Statens haverikommission
Swedish Accident Investigation Board

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Report RL 2003:19e

Incident involving aircraft OH-SAT and a passenger car at Stockholm/Arlanda airport, AB County, Sweden on the 18th of December 2001

Case L-002/02

SHK investigates accidents and incidents with regard to safety. The sole objective of the investigations is the prevention of similar occurrences in the future. It is not the purpose of this activity to apportion blame or liability.

Translated from the original Swedish by Ken Welch, at the request of the Swedish Accident Investigation Board.

In the event of discrepancies between the English and the Swedish texts, the Swedish text is to be considered the authoritative version.

The report is also available on our Web site: www.havkom.se

Statens haverikommission (SHK) Swedish Accident Investigation Board

Postadress/Postal address	*Besöksadress/Visitors*	*Telefon/Phone*	*Fax/Facsimile*	*E-mail Internet*
P.O. Box 12538	Wennerbergsgatan 10	Nat 08-441 38 20	Nat 08 441 38 21	info@havkom.se
SE-102 29 Stockholm Sweden	Stockholm	Int +46 8 441 38 20	Int +46 8 441 38 21	www.havkom.se

2003-05-28 L-002/02

Swedish Civil Aviation Administration

601 79 NORRKÖPING

Report RL 2003: 19e

The Swedish Accident Investigation Board (Statens haverikommission, SHK) has investigated an aircraft incident that occurred on the 18th of December 2001 at Stockholm/ Arlanda airport, AB county, Sweden, involving a vehicle and an aircraft with registration OH-SAT.

In accordance with section 14 of the Ordinance on the Investigation of Accidents (1990:717) the Board herewith submits a final report on the investigation.

Lena Svenaeus

Monica J Wismar Henrik Elinder

Contents

Abbreviations

AIP	Aeronautical Information Publication
AR	Airport Regulations
ATC	Air Traffic Control
ATPL (A)	Airline Transport Pilot License (Aeroplane)
BCL	Swedish regulations for civil aircraft
CAA	Civil Aviation Administration
CPL (A)	Commercial Pilot Licence (Aeroplane)
ºC	Degrees Celsius
cm	Centimeter
FLORA	Airport operations reporting
FOR	Flight Occurrence Report
GND	Ground
hPa	Hectopascal
hr/ hrs	Hour/ hours
km	Kilometer
LFV	Civil Aviation Administration (Swedish)
LVP	Low Visibility Procedure
m	Meter
MHz	Megahertz (cycles per second)
PC	Proficiency check
QNH	Atmospheric pressure at mean sea level
SMHI	Swedish Meteorological and Hydrological Institute
TWR	Tower
UTC	Universal Time Coordinated

Report RL 2003:19e

L-002/02
Report finalized 2003-05-28

Aircraft; registration, type	OH-SAT, SAAB 2000
Class, airworthiness	Normal, valid certificate of airworthiness
Owner/ operator	Swedish Aircraft Holding AB/ Air Botnia
Time of occurrence	2001-12-18, 15:49 hrs during darkness *Note:* All times are given in Swedish standard time (UTC + 1 hr)
Place of occurrence	Stockholm/ Arlanda airport, AB County, (pos. 5939N 01755E; 38 m above sea level, exit from Ramp G)
Type of flight	Scheduled traffic
Weather	Actual weather according to SMHI's analysis at 15:20 hrs: wind 230°/6 knots, visibility > 10 km, no clouds below 5 000 feet, temperature/ dew point +1/–1 °C, QNH 1018 hPa.
Persons on board; crew	2/1
passengers	10
Passenger car	Volvo 745, one person on board, unknown company identification
Injuries to persons	None
Damage to aircraft	None
Other damage	None
Commander:	
Sex, age, certificate	Male, 37 years old, ATPL (A) certificate
Total flying time	3035 hours, of which 203 hours on the type
Flying time previous 90 days	154 hours, all on the type
Number of landings previous 90 days	156
Co-pilot:	
Sex, age, certificate	Male, 29 years old, CPL (A) certificate
Total flying time	1479 hours, of which 292 hours on the type
Flying time previous 90 days	153 hours, all on the type
Number of landings previous 90 days	161
Cabin crew	One cabin attendant employed 2000-05-02

The Swedish Accident Investigation Board (SHK) was notified on the 7th of January 2002 that an incident involving an aircraft with registration OH-SAT and a passenger car had occurred at 15:49 hrs on the 18th of December 2001 Stockholm/Arlanda airport, AB county.

The incident has been investigated by SHK represented by Lena Svenaeus, Chairperson, Monica J Wismar, Chief Investigator Flight Operations, and Henrik Elinder, Chief Technical Investigator Aviation. The Board was assisted by Kåre Rumar as road safety expert.

The investigation was followed by Max Danielsson representing the Swedish Civil Aviation Administration.

Summary

The pilots in an aircraft of type SAAB 2000 had been cleared to taxi out from Ramp G at Stockholm/Arlanda airport to the holding position for runway 19R for a scheduled flight to Oulu in Finland. Darkness prevailed and in conjunction with the clearance the pilots were requested to keep a watch for an in-taxiing aircraft that had just landed on runway 26.

In order to come out onto the taxi system from Ramp G, all aircraft must cross a transport road for ground vehicles that runs parallel with a taxiway. When the commander had begun to taxi out and the aircraft was essentially at the intersection, he cast a quick glance to the left and saw a white car, of the type Volvo 745, approaching the aircraft on the transport road with an estimated speed of 40–50 km/h. In order to avoid a collision, he was forced to make a strong braking of the aircraft. He saw the vehicle pass under the nose of the aircraft and judged the vehicle's closest distance to the aircraft to be four to five meters.

All persons in the cabin sat in their seats with seatbelts fastened and no one was injured. Neither the car nor the driver has been able to be identified.

Despite the fact that the airport has a well functioning traffic safety system, the investigation has shown that deficiencies exist, which should be rectified in order to increase the safety for both aircraft and ground vehicles. Areas in which improvement can be made are, for example, design of level intersections, signs and signals, identification of ground vehicles, driving permit training, routines for the airport divergence report, monitoring and follow-up of ground traffic.

An unambiguous cause to the incident has not been possible to isolate. The incident resulted as a consequence of several independent weaknesses in the interaction between ground vehicles and aircraft at the airport.

Recommendations

The Swedish Civil Aviation Administration is, as regards Stockholm/Arlanda airport, recommended to:

- carry out a review of the road system's signs and signals *(RL 2003:19e R1),*
- improve the identification system with respect to vehicles *(RL 2003:19e R2)*,
- improve the content of the driving permit training, pedagogy, and examination *(RL 2003:19e R3)*,
- change the existing divergence reporting system to a non-punitive system in the greatest extent possible *(RL 2003:19e R4),* and
- introduce systematic traffic monitoring and traffic follow-up *(RL 2003:19e R5)*.

1 FACTUAL INFORMATION

1.1 History of the incident

On the 18th of December 2001, an aircraft of type SAAB 2000 with the flight number KF 454, belonging to the airline Air Botnia, was positioned on Ramp G at Stockholm/Arlanda airport. The pilots were cleared to taxi to the holding position for runway 19R via taxiway Z for a flight to Oulu in Finland. In conjunction with the clearance the pilots were requested to keep a watch for an intaxiing aircraft that had just landed on runway 26. Darkness prevailed and the aircraft's navigation lights, anti-collision lights, and taxi lights were illuminated. The company logo on the tail of the aircraft was also illuminated.

In order to reach taxiway Z from Ramp G, all aircraft must cross a transport road for ground vehicles that runs parallel with the taxiway. When the commander had begun to taxi and was approaching the transport road, he saw the aircraft taxiing on the high speed turnoff (XC) from runway 26. He also noted that several vehicles were on the transport road to the right of the Air Botnia aircraft, which were waiting for the aircraft to pass.

When the aircraft was essentially at the intersection, the commander glanced quickly to the left and saw a white car, of type Volvo 745, approaching the aircraft on the transport road with an estimated speed of 40–50 km/h. The vehicle did not slow down. In order to avoid a collision, the commander was forced to make a strong braking of the aircraft. He saw the car pass under the nose of the aircraft and judged the vehicle's closest distance to the aircraft to be four to five meters. Before the car disappeared on the right side of the aircraft, he thought he saw the car's brake lights illuminate for a short time. He cannot remember seeing any company identification on the car.

The commander reported the incident to traffic controllers on the taxi frequency (GND). The driver of the car did not subsequently identify him/ herself. Additionally, the occurrence was not reported by any of the drivers of the vehicles that waited on the other side of the intersection.

