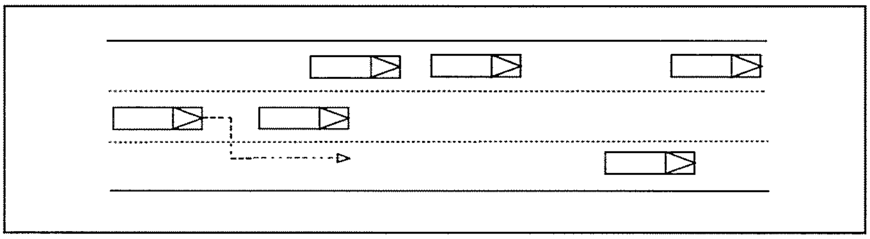
(a) BEHAVIOUR	(b) REACTION OF BEHAV (RISKY) NOT RISKY	RISKY
CORRECT = code 0	code 0	code 1
INCORR BEHAVIOUR		
overtaking right = 1	without reaction = 2	without reaction = 4
pushing beh = 2, other = 3	with reaction = 3	with reaction = 5

MANOEUVRE-CODING vihicle	manoeuvre
1 = p.c./ motor (< 6mtr)	1 = pushing bahaviour
2 = lorry	2 = to brake
	3 = overtaking to the right
	4 = overtaking to the left
	5 = keep your lane
	6 = cutt off to the right
	7 = cutt off to the left
	8 = diffuse behaviour
	9 = other

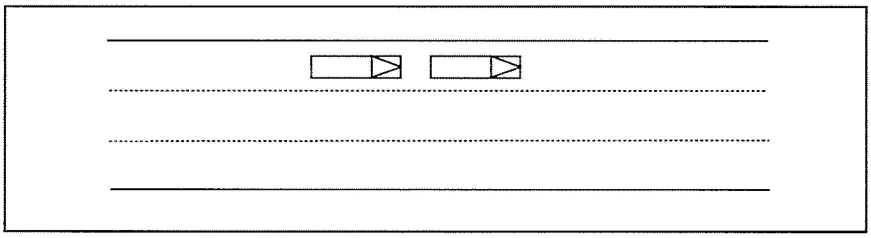
COMPARISONS BETWEEN SWOV AND LUND. APPENDIX II
(Portico, camera nr. 2., 26th of november 1993)

Nr.	Video time	Type of disturbance

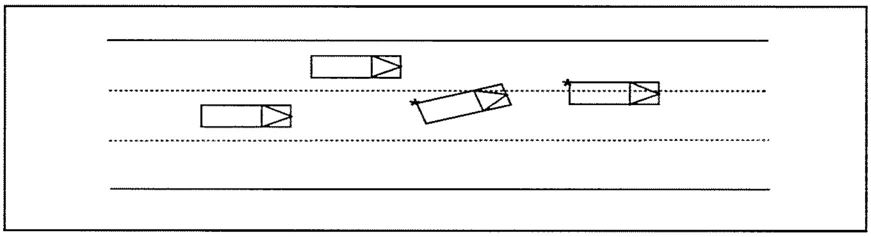
1. 00.38.48 Pushing/overtaking-to-the-right (risky)
score: SWOV: yes; LUND: no



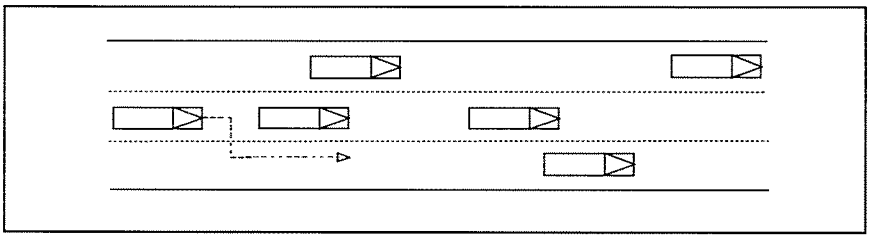
2. 01.02.05 Pushing (risky)
score: SWOV: yes; LUND: no



3. 01. 19.53 Diffuse behaviour (not risky)
score: SWOV: yes; LUND: yes



4. 01.30.09 Overtaking-to-the-right (not risky); after a reanalysis, SWOV scored this situation too.
score: SWOV: no; LUND:yes



Detailed description of the comparison between the scores from video made by SWOV and LUND with loop-detector configurations, including speed and headway data.

File name: 32602.numb; date: 22-11; time: 8.50 - 11.50

0.11.29 (type of disturbance: pushing/risky + LUND)

- Lorry (speed 143 km/h; headway 34.7) on the left lane, marked as unreliable, actually two cars (high speed and short headway). Driver of the car on the right lane (speed 108 km/h; no headway (= 0.0)) wanted to overtake a car in front (not shown in the pattern) but, the middle lane was occupied. Therefore, the driver brakes. After the middle lane is "free" the driver overtakes to the left.

