CAJ HOLM
E-mail: caj.holm@traficon.fi
Traficon Ltd.
Länsiportti 4, FIN-02210 Espoo, Republic of Finland
RONALD WESTERMARK
E-mail: ronald.westermark@tiehallinto.fi
Finnra, VUOLI-project
Laivanrakentajantie 2 A, Helsinki, Republic of Finland
MARIO ANŽEK, D.Sc.
E-mail: mario.anzek@fpz.hr
University of Zagreb,
Faculty of Transport and Traffic Sciences
Vukelićeva 4, HR-10000 Zagreb, Republic of Croatia

Traffic Management
Preliminary Communication
Accepted: May 22, 2006
Approved: Oct. 16, 2006

VUOSAARI HARBOUR ROAD TUNNEL TRAFFIC MANAGEMENT AND INCIDENT DETECTION SYSTEM DESIGN ISSUES

ABSTRACT

Helsinki is constructing in Vuosaari a new modern and effective cargo harbour. All cargo harbour activities will be concentrated there. The total project includes the harbour, a logistics area, traffic connections (road, railway and fairway) and a Business Park. The road connection goes through the Porvarinlahti road tunnel. The harbour will commence operating in 2008. This paper gives an overview of the tunnel design phase functional studies and risk analysis tunnel incident detection system design issues and some specific environmental features of the tunnel.

KEY WORDS

Vuosaari harbour, road tunnel, traffic management, incident detection system, design issues

1. GENERAL FEATURES OF THE TUNNEL

The Porvarinlahti tunnel is a twin-tube 1600 metres long tunnel with 2+2 lanes. It is so far the longest road tunnel in Finland. It serves the harbour, the business area linked to the harbour and also the quite large Vuosaari housing area next to the harbour. The estimated ADT in the year 2025 is 26,000, of which 36% are lorries and articulated vehicles.

The tunnel has cross-connections between the tubes at 100-metre intervals, escape routes leading to these on both sides of the carriageway and lay-bys at about 500-metre intervals. The longitudinal gradient of the diving tunnel is 3.9% and the horizontal curve radii 700m. Due to the tight geometry the normal tunnel speed limit is 70km/h. There is a 500-metre street section from the south end of the tunnel to the harbour gate and an interchange right outside the tunnel, connections to car parks and service facilities for lorries and a roundabout close to the gate.

2. MANAGEMENT DECISIONS SUPPORTED BY FUNCTIONAL STUDIES

Comprehensive functional studies were carried out to support the decision about how to control traffic during incidents and tunnel maintenance. Initially it was assumed that during the closure of a tunnel tube, traffic would be controlled bi-directionally through the other tube. The main alternative was to divert traffic during tunnel closures. Another studied alternative was to control the goods transports bi-directionally through one tube and divert the rest of the traffic. The final decision was to always divert traffic when a tunnel tube is closed.

Traffic prognoses were computed for the various management schemes: one lane closed in a tube, one tube closed and traffic controlled bi-directionally through the other tube and one tube closed and all or part of the traffic diverted to the by-pass route. All these with morning peak, daytime and afternoon peak traffic. The functionality of the network was studied in detail by simulating traffic behaviour [1].

The risks of bi-directional traffic in one tunnel tube were compared to the risks of diverting the traffic on the by-pass route [2]. The temporary conditions were assumed to occur during 2% of the tunnel operation time. Three alternatives were studied: bi-directional flow for all traffic, deviation of all traffic and bi-directional flow for lorries and articulated vehicles

Table 1 - Risk during normal operation for one year and total additional risk during temporary conditions (2% of the operation time) compared to normal conditions

2025 All figures: /year	Normal	Addition by		
		Contra flow all traffic	Rerouting all traffic	Contra flow HGV traffic + rerouting of other traffic
Accidents	0.82	0.004 – 0.015	0.049 – 0.053	0.066 – 0.076
Fatalities in accidents	0.096	-0.0004 – 0.0005	0.0027 – 0.0056	0.0037 – 0.0079
Fires	0.736	-0.0003 – 0.0009	0 – 0.01	≈ 0.01
Fatalities in fires	0.012	0.0011 – 0.0014	-0.0001	0.0009 – 0.0011
Fatalities total	0.115*	0.0007 – 0.0019	0.0026 – 0.0055	0.0046 – 0.0090

* including also "DG accidents" and "other accidents"

and deviation of car, van and bus traffic. For bi-directional flow in one tube the speed limit in the tunnel is 60km/h, for normal operation the speed limit is 70km/h.