All persons in the cabin sat in their seats with seatbelts fastened. No one was injured

The incident occurred at position 5939N 01755E; 38 m above sea level at the exit from Ramp G.

1.2 Injuries to persons

	Crew	*Passengers*	*Others*	*Total*
Fatal	–	–	–	–
Serious	–	–	–	–
Minor	–	–	–	–
None	2/1	10	1	14
Total	3	10	1	14

1.3 Damage to aircraft

None.

1.4 Other damage

None.

1.5 The crew

1.5.1 The commander

The commander, male, was at the time 37 years old and had a valid ATPL (A) certificate.

Flying time (hours)			
Previous	*24 hours*	*90 days*	*Total*
All types	1.5	154	3 035
This type	1.5	154	203

Number of landings on this type previous 90 days: 156.
Type rating was completed on the 10th of August 2001.
Previous PC carried out on the 10th of August 2001 on SAAB 2000.

1.5.2 The co-pilot

The first officer, male, was at the time 29 years old and had a valid CPL (A) certificate.

Flying (hours)			
Previous	*24 hours*	*90 days*	*Total*
All types	1.5	153	1 479
This type	1.5	153	292

Number of landings on this type previous 90 days: 161.
Type rating was completed on the 10th of June 2001.
Previous PC was carried out the 10th of June 2001 on SAAB 2000.

1.5.3 The cabin crew

A female cabin attendant was on duty in the cabin. She was employed in the company on 2000-05-02.

1.6 The aircraft

The aircraft had a valid certificate of airworthiness.

1.7 Meteorological information

Actual weather according to SMHI's analysis at 15:20 hrs: wind 230°/6 knots, visibility >10 km, no clouds below 5 000 feet, temperature/dew point +1/–1 °C, QNH 1018 hPa.

1.8 Aids to navigation

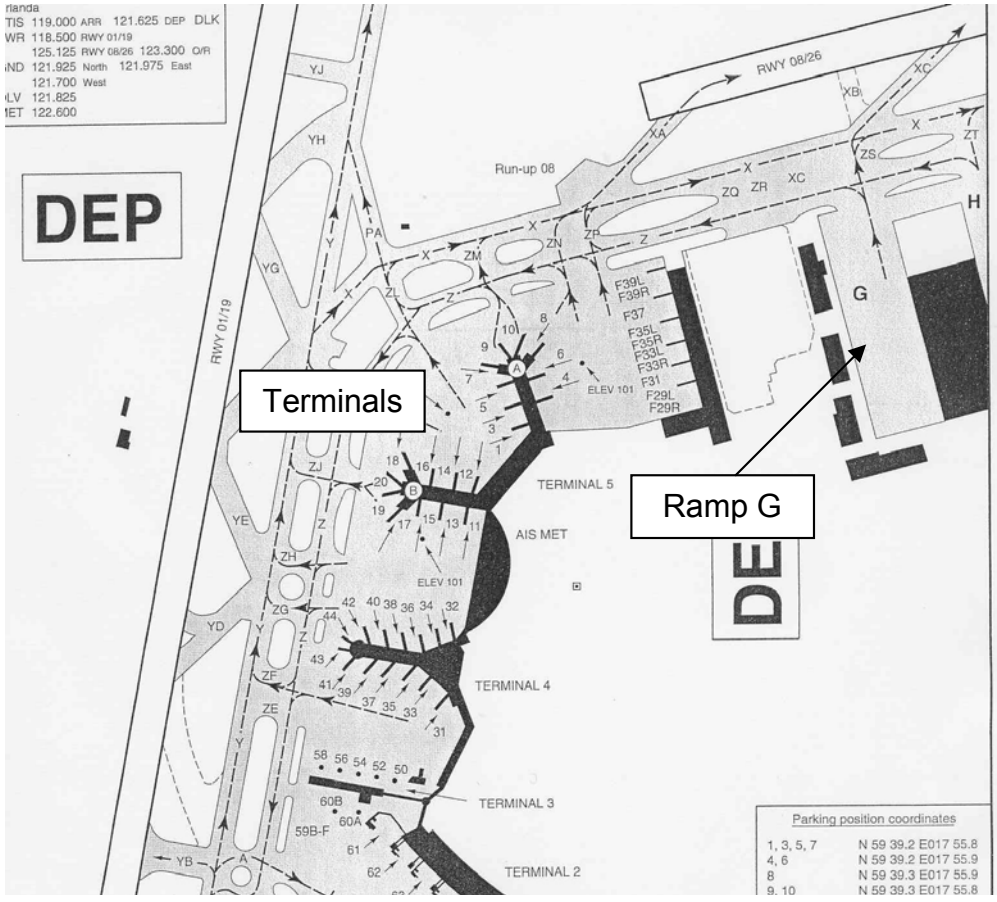
Not applicable.

1.9 Communications

Radio communication had been established between the aircraft and ATC ground control on frequency 121.700 MHz (GND). The aircraft had been cleared to taxi to the holding position for runway 19R via taxiway Z. In conjunction with the clearance the pilots were requested to keep a watch for a landing aircraft on runway 26 that would taxi in on taxiway Z. Directly after the incident, the commander reported the occurrence to ATC. To the best of SHK's knowledge, ATC has not written a report on the incident.

1.10 Aerodrome information

Stockholm/Arlanda airport is designed according to the Swedish AIP. Ramp G consists essentially of the ramp area at Arlanda's old terminal that is situated approximately one kilometer east of the present terminals. Passengers and crewmembers are transported via bus to and from aircraft that are parked on Ramp G.



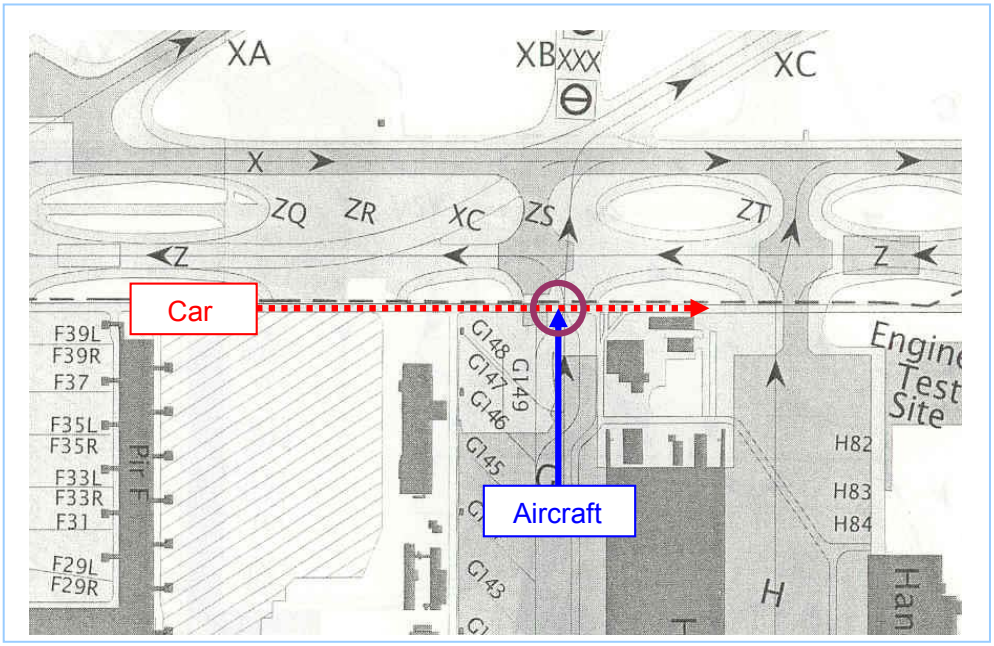
Terminals and Ramp G

1.11 Flight recorders

SHK was first notified of the incident on the 7th of January 2002. By this time the aircraft had been in operation several days and the data from the flight- and cockpit voice recorders had not been saved.

1.12 Incident site

The incident occurred at an intersection between an exit from Ramp G to taxiway Z and the ground transport road, which runs parallel to the taxiway and lies between the ramp and the taxiway. The ground transport road along this stretch is governed by LVP as elucidated in 1.16.4.



Paths of the passenger car and the aircraft

1.13 Medical information

No medical investigation was carried out.

1.14 Fire

There was no fire.

1.15 Survival aspects

Not applicable.