1.38.6 (type of disturbance: pushing/not risky)

- Lorry (speed 118 km/h; headway 61.9) actually two cars.

1.46.4 (type of disturbance: pushing/risky)

- Lorry (speed 143 km/h; headway 15.1) actually two cars.

2.04.02 (computer time: 2.03.57) (type of disturbance: other/risky + LUND)

- Car + van on middle lane (speed and headway illegible). Car (speed 123 km/h; headway 15.1) wants to overtake-to-the-left, but the left lane is occupied. Therefore, an abrupt brake was needed.

File name: 32702.numb date: 23-11 time: 8.24 - 11.24

After synchronising video and loop detector time, approximately one minute difference between video and loop detector time was found (video time is one minute earlier). To connect the descriptions to the computer patterns (see Appendix IV), only the computer time is given here to facilitate comparison.
No corresponding patterns could be found on the second loop detector file (file name: 32703). Verification of the pattern with the video picture was necessary, also the interpretation. Only one computer pattern available.

0.07.10 (video: 06.05) (type of disturbance: other/risky + LUND)

- Car on middle lane (speed 130 km/h; headway 15.5) cut in on left lane just behind car (134 km/h; headway 35.1) and in front of car (speed 125 km/h; headway 23.1).

0.09.03 (video: 07.57) (type of disturbance: other/risky)

- Car on the right lane (speed 141 km/h; headway 115.4) cut off to the right, just in front of car (speed: 122 km/h; no car in front) on the middle lane. As a consequence, the latter had to brake.
- Mark the difference between the speed of the car on the right lane and the car in front of it on the same lane, speed 78 km/h!!).

0.11.37 (video: 10.32) (type of disturbance: overtaking-to-the-right/risky + LUND)

- Car on middle lane (speed 110 km/h; headway 33.2) drives up close to the car in front (speed 106 km/h; no headway). Overtaking to the left is not possible. Left lane is occupied. Therefore the driver brakes. At that moment car on the left lane (speed 118; headway 9.1) makes an overtaking manoeuvre to the right and had to brake too.

0.14.21 (video: 13.16) (type of disturbance: correct behaviour/risky + LUND)

- On the right lane: both cars (speed 78 km/h; headway 16.9 and speed 84 km/h; headway 16.9) have to brake because of the existence of car (speed 67 km/h; headway 81.8) in front of them. Traffic on the middle lane makes an overtaking-to-the-left manoeuvre impossible.

0.17.46 (video: 16.41) (type of disturbance: correct behaviour/risky)

- Same situation (as 14.21) on the middle lane. Car (speed 89km/h; headway 9.8) brakes for car in front on the same lane (speed 87 km/h; headway 48.4).

0.21.42 (video time: 20.38) (type of disturbance: overtaking-to-the-right/risky + LUND)

- Lorry (speed 130; headway 158.3), marked unreliable, actually two cars.

0.23.08 (video time: 23.03) (type of disturbance: correct behaviour/risky)

- Left lane is occupied. Car (speed 132; headway 53.6) on middle lane keeps its lane. Next, has to brake for car in front (speed 105; headway 20.1).

File name: 32802.numb date: 24-11 time: 8.14 - 11.14

0.11.50 (type of disturbance: pushing/risky + LUND)
- Car on middle lane (speed 123 km/h; no relevant headway) and car on left lane (speed 113; headway 143.6) passed the loop detector at the same time. Therefore, recognized as lorry by the computer. Very short headway between the cars (speed 113 km/h; headway 7.3; speed 115 km/h; headway 6.9; and speed 113 km/h; headway 143.6) on the left lane.

0.28.31 (type of disturbance: other/risky + LUND)
No comparable pattern could be found on the second loop detector file (file name: 32803). After screening the video tape the proper computer pattern could be found. Only one computer pattern available.
- Car (speed 138 km/h; headway 24.2) on the middle lane cut in to the left in front of car (speed 127 km/h; headway 79.1) on the left lane. After this manoeuvre the first car cuts off to the right just in front of car (speed 111 km/h; no headway).

0.30.8 (type of disturbance: correct behaviour/risky)
- Speed difference between car (speed 143 km/h; headway 119.8) on the left lane and car (speed 130 km/h; headway 40.1) on the middle lane, approaching car in front on middle lane (speed 101 km/h; headway 37.3).

0.35.4 (type of disturbance: correct behaviour/risky)
- Lorry (speed 73 km/h; headway 25.7) actually two cars, short headway to car in front (speed 67 km/h; headway 58.0).

0.37.34/5 (type of disturbance: other/risky + LUND)
- Two cars on the middle lane (speed 105 km/h; headway 7.4) and (speed 107 km/h; headway 76.2). Second instance, car from behind decelerates (speed 101; headway 29.2).

0.38.21/2 (type of disturbance: pushing/risky)
- Lorry (speed 127; headway 65.7) actually two cars.