Deviation of the traffic would lead to insignificant increase in accidents compared to bi-directional traffic. Table 1 summarises the total additional risks including both the risks for the traffic in the tunnel and the re-routed traffic.

Neither the functional studies nor the risk analysis showed any remarkable difference between the two alternatives. The final decision was based on the ventilation system design. Longitudinal ventilation was chosen due to technical and financial reasons and it did not support bi-directional traffic.

Another carefully studied risk factor was the fluency of the harbour gate. The automatic access control system that meets the IMO ISPS security code operates on two lanes. It was assumed that problems at the access control point could rapidly develop a queue of lorries outside the harbour that could even reach the tunnel. The gate operation was simulated in various traffic situations and altering the access control system functionality to emulate system malfunction. It was found that even one operating lane could handle the incoming traffic. However, the access control system will generate an automatic alert to the tunnel management system in cases of malfunction and drivers can be warned by VMS messages.

3. INCIDENT DETECTION SYSTEM DESIGN

The traffic management system is designed to give the operator appropriate tools for normal traffic management, for ensuring traffic safety and fluency in exceptional situations and also for ensuring safety during maintenance of the tunnel and its equipment.

Traffic monitoring and incident detection systems include two traffic point measuring stations, one about 500 metres outside the northern tunnel end and one on the deviation route, 19 CCTV cameras that cover the entire tunnel, its access roads and the main junctions of the deviation route and an automatic incident detection system with 46 cameras. Road and weather conditions are monitored by three road weather stations, visibility and emission measuring in the tunnel and a haze measuring sensor at the southern tunnel end.

The experiences and lessons learnt from two earlier Finnish tunnels with incident detection based on video image processing, especially the Isokylä motorway tunnel on E18 [3], were taken into consideration when defining the system requirements. Initially, the incident detection system at Isokylä gave many false detections, up to 96% of the total number. The distribution of all detections during the first survey period is given in Table 2.

Table 2 - Monthly distribution of alarms during the survey period

Month	All	False	Correct	False/day
December	380	93%	7%	11.42
January	483	98%	2%	15.32
February	135	93%	7%	4.5
March	81	93%	7%	2.42
April	69	96%	4%	2.2
June	53	98%	2%	1.73

The false detections concentrated mainly in the winter period, especially when the road surface was snowy or wet. Incident detection right outside the tunnel and at the tunnel entrance proved difficult and generated too much faulty detection. Water on the carriageway was another source of false detection. Passing cars cut the light reflected from the wet surface and generate false detections. Other fault sources were also recorded, for instance, fluttering wet trailer cover roofs and snow dropping from the trailer roofs.

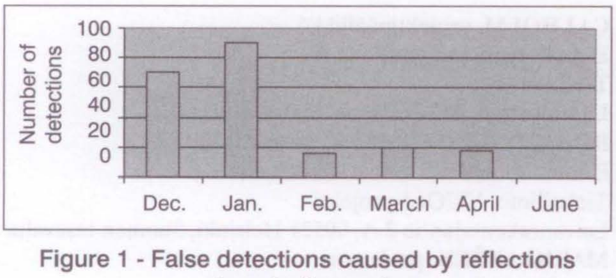

Figure 1 - False detections caused by reflections from trailer roofs

Figure 1 shows the monthly variation of false detections from trailer roofs. During spring and summer, false detections were generated outside the tunnel by sharp changing shadows on a partly cloudy day.

The system was re-configured after about one and a half year's operation but it did not, according to a second survey, give significant improvements in the system operation. Still over half of the false alarms were caused by shadows and each of the following phenomena, reflections from a trailer roof, wet road surface and wheel tracks on the road surface, produced about 10% of the false alarms.

