Investigation of Runway Incursion

Joakim Markne

Carl Ström

2013-12-17
Investigation of Runway Incursion

Examensarbete utfört i Logistik vid Tekniska högskolan vid Linköpings universitet

Joakim Markne
Carl Ström

Handledare Valentin Polishchuk
Examinator Tobias Andersson Granberg

Norrköping 2013-12-17
Upphovsrätt

Detta dokument hålls tillgängligt på Internet – eller dess framtida ersättare – under en längre tid från publiceringsdatum under förutsättning att inga extraordinära omständigheter uppstår.

Tillgång till dokumentet innebär tillstånd för var och en att läsa, ladda ner, skriva ut enstaka kopior för enskilt bruk och att använda det oförändrat för ickekommersiell forskning och för undervisning. Överföring av upphovsrätten vid en senare tidpunkt kan inte upphäva detta tillstånd. All annan användning av dokumentet kräver upphovsmannens medgivande. För att garantera äktheten, säkerheten och tillgängligheten finns det lösningar av teknisk och administrativ art.

Upphovsmannens ideella rätt innefattar rätt att bli nämnd som upphovsman i den omfattning som god sed kräver vid användning av dokumentet på ovan beskrivna sätt samt skydd mot att dokumentet ändras eller presenteras i sådan form eller i sådant sammanhang som är kränkande för upphovsmannens litterära eller konstnärliga anseende eller egenart.

För ytterligare information om Linköping University Electronic Press se förlagets hemsida http://www.ep.liu.se/

Copyright

The publishers will keep this document online on the Internet - or its possible replacement - for a considerable time from the date of publication barring exceptional circumstances.

The online availability of the document implies a permanent permission for anyone to read, to download, to print out single copies for your own use and to use it unchanged for any non-commercial research and educational purpose. Subsequent transfers of copyright cannot revoke this permission. All other uses of the document are conditional on the consent of the copyright owner. The publisher has taken technical and administrative measures to assure authenticity, security and accessibility.

According to intellectual property law the author has the right to be mentioned when his/her work is accessed as described above and to be protected against infringement.

For additional information about the Linköping University Electronic Press and its procedures for publication and for assurance of document integrity, please refer to its WWW home page: http://www.ep.liu.se/

© Joakim Markne, Carl Ström
Abstract

Runway incursions (RWYI) are a daily phenomenon in the world and is a threat to safety. The severity of a RWYI can be high and it is a problem that is subject to improvements. The purpose of this report is to present the findings after an investigation of RWYI in general and what is being done to prevent it in Sweden. The main focus is to present the problem from an air traffic controller (ATCO) and pilot perspective. However, we are also presenting all the different stakeholders involved in the problem followed with associated risks and means to prevent a RWYI from happening. We also present technical aids and working methodology used today in air traffic control towers in Sweden and in addition some technology implemented abroad. Some suggested improvements that the stakeholders can take into consideration when developing their work to reduce the risk for a RWYI is also presented.

The method used during the investigation has mainly been literature studies, interviews with different stakeholders and study visits to Bromma tower, Arlanda tower and SAAB/Linköping tower.

We have found that the pilots and vehicle drivers are the most contributing stakeholders to a RWYI in Sweden. The investigation also shows that ATCOs and pilots share some opinions regarding risks but also improvements. Both ATCOs and pilots agree that weather with bad visibility, as well as darkness, is increasing the risk for an incident or accident to happen. Furthermore, complacency, fatigue and tiredness are also risks that are shared between ATCOs and pilots.

We have also found that airports have different means to prevent a RWYI. At Arlanda, the ATC system is well developed with electronic equipment and stop bars at the taxiways, which is not the case for either Bromma or SAAB/Linköping airport. Even pilots in different airlines operate differently when about to enter a runway and there is no standard operating procedure (SOP) developed in all companies.

Some of the suggested improvements are to implement stop-bars on every airport and that it should be mandatory to equip vehicles operating on the maneuvering area with maps.
Table of content

Abstract .................................................................................................................................................... i
List of Figures ........................................................................................................................................... v
List of tables ............................................................................................................................................. v
Glossary and definitions ......................................................................................................................... vi
1. Introduction ..................................................................................................................................... 1
   1.1 Background .................................................................................................................................. 1
   1.2 Company description .................................................................................................................. 1
   1.3 Purpose ....................................................................................................................................... 1
   1.4 Delimitations ............................................................................................................................ 2
   1.5 Method ....................................................................................................................................... 2
   1.6 References ................................................................................................................................... 3
   1.7 Structure of Report ..................................................................................................................... 3
2. Runway incursion ............................................................................................................................... 4
   2.1 Runway incursion severity classification .................................................................................... 4
   2.2 Runway incursions in Sweden ..................................................................................................... 4
      2.2.1 Pilot factors ........................................................................................................................... 6
      2.2.2 Airport and vehicle driver factor ......................................................................................... 6
      2.2.3 ATC factors .......................................................................................................................... 7
3. Stakeholders .................................................................................................................................... 8
   3.1 ATC ........................................................................................................................................... 8
   3.2 Airport ....................................................................................................................................... 8
   3.3 Pilots ........................................................................................................................................ 9
      3.3.1 Airline pilots ......................................................................................................................... 9
      3.3.2 General aviation pilots ........................................................................................................ 9
   3.4 The Swedish Transport Agency ................................................................................................. 9
4. Factors increasing the risk for a runway incursion .......................................................................... 10
   4.1 ATC factors ............................................................................................................................ 10
   4.2 Airport factors ........................................................................................................................... 10
   4.3 Pilot factors ............................................................................................................................ 11
   4.4 Communication factors ......................................................................................................... 11
   4.5 Weather factors ....................................................................................................................... 11
5. Means of preventing runway incursions ....................................................................................... 13
   5.1 ATC means to prevent a RWYI ............................................................................................... 13
5.2 Airport and vehicle driver means to prevent a RWYI ............................................................ 13
5.3 Visual means to prevent a RWYI ........................................................................................... 13
  5.3.1 Signs ................................................................................................................................... 13
  5.3.2 Markings ............................................................................................................................ 14
  5.3.3 Lights .................................................................................................................................. 15
5.4 Pilot means to prevent a RWYI .............................................................................................. 15
5.5 Means to prevent a RWYI by communication ....................................................................... 16
5.6 Means for The Swedish Transport Agency to prevent a RWYI .............................................. 16
5.7 Follow-ups to prevent a RWYI ............................................................................................... 16
6. Summary of study visits ................................................................................................................. 17
  6.1 Bromma airport ..................................................................................................................... 18
    6.1.1 Risks ................................................................................................................................... 19
    6.1.2 Improvements ................................................................................................................... 19
    6.1.3 Follow-up ........................................................................................................................... 19
  6.2 Arlanda airport ...................................................................................................................... 20
    6.2.1 Risks ................................................................................................................................... 21
    6.2.2 Improvements ................................................................................................................... 22
    6.2.3 Follow-up ........................................................................................................................... 22
  6.3 SAAB/Linköping airport ......................................................................................................... 23
    6.3.1 Risks ................................................................................................................................... 25
    6.3.2 Improvements ................................................................................................................... 25
    6.3.3 Follow-up ........................................................................................................................... 25
7. Compilation of the inquiry sheets sent to pilots ........................................................................... 26
  7.1 General aviation .................................................................................................................... 26
    7.1.1 Risks ................................................................................................................................... 26
    7.1.2 RGL ..................................................................................................................................... 26
    7.1.3 Working methodology ....................................................................................................... 27
    7.1.4 Improvements ................................................................................................................... 27
  7.2 Airline pilots ........................................................................................................................... 28
    7.2.1 Risks ................................................................................................................................... 28
    7.2.2 RGL ..................................................................................................................................... 28
    7.2.3 Working methodology ....................................................................................................... 28
    7.2.4 Improvements ................................................................................................................... 29
8. Abroad and future systems ............................................................................................................. 30
Air Traffic and Logistics Final Report
Linköping University
2014-01-14