0.58.50 (type of disturbance: pushing/risky)
No comparable pattern could be found on the second loop detector file (file name: 32803). After screening the video tape the proper computer pattern could be found. Only one computer pattern available.
- Car (speed 130 km/h; headway 144.2), marked unreliable, actually 2 cars. The car in front is pushed to the middle lane.

1.05.50/1 (type of disturbance: pushing/risky)
- Car (speed 138 km/h; headway 0.0) is pushed to the middle lane by car (speed 153 km/h; headway 0.0). Turning to the middle lane the driver brakes and therefore cuts off car (speed 130 km/h; headway 6.2).

1.17.59 (type of disturbance: pushing/risky)
- Lorry (speed 108 km/h; headway 49.0) actually a car and a van with a very short headway in between.

1.19.49 (type of disturbance: pushing/risky)
- Lorry, marked unreliable. On the second pattern the lorry actually has become 2 cars; car nr. 1 (speed 125 km/h; headway 0.0) and car nr. 2 (speed 126 km/h; headway 12).

1.47.19 (type of disturbance: correct behaviour/risky)
- Car (speed 90 km/h; headway 43.5) on the right lane, cut in (just behind car: speed 100 km/h) to the middle lane to overtake lorry in front.

1.48.52 (type of disturbance: overtaking-to-the-right/risky)
- Car (speed 98 km/h; headway 153.6) on the middle lane; car (speed 150 km/h; headway 0.0) on the right lane. The latter overtakes-to-the-right by 'keeping its lane'.

File name: 32902.numb date: 25-11 time: 8.13 - 11.13

0.14.17/8 (type of disturbance: pushing/risky)
- Two cars on the left lane (speed 150 km/h; headway 49.7 and speed 145 km/h; headway 6.4); pushing situation.

0.18.06 (type of disturbance: pushing/risky)
- Lorry (speed 64; headway 145.7), marked unreliable, actually two cars.

0.18.08 (type of disturbance: pushing/risky)
- Car (speed 130 km/h; headway 45.1) is pushed to turn to the middle lane by van (speed ?; headway 3.8?).

0.22.32 (type of disturbance: pushing/risky)
- Car (speed 158 km/h; headway 10.4) on the left lane is driving up close to car (speed 76 km/h !?; headway 196.9), also on the left lane.

0.57.07 (type of disturbance: other/risky)
- Car (speed 89 km/h; headway 103.7) drives in the middle of two lanes.

1.04.09/10 (type of disturbance: overtaking-to-the-right/risky)
- Car on the middle lane (speed 143 km/h; headway 35.0) overtakes the car in front (speed 106 km/h; headway 0.0) to the right.
- Car (speed 120 km/h), marked as unreliable, crosses the loop detector by turning to the right lane.

1.49.08 (type of disturbance: other/risky)
- Van on the left lane (speed 105 km/h; headway 26.9) crosses the loop detectors while changing lanes from left to middle lane. Next, changes his mind and returns to the left lane (probably caused by car (speed 54 km/h; headway 72.2))?

1.50.04 (type of disturbance: pushing and overtaking-to-the-left/risky)
- Lorry (speed 141 km/h; headway 0.0), marked as unreliable, actually car with trailer.

<u>File name: 33002.numb   date: 26-11   time: 8.09 - 11.09</u>

After synchronising video and loop detector time, approximately one minute difference between video and loop detector time was found (video time is one minute earlier). To connect the descriptions to the computer patterns (see Appendix IV), only the computer time is given here.

8.38.10 (video time: 0.28.10) (type of disturbance: other/risky)
No corresponding pattern could be found on the second loop detector file (file name: 330003). Verification of the pattern with the video picture was necessary. Only one computer pattern available.
- Two cars on left lane (second car: speed 115 km/h; first car: speed 113 km/h). Second car swerve to the right and is blocked by car on the middle lane (speed 87 km/h).

0.30.19 (video time: 0.29.19) (type of disturbance: overtaking-to-the-right/risky)
- Car (speed 107 km/h; headway 84.3) on the left lane, indicates direction to the right after passing a car on the middle lane. Car on the right lane (speed 106 km/h) entered the video screen on the middle lane. This driver overtakes to the right, because left lane is blocked.

0.39.17 (video time: 0.38.17) (type of disturbance: other/risky)
- Car (speed 115 km/h; headway 22.7) crossed the loop detector by changing lanes (from left to middle). Middle lane is blocked, therefore the driver turns back to the left lane by cutting in to the left.

0.39.49 (video time: 0.38.48) (type of disturbance: pushing/risky <u>and</u> overtaking-to-the-right/risky)
- Lorry (speed 105 km/h; headway 33.1), marked as unreliable, actually car + van. Car on the middle lane (speed 125 km/h; headway 24.2) overtakes car in front (speed 99 km/h; headway 109.6) on the right side.