1.16 Stockholm/Arlanda airport[1]

1.16.1 General

Stockholm/Arlanda airport is owned and operated by the Swedish CAA. The Swedish Aviation Safety Authority shall approve flight operations at the airport. Other activities shall be operated according to the applicable regulations. The operational responsibility for the Safety Management (safety improvement work and directives) rests with the posts of the Airport Safety Manager and the Airside Safety Duty Officer.

As far as it is known, there does not exist standardized traffic rules governing ground vehicles at large airports within and outside of Sweden.

[1] Note. Refers to status at the time of the incident.

1.16.2 Design of the road system

The area outside of the closed off area of the airport is called Landside and the area inside it is called Airside. Airside is divided into a manoeuvre area, an authorization area, and an operational area[2]. The manoeuvre area consists of the takeoff/landing runways and the taxiways. This area may only be utilized by aircraft and ground vehicles that have radio communication with ATC (GND). The authorization area consists of ramps that are connected to the terminals and hangars as well as different types of transport roads. Within the authorization area, aircraft and ground vehicles may operate without radio communications under certain conditions. The operational areas consist of limited areas in direct connection to different types of service facilities that are situated near Landside.

Yellow day markings indicate taxiways for aircraft while white day markings indicate roads for ground vehicles. The safety areas around parked aircraft on the ramp are marked with red boundaries.

Entrance to the airport's authorization area requires special permission. Identification badges have different colour markings, which indicate which areas the person holding the badge has the right to enter.

Roads intended for ground vehicles are divided into three classes: red, white, and green class. Each class requires a particular driving permit, which is indicated on the respective driver's badge. The red class is composed of the so-called Inner Transport Route that runs between the manoeuvre area and the authorization area at the hangars and terminals, except for the stretch between Terminal 3 and Terminal F. The red class also includes the so-called City Road that runs along and under the terminals. The white class applies to the Inner Transport Route along the stretch between Terminal 3 and Terminal F. The green class is composed of the transport road that runs around the entire runway system at Arlanda airport. Positions in the road system where the required permit changes are normally indicated with signs in the respective colour.

The road system (marked in red) for the terminals and ramps at Arlanda airport

[2] The operational area has been discontinued as of the 1st of January 2003.

1.16.3 Rules and regulations for vehicle traffic

Vehicle traffic on the airport is principally regulated by the Swedish regulations for civil aviation, foremost BCL-F 3.1, which is published by the Swedish CAA, as well as by the AR, which is the airport's own governing and safety regulations. The traffic in the authorization areas is also governed by the Swedish Road Traffic Ordinance.

While within the authorization area, vehicles shall be driven within the vehicle thoroughfares that are marked with white paint. Motor vehicles that operate within authorization area shall be equipped with a valid vehicle permit. Additionally, motor vehicles shall be marked with company identification, so that it is clearly distinguishable to which company the vehicle belongs. (This does not apply to vehicles with authorization to drive only within the operational areas). Vehicles that are allotted temporary vehicle permits, but lack company identification, shall be allotted visitor signs at Swedish CAA's manned gates.

In order to be allowed to drive a motor vehicle within the authorization area, the driver is required to carry during the transit a valid driving license applicable to the motor vehicle in question, as well as a valid so-called driving permit. Motor vehicles may be operated within the authorization area by drivers without a driving permit under the prerequisite that the driver is escorted by a person with a valid driving permit. A security company at the airport is responsible for such escorts. The escorted vehicle shall be equipped with "Escorted" signs, which can be given out at Swedish CAA's manned gates.

Drivers, which operate vehicles within the authorization area without carrying a valid driving license for the vehicle in question and a valid driving permit, shall be escorted the nearest way to his/ her place of work within the authorization area or to the nearest gate. Driving within the authorization area may only occur in conjunction with a duty assignment.

Aircraft, including towed aircraft, always have the right of way before vehicle traffic. For vehicle drivers, this implies that if an aircraft is within a distance of 100 meter from an intersection and approaching the intersection, the vehicle may not be driven through the intersection before the aircraft has passed.

Within the authorization area there is a general speed limit of 30 km/h. The maximum speed within 15 meters from a parked aircraft is 15 km/h. Vehicles that are driven in the manoeuvre area, after having received permission from ATC to do so, are not subject to the speed limit.

When operating on the ramp, vehicles shall be driven within vehicle routes marked with white paint. Exceptions are permitted when the vehicle shall be moved from a vehicle route to an airplane or building. The vehicle shall then be moved the shortest way to/from the marked vehicle route.

Yellow or orange blinking/rotating beacons shall be used for movement outside of the marked vehicle roads. An exception applies for the above named short movements. It is forbidden to operate a vehicle inside the red safety zone when the airplane's anti-collision lights are illuminated.

Only vehicles with a gross weight exceeding 3.5 tons, except for certain special exceptions, are allowed on the Inner Transport Route between Terminal 3 and Terminal F. On this stretch, it is only permitted to use a mobile telephone if using a "hands-free" or an earpiece.

1.16.4 LVP

In haze or fog conditions, when the horizontal visibility decreases to less than 600 meters, the TWR can decide to implement LVP. This is indicated by a

steady red light from double lamps on the signal poles, which are positioned on each side of the affected road section.

This indicates to vehicle traffic that certain rules change. Vehicle traffic that intends to drive along a LVP section must have radio contact with ATC (GND). The vehicle shall indicate its presence through the use of a blinking/ rotating yellow/ orange beacon. Vehicles that are not equipped with a radio and a blinking beacon can pass under the escort of a vehicle with the requisite equipment.

LVP-sign with warning lamps

1.16.5 Vehicles and vehicle permits

All motor vehicles that traffic Stockholm/Arlanda airport shall have a vehicle permit. These permits are issued by the Swedish CAA security service. There are four types of vehicle permits: red, pink, white, and temporary. The permit shall be placed in a plastic pocket on the windshield's lower left corner or the dashboard's top left so that it can be inspected through the windshield. The permit is printed on ordinary paper (non-retroreflective).

The vehicle permits are yearly. Exceptions consist of the temporary permits that are valid for a maximum of seven days during a calendar year. Vehicles with a red vehicle permit may move freely within the airport's authorization area and between the authorization area and Landside. Vehicles with a pink vehicle permit may only operate within the airport's authorization area and may not under any circumstance leave the area. Vehicles with a white permit may travel freely within the airport's operational areas and between the operational areas and Landside.

All vehicle permits, except for the pink, can be used for several vehicles, however only for one vehicle at a time. For 2002, there were 1 362 red, 571 pink, 271 white, and 3 606 temporary valid permits. In total 2 211 vehicles were registered. The temporary permit is the most common. In November 2002 alone, 557 such permits were issued

There is also a requirement that the vehicle shall be marked. The company's identification, which shall have an outer dimension of at least 30 x 15 cm, shall be placed on both sides of the vehicle.

Every company that has vehicles with issued vehicle permits shall have an official stationed at the airport who is responsible for the vehicles.

1.16.6 Driving permits

In order to be issued a driving permit, the individual must have a valid driving license and must have associated with his or her duty an unavoidable requirement to operate a vehicle within the authorization area. In addition, the driver shall have completed a training programme and been approved by one of the Swedish CAA's authorized training coordinators.

A driving permit is valid for two years. Subsequently, the driver can have his or her driving permit renewed for another two years at a time by undergoing and passing a refresher training programme.

As soon as a driving permit ceases to be valid, or if the possessor does not in his or her duty unavoidably have a requirement to operate a vehicle in the authorization area, the driving permit is revoked. The driving permit is also revoked if the holder of the permit is guilty of repeated traffic offences or certain serious traffic offences. It is the responsibility of the driver to report such circumstances. A condition for the driver to recover the driving permit is that he or she has passed a refresher training.

The number of valid driving permits in November 2002 was 5 682. During 2002, 1 740 drivers went through basic driver training and 2 073 went through refresher training.

1.16.7 Training programme for driving permits

The Airport Safety Manager is responsible for quality control of the training programme that is required to receive a driving permit. Procedures and goals are described in a particular document (H.07.5). The training programme consists of approximately two hours theory with a training folder, the document "Att arbeta på flygplats" (Working at Airports), overhead material, a training video, as well as a map of the airport as teaching aids. The training includes a practical part of approximately two hours driving around the airport. The training programme is concluded with a written test. Refresher training contains only the theoretical part, which corresponds with the theoretical part in the basic training. The training coordinators (teachers) are quality controlled annually.

1.16.8 Traffic safety system

The traffic safety system at Stockholm/Arlanda airport is based on the operations management continually following-up which so-called problem conditions that can occur, what effect on flight safety they can have, as well as which risk- reducing measures must be taken. The Safety Testimony is a document that shall show that the airport's organisation is convinced that the safety requirements are fulfilled. The document shall also show that the system (people, equipment, manuals) fulfils the safety requirements.