8.1 Runway Status Lights................................................................. 30
8.2 Final Approach Runway Occupancy Signal................................. 31
8.3 Volumetric stop bar control sensor............................................. 31
8.4 Tower Surface Management System .......................................... 31

9. Findings from the investigation .................................................. 33
  9.1 ATC findings ........................................................................ 33
  9.2 Pilot findings ....................................................................... 34
  9.3 Airport findings .................................................................... 34
  9.4 The Swedish Transport Agency findings .................................. 35

10. Conclusion .............................................................................. 36
  10.1 Suggested improvements ......................................................... 38

References .................................................................................. 40
Appendix A – Bromma intervjuer .................................................. i
Appendix B – Arlanda Interveiw ..................................................... iv
Appendix C – SAAB/Linköping intervjuer ....................................... vi
Appendix D – General Aviation inquire sheet ................................. viii
Appendix E – Airline pilot inquire sheet ......................................... x
List of Figures

Figure 1. Number of runway incursions in Sweden (LFV, 2013).............................................................. 5
Figure 2. Amount of RWYI from January 2012 to April 2013 with ATS contribution (Magnestrand,
Uppdrag RWYI - Statistik, 2013). ............................................................................................................. 5
Figure 3. Holding point runway 11-29. .................................................................................................. 14
Figure 4. Holding point runway approach area (Studyblue, 2013). ...................................................... 14
Figure 5. ILS holding point sign (Studyblue, 2013). ............................................................................... 14
Figure 6. No entry. ................................................................................................................................. 14
Figure 7. Holding point marking. ........................................................................................................... 14
Figure 8. ILS holding point marking (Ögren, 2013) ................................................................................ 15
Figure 9. RGL......................................................................................................................................... 15
Figure 10. Red row of lights is the stop bar (Ögren, 2013).................................................................... 15
Figure 11. Bromma tower (Stockholm - Bromma, 2010) ...................................................................... 18
Figure 12. FPB with strips (FORDON) marking that the runway is occupied. ........................................ 18
Figure 13. Arlanda tower. ...................................................................................................................... 20
Figure 14. Runway is occupied, marked in the electronic FPB with a strip. ............................................. 20
Figure 15. Runway is closed illustrated by red crosses on the Surface Movement Radar. .................... 21
Figure 16. Surface Movement Radar at Arlanda. .................................................................................. 21
Figure 17. Panel to control the lights including stop bars. .................................................................... 21
Figure 18. SAAB/Linköping tower. ......................................................................................................... 23
Figure 19. Camera view in the tower. ................................................................................................... 23
Figure 20. Vehicle on the runway marked by a big strip (FORDON) and a specific strip for the vehicle
(45). ....................................................................................................................................................... 24
Figure 21. Gas-cannon to scare birds. ................................................................................................... 24
Figure 22. The red lights are the RELs (Skybrary, 2013b). ................................................................. 30
Figure 23. Pilot view of THLs, the red lights along the centreline (Skybrary, 2013b). ......................... 30
Figure 24. "Follow the greens" (Ögren, 2013). ...................................................................................... 31

List of tables

Table 1. Contributing stakeholders during the period January 2012 to April 2013 (Magnestrand,
Uppdrag RWYI - Statistik, 2013). ............................................................................................................. 6
Table 2. Summary of the main ATC findings. ........................................................................................ 33
Table 3. Summary of pilot findings. ........................................................................................................... 34
Glossary and definitions

ACR – Aviation Capacity Resources AB
ADS-B – Automatic Dependent Surveillance-Broadcast
ATC - Air Traffic Control
ATCC - Air Traffic Control Centre
ATCO - Air Traffic Controller
ATS - Air Traffic Control Service
CD – Clearance Delivery
FAA – Federal Aviation Administration
FAROS – Final Approach Runway Occupancy Signal
FDA – Flight Data Assistant
FOD – Foreign Object Debris
FPB - Flight Progress Board
GPS – Global Positioning System
ICAO - International Civil Aviation Organization
IFR – Instrument Flight Rules
ILS – Instrument Landing System
NSA – National Safety Authority
NUAC – Nordic Unified Air Traffic Control
PAPI – Precision Approach Path Indicator
PC – Proficiency Check
REL – Runway Entry Light
RGL – Runway Guard Light
RWYS – Runway Status Light
RWY – Runway
RWYI - Runway Incursion
SMR – Surface Movement Radar
SOP – Standard Operating Procedure
THL – Take-off Hold Light
TSMS – Tower Surface Management System
VFR – Visual Flight Rules
WS – Watch Supervisor

Complacency – “A feeling of contentment or self-satisfaction, especially when coupled with an unawareness of danger, trouble, or controversy” (The free dictionary, 2013).

General aviation (GA) – “All civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire” (Transport Canada, 2013).

Heads-down – “Concentrating, usually so heavy and for so long that everything outside the focus area is missed” (Dictionary.com, 2013).
Hot spot – “A location on an airport movement area with a history of potential risk of collision or runway incursion, and where heightened attention by pilots and drivers is necessary” (FAA, 2013a).


Maneuvering area – “That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, excluding aprons” (Eurocontrol, 2013a).

Movement area – “That part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and the apron(s)” (Eurocontrol, 2013b).

Read-back – “A procedure whereby the receiving station repeats a received message or an appropriate part thereof back to the transmitting station so as to obtain confirmation of correct reception” (ICAO, 2001).

VFR Traffic – Traffic conducted in accordance to the Visual Flight Rules (ICAO, 2007a)
1. Introduction

The report is written on behalf of LFV to investigate the phenomena runway incursion (RWYI). This chapter brings up the background to the problem followed by a presentation of LFV. Furthermore, this chapter contains the purpose of the report and its delimitations. The method chosen is also presented followed by a brief presentation of the main references and the structure of the report.

1.1 Background

This thesis is the last part of the air traffic controller education at Linköping University. Since the programme’s main focus has been air traffic and logistic, the problem concerning RWYI seems relevant and interesting, both from an air traffic controller point of view as well as from a logistic perspective. The initiative to the problem statement was provided by the company LFV, which will be described further in chapter 1.2.

According to International Civil Aviation Organization (ICAO), in PANS-ATM DOC 4444, the definition of a RWYI is as follows:

“Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take-off of aircraft.”

(ICAO, 2007a)

The protected area consists of the actual runway and a buffer zone around it. The buffer zone includes parts of taxiways and service roads leading to or from the runway and its size differ depending on the length and width of the runway.

The severity of a RWYI is high because aircraft operates at high velocities on and close to the runway. It is a recurring phenomenon at airports around the world and it is therefore a subject worth looking into.

1.2 Company description

LFV is the main provider of air traffic control services in Sweden. The company’s business model is that LFV “Deliver safe, efficient and environmental friendly air traffic control services for civil and military aviation” (Vision, Strategi och kärnvärden, 2012). The company has around 1300 employees operating at 32 different locations in Sweden, and the main office is located in Norrköping (Vår organisation, 2011). LFV is, together with the Danish ATC provider Naviar, co-owner of a company called Nordic Unified Air traffic Control (NUAC) providing ATC at the three air traffic control centres (ATCC) located in Stockholm, Malmö and Copenhagen. LFV also operates most of the air traffic control towers in Sweden.

1.3 Purpose

We have investigated RWYI in general and how different stakeholders in Sweden work to prevent it. The different stakeholders are air traffic control (ATC), airline pilots, general aviation (GA) pilots and airports but also partially the regulatory authority in Sweden, the Swedish Transport Agency. By looking at technical systems used in other countries, we have also examined if there are other
technical aids which might be implemented in Sweden in the future. Questions that are discussed in the report are, inter alia:

- What are the different stakeholders doing to prevent RWYI from happening?
- What are the pilots and ATCOs opinion about the work being done to prevent RWYI?
- Given current technical aids and work methodology in Sweden, can the stakeholders approach the problem in another way?