0.40.0 (video time: 0.39.00) (type of disturbance: pushing/risky)
- Car (speed 121 km/h; headway 5.8) is pushing car (speed 120 km/h; headway 25.6). Further on, an overtaking manoeuvre to the right is probably carried out.

0.40.27 (video time: 0.39.27) (type of disturbance: other/risky)
- Car (speed 120 km/h; headway 5.0) started an overtaking manoeuvre to the right, changed his mind and kept pushing.

0.41.41 (video time: 0.40.41) (type of disturbance: overtaking-to-the-right/risky)
- Overtaking to the right manoeuvre by car (speed 153 km/h; headway 41.4), but right lane is blocked.

0.42.44 (video time: 0.41.44) (type of disturbance: pushing/risky)
- Lorry (speed 138 km/h; headway 11.9), marked as unreliable, actually two cars. Changing lanes car (speed 118 km/h; headway 17.1) crosses the loop detectors.

0.43.10 (video time: 0.42.10) (type of disturbance: pushing/risky)
- Lorry (speed 127 km/h; head way 0.0), marked as unreliable, actually two cars. Car in front indicates direction to the right (middle lane).

0.44.18 (video time: 0.43.18) (type of disturbance: pushing/risky)
- Two cars on the left lane (speed 127 km/h and 122 km/h). Driver of car (speed 89 km/h; headway 6.1) overtakes to the left in front of oncoming cars on the left.

0.54.07 (video time: 0.53.07) (type of disturbance: pushing/risky)
- Car (speed illegible; headway 1.2) is overtaking car (speed 125 km/h; headway 0.0). The latter changed lanes to the right. Both cars are interpreted as lorry, marked as unreliable.

1.02.48 (video time: 1.01.48) (type of disturbance: pushing/risky)
- Lorry (speed 134 km/h; headway 91.7), marked as unreliable, actually two cars.

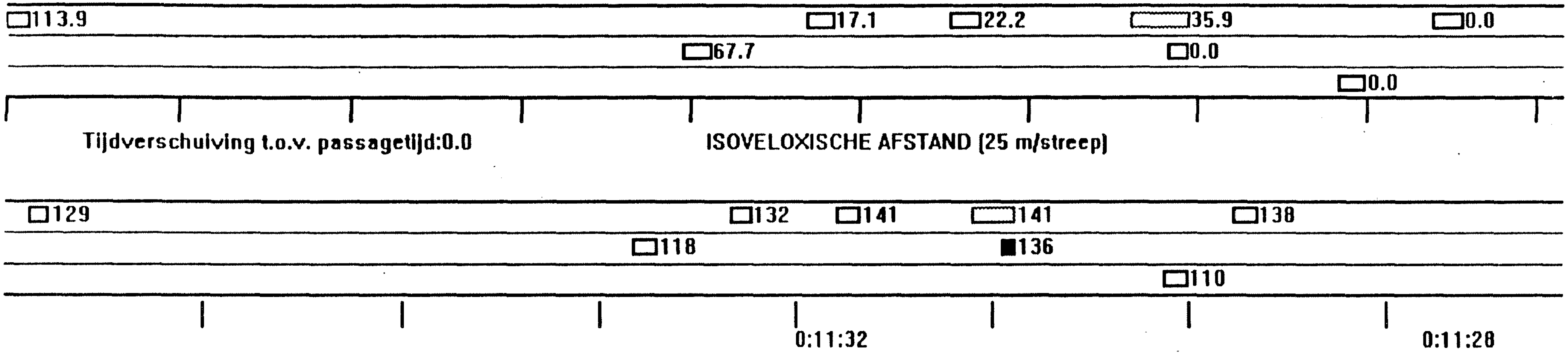
1.03.06 (video time: 1.02.05) (type of disturbance: pushing/risky)
- Lorry (speed 129 km/h; headway 114.6), marked as unreliable, actually two cars. Car, coming from behind, overtakes car in front on the right side.

2.14.14 (video time: 2.13.14) (type of disturbance: pushing/risky)
- Lorry (speed 138 km/h; headway 0.0), marked as unreliable, actually two cars.

c:\blux\e32603.num
Begintijd : 23:1:26
Eindtijd : 23:0:56
Traject : 8
Animatiestap: 20

TTC grens : 2
Opdruk afstand : 4
Inhaal interactie: 4
Reactietijd noodstop:1

STATUS : POSITIE BER.



c:\blux\e32602.num
Begintijd : 23:0:18
Eindtijd : 22:59:40
Traject : 8
Animatiestap: 20

TTC grens : 2
Opdruk afstand : 4
Inhaal interactie: 4
Reactietijd noodstop:1

STATUS : POSITIE BER.