The functional requirements for the Porvarinlahti incident detection system were tuned according to the delivery acceptance tests carried out in the Isokylä tunnel, for instance detection of 98% of stopped vehicles within 10 seconds and 95% of ghost drivers in 5 seconds, etc. The incident detection system was also designed not to cover the road sections outside the tunnel as it was concluded that it would lead to an increasing number of false alarms.

The Finnish Road Administration had also developed a formula for defining the acceptable level of faulty detections and this was included in the system requirements. According to this formula the maximum acceptable number of false alarms during one day is 0.025 * (the number of detection functions) * (the number of cameras). The detection functions are a stopped vehicle, a slow moving vehicle and a vehicle moving in the wrong direction, a so-called "ghost driver". According to the formula, the acceptable number of daily false alarms shall not exceed 0.025*3 detection functions*46 cameras = 3.5 alarms.

The first months of the tunnel operation are the most difficult for the incident detection system. It comprises the period when the system has to be tuned to work in real operation with real traffic. Before that, the functionality can be tested only by making use of single test vehicles or a group thereof, not real traffic. Thus, the functional requirements allow a tuning period of one year. A ten times higher false detection rate is accepted during the first three months, five times higher during the following three months and three times higher after half a year's operation. After one year in operation the system must meet the calculated value of maximum 3.5 false alarms per day.

4. SPECIFIC PROBLEMS OF THE PORVARINLAHTI TUNNEL

A specific problem of the tunnel is the dazzling sunlight at its southern end. The sun shines during 11 days a year, 26 – 31 January and 11 – 15 November, if it is a clear day, directly into the tunnel tubes. This is a significant traffic safety issue. A southbound driver will practically see nothing at the end of the tunnel and when leaving it. Even a northbound driver may have problems if he happens to look at the rear mirrors.

The harbour gatehouse has been designed 40 metres high to protect the tunnel from the worst haze. To prevent accidents, the control centre receives a cloudiness forecast from the Meteorological Institute and a dazzle measuring sensor alert at an actual situation. Drivers are warned about the dazzle with VMSs and the speed limit is lowered. Figure 2 shows a similar situation on the Helsinki Western Artery. Even on the open road, where the driver can prepare himself, the dazzle is a serious problem. A sudden dazzle at the tunnel end is much worse.

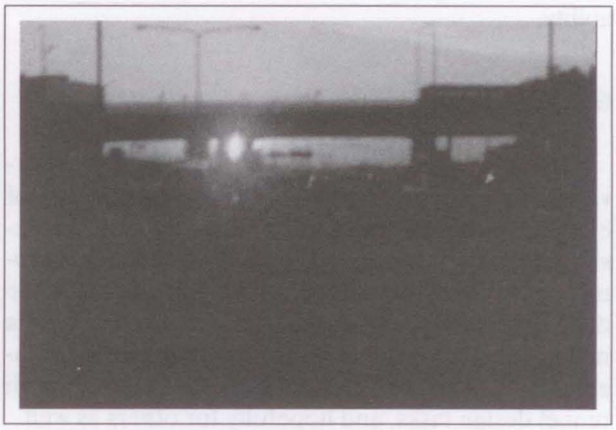

Figure 2 - Dazzling sunshine on the Helsinki Western Artery

As the tunnel is close to the sea, fog at the end of the quite long tunnel may also be a problem. The Finnish Meteorological institute studied the situation [4] and the conclusion was that the most surprising fog situations for the drivers would occur during March – April when inland fog would disappear rapidly due to sunshine but fog would remain at the sea around the clock. The traffic management system operator can react to heavy fog with similar measures as in case of the dazzle.

5. CROATIAN EXPERIENCES AND ISSUES

The question discussed in Croatia is the human – technology interrelation. Are all the applications understandable to the driver or are the multiple information interfaces, variable road signs, VMS text information, signals, barriers, loudspeaker information, understandable and do they provide unambiguous information? Are the services and interfaces on a human scale?