1.4 Delimitations

Even though RWYI are a phenomena that are widely spread over the world, the thesis will focus on RWYI in Sweden. However, the thesis will present different technical aids both used in Sweden and abroad. Furthermore, even though military traffic is an essential part of the overall air traffic, it will not be included.

Since the Swedish air traffic control market is exposed to competition a rather new actor, Aviation Capacity Resources AB (ACR), has established. However, LFV will be the only ATC Company in Sweden treated in the thesis since they are more established on the Swedish market.

1.5 Method

There have been a number of different methods used to create the report. To acquire enough knowledge regarding the subject, a literature study was made. The knowledge gathered has then been used to come up with questions for interviews to different stakeholders but also to be well informed when making the study visits to the air traffic control towers and the airport.

The study visits to the air traffic control towers were made to gather knowledge about actual working methodology and any specific technical aids used to prevent a RWYI from happening. Bromma, Arlanda and SAAB/Linköping were visited, since the towers all differ in size and amount/type of traffic, to see if there were any differences in working methodology and technical aids depending on the tower.

During these study visits, interviews were held with air traffic controllers (ATCOs) to gather opinions regarding the system used, working methodology and risks etc. Both close-ended as well as open-ended questions were asked during these interviews. The open-ended questions were asked in order to get a better and deeper understanding because the interviewees could elaborate their answers.

To get a pilot perspective on the problem, inquiry sheets were sent to both GA pilots as well as airline pilots. Both GA pilots and airline pilots were chosen to get opinions from pilots operating at different airports, with different type of aircraft and perhaps during different weather conditions.

Opinions from the inquiry sheets from pilots and interviews from ATCOs will be used to find suitable physical technical aids that will reduce the probability for a RWYI.
1.6 References

One of the most important sources for the report is the DOC 9870 Manual on the prevention of runway incursions. This has been used to acquire necessary knowledge to perform interviews as well as a basis when writing parts of the report. The manual is published by the ICAO and it is considered reliable since ICAO is an official United Nation agency. Other sources used in the literature study are Airbus and the Federal Aviation Administration (FAA). Airbus is considered trustworthy since they have had a key role in the industry for many years (Airbus, 2013a). FAA is also considered reliable as a source since FAA is the national aviation authority in the USA.

Furthermore, a major part of the research and gathering of information has been made through study visits and interviews with different stakeholders. The information gathered through interviews may not speak for all involved personnel. The interviews are however made to get a better understanding of the opinions from some of the involved persons.

Axel Magnestrand, the mentor for this thesis, works as an air traffic controller and also investigates incidents. Therefore he possesses knowledge about the subject and will be used as a reference. He has long experience from the industry and has provided statistics and opinions regarding the subject, RWYI.

1.7 Structure of Report

The report begins with a general presentation of the subject RWYI in chapter 2 and is in the same chapter followed by statistics regarding RWYIs in Sweden. After the general presentation, the different stakeholders are presented in chapter 3 and the chapter that follow, chapter 4, addresses general factors and risks for a RWYI. Chapter 5 brings up means to prevent a RWYI. In chapter 6 are the study visits to the control towers presented together with the main results from the interviews held. Chapter 7 presents the summarized versions from the inquire sheets sent to the pilots. Some abroad and future systems that could be implemented in Sweden are presented in chapter 8. Lastly, the main findings are presented in tables in chapter 9 followed by a conclusion together with some suggested improvements in chapter 10.
2. Runway incursion

This chapter describes RWYI in general and also the ICAO classification scale. Some statistics from the last years in Sweden are also presented. As mentioned in chapter 1, RWYI is a phenomena defined as follows:

“Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take-off of aircraft.”

(ICAO, 2007a)

This definition is only applicable to airports where there is an air traffic control tower operational (AOPA, 2013). The severity of a RWYI is high but might differ depending on situation and type of vehicles or persons involved. For example, there could be a RWYI with a single aircraft involved where there is no risk for any party of being hurt. There could also be two or more aircraft/vehicles involved where there is a major risk for, or even is, a collision with lots of casualties. In either case, RWYI might be a serious threat to safety. One of the most severe RWYI in history took place at Tenerife in 1977 where two Boeing 747 jumbo jets collided on the runway. The primarily cause for the accident were one of the involved aircraft taking off without a clearance (Aviation Safety Network, 2013).

2.1 Runway incursion severity classification

Even though a RWYI in some way is a deviation from the rules, a clearance or instruction, the severity of a RWYI may differ. Therefore, there is a classification scale grading the severity. Below is the ICAO classification scale:

- Category E – It is not possible to scale the severity of the RWYI because of conflicting evidence.
- Category D – The category D RWYI includes the incorrect presence of an aircraft, vehicle or person on the runway. However, the category D incidents have no immediate consequences regarding the safety.
- Category C – A RWYI were there is sufficient time or distance to avoid an accident.
- Category B – The category B incidents are characterized by a decrease in separation were time critical manoeuvres are taken to avoid a collision.
- Category A – The most serious of incidents were a collision is avoided by narrow margins.
- Accident

(ICAO, 2007b)

2.2 Runway incursions in Sweden

In Sweden, LFV is the main provider of air traffic control service (ATS). LFV has 32 tower units controlling respective aerodrome (LFV, 2013). At every aerodrome there is a potential risk for a RWYI to happen. However, since the amount of traffic and the complexity of aerodrome layout differs between different airports, the risk is not equally big everywhere. In Figure 1, the number of RWYI in Sweden over the last years is presented.
Recent statistics for period between and including January 2012 to April 2013 has also been compiled by LFV. The results are presented below in Figure 2.

During this period of time, most RWYI has happened during the winter season in Sweden. The recent winters has been providing lot of snow which has an impact on the work at airports. In December 2012, 60 % of all RWYI in Sweden has involved one type of snow clearing vehicle (Magnestrand, Uppdrag RWYI - Statistik, 2013). Table 1 shows how much different stakeholders have contributed to a RWYI during the same period as in Figure 2.
Table 1. Contributing stakeholders during the period January 2012 to April 2013 (Magnestrand, Uppdrag RWYI - Statistik, 2013).

<table>
<thead>
<tr>
<th>Month</th>
<th>ATS</th>
<th>Airport/Vehicle drivers</th>
<th>Pilot</th>
<th>Total/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>January -12</td>
<td></td>
<td>4</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>February -12</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Mars -12</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>April -12</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>May -12</td>
<td>1</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>June -12</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>July -12</td>
<td></td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>August -12</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>September -12</td>
<td></td>
<td>2</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>October -12</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>November -12</td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>December -12</td>
<td>11</td>
<td>3</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>January -13</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>February -13</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Mars -13</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>April -13</td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>16</td>
<td>52</td>
<td>63</td>
<td>128</td>
</tr>
</tbody>
</table>

As seen in table 1, the sum of the contributing stakeholders may be higher than the total number of RWYI. It is because more than one stakeholder can contribute to a single RWYI (Magnestrand, Uppdrag RWYI - Statistik, 2013). There could be many reasons contributing to a RWYI and each stakeholder contributes in their own way. A compilation of the main factors contributing to RWYIs for the period January 2012 to April 2013 in Sweden shows the following.

2.2.1 Pilot factors
For pilots, the main contributing factors to RWYIs in Sweden during the period January 2012 to April 2013 were:

- Pilots taxiing beyond the holding point for the specific runway where the RWYI took place.
- Pilots landing and taking off without a clearance.