113.5 15.9 21.9 34.7 0.0
64.6 0.0
0.0

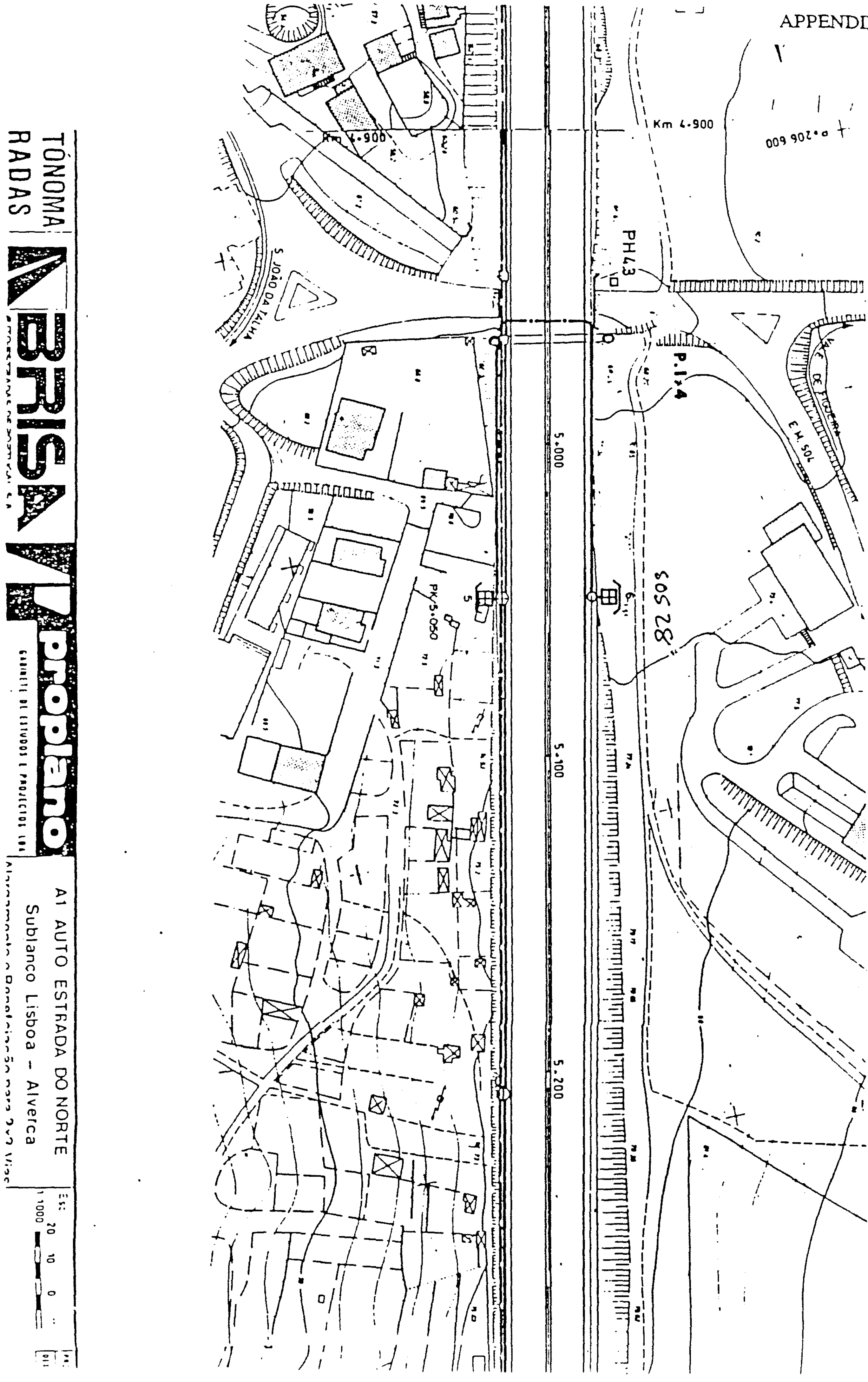
Tijdverschuiving t.o.v. passagetijd:0.0

ISOVELOXISCHE AFSTAND (25 m/streep)