In Finland, it is normally not allowed to provide the driver with more than one type of information at one cross section. As an example, a VMS information board above the carriageway cannot be combined with lane signals. Similar experiences have been heard, for instance, also from Switzerland. To every new problem, the first proposed solution is to add a new sign, preferably a variable sign, although the driver has a limited capacity to understand multiple overlapping messages.

Human scale of ITS can be considered as a separate aspect related with usability. A general relation between effectiveness, efficiency and satisfaction (user comfort) and human scale of ITS depends on context, application domain, user experience, etc. Future research should emphasize the importance of holistic measuring of all the relevant aspects of ITS usability.

6. CONCLUSIONS

The traffic management design task of the Porvarinlahti tunnel was demanding due to the lack of earlier Finnish experience of similar tunnels. The design work was partly done in parallel with the development of national tunnel design guidelines. Some of the decisions were specific for this tunnel, some were of a more general type but in both cases they provide valuable know-how and experience for the future Finnish tunnel design tasks, and hopefully for others as well.

CAJ HOLM, projektipäällikkö
E-mail: caj.holm@traficon.fi
Traficon Oy
Länsiportti 4, 02210 Espoo, Suomen tasavalta
RONALD WESTERMARK, projektipäällikkö
E-mail: ronald.westermark@tiehallinto.fi
Tiehallinto, VUOLI-projekti
Laivanrakentajantie 2 A, 00521 Helsinki, Suomen tasavalta
MARIO ANŽEK, professori
E-mail: mario.anzek@fpz.hr
Zagrebin yliopisto,
kuljetus ja liikennesuunnittelutiedekunta
Vukelićeva 4, 10000 Zagreb, Kroatia

TIIVISTELMÄ

VUOSAAREN SATAMAAN JOHTAVAN MAANTIETUNNELIN LIIKENTEENHALLINTA- JA HÄIRIÖNHAVAINTOJÄRJESTELMÄN SUUNNITTELUKYSYMYKSIÄ

Helsinki rakentaa Vuosaareen uuden, nykyaikaisen ja tehokkaan kappaletavarasataman. Kaikki kaupungin rahtisatamatoiminnat keskitetään sinne. Kokonaishanke käsittää sataman, siihen liittyvän logistiikka-alueen, sataman liikenneyhteydet (tie-, rautatie- ja väyläyhteyden) sekä liiketoiminta--alueen. Tieyhteys kulkee Porvarinlahden tunnelin kautta. Sataman toiminta alkaa vuonna 2008. Tässä esityksessä annetaan yleiskuva tunnelin suunnitteluvaiheen toiminnallisista selvityksistä ja riskianalyyseistä, tunnelin häiriönhavaintojärjestelmän suunnittelukysymyksistä sekä muutamista tunnelin toimintaympäristön erityispiirteistä.

KEY WORDS

Vuosaari harbour, road tunnel, traffic management, incident detection system, design issues

LITERATURE

[1] **H. Mattila**, Traficon Ltd, *Vuosaaren sataman liikenneyhteydet, Tie- ja katuverkon sekä sataman porttialueen toimivuustarkastelut* (*Vuosaari harbour traffic connections, Functional analysis of the road and street network and the harbour gate area*), Helsinki, October 2005

[2] **Niels-Peter Hoj**, HOJ Consulting GmbH, Vuosaari Project, Porvarinlahti Road Tunnel, Risk during temporary conditions, Brunnen, March 2005

[3] **Sauli Pahlman**, Finnra, Isokylän tunnelin häiriönhavaitsemisjärjestelmän toimivuusanalyysi (Functional analysis of the Isokylä tunnel incident detction system), draft report, Helsinki, 2005

[4] **Pekka Plathan**, Finnish Meteorological institute, Sumut Porvarinlahden tunnelin eteläpäässä (Fogs at the southern end of the Porvarinlahti tunnel), Helsinki, May 2005

[5] **Anžek M., Bošnjak I.**: *Measuring Real Usability of ITS*, 14th International Symposium on Electronics in Transport – ISEP 2006, Ljubljana, 2006