(Magnestrand, Uppdrag RWYI - Statistik, 2013)

2.2.2 Airport and vehicle driver factor
The main contributing factor to RWYIs in Sweden during the period January 2012 to April 2013 for the airport and vehicle drivers was:
• Vehicles and persons being on, or too close, to a runway without a clearance from ATC. External stakeholders normally not operating at the airport included.

(Magnestrand, Uppdrag RWYI - Statistik, 2013)

2.2.3 ATC factors

When ATC contributed to RWYIs during the period from January 2012 to April 2013, these were the main factors:

• Deviation from the standard working methodology and routines, for example not marking vehicles occupying the runway in the flight progress board (FPB) or not looking in the FPB when clearing an aircraft to land or take off.
• ATCO forgetting about clearances that has been given to a vehicle or aircraft.
• Lack of Situation Awareness
• Not using standard phraseology.

(Magnestrand, Uppdrag RWYI - Statistik, 2013)
3. Stakeholders

At airports, many different stakeholders are operating at a daily basis. Stakeholders operating on the movement area are in one or another way subject to the risk for a RWYI since the movement area partly consists of the runway. Stakeholders included in the report will therefore be ATC, airport, airliners, general aviation (GA) and the Swedish Transport Agency. The ATC is not part of the stakeholders that physically operates at the movement area. However, ATC is responsible to provide a safe and efficient flow of air traffic including separating aircraft and vehicles with each other on the manoeuvring area, and therefore ATC will be included in the report (ICAO, 2007a). Another stakeholder not physically involved on the manoeuvring area, but which in one way is involved, is the Swedish Transport Agency. The stakeholders mentioned are described in detail below.

3.1 ATC

Air traffic controllers (ATCOs) are involved with everything that happens on the maneuvering area. They are the connection between all aircraft, vehicles and other parties that operate there. ATCOs operating an airport are stationed in a tower in the vicinity of the runway so they can see all traffic on the runway and taxiways. Operating on a runway or taxiways always requires a clearance from an ATCO (ICAO, 2007a).

On busy airports there are one or more ATCO(s) controlling the traffic on ground. It can be divided so one ATCO handles all vehicles and one ATCO handles all aircraft. This is normally used when there is much movement on the runway or taxiways which can be due e.g. snow sweeping. On smaller airports one ATCO is usually enough to handle all traffic, both in the air and those on ground. (Karlstedt, 2013). ATCOs on smaller airports often have other tasks than just handling the traffic. They could, for example, do weather observations and a lot of telephone lines are directly connected to the tower. They are basically the hub at especially smaller airports (Magnestrand, 2013).

3.2 Airport

Operating an airport involves many different stakeholders that need access to the movement area. These are mainly firefighters, bird control cars, towing trucks, snow clearing vehicles and service vehicles. To execute their work they sometimes have to cross a runway or even drive along it. This requires clearance from ATCO and can result in a RWYI if the clearance is not followed or is inaccurate (Äkerlind & Örtlund, 2007). Signs, markings and lights are also included in the airport as a stakeholder. At most airports in Sweden, the equipment in the tower is also owned by the airport (Magnestrand, 2013).

Every airport has at least one firefighter station on the airside to enable a fast response time during an emergency. Firefighters need to simulate emergencies often to stay in shape and they usually need access to the runway. Even during a real emergency clearance is required from the ATCO to cross the runway (Ström, 2013).

Bird control cars are often required to keep the runways free from birds during landing and takeoff. If birds are spotted around the runway by a pilot, ATCO or anyone else operating close to the
runway, the bird control car is called in. To keep the birds off the runway the bird control car drives along it and shoots with a rifle containing empty shells (Åkerlind & Örtlund, 2007).

To handle the logistics with aircraft on the airport it is sometimes necessary to change gates or move them to a hangar. When this is needed the aircraft is usually empty and it is moved with a towing truck. These trucks might have to cross the runway during towing (Åkerlind & Örtlund, 2007).

Snow clearing vehicles are used during winter to keep the runway as clear as possible from both ice and snow. During heavy snowfall these vehicles may need to sweep the runway between every landing/takeoff which requires much interaction with the ATCO. To facilitate this at airports with much traffic, a snow clearing vehicle coordinator is handling all the communication with ATCO and forward instructions to the vehicle drives (Vinberg, 2013). At smaller airports it is not common to have a coordinator for the snow clearing vehicles. When a snow clearing vehicle coordinator is not present, every vehicle needs its own clearance to access the RWY or other parts of the maneuvering area (Magnestrand, 2013).

Service vehicles are maintenance cars and runway inspection cars. Maintenance cars are to ensure that all signs, markings and lightning are maintained properly and clearly visible during all weather conditions. Runway inspection cars can be ordered to check the runway for Foreign Object Debris (FOD) which is objects that can damage an aircraft (Fodnews, 2013).

3.3 Pilots
In the report, focus is put on both airline pilots and general aviation pilots. They are separately described below.

3.3.1 Airline pilots
The airline pilots are operating scheduled flights on a daily basis. They operate on both large and small airports. An airline can be specialized in carrying cargo or traveling passengers and the aircraft size operated can vary from large, e.g. Boeing 747, to small, e.g. Beech King Air (The free dictionary, 2014).

3.3.2 General aviation pilots
Normally general aviation is referred as private pilots that fly smaller airplanes, gliders and powered parachutes on less busy airports. This is partly true but the majority of the general aviation actually consists of school flights, emergency medical services and business travel etc. (IAOPA, 2013). They operate like the airline pilots and should be treated the same way.

3.4 The Swedish Transport Agency
The Swedish Transport Agency is the National Safety Authority (NSA) in Sweden. They are the responsible organ for rules, regulations and follow-up for the aviation industry in Sweden. Furthermore, they are the responsible organ for licensing and certificates in the industry, both for pilots and airports (Transportstyrelsen, 2013).
4. Factors increasing the risk for a runway incursion

When air traffic is increasing, the likelihood for a RWYI will also increase. The risk may be higher since there will, if the traffic is increasing, be more movements per given time unit at each airport and therefore be more traffic that are subject to the risk for a RWYI. There are more factors that might contribute to the risk for a RWYI if the traffic is increasing. Some of them are listed below:

- Capacity enhancing procedures that are put into action, which for example may result in shorter distances between aircraft on final approach.
- More complex airport structure which might lead to non-standard taxi routes for aircraft but also making it harder for pilots and ground staff to be aware of their position if they are unfamiliar with the airport.
- Environmental factors pressuring the air traffic controller (ATCO) to make many configuration changes. These changes might for example be to use a specific runway in regards to noise pollution over a specific area at a specific time.

(ICAO, 2007b)

The examples above are all related to the increase of air traffic. However, there are more factors contributing to an increased risk for a RWYI. These factors might be inadequate training for pilots, ATC and ground staff as well as bad weather and poor visibility. Factors increasing the risk are more detailed described below.

4.1 ATC factors

Recent statistics show that ATC are contributing to around 12-16 % of all RWYI in Sweden (LFV, 2013). One of the contributing factor includes the radio communication and misunderstandings on the radio frequency (Eurocontrol, 2013c). However, a RWYI may also be the result of the ATCOs lack of situational awareness. This could be due to many reasons such as high workload, bad visibility from the control tower or degraded systems making it harder to maintain the high level of situational awareness (AIRBUS, 2004). Those reasons could also lead to the ATCO forgetting about previous actions made such as lining up an aircraft on the runway, clearance or instruction given to pilot/vehicle driver, or a runway that might be closed. Depending on the amount of traffic, ATCO may also misidentify an aircraft/vehicle or the position of it which could in the end lead to a dangerous situation (ICAO, 2007b).