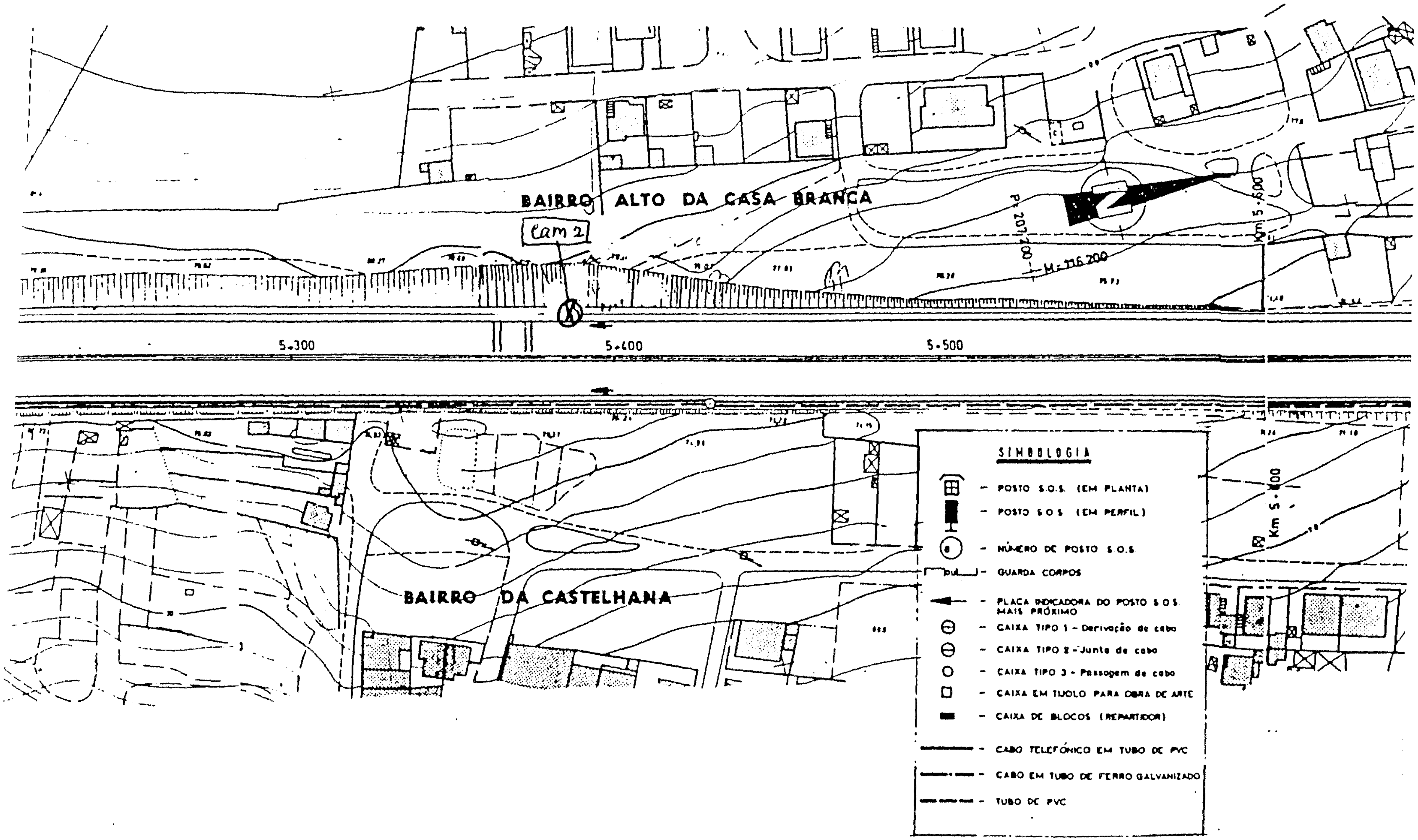
129 132 138 143 138
118 141
108

0:11:29 0:11:25

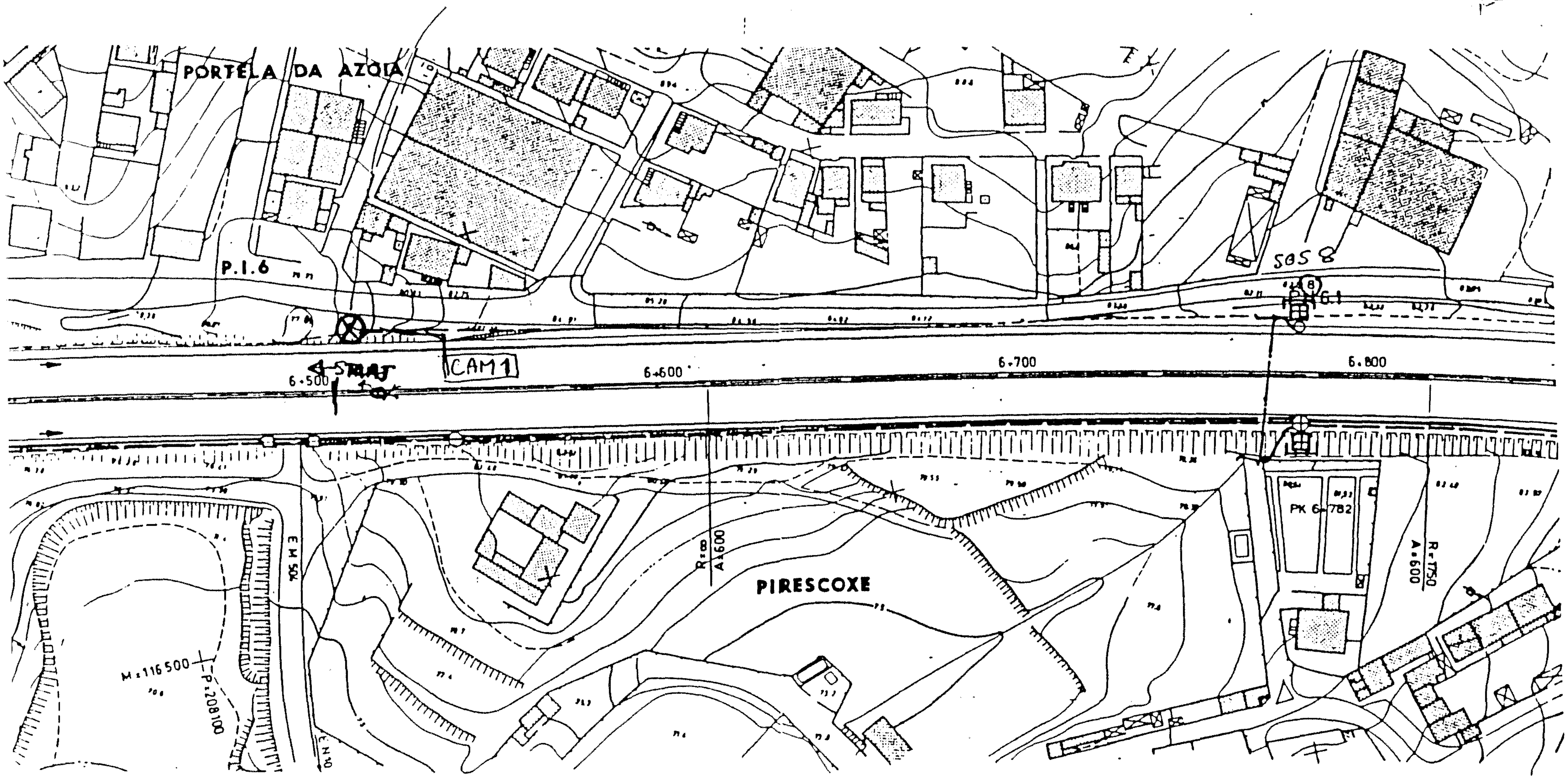
APPENDIX V