Identified risks are documented in a so-called risk list. Each risk in this list is analysed in order to identify the problem area, classify the degree of seriousness, and calculate the likelihood for an undesirable event. Based on this, a risk assessment matrix is made in which one can determine if the risk situation is acceptable, should be reviewed (modified), or is unacceptable (measures must be taken directly).

If measures should be taken for a risk situation, proposals as to how this should occur are designed. Subsequently, the effect of proposed measures are analysed and evaluated to determine if they lead to an acceptable risk level.

1.16.9 The airport divergence report system

According to the BCL and the AR, a person who detects a disturbance or divergence from the applicable regulations shall, without delay, report this to his or her nearest superior. Concerning the reporting of airport operative occurrences, a reporting system called FLORA shall be used. The majority of the accidents and incidents, where ground vehicles are involved, are classified as flight safety related and reported in FLORA.

The FLORA form shall be available from the nearest supervisor. Completed reports shall be sent to the report coordinator via computer, fax, or internal mail. If the report contains a requirement for immediate action, the Airport Duty Officer shall be contacted.

The analysis of the incidents follows the risk assessment matrix that is presented in the Handbook for System Safety Analysis. In this context, risk means weighing the degree of seriousness with the probability of occurrence. Included in the analysis are three elements: What can happen? How likely is it to happen? What consequences can it have?

For unknown reasons, the actual incident was not reported in FLORA. Neither was it documented in any other manner. The incident came to the attention of ATC via the FOR that the commander of the Air Botnia aircraft wrote. The analysis of the actual incident has been presented to the Swedish Aviation Safety Authority in a report with reference number FL.2001-0793. The report indicates that at the same place – between Ramp G and taxiway Z – during 2001 there were three incidents reported between taxiing aircraft and vehicles. During the same period, approximately 25 000 aircraft movements have occurred past this position. On the basis of these statistics, the Airport Safety Controller has assessed that the likelihood for a collision according to the risk assessment matrix must be considered remote and that the occurrence was of a less serious character. The airport's judgement is therefore that the risk is acceptable.

1.16.10 Accident and incident follow-up

When an incident or an accident occurs, a judgement is first made as to whether or not an acute measure is motivated. Afterwards, a FLORA report is written, which is sent on to the report coordinator for registration and monitoring.

The disturbance is classified on the basis of which consequences for flight safety it can give rise to during takeoff, landing, or taxiing. Thereafter, the report goes on to the Airport Safety Controller, Airport Safety Management, Airport Safety Committee, Structure Development Forum, as well as the Swedish Aviation Safety Authority.

The situation is assessed from a risk viewpoint and then handled in a risk list in the same manner as described above for risk situations. Through the entire process feedback is received so that the different parties are kept in-

formed about what is happening and which measures are planned for lowering the risks.

1.16.11 Monitoring of vehicle traffic

The Swedish CAA's Airside Duty Officer and the Swedish CAA's engaged contractor, Falck Security, are responsible for the surveillance of vehicle traffic within the authorization area. This includes, among other things, the right to stop and check vehicle permits as well as driving permits and licenses. It also occurs, although rarely, that the police inspect vehicle traffic.

Within the manoeuvre area, ATC (GND) is responsible for monitoring and directing all vehicle traffic. Contact between GND and vehicle traffic is made via radio on the initiative of the vehicle drivers. GND has no responsibility for vehicle traffic within the authorization area and continuous monitoring of such traffic does not occur.

1.16.12 Sanctions

Traffic offences can result in penalty points on the driving permit and on the authorization badge according to the AR. These regulations also make clear which type of traffic offence can result in the driving permit being revoked. Three traffic offences, which occur within one year, result in the driving permit being revoked. Driving in the authorization area without a driving permit results in a penalty point on the authorization badge that has been issued to the driver. Receiving two penalty points within one year results in the badge being revoked.

A company's business contract can be subject to review, if repeated infringements of rules are noted.

1.17. Observations from investigation, etc.

1.17.1 General

Measurement of the traffic volumes concerning ground vehicles at Arlanda airport occurs, but such measurement is not carried out regularly. Furthermore, comparative statistics concerning vehicle related incidents do not exist. Also missing are routines to gather vehicle drivers' opinions about the rules and road environment at the airport. An appraisal of to what extent incidents are reported is not made at Arlanda. There is therefore no knowledge of how large the hidden figures (the unreported incidents) could possibly be.

1.17.2 Signs and signals

At the time of the incident, the stop sign in front of the intersection in question at Ramp G consisted of a six-sided board with two white crossing aircraft on a red background. The sign was partly obscured by a sign prohibiting turns to the right (see the photograph next page).

At the intersection in question, the sign with red signal lamps that indicate when LVP is in effect was placed approximately 20 meters before the stop sign.

All of the road signs on the airport are retro reflective (normal level). No sign is internally or externally illuminated.

The incident intersection at Ramp G from the car driver's perspective

1.17.3 Road markings

The different road markings (white for vehicle drivers, yellow for pilots, red for the aircraft safety zone) are not visible under snow cover. This results in difficulty for the pilots and drivers of the ground vehicles to follow the directional guidance provided by the markings. This even applies for the stop and yield lines that are located at stop and yield signs.

1.17.4 Visibility

Several of the intersections between the Inner Transport Route and the respective taxiway are not at right angles. This means that drivers of vehicles that have limited visibility at an angle behind them to the right can have difficulty detecting aircraft.

Furthermore, it has been noted that certain intersections between the Inner Transport Route and the taxiways are very wide seen from the vehicle's driver seat, which complicates visual investigation of the area.

Finally, it can be observed that the ramp leading up from one of the tunnels on the Inner Transport Route (the east/ north) is obscured.

1.17.5 LVP

With the implementation of LVP, all drivers of ground vehicles must contact GND. ATC has no technical equipment that makes it possible during LVP to follow ground vehicle movements within the areas where radio communication between GND and vehicles are required. During LVP, GND can only give the go-ahead for passage under the driver's own supervision and at his/ her own risk.

1.17.6 Vehicles and vehicle permits

It is not clear from the AR for which areas within the airport the temporary vehicle permits are valid.

The ability to easily identify vehicles varies considerably, because different types of company markings and logos are used.

Concerning several of Falck's vehicles, which are equipped with central blinking warning beacons on the roof, it has been noted that the warning beacon is not visible from the side, because it is obscured by the outside mounted blue emergency response lights.

1.17.7 Training programme for driving permits

The theoretical part of the training programme takes place in the form of a lecture. The practical part consists of driving around the airport in a mini-bus with demonstrations of the different situations. Each student is essentially a passenger and is only allowed to drive a few hundred meters.

A large portion of the education is devoted to flight safety aspects, for example the importance of removing or reporting objects that can cause damage to aircraft.

In the driving education, a lot of emphasis is placed on the students learning where at the terminals and other places of installation the so-called ramp alarms (fire alarm and stop guides) are placed and how they are marked.

The examination of first-time students as well as participants in the first refresher course takes approximately 20 minutes. The test consists of 40 multiple-choice questions with three possible answers to each question. Thirty correct answers are required to pass the exam. There is only one version of the test.

The test used for the first refresher training as well as for the first re-test uses the same questions as for the first-time test.

Participants in refresher course no. 2 and students that must take additional re-tests have to take an exam at a computer where they are to answer a number of questions that are randomly selected by the computer from a large question bank.

The document that describes the procedures and training goals for driving permit training (H.07.5) states that a written as well as a verbal exam shall be carried out. As far as SHK has gathered, there is no verbal examination. As well, there is no driving test during the refresher training.

1.17.8 The airport divergence report system

During the driving permit training programme, it is taught that incidents and other flight safety related occurrences shall be reported. The main motive for this is stated to be that one can quickly repair damaged material, get a hold of the person(s) who infringed upon the rules, as well as in the long term improve safety. Vehicle drivers who report their own incidents/mistakes are punished, if it is judged that they infringed upon a rule.

That the commander reported the current incident is corroborated by ATC. It has not been possible to find an explanation as to why it was not logged and reported according to the applicable regulations.

1.17.9 Monitoring of vehicle traffic

According to those responsible for safety at the airport, the driving discipline varies amongst the drivers that traffic the road network. A study to determine if driving discipline is better or worse within a special category of drivers has not been made.