4.2 Airport factors

The airport itself is in different ways a part of the problem with RWYI and a complex airport layout might increase the risk (ICAO, 2007b). Included in the airport perspective is the layout but also signage, lights and markings. Factors that may contribute to confusion or affect situational awareness for pilots/vehicle drivers are if the airport is congested with lots of movement on the ground (different aircraft, vehicles or persons) but also parallel runways and complex intersections. Even if the pilots are able to navigate around the airport and are familiar with it, such things might be distractive during taxing thus increasing the risk for an incident or accident (AIRBUS, 2004). Signs and markings are placed on the movement area so that pilots and vehicle drivers easily should be able to navigate around the airport. However, if signs are missing, lights are broken, markings are blurry or if any of them are not operational to the latest standard it might lead to confusion in
cockpit thus impair the situational awareness. Lastly, any changes to the airport structure or configuration due to construction work or any other reason may lead to non-standard operations and procedures. ATC may be forced to issue taxi instructions that are very complex or use a runway for taxiing, all actions with a potential effect on safety (AIRBUS, 2004).

4.3 Pilot factors
The pilot factors contributing to a RWYI is besides the communication part mentioned in 4.1, different difficulties when taxiing and also lack of situational awareness; the pilots may believe they are at one location when they in reality are not. This could be due to the lack of good signage or markings at the aerodrome. An additional factor where a pilot is involved is when receiving instructions during periods of high workload in cockpit, for example during touchdown (ICAO, 2007b).

A RWYI may occur due to the pilots not following a given taxi instruction. The reason why the instruction is not followed could be due to many different reasons. It could be the result of poor preparation by the crew, difficult instructions by ATC, distraction in cockpit or the taxi route given is not the same as the expected one. Other factors regarding the taxiing of aircraft that may increase the risk for a RWYI is the airport layout. If the layout is complex or the pilots are unfamiliar with the layout, the risk may be increased. On the other hand, if the flight crew is very familiar with the airport, they may taxi with too high speed and at the same time have a feeling of complacency, both increasing the risk for a RWYI (AIRBUS, 2004).

4.4 Communication factors
As mentioned in chapter 4.1, one of the contributing factors is the radio communication, both between ATC and pilots as well as between ATC and vehicle drivers. The failures regarding communication are more or less linked to each other in some way. For example, if a controller uses non-standard phraseology the pilot might have difficulties of giving a correct read-back. Non-standard phraseology and wrong read-backs are some of the factors that may contribute to a RWYI. Beyond this example, factors regarding the ATC and communication might be the ATCO not correcting the wrong read-back, an overlong or very complex instruction given to the pilot or vehicle driver leading to misunderstanding, or a pilot accepting and following an instruction that the ATCO gave to another aircraft (ICAO, 2007b).

4.5 Weather factors
Factors that may contribute to a RWYI is any kind of weather affecting the visibility for either the ATCO or pilots/vehicle drivers. It could be that the ATCO do not see any movements on the ground even if there are. It could also be the case that pilots do not see other aircraft or vehicles even though they are close to each other. In a case were ATCO cannot see the traffic on the ground and also lacks a surface movement radar, they have to rely on correct position reports from the pilots. If the pilots in that case are giving wrong position reports, a potentially dangerous situation may occur. Examples of weather that might reduce the visibility to some or major extent are:

- Haze/Mist
- Fog
- Light or heavy rain
Beyond the potential hazards regarding low visibility, snow and ice might cover markings on the ground as well as signs and lights. In all cases, the result of these types of weather might be that pilots and vehicle drivers are unable to see such markings or miss important signs (AIRBUS, 2004).

- Light or heavy snow
- Low sun that dazzles
5. Means of preventing runway incursions

There are many ways of preventing a RWYI of happening. This chapter describes some general means to prevent a RWYI from happening from different stakeholders’ perspective. A RWYI can occur due to active or latent failures or a combination. To reduce the risk there are recommendations in communication associated with runway instructions and what pilots, airport operators, ATCOs, and vehicle drivers should think about when operating on the maneuvering area close to or on a runway (ICAO, 2007b).

5.1 ATC means to prevent a RWYI

Air traffic controllers should issue departure clearances before taxi if possible. Stop bars (explained in 5.3.3) should be operated manually by ATC. Pilots and vehicles should never be issued clearance to cross a runway when the stop bars are activated, even though the runway is not in use. A clearance to cross a runway should be short, concisely and only involve instructions to cross the runway, even though the runway is not in use. If practicable, routine routes should be implemented to facilitate for pilots and, if possible, fragmentize taxi instructions to reduce their workload. ATC should be aware of the “hot spots” at the airport and be extra cautious when aircraft or vehicles are around them. Instructions to hold before a runway on an oblique or angled taxiway, with reference to the runway, should be avoided since this could limit the pilot’s view of the runway. Controllers should, when applicable, keep an eye on aircraft entering the runway even though SMR is available (ICAO, 2007b).

5.2 Airport and vehicle driver means to prevent a RWYI

One important factor is the design of the runways and taxiways. With fewer crossings of taxiways and runways the physical possibility for a runway incursion will reduce. All signs, markings and lightning should be visible at all times and during construction information about what areas that are affected should be spread. Vehicle drivers should hold a special driver license to operate at the maneuvering area as well as an education about radio communication. If a vehicle driver is in doubt about an instruction or is uncertain of its position he/she should ask ATC immediately. Vehicle drivers should always try to monitor the frequency as much as possible to get an understanding about the traffic situation, even in cases were no contact is required with ATC (ICAO, 2007b).

5.3 Visual means to prevent a RWYI

To reduce the risk of RWYI there are signs, markings and lightning guarding the runway and providing information necessary for pilots and other vehicle drivers operating on or nearby the runway. These signs, markings and lights should be visible at all times. There are also be charts to help pilots navigate around the maneuvering area (ICAO, 2007b).

5.3.1 Signs

At every airport controlled by an air traffic control tower, there are signs on the ground providing important information to all pilots and vehicle drivers operating there. The signs are there to help the pilots and vehicle drivers to navigate around the airport as well as giving information about runways and holding points. The most important signs from an RWYI perspective are the following:
5.3.2 Markings
As for the signs, markings on the pavement give the pilot or vehicle driver important information regarding position but also helps them to navigate around the airport. From a RWYI perspective, the ones below are considered the most important:

Holding point for a taxiway leading to a runway. Indicates the entrance to the runway.

Figure 7. Holding point marking.
5.3.3 Lights
In addition to signs and markings, there are lights at the airport with different meanings. Lights may show the centre or edges of taxiways or runways. There are also lights to protect the runway area. Those are described below:

These runway guard lights (RGL) are information for the pilot or vehicle drivers showing there is a runway ahead (Magnestrand, 2013).

The stop bars are co-located with the holding point markings and signs at the taxiways. The stop bar lights are unidirectional red and may not be crossed by any aircraft or vehicle unless they are deactivated by the ATCO. However, not every airport is equipped with stop bars (Skybrary, 2013a).

5.4 Pilot means to prevent a RWYI
It is mandatory that pilots possess sufficient knowledge regarding airport signs, markings and lightning so that no uncertainty can arise during taxi. Before commencing taxi pilots should plan their route on a chart. Pilots should only accept clearance of crossing a runway if there is nothing else embedded in it to avoid confusion. If a clearance is received to line up on a runway the pilot should reject it given that takeoff cannot be commenced within 90 seconds, or the pilot should inform ATC that he/she is required to hold on the runway. Pilots should always be fully aware of their position on the airport and if in doubt contact ATC immediately. During taxi pilots should avoid “heads-down” procedures to keep focus on the taxi operation (ICAO, 2007b).
5.5 Means to prevent a RWYI by communication
Since all permission to enter a runway is given through the radio it is essential that the communication is as clear as possible. To reduce the risk of mixing up aircraft with each other the full call sign and standard phraseologies should be used at all times when issuing runway associated clearances. There should also be follow-ups to verify that everyone on the frequency are familiar with the standard phraseology and what phrases that require read-back. It should also be avoided to use the national language on international airports so that everyone listening on the frequency can understand and improve their situational awareness. Furthermore, everyone operating on a runway should be on the same frequency (ICAO, 2007b).