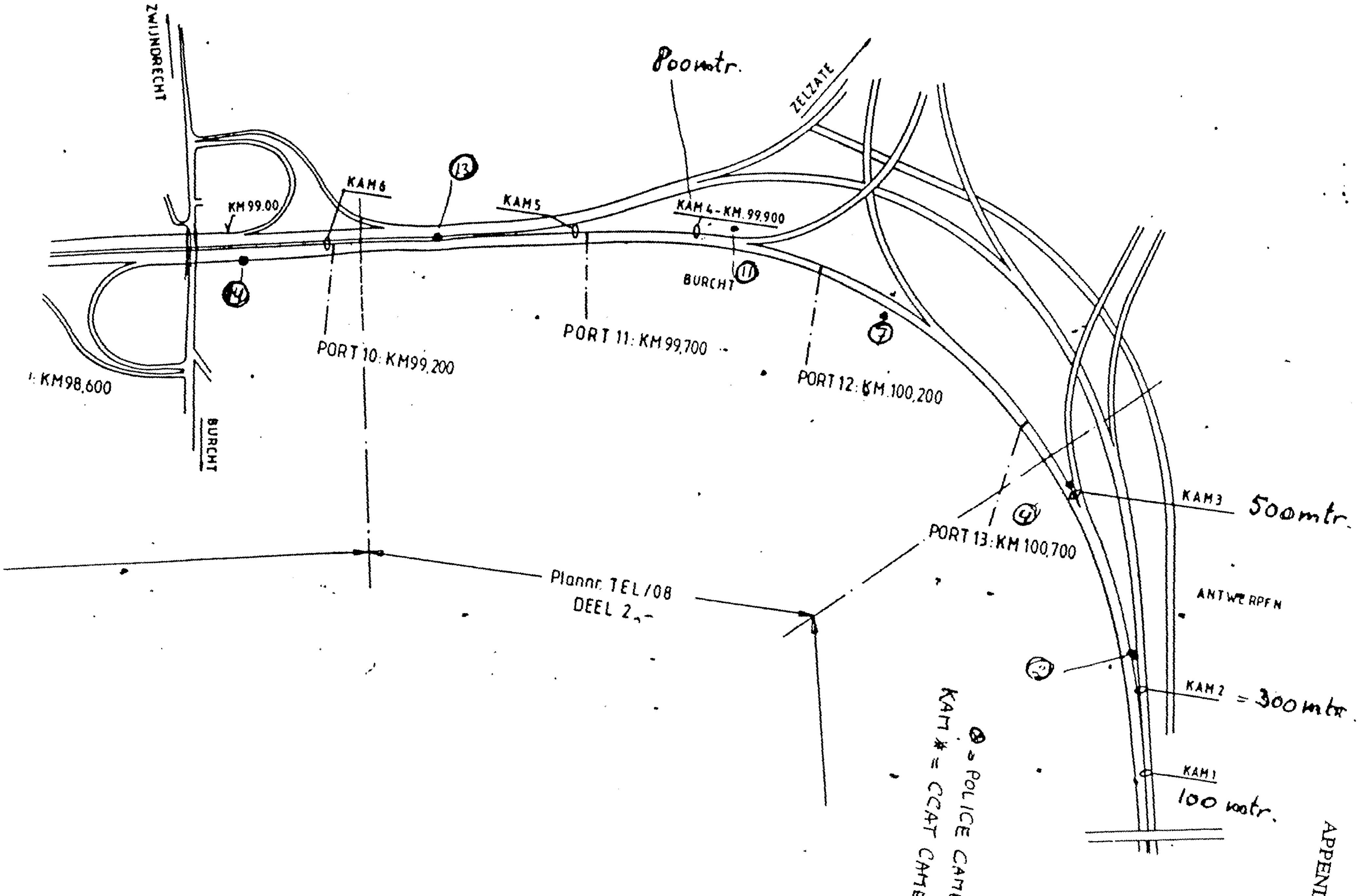
A1 AUTO ESTRADA DO NORTE
Sublanco Lisboa - Alverca
BRISA
propiano
Km 4.900
PH43
P.I.4
5.000
5.100
5.200
PK 5.050
S. JOÃO DA TALHA
E.M. SOL