Monitoring to ensure that vehicle drivers follow the applicable rules is carried out primarily by Falck Security and secondarily by the Airside Safety Duty Officer (previously by the Airport Duty Officer). It occurs, although rarely, that the surveillance is performed by the police. The general understanding is that the primary task of the surveillance is the protection against criminal activity (security).

The degree of monitoring (for example, number of hours, special occasions, special situations) is not documented.

1.17.10 Sanctions

During 2002, 122 driving permits received penalty points, 31 driving permits were revoked and 23 badges received penalty points, of which 5 badges received more than one penalty point.

The offences that resulted in consequences during 2002 can be divided into the following types of offences: lacking driving permit 27, forgotten driving permit 7, exceeding maximum speed limit 76, other 55.

1.18 Additional information

1.18.1 Measures taken after the incident

As a consequence of the actual incident and with the intention of decreasing the risk for collision between aircraft and ground vehicles, the following measures, among others, have been taken along the Inner Transport Route at Ramp G:

- The stop signs have been replaced with a type of sign that is used in the public road network.
- The sign prohibiting right hand turns has been removed.
- LVP-signs/lamps have been complimented with booms that lower manually with LVP conditions.
- During LVP, all vehicle traffic is prohibited on sections of the Inner Transport Route that is regulated by LVP.
- During LVP conditions, contingency for driving around the whole of Ramp G has been created.

New type of stop sign at Ramp G

LVP-booms at Ramp G

1.18.2 Previous traffic safety studies

Studies of the interplay between vehicles and aircraft at Arlanda have been carried out previously. For example, traffic studies were performed in 1988 by Kjessler & Mannerstråle and vehicle studies at Arlanda were performed in 1989 by Thyréns. The most in-depth study was carried out in 1997 as a diploma work at the Department of Technology and Society, Lund Institute of Technology (Arvidsson 1998).

SHK has, to a very limited extent, chosen to use the results and experiences from these studies. The reason is that the traffic, infrastructure, and system of regulations has changed to a large degree since these studies were carried out, in part most likely as a result of what came out of these reports.

The sections in the study that deal with drivers' behaviour, judgements, and views, however, concern aspects that are not so easily changed. One can therefore assume that these results still have certain relevance.

Arvidsson (1998) established, among other things, that a very large proportion of vehicles were lacking identification marking. One third of the drivers did not have relevant driver training (the requirement for driving permits had been in effect for approximately one year at this point). The proportion of drivers that exceeded the then applicable speed limit (40 km/hr) was approximately one third. Now the speed limit has been lowered to 30 km/hr and one can only expect that this proportion is even greater, if monitoring is not substantially improved.

Further, Arvidsson states that approximately 15 percent of drivers drove faster than 50 km/hr and even speeds of over 80 km/hr were recorded (the speed limit at that time was 40 km/hr). Many of the vehicles did not follow the road markings on the Inner Transport Route and did not obey stop signs or right of way rules with regard to aircraft. It was even observed that vehicles passed other vehicles in connection with yield situations.

Only one third of the vehicle drivers that were involved in the 44 reported incidents could be identified. Nearly half of the questioned drivers did not know what LVP involved. Monitoring of vehicle traffic occurred primarily on the City Road and during daylight. Furthermore, it is stated that unauthorized vehicles had been detected on the Airside and that it was not uncommon that certain vehicles on the Airside were lacking adequate lighting for darkness or poor visibility. The number of unreported cases (the hidden figures) when it came to incident reporting for vehicle drivers as well as for pilots was very high. During 1997, 44 incidents between taxiing aircraft and vehicles were reported. Arvidsson estimated that the true number was greater than 125.

Arvidsson (1998) proposed, among other things, that light vehicles should be prohibited on the Inner Transport Route with the aim of reducing the vehicle volume on this stretch. This proposal has since been implemented.

1.18.3 Road traffic safety work

The current incident can be considered a road traffic incident, despite the fact that one of the parties involved was an aircraft. Extensive research has been carried out and a great deal of knowledge exists within the area of traffic safety. Appendix 1 contains a compilation of information about strategies and methods that are used in the road traffic safety work and which are deemed relevant for the issues in this investigation.

1.18.4 Other observations

A comparatively large part of driver training is devoted to the ramp alarm's function and positioning. This information is important, but concerns not only

vehicle drivers, but all persons who are in the authorization area. The ramp alarms are positioned in different places at the different terminals and the other places of installation. Moreover, they are marked and distinguished in different ways and placed differently in relation to each other.

2 ANALYSIS

2.1 The incident

The incident that is dealt with in this report can be described as a road traffic incident, despite the fact that one of the parties involved is an aircraft. In Appendix 1, which contains information concerning research results in road traffic, there is also a discussion about the possible significance of these findings when applied to the conditions at Arlanda airport. The analysis and conclusions presented below are also further illustrated in the appendix.

When the aircraft left Ramp G, the pilots had been cleared to taxi to the holding position for runway 19R. ATC had requested that they keep a look out for the aircraft taxiing from runway 26. According to applicable rules, the pilots in this situation do not need to concern themselves with possible vehicle traffic in the vicinity of the aircraft. Rather, they should be able to concentrate on aircraft movements within the manoeuvre area.

It can be regarded as a coincidence that the commander in this situation looked to the left and saw the car approaching the aircraft. According to the commander's assessment, the car had most likely collided with the aircraft if he had not made an abrupt braking. SHK therefore considers that the occurrence was serious from a safety point of view.

Since neither the car nor the driver of the car have been identified, it has not been possible to positively ascertain why the car did not stop at the stop sign at the exit from Ramp G. Naturally, one can not exclude the possibility that the driver of the car consciously ignored his obligation to stop in order to be able to cross the intersection in front of the taxiing aircraft. Considering the consequences of a possible collision with a passenger plane, it is more likely to believe that the driver of the car for some reason did not notice the exit from the ramp and the taxiing aircraft before it was too late. The fact that the car's brake lights were illuminated a short instant after passing in front of the aircraft can be interpreted as that the driver first after the passage understood what had happened, but then felt that there was no reason to stop.

The possibility that the driver of the car did not detect the exit could have been due to inattention and/or too high speed, but could also have had connection with the stop sign at this place being obscured by a sign prohibiting right hand turns (see picture in section 1.17.2), or the fact that all of the signs at this place had poor visibility because it was dusk and the signs were only retroreflective. At a large airport such as Arlanda airport there is a large number of steady and moving light sources at different heights and different intensities and colours, which complicate driving during darkness and poor visibility.

If the driver realized his mistake, he or she should have reported the occurrence according to the applicable regulations. If this had occurred, valuable information may have been brought to light, which could have been used in the future to reduce the risk for a similar incident.

However, this cannot explain why a report was not submitted by any of the drivers that waited on the other side of the intersection, and that reasonably

must have observed the occurrence. An explanation could be that it is considered disloyal to report occurrences in which other drivers are involved. In any event, the neglect to report the incident indicates that the vehicle drivers lack an understanding of the importance of divergence reporting.

The existing system with different types of reprimands for committing infringements on the applicable regulations does hardly encourage reporting of one's "own mistakes". This could have been a contributing factor to the driver in this case leaving the scene of the incident and choosing to remain anonymous.

The commander did not observe any company identification on the car, which can be an indication of insufficient control of vehicle marking within the authorization area. It can also be an indication that the signs are too small and/or improperly placed and therefore do not fulfil their function.

Despite the fact that the commander immediately reported the incident to GND, no action was immediately taken, nor was any report submitted later by ATC. This is a departure from the applicable regulations and unfortunate from an investigation point of view. It has not been possible to find an explanation for this. If the incident had been directly reported to the Airside Duty Officer, it might have been possible to identify the vehicle or its driver.

2.2 Traffic environment and vehicle drivers

2.2.1 The road system

The problem with the infrastructure for road traffic at an airport that is continually under construction and expansion is classic. The situation at Arlanda airport constitutes no exception. The road system has changed as the airport has grown. Understandably, during this expansion the needs of the air traffic have been prioritized. The road traffic has been forced to adapt to the constant changes and expansion. This has resulted in the road system becoming a "patchwork" of more or less functioning roadways.

The ideal situation for road traffic as well as air traffic would be an environment where, through avoiding the use of level crossings, vehicle traffic and air traffic never came in conflict with each other. Expressed in the terms found in the description in Appendix 1, one would thus have reduced the risk of collision between vehicles and aircraft through the drastic reduction of exposure (E).