5.6 Means for The Swedish Transport Agency to prevent a RWYI
The Swedish Transport Agency is responsible to follow-up if the rules and regulations regarding visual aids on airports in TSFS 2012:92 are complied with. The follow-up is done periodically for all airports but with different long intervals depending on the size. Arlanda is, for example, checked every year whilst a small airport is checked with three to four years interval. However, if there is an indication that something might be wrong, the airport is checked an extra time (Burman, 2013).

Since the Swedish Transport Agency also is responsible for certification and follow-up for pilots, proficiency check (PC) is carried to ensure that the pilots possess enough knowledge before a license is prolonged. A PC is performed with a flight instructor to ensure that the pilot has the knowledge and skills to hold a license. It is done when the required amount of flying hours during a year for a pilot is not fulfilled. During the PC, there are no mandatory questions about signs or markings on the airport, but it could be included if the flight instructor decides to ask about it (Wastesson, 2013).

5.7 Follow-ups to prevent a RWYI
In case of a runway incursion it is mandatory for all involved parties to write a report about what happened and the reason for it. The involved persons are also encouraged to call ATC and discuss the matter and if needed contact a psychologist. These reports are used to find reoccurring problems and the reason for them so they can be taken care of (ICAO, 2007b).
6. Summary of study visits

During this thesis Bromma tower, Arlanda tower and SAAB/Linköping tower were visited to learn about their work methodology and what technical aids they used to prevent RWYI. To get an understanding of what differences there can be between airports working methodology three differently busy airports were chosen.

The busiest is Arlanda where there can be up to eight ATCOs working at the same time and they mostly handle IFR traffic. Arlanda is also the only civil airport in Sweden that has the possibility to perform parallel runway operations. Bromma is a busy airport with one runway and can have two ATCOs and one air traffic controller assistant working at the same time. They handle a mix of VFR and IFR traffic. SAAB/Linköping is not so busy with one runway and handles both IFR and VFR traffic.

During the visits interviews were held with ATCOs to ask about their opinions and working methodology regarding RWYI. Below, a summarized version for each tower visited is presented together with pictures illustrating different technical aids. During the study visits, observations were made regarding working methodology and also technical aids that the ATCOs used, also included in the summarizing chapters below. For more details and full answers from the interviews, see Appendix A, Appendix B and Appendix C.
6.1 Bromma airport

Bromma airport has one runway, 12/30. The tower is situated on top of a nearby hill with a good view over the manoeuvring area and aprons. During busy hours, the work is divided between one ground controller and one controller in charge of the runway and airborne aircraft.

![Bromma tower](image)

Figure 11. Bromma tower (Stockholm - Bromma, 2010)

The general opinion among the ATCOs is that enough work is being done to prevent a RWYI. However, they all agree on that there are some external factors that may increase the risk (Appendix A).

The ATCOs working methodology is always important to keep a high level of safety. During circumstances with reduced visibility it is crucial to have an updated FPB with all the necessary information. The FPB at Bromma is the only technical aid used as a reminder to the ATCO that the runway is blocked or occupied. When the runway is blocked or occupied the ATCO uses a strip as a marking, which is placed under the runway in use, shown in Figure 12 (Appendix A).

![FPB with strips](image)

Figure 12. FPB with strips (FORDON) marking that the runway is occupied.
The interviewees state that it is important to get a correct read-back when issuing clearance as well as before removing the strips that indicates the runway is occupied. They also agree on the present working methodology is enough to prevent a RWYI (Appendix A).

6.1.1 Risks
At Bromma, ATCOs opinion is that snow clearing and bad visibility are factors increasing the risk for a RWYI. Examples of bad visibility are heavy snowfall, sun that dazzles and darkness. Apart from the snowfall reducing the visibility from the tower, a lot more vehicles are present on the manoeuvring area thus increasing the risk for a RWYI. The sun is particularly a factor when using runway 30 and the runway is wet, creating a blind spot for the ATCO around the threshold. Darkness does not reduce visibility in the same way, but it might be confusing for the controllers to dissociate aircraft lightning, aerodrome lightning and lights at buildings in the vicinity. The biggest external risks are the following:

- Vehicles operating a whole day with a similar clearance, but who at some points get an alternate clearance instead. They might be so used to the standard clearance that they follow it instead even though it has changed.
- Unusual procedures for VFR pilots and helicopters.
- External stakeholders who are not used to the environment and requirements performing work at the airport.

When it comes to the ATCOs state of mind, complacency and fatigue are considered to be risks that may contribute to an incident. ATCOs also pay extra attention to pilots that seems to be unfamiliar with the airport and school flights. For example, they do not receive clearance during taxi so they can be fully focused on taxiing.

(Appendix A)

6.1.2 Improvements
The ATCOs general opinion is that enough work is being done to prevent a RWYI, but some improvements can always be done. One suggestion is the implementation of stop bars at the holding points warning the ATCO when being passed by any vehicle or aircraft. One opinion is also that snow clearing vehicles could have their own frequency to discuss internal matters, thus reducing the occupancy on the ATC frequency. Furthermore, a surface movement radar could be a great asset when visibility is low (Appendix A).

6.1.3 Follow-up
When a RWYI has occurred, the ATCO writes a report and if the RWYI is severe they got relieved from the working position. If the RWYI has a low impact on safety, ATCOs often encourage the involved parties to call the tower to discuss what happened. Bromma tower has also formulated an extra inquiry sheet for pilots, vehicle drivers or airport personnel to fill out in case of an incident (Appendix A).
6.2 Arlanda airport

The airport has three runways which are 01L/19R, 01R/19L and 08/26. The tower is situated in the middle of them all to provide a good view for the controllers working. During busy hours, work may be divided between up to eight controllers as follows:

- Three ground controllers.
- Two controllers in charge of the runways.
- One clearance delivery (CD).
- One Flight Data Assistant (FDA).
- One Watch Supervisor (WS).

According to the interviewee, the working methodology and technical aids at Arlanda is sufficient. The working methodology to prevent a RWYI at Arlanda is equal to Bromma but the ATCOs at Arlanda have more electronic equipment. The FPB and the strips are all electronic but serve the same purpose as the analogue systems, Figure 14 (Appendix B).

If a runway is blocked or closed due to vehicles, a vehicle strip is placed in the active runway bay and the runway becomes blocked at the surface movement radar, as shown in Figure 15. The surface movement radar is another technical aid provided to the controllers to show any vehicle or aircraft on the ground equipped with a transponder (Figure 16) (Appendix B).
In addition to these electronic equipment helping controllers in their daily work, Arlanda has stop bars to every taxiway leading to a runway. A stop bar is a row of red, unidirectional, lights controlled from the tower indicating the holding point. No vehicle or aircraft may cross a stop bar which is active. It is the ATCOs job to activate and de-activate them accordingly. The stop bar panel is illustrated in Figure 17 (Appendix B).

6.2.1 Risks

On Arlanda, a number of different scenarios or factors are increasing the risk for a RWYI. These are as follows:

- Mixed operations, meaning the same runway is used for arriving and departing aircraft. Pilots at Arlanda are generally not used to this type of operations.
- Pilots that are unfamiliar with the airport.
- Seasonal employees and other stakeholders normally not operating at Arlanda e.g. snow clearing personnel.

ATCOs at Arlanda stated that factors like darkness, fog and snow all affect the work. Darkness and fog may lead to tiredness. Snowfall also affects the work, contributing to more talk on the frequency and a louder environment in the tower. This may lead to fatigue thus having an impact on performance (Appendix B).
6.2.2 Improvements

According to the interviewee, there is no need for additional technical aid or improved working methodology. However, the surface movement radar is sometimes showing “ghost-echoes” which are echoes on the radar screen that in reality does not exist. The controller may be fooled by these echoes, believing there is actually an aircraft or vehicle at the position of the echo.