ORTE erca 2x2 Vias	Esc 1:1000 20 10 0	PROJECTOU DESENHOU	SUBSTITUI	Nº PROCESSO PROPLANO 344/89	DESIGNAÇÃO PROJECTO DE EXECUÇÃO TELECOMUNICAÇÕES	Nº DE ORDEM



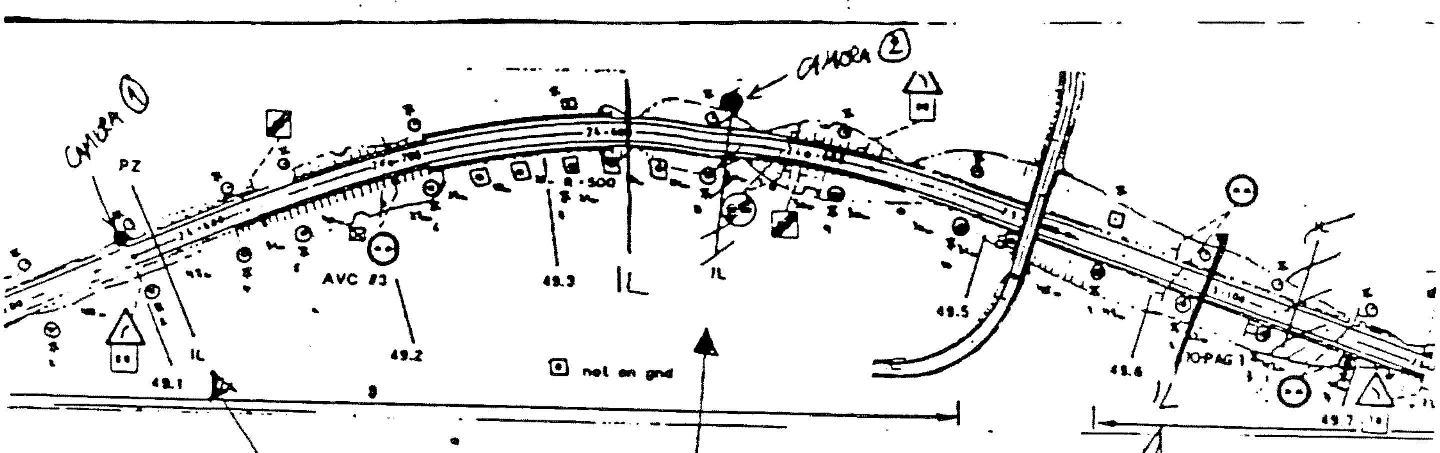
A1 AUTO ESTRADA DO NORTE | ESC 20 10 0 10 | PROJECTOU | SUBSTITUI | Nº PROCESSO PROPLANO



ZWIJNDRECHT
BURCHT
KM 99.00
KM98,600
KAM 6
13
KAM 5
800mtr.
ZELZATE
KAM 4 - KM. 99.900
BURCHT
11
7
PORT 10: KM99,200
PORT 11: KM99,700
PORT 12: KM.100,200
PORT 13: KM 100,700
KAM 3
500mtr.
ANTWERPEN
KAM 2
= 300 mtr.
KAM 1
100 mtr.
Plannr. TEL/08
DEEL 2
⊗ = POLICE CAME
KAM * = CCAT CAME

APPENDI

APPENDIX VII



The markings IL stand for inductive loops