During recent years, several measures have been taken in order to improve the situation for road traffic. Among other things, the City Road and two tunnels have been built to reduce the exposure. It is now also prohibited for passenger cars to traffic the Inner Transport Route between Terminal 3 and Terminal F, measures that probably have been effective.

Despite these measures, it is SHK's opinion that there still exist deficiencies in the road system where an adaptation to the driver's situation would be desirable.

– The view from the ramp leading up from the east exit of the eastern of the newly built tunnels is obscured with respect to possible taxiing aircraft. These taxiing aircraft should be appropriately indicated for the driver who is on the way up out of the tunnel.

– Many of the intersections between the Inner Transport Route and the taxiway system are not at right angles to each other. Taxiing aircraft on the taxiway system can appear from right angles to either side as well as from oblique

angles forward or behind the vehicle driver, for example, at Ramp G. This makes it difficult for the vehicle drivers to search the intersection before they proceed across it. The taxiing aircraft sometimes approach at a relatively high rate of speed. This search of the intersection becomes especially difficult during conditions with limited visibility. Even in this situation, drivers do not receive assistance from ATC (GND).

– Certain intersections between the Inner Transport Route and the taxiways are very broad. Drivers must search a large area to assure themselves that they can cross the intersection without conflicting with taxiing aircraft. This is especially difficult during conditions with limited visibility. ATC cannot help the drivers with the present technology available to them, although this would be desirable.

2.2.2 *Signs, signals, etc.*

Certain improvements have been made regarding the design and positioning of the signs. The signs are of course retroreflective, but taking into account the large number of distracting lights that exist on the Airside and the particular importance that the signs have during limited visibility (LVP), their ability to be seen is unsatisfactory, especially on the Inner Transport Route. It is SHK´s opinion that the signs that are positioned here should be internally illuminated. Such signs capture the attention of the intended users better and are easier to read, particularly during limited visibility and conditions when the sign becomes filthy. Since electricity has been drawn to the different positions in question, such a change should not be particularly costly.

The signs that indicate which stretches of road are affected by LVP and the signals, the double red lamps, that indicate that LVP is in effect have a place of particular importance. The signs have a low readability. The signals are symbolic and their meaning is not self-evident. It has been shown in earlier studies (Arvidsson 1998) that a large proportion of the drivers did not know what the signs meant and what LVP meant in terms of driving behaviour. In addition, the signals and signs are not always positioned at the same place. Apart from the booms that have now been installed, it is SHK's opinion that the LVP signs should be internally illuminated when LVP is in force and otherwise extinguished. The double signals should be placed on top of the same pole as the signs for LVP.

The ramp alarm is of great importance for the safety at an airport. It is important that everyone within the area knows when and where different alarms shall be set off. The time factor can be very critical. It is unsatisfactory for the safety that the ramp alarms are not placed and marked in a homogeneous manner. It should be important to introduce a standard concerning the ramp alarms placement and marking.

2.2.3 *Road markings*

The three classes of roads are symbolized and displayed with the colours red, white, and green. The colours are also utilized on the driver's authorization badges. This colour code is unsuitable when considering that many vehicle drivers have colour blindness, particularly in the ability to distinguish the difference between red and green.

The road markings play a particularly important roll for drivers at an airfield, because they decide where one may drive and not drive in an otherwise open area. They even mark borders, for example the red lines, where different speed limits apply. Snow cover, wet roadways, darkness, and dirty roads greatly limit the ability to see these road markings. It thus becomes difficult for

the drivers to follow the rules, because they cannot clearly see and read these markings. Unfortunately, it is complicated to rectify this problem. A possible solution could be the use of illuminated markings similar to the type used for aircraft. The implementation of this solution for at least the stop lines would be desirable.

2.2.4 LVP, visibility in darkness

The most difficult situation involving the interaction between vehicles and aircraft is diminished visibility, particularly when the visibility is so degraded that LVP is implemented. Even if physical barriers in the form of booms that can be lowered have now been introduced, it is urgent to ensure that all vehicle drivers know what LVP entails and how they shall alter their driving behaviour.

Traffic during darkness involves particular problems for the vehicle driver. It is known from research about traffic during darkness that forward visibility with dipped headlights is often not more that 20 to 40 meters. Such limited visibility is unsatisfactory from a safety point of view. Moreover, at an airport vehicle drivers are subjected to a large number of distracting light sources from different angles, at different levels, and in different colours and intensities. The lighting at an airport is, as one might expect, adapted for air traffic and not to vehicle traffic. Consideration should therefore be given to encouraging the use of full beam headlights (at least short flashes) as required and if the circumstances allow.

Using the regulations to lower the risk for accidents can of course occur in many different ways. Apart from lowering the exposure by different physical means, at Arlanda one has attempted to reduce the accident risk through more stringent rules for drivers such as, for example, reduced speed limits, ban against mobile telephone use without the use of “hands-free”, etc. It is known from the experiences in road traffic that measures such as these have effect, in particular the reduction of speed limits, but that the effect is limited, especially if enforcement is not effective.

2.2.5 Support from ATC

In conjunction with LVP the vehicle drivers appear to expect full support from ATC in the tower at the same time as the personnel in the tower feel they do not have the possibility to take responsibility for vehicle movements along the Inner Transport Route, mainly because of weaknesses in the ground radar system and lack of other technical aids. There is cause for informing the respective parties in more detail of their duties and responsibilities in this matter.

2.2.6 Training programme for driving permits

Education, information, and training are significant preventative measures if one wants to deal with the human factor and reduce accidents and incidents, for further information, see Appendix 1.

The number of registered infractions in vehicle traffic at Arlanda is large. The true number is most likely even larger. A lot of evidence indicates that the training for driving permits is inadequate. According to SHK’s understanding, there are grounds for complementing the present education – both the theoretical and the practical portions – as well as making the examination requirements more stringent.

To a higher degree the education should be designed as an active pedagogy with questions, answers, and discussions between the instructor and students. Further, it would be advantageous if a pilot could take part in some element, so that the drivers also receive a perspective from the "flying side".

The examination should be revised so that the question bank is expanded and the questions as well as the multiple-choice answers can be selected randomly to make up an exam. It should have an even distribution of questions pertaining to the different areas for every exam. New questions can be inserted for trial in the real exams. Statistics should be conducted over the results.

It is also critical that divergence reporting, and most importantly the motive for it, becomes a larger part of the education. It should be clear for everyone that the main purpose of the reporting is to attempt to find an explanation for the incident that occurred and the mistakes that were made. The goal is to be able to take appropriate measures and minimize the risk for the recurrence of similar events. The great importance of reporting, in that it successively increases safety at the airport, must be emphasized more in the education. Every student should also receive a report form and learn practically how to fill out the form in a suitable manner.

2.3 Traffic safety system

2.3.1 General

SHK's impression is that Arlanda airport in a general sense has a well functioning traffic safety system. The ambition level is high and through the years the airport has identified and taken measures against many safety shortcomings using a systematic safety work. After the actual incident, a number of measures have been taken, which have reduced the potential for collision between ground vehicles and aircraft at the exit from Ramp G. Despite this, the investigation has brought to light a number of weaknesses in the system, which motivate additional improvement measures.

2.3.2 The airport divergence report system

The pilot's divergence reporting has a decisive importance in the continual flight safety work. A similar positive development should be possible to achieve when it concerns incidents and accidents between vehicles and aircraft. However, this assumes that the vehicle driver's divergence reporting will be as effective as the pilot's. As the above accentuates, this places a requirement that the drivers are educated and motivated to report.

It is obvious that one cannot expect that drivers will report to any great extent if they themselves or their fellow workers will be punished. Drivers that report their own incidents and mistakes should therefore escape punishment to the greatest extent possible. A good safety culture is characterised by the attitude that it is reprehensible to *neglect* to report.

A problem with this line of thinking lies in the AR for Arlanda airport. It is built on the understanding that infringements of rules are best dealt with through punishment and that driving discipline must be enforced through threat of different disciplinary consequences – from issuing penalty points to revoking the driving permit and authorisation. In an assessment of 25 types of offences in which the offending drivers risk consequences, there are many cases that in real situations can imagined to be due to unsuitable design of the physical environment, indistinct signs, unclear instructions, deficient education, tiredness, or other causes that along with an understanding of the driver's situation and known limitations in the human ability should not be character-

ised as serious faults. In these cases, there is no improvement of safety by giving out penalty points to the driver or revoking the driving permit.