Except from external stakeholders normally not operating at Arlanda, the personnel working on the ground are well educated and are aware of rules and regulations, according to the interviewee. (Appendix B)

6.2.3 Follow-up

In case of a RWYI, Arlanda has implemented relief routines which mean the affected controller is relieved from the working position. They also write a report on the occurrence, have a talk with the WS and, if needed, also a doctor. The vehicle driver or pilot involved is, as on Bromma, encouraged to call the tower to discuss the situation (Appendix B).
6.3 SAAB/Linköping airport

SAAB/Linköping airport is one of two airports in Linköping. The runway configuration is 11/29. The tower is placed close to the runway on the airside, slightly closer to the threshold for runway 29.

The view of the runway is good, but parts of the maneuvering area are blocked by buildings. The ATCOs need to have visual contact with everyone operating on the maneuvering area so they have two cameras covering the areas which are not seen from the tower. Figure 19 shows the camera screen in the tower. Expansion of the airport have created this unfavorable layout as vehicles and personnel have to access the maneuvering area to relocate from civil terminal, fire-fighting facilities, fuel facilities, garages etc. As airport personnel have several roles, this leads to heavy use of the taxiways for airport vehicle movements in the area where cameras are used to monitor ground movements. Because of this, extra capacity is required from the ATCO to keep track of all the vehicles moving back and forth.

As in Bromma tower the FPB is the only technical aid used to indicate that the runway is occupied or blocked by an aircraft or vehicle. One difference from Bromma tower is that they use a larger strip in the FPB to cover both the inbound and outbound bay, Figure 20e. The reason they have one big strip instead of two small, one in each bay, is to avoid the risk of just placing one strip in the outbound bay and miss it when looking in the inbound bay which may be empty. In addition to the big strip, they have one strip for each vehicle that is on the runway also shown in Figure 20 (Appendix C).
SAAB/Linköping has also implemented a remotely controlled gas-cannon system to scare birds, as a complement the bird control car, Figure 21. The cannons are placed on different locations along the runway and if the ATCO spots any bird activity he/she can remotely ignite some gas which produces a loud explosion, scaring the birds away.

According to the interviewees the working methodology is sufficient since actions are taken directly in case of an incident. There are not so many ATCOs working at SAAB/Linköping tower so after an incident they discuss possible actions to be taken during meetings (Appendix C).
6.3.1 Risks
As on Bromma and Arlanda airport there are some common identified risks among ATCOs, these are;

- Darkness, especially combined with rain. These circumstances make it harder to get a good view from the cameras.
- Snow clearing when a lot of vehicles are involved. Sometimes vehicles leaves the runway and frequency without reporting, which leaves the ATCO in an uncertainty phase.
- Pilots and vehicle drivers that are not used to the airport layout.

School flights operating VFR and foreign GA pilots might be a risk if not treated the correct way. If the ATCO can hear that there might be some confusion regarding instructions or clearances he/she pays extra attention to read-backs. They also try to be more explicit and simple on the frequency to those pilots. Routine-like clearances to vehicle drivers are also considered as a risk since it is a possibility the involved stakeholders take clearances for granted. This can lead to sloppy read-backs. It was also stated that some of the vehicles and aircraft has poor radio quality thus affecting the communication with ATC (Appendix C).

6.3.2 Improvements
The general opinion among ATCOs is that enough work is being done to prevent RWYI. One suggestion is however to equip all vehicles with ADS-B, which is a GPS technique. A screen in the tower will then be able to show all movements on the area which is covered by cameras today. To give the vehicle drivers and service personnel a better understanding about the different parts of the maneuvering area, an education is planned this fall (2013) lead by an ATCO (Appendix C).

6.3.3 Follow-up
In case of a severe RWYI the ATCO in position will be relieved and immediately writes down what happened to be able to fill out a full report when possible. ATCO also inform the involved vehicle driver or pilot that an occurrence report will be written and encourage them to call the tower, or even meet up in the tower, to discuss the event (Appendix C).
7. Compilation of the inquiry sheets sent to pilots

There are different types of pilots operating on airports in Sweden. These are GA pilots, airline pilots and military (not included in the report). They all might operate on different sized airports and with different conditions for example regarding view from the cockpit and experience. All of them are subject to the risk of a RWYI. Below is a summarized version of the answers from the inquiry sheets that was sent to the pilots. One of the questions asked was explicitly regarding the location of RGL since it was brought up to discussion on the study visit to Bromma tower. A total of seven pilots with different qualifications were inquired. However, since two of them where helicopter pilots not operating on controlled airports, their answers are excluded from the report. Among the other five, there are two airline pilots, one former airline pilot, one ambulance pilot and a VFR pilot. All of them answered the inquire sheet sent to them and their full answers to the questions are provided in Appendix D and Appendix E.

7.1 General aviation

Two general aviation pilots were inquired. One of them, Petter Naef, is the chairman of Sturup Flygklubb, and the other one, Jonatan Thorén, is an ambulance pilot and flight instructor. Their opinion regarding signs, markings and risks varied. The chairman opinion is that all signs and markings are sufficient to avoid a RWYI. The education and follow-up regarding these signs and markings are also considered enough from his point of view (Appendix D).

The ambulance pilot thinks that the runway markings and signs could be improved, even though these signs are the best at most airports. He also thinks the follow-up on knowledge and education regarding signs and markings could be improved. However, the current knowledge is sufficient to avoid immediate danger (Appendix D).

7.1.1 Risks

The biggest factor contributing for a GA pilot to miss or taxi beyond a sign or marking is darkness, weather with reduced visibility and heavy precipitation. A problem during winters with a lot of snow is also that it may cover markings on the ground as well as snow banks blocking the view of the signs. During darkness, on large airports with many intersections, all the lights could sometimes be confusing and pilots may be misguided (Appendix D).

7.1.2 RGL

The chairman of Sturup Flygklubbs opinion on the runway guard lights (RGL) and their location is that they are appropriately placed. They have never been misleading according to him and the RGLs are placed on a good distance from the runway. Simply, he thinks they fulfill their purpose (Appendix D).

The ambulance pilot thinks the RGLs should be placed in line with the holding point and stop bar. This is however not the case at all airports, and he believes that the location of them can sometimes be misleading. This applies especially during winter when markings on the ground may be covered with snow or ice (Appendix D).
7.1.3 Working methodology
Depending on type of aircraft, there could be one or two pilots in the cockpit. If there are two pilots, sometimes one pilot is taxiing the aircraft while the other is reading checklists. Best practice should be both looking out from the cockpit during taxi, i.e. avoid head down assignments. Pilots should also plan their taxi beforehand, especially when taxiing on complex airports (Appendix D).

7.1.4 Improvements
The chairman thinks that the stakeholders operating around and on the airport are doing enough to prevent a RWYI. The ATCOs have good supervision of taxiing aircraft and the airport layout is also good. When taxiing, the pilot is solely responsible to follow signs and markings. However, a SMR could be helpful for the ATC, but other than that, he is satisfied with the involved stakeholders work to prevent a RWYI and suggested no other improvements (Appendix D).

The ambulance pilot thinks there should always be stop bars at every entry to a runway, at all airports. He also suggested that the RGLs should be aligned with the holding point/stop bars. A solution to complex/long taxi instructions could be lines with different color on the taxiways so that the ATCO simply could say “Follow the blue line” instead of “Taxi to stand 56 via right turn on to Y, left on UG on to U and left on ZM”. A standardized system regarding taxiing should also be implemented, for example clockwise taxiing, where possible (Appendix D).
7.2 Airline pilots
The inquiry sheet was sent to two airline pilots and one former airline pilot to get their opinions on the subject RWYI. The active airline pilots are flying domestic flights as well as international ones. They have experience from both large and smaller airports and they are flying medium sized jet aircraft (B737). The third one is a former airline pilot who mostly flew domestic flights for a smaller company. They all agreed on that signs and markings are sufficient and well placed (Appendix E).