It is a large changeover and somewhat of a shift in the system to begin to apply the same approach towards errors within road traffic as within air traffic. However, at Arlanda airport there is an established safety culture that contains the valuations and the methods that in the long run should encompass even the vehicle drivers at the airport. A revision of the AR with the goal of successively and to the largest extent possible replacing the disciplinary measures with other safety increasing measures is desirable. Along this line of thinking, one can also consider if a greater responsibility can be placed with the companies whose employees drive vehicles at Arlanda. The company should be encouraged to work actively to develop a safety culture among its drivers. Additionally, when it comes to the selection of drivers who shall have the task of driving at the airport, the company has a key role. The Swedish CAA has the ability, through the contracts that they make with the companies, to set different types of requirements to attempt to ensure that no unsuitable drivers are employed for this purpose.

2.3.3 Follow-up

A condition in order to be able to calculate the risks and follow the risk development is knowledge about exposure. According to what SHK has gathered, there does not exist a regular measurement of volume and composition of road traffic within Airside, which is something that should be done.

Likewise, statistics should continually be gathered on the different types of infractions that are observed. According to what SHK understands, there is a basis for this available, but it is only brought up on demand. Such follow-up should occur continuously, so that necessary measures can be taken as soon as possible.

Finally, one should regularly sample drivers' and pilots' views and experiences on the safety concerning incidents between vehicles and aircraft. There is reason to believe that the number of unreported incidents is very high. Such cooperation with the drivers where they do not run the risk of punishment should give the possibility to estimate the number of conflicts between vehicles and aircraft with greater certainty. Additionally, it would most likely also result in a number of good suggestions for improving safety.

2.3.4 Monitoring of vehicle traffic

With so many different drivers, such a large exchange of drivers, so many rules, and such limited training, supervision is the most significant factor for good driving discipline under the present conditions. A plan for systematic monitoring of vehicle traffic at Arlanda airport does not appear to exist. A plan for systematic monitoring should be developed. Monitoring should be intensified, but not such that it becomes predictable as a consequence.

Such a plan shall specify the number of inspectors at different positions as well as the items that should be checked (speed, obligation to stop/ yield, driving permit, vehicle permit, driving under the influence of alcohol, general driving discipline, etc.)

In order for the monitoring of the driving behaviour to be more effective, the driving permit should be easier to see and read. It should be placed up against the windshield and be very clear concerning the type of permit. They should also include an identification number. Additionally, they possibly should be made with retroreflective material.

2.3.5 *Identification of vehicles*

There are several reasons for easily being able to identify all vehicles that have permission to traffic the authorization area. It shall be easy to detect possible unauthorized vehicles within the area. It shall be possible to take actions against flagrant infringements. SHK's impression is that the present identification requirements are not satisfactory. The existing company markings and logos are in many cases not sufficiently clear and legible, particularly not in darkness and limited visibility. All vehicles should be marked such that the type of permit as well as the identification number can be seen from a long distance and in darkness.

Earlier it was mentioned that red and green markings on the drivers' badges are unsuitable considering that many drivers have colour blindness (in the red and green area) and therefore cannot distinguish between these colours with sufficient certainty. The same criticism can be directed towards the choice of pink as a colour for a vehicle permit. For an individual with imperfect colour vision, pink can appear white or grey in colour.

From what SHK has gathered there is no follow-up of how many temporary passes are in circulation. There are grounds to introduce routines that ensure that the return of such permits is 100 percent. One method to gain control over the return could be to place more responsibility on the companies that supply the drivers.

3 CONCLUSIONS

3.1 Findings

a) The pilots were qualified to perform the flight.
b) The incident aircraft had a valid certificate of airworthiness.
c) The incident car was operated in a manner conflicting with applicable regulations.
d) The incident car and its driver could not be identified.
e) The incident was neither reported by the vehicle driver or ATC, nor by any of the vehicle drivers who waited on the other side of the intersection in question.
f) Certain level crossings with the taxi system are unsuitably designed.
g) The road system's signs and signals can be improved.
h) Identification of the vehicles can be improved.
i) Training and examination for driving permits can be improved.
j) Routines for divergence reporting can be improved.
k) Systematic monitoring of driving discipline is lacking.
l) Statistical follow-up of traffic volumes is lacking.
m) The responsibility relationship between vehicle drivers and ATC during LVP is perceived as being unclear.

3.2 Causes of the incident

An unambiguous cause to the incident has not been possible to isolate. The incident resulted as a consequence of several independent weaknesses in the interaction between ground vehicles and aircraft at the airport.

4 RECOMMENDATIONS

The Swedish Civil Aviation Administration is, as regards Stockholm/Arlanda airport, recommended to:

- carry out a review of the road system's signs and signals *(RL 2003:19e R1),*
- improve the identification system with respect to vehicles *(RL 2003:19e R2)*,
- improve the content of the driving permit training, pedagogy, and examination *(RL 2003:19e R3)*,
- change the existing divergence reporting system to a non-punitive system in the greatest extent possible *(RL 2003:19e R4),* and
- introduce systematic traffic monitoring and traffic follow-up *(RL 2003:19e R5)*.

APPENDIX 1

Road traffic safety work

Principles, strategies and methods

A traditional method of attacking the problem of road traffic accidents is with the three "E"s:

- Education (improve the road-user's performance with the help of information, training and examination)
- Enforcement (ensure correct behaviour through effective supervision and penalties)
- Engineering (design roads, vehicles and traffic guidance such that the risk for accidents and injury is reduced)

It is reasonable to assume that these three methods of attack are also available at an airport. However, road traffic at an airport differs from normal road traffic. There are special rules and directives that the drivers must follow. Special training is therefore required for the drivers. Despite this, there occur – according to studies that have been made – many infringements of the applicable rules and directives. For this reason, a system for monitoring the driving discipline and a scale of sanctions against drivers and companies has been created. This system has not proven to be particularly effective since it has been established that drivers continue to break the rules.

Another and more general method of attacking the problem is to modify the system. An example of this strategy is when one concentrates on avoiding potential conflict points. One tries to create crossings that are not on the same level (use over-/underpasses). Cycle traffic is separated from motor traffic and pedestrian traffic from cycle traffic. Similar strategies can be applied to vehicle traffic within an airport environment.

A more modern method of tackling the problem is to see traffic accidents (A) and injuries they cause (I) as a consequence of three variables:

- Traffic volume, the exposure (E)
- Risk for a given accident given a certain traffic volume (A/E)
- The consequence of an injury given an accident (I/A)

This approach is illustrated in figure 1 where it can be seen that the amount of injury (volume of the element) is determined by the product of these three variables. Consequently, one can influence (reduce) the amount of injury through manipulating one or several of these variables.

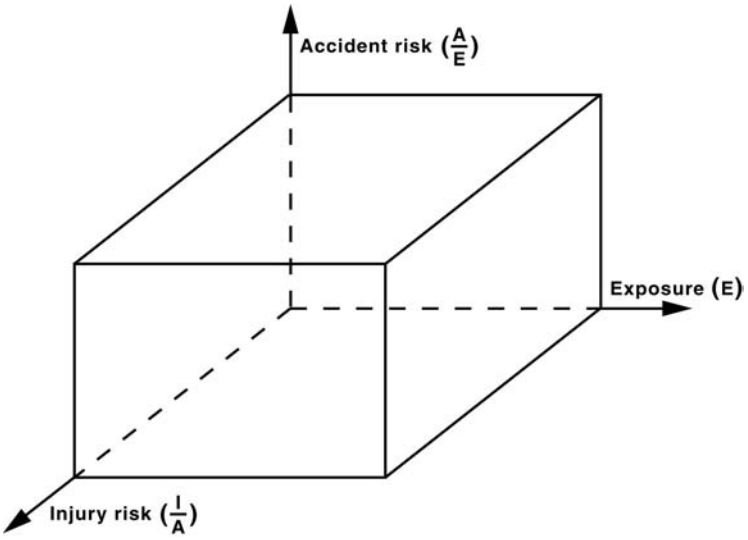


Fig. 1

When it comes to the interaction between vehicles and aircraft at an airport, one can apply the corresponding thought process. One can reduce incidents and accidents through lowering exposure or traffic volume.

Furthermore, one can reduce the risk for accidents, given a certain traffic volume or exposure, through forbidding mobile telephone calls on certain stretches of road. One can also reduce the consequence of an accident through successive speed reductions the nearer the vehicle comes to an aircraft. In order for this approach to be fully applied and give a basis for statistics, firstly knowledge of the traffic volumes is required, secondly all incidents must be reported.

A problem for the safety work on road traffic is that accidents are relatively uncommon. This fortunate fact results, however, in a rather poor statistical basis for the different safety measures taken. Within air traffic, this problem is even more pronounced. Within road traffic, one has attempted to define the incident in such a clear manner that statistics about incidents often can replace accident statistics. In this way, one can quickly build an understanding of which situations are dangerous.

When it comes to utilizing experiences from incidents in the safety work, air traffic lies far ahead of road traffic. However, the situation is different when it comes to incidents between vehicles and aircraft. For this type of incident, the level of reporting seems to be alarmingly low (Arvidsson 1998).

With road traffic, one has investigated if the "seriousness level" relating to incidents corresponds with accidents that have occurred at the same place. In this case, one has found that if one defines an incident as a situation where a time interval of one second or less separates two vehicles on a collision course, the statistics of these occurrences seem to agree with accident statistics over the long term.

Results and preventative measures dealing with drivers' errors

We know from accident and incident statistics, both within aviation as well as road traffic, that human errors are very common as a dominant or at least the instigating factor in accidents. It is what we commonly refer to as "the human factor". To err is to be human. Everyone makes mistakes now and again. We must try to decrease these errors and the consequences of them by making the system as forgiving as possible.

A common view when it comes to choosing methods to combat human errors is illustrated in figure 2, where three methods of attack are described:

1. The traditional way is to try to eliminate all the operators (drivers) that do not pass the tasks. With different selection methods, one tries to eliminate the drivers that do not meet the demands of the system.
2. Another possibility is to attempt to improve the driver's capability through monitoring, education, information, training, as well as preventing the driver's capability from being adversely affected by alcohol, drugs, tiredness, or sickness.
3. The third and in the long run the best method of reducing human error is to adapt the vehicles and environment to the human limitations when it concerns, for example, perception, decision making, and reaction capability.

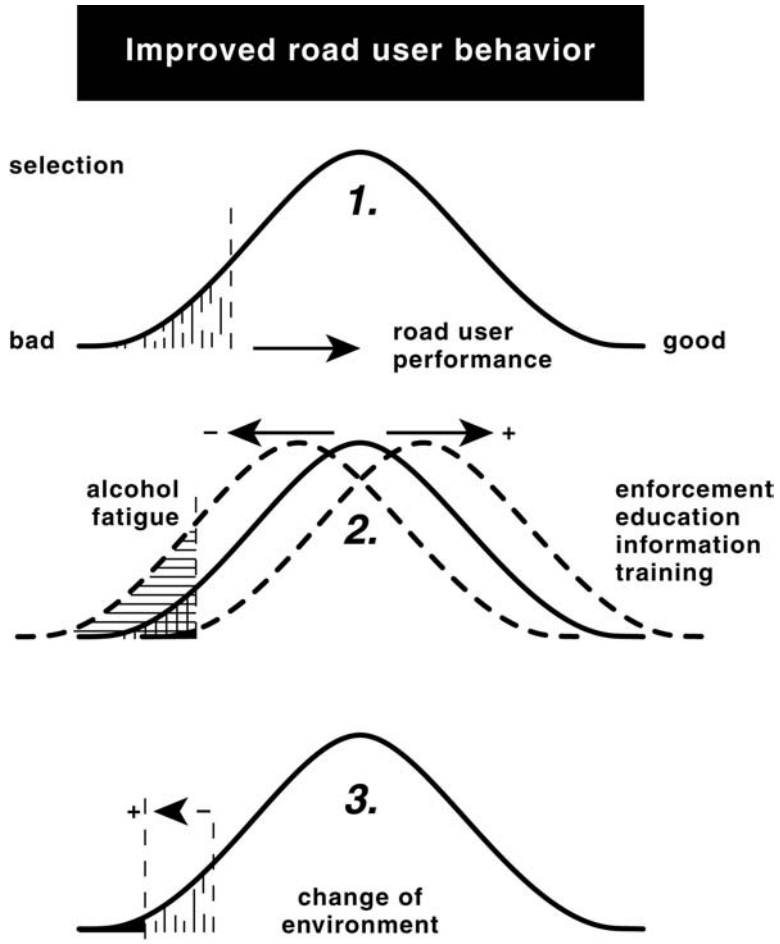


Fig. 2

The driver's perception

The most common human error in road traffic is a far too late detection of the problem. This is the explanation police most often hear after a collision has occurred. Detection of other relevant objects or events is due mainly to the following:

- What one expects to see (anticipation)
- How strong the stimulation is
- How well one scans the situation
- How good sight and hearing one has

Drivers who have driven for a long time in road traffic have through the years developed a series of expectations, which to a great extent govern the likelihood for detection. One sees what one expects to see. Entirely new situations and entirely new objects have a lower likelihood for timely detection than, for example, cars in normal situations. Here possibly lies a problem for vehicle drivers at an airfield. They have developed expectations primarily for vehicles in ordinary traffic. The likelihood that these drivers will timely detect aircraft, which look completely different and behave in a different manner and in different situations than vehicles, is relatively lower.

Furthermore, it can very well be that the degree of stimulation that an aircraft provides in many situations, despite its larger size, can be less than that from a vehicle. In order that unusual situations and objects shall be detected in good time, the degree of stimulation they provide must be strengthened. This is one of the reasons that maintenance work on roadways must be overly prominent. The drivers do not anticipate obstructions on a motorway. In fact, warning lights were made obligatory in Sweden 25 years ago for just this purpose of increasing stimulation. The vehicles are detected easier, even in situations where other road-users do not expect them. Even aircraft have a kind of warning lights (anti-collision lights), but the lights are intended for other aircraft and their pilots, rather than for vehicles and their drivers.

One can consequently expect that the likelihood of a certain event occurring effects the perception. If one passes an intersection a large number of times without encountering an aircraft taxiing in or out, the likelihood that a taxiing aircraft will be detected in time decreases. Alternatively, the aircraft must be very well marked (distinguished) in order to be detected with the same probability as it would at an intersection having a high frequency of taxiing aircraft.

How accurately one scans the area or situation depends on knowledge, education, and experience. Knowledge refers primarily to knowledge of one's own limitations in the ability to be continually attentive. Education contributes not only to this knowledge, but also to informing in which situations the scan's reliability is most critical. Experience refers to the fact that the driver subconsciously adapts his scan technique to the likelihood of a conflict occurring. If one rarely encounters an aircraft at a certain intersection, one's level of attentiveness and precision in the scan will decrease. The requirements for vision and hearing for drivers at Arlanda airport are the same as for drivers in ordinary road traffic. However, these requirements are lower than those required for pilots.

A special aspect of a driver's visual ability is the ability to distinguish colours. It is only with professional drivers in passenger traffic with more than 10 passengers that there exists a requirement for normal colour vision (this is required of all pilots). It is known that approximately 8 % of the male population have colour blindness (most commonly with difficulty in distinguishing between red and green).

Road traffic during darkness

We know that road traffic during darkness is two to three times more risky than corresponding traffic in daylight. The main reason for this increased risk is the decrease in visibility. The human eye is evolved for daylight and functions relatively poorly in traffic under darkness. Contrast sensitivity is decreased and sensitivity to being dazzled by bright lights is increased. All in all this means that if drivers are to be able to detect objects and read signs during darkness, the contrasts must be greater than in daylight. The most common method of creating such enhanced contrasts in traffic during darkness is to use retroreflective material. Reflex material, on the other hand, works only in headlights or strong, directed light. If the object or sign is oriented away from the light source, it must be separately illuminated.

Within areas with many distracting lights and where one deems that signs are particularly important, retroreflective materials with increased reflection capability or separately illuminated signs are used. An even better solution is to use internally illuminated signs, which are easiest to read and most resistant to worsened conditions such as fog and the sign becoming filthy.

Apart from reduced potential in detecting objects and reading text in traffic during darkness, the ability to orient oneself in the surroundings is to a high

degree deteriorated. In daylight the driver can, with the help of the background in his or her field of vision, orient him/herself and judge own and other's separation and speed. In traffic during darkness, the background is often not visible and this complicates the driver's ability to make judgements of different types.

Lighting at airports is primarily arranged to serve the air traffic while at the same time it should not disturb the air traffic. The visual environment at an airport is difficult for the vehicle driver. There are many flashing lamps and irrelevant light sources for the driver that complicate the task of maintaining attention directed towards the correct area and creating proper anticipations. The road markings become difficult to see and interpret at sufficiently long distance.

Dipped headlights are the vehicle light's weak point. The forward visibility with dipped headlights is often as little as 20 to 40 meters. It is unclear if drivers feel that they may drive with full beam headlights at airports, because the risk of dazzling an aircraft increases significantly.