When it comes to the education and follow-up on the knowledge regarding the subject there are different opinions. Two of the pilots thinks there is enough education, even though it is a fairly small part of the pilot training, and every time they fly they feel like they gain more experience and knowledge and therefore no follow-up is needed. The third one thinks there could be more follow-up and education in the subject (Appendix E).

7.2.1 Risks
One pilot stated that there are cases where signs are not placed where they are expected to be. This could lead to confusion and is a potential risk for a RWYI.

Conditions increasing the risk for a RWYI are, according to the airline pilots, darkness, heavy precipitation and reduced visibility. There is also a potential risk when the taxiway is wet, making it harder to see markings on the ground. In those cases, it is important to have good signage at the airport. During winter, signs can be missed due to snow banks and there is a possibility that markings are hard to spot due to snow or ice on the taxiways. Another consequence during cold weather is the need for de-icing. The de-icing process often involves more procedures than usually which may reduce the focus on signs during taxi (Appendix E).

The conditions that affect the pilots most negatively are complacency, stress and tiredness. Complacency is especially a factor on airports where pilots are usually given the same instruction/clearance every time they visit it. An example is from Arlanda where pilots going to depart usually get the instruction “line up in sequence” directly on first contact with the departure controller even if they are number 7 in sequence. Even though the instruction is not given to the pilots there is a risk that they line up on the runway anyway since they are used to that procedure. Another risk, not only applicable to RWYI but to aviation in general, is if the cooperation between the pilots is poor (Appendix E).

7.2.2 RGL
Two of the pilots have not thought about the location of the RGL but think they are good help to indicate that there is a runway ahead. The third pilot thinks that it should be mandatory from an airport perspective to place the RGL aligned with the holding point. Anything else could be confusing (Appendix E).

7.2.3 Working methodology
To avoid a RWYI it is important that both pilots in the cockpit are well aware of the clearance/instruction given, for example to line up on the runway. Even if it is not a standard operating procedure (SOP) in all companies, all pilots answering the inquiry sheet stated that they
orally confirmed the clearance/instruction with each other. They also mentioned that they visually confirm that the runway/final approach is clear before entering the runway (Appendix E).

7.2.4 Improvements

The general opinion among the airline pilots is that all airlines should introduce some kind of SOP regarding the communication between the pilots so, even when it is obvious, they need to confirm that they are cleared to enter the runway. It is also important to always use standard phraseology to avoid misunderstandings, both between the pilots as well as between ATC and pilots (Appendix E).

Furthermore, it is also suggested to implement stop bars at every entry to a runway on all airports. These are not only a visual aid, they can also confirm the clearance given to the pilots. For example, they get de-activated by ATC when pilots are given clearance to line up on the runway. One pilot also stated that the taxi-system used at Heathrow, where pilots follow green lights showing the route which should be followed, is very good and reduces the risk of getting lost (Appendix E).

Another opinion and suggested improvement is that both ATC and pilots should gain more knowledge about each other’s work by, for example, arrange study visits (Appendix E).
8. Abroad and future systems

RWYIs are and will always be a great danger to aircraft and vehicles operating on an airport, both in Sweden and abroad. However, new systems abroad may be implemented in Sweden in the future to reduce the risk for an incident or even an accident. This chapter brings up some systems developed and also implemented abroad.

8.1 Runway Status Lights

Upcoming technology that has been implemented abroad, for example at some major airports in the USA such as Washington Dulles and Orlando International, are the Runway Status Lights (RWSL). RWSL are red lights embedded in the taxiways and runways and serves the purpose of reducing the risk for a RWYI thus increasing the runway safety. It is done by increasing the situation awareness of pilots as well as vehicle drivers operating at airports. The RWSL consist of two types of warnings; Runway Entry Lights (RELs) and Take-off Hold Lights (THLs). The system will operate fully automatically without the need for a human (ATCO) to make any inputs. RWSLs is an extra safety net and the lights are good help to involved stakeholders when there is reduced visibility at the airport and hard to see other traffic (FAA, 2013c).

The RELs give pilots and vehicle drivers a warning if it is unsafe to enter or cross a runway. It might, for example, be because of one aircraft taking-off from the runway. The lights are placed after the holding point for the runway and are, as mentioned earlier, red lights indicating the occupancy of the runway, Figure 22. Even if a pilot receive an instruction from the ATCO to cross a specific runway and the RELs are illuminated, pilot should not cross the runway but inform the ATCO about the illuminated lights (FAA, 2013c).

The THLs are embedded in the runway and give pilots a warning if it is unsafe to take-off because of
an aircraft or a vehicle that currently is on the runway or about to enter the runway. The lights are just a warning to increase the situation awareness in cockpit but pilots should not take-off, even if a clearance is given to do so, if the lights are illuminated (FAA, 2013c). Figure 23 shows what the THLs might look like from a pilot perspective if there is another aircraft or vehicle on the runway.

8.2 Final Approach Runway Occupancy Signal

Final Approach Runway Occupancy Signal (FAROS) is a tool developed to reduce the amount of RWYIs and its severity. It has been tested at Long Beach International Airport and Dallas Ft. International Airport but has not been implemented elsewhere. This system warns pilots on final approach that it is unsafe to land if the runway is already occupied by an aircraft or vehicle. FAROS is connected with the Precision Approach Path Indicator (PAPI) for the given runway. If FAROS detects that the runway is occupied by an aircraft or vehicle, the PAPI lights starts to flash instead of their normal steady lights. This system is totally automatic and does not involve any action from ATC (FAA, 2013d).

8.3 Volumetric stop bar control sensor

On airports where stop bars are used it is possible to complement them with Stop bar Control Sensors. These sensors are placed at the stop bars and can, with the help of micro waves, detect movements of aircraft or vehicles that trespasses a stop bar. If this occurs a warning is sent to the ATCO. This can be useful during LVP where the ATCOs cannot visually confirm that an aircraft have stopped where it is supposed to (Southwest Microwave, 2013).

8.4 Tower Surface Management System

This is a system used on some of the world’s largest airports, for example in Berlin and Dubai, to facilitate taxi for pilots and reduce workload on ATCOs. Tower Surface Management System (TSMS) is a software that processes all the given clearances and taxi routes. It can also suggest a specific taxi route for an aircraft, taken the traffic situation into account. Whether the suggested route is chosen or not is up to each controller to decide. In either case, the chosen taxi route is indicated by steady green lights in the center of the taxiway so pilots easily can follow, and taxi according to their clearance. One benefit of this system is that pilots do not get disorientated as easily thus reducing the risk for a pilot to mistakenly enter a runway. It also reduces workload for both the pilots and ATCOs. In addition, the system detects runway incursions, in a similar way as mentioned in 8.3, and alerts the ATCO (ATRiCS, 2013).

At London-Heathrow a system similar to this is used and a clearance from the ground controller could be like “SAS123, Follow the greens, hold at SATUN”, instead of a long and complex clearance. Figure 24 shows the view from cockpit when following the greens (Appendix E).
9. Findings from the investigation

This chapter summarizes the main findings during the investigation. The main stakeholders looked at has been ATC and pilots, and summarized versions are presented in Table 2 and Table 3.

9.1 ATC findings

The three different airports visited all differed in size, technical aids and type of traffic. Despite that, the same types of problems regarding RWYI occur at all airports. Some of the problems are related to the weather, which is one factor that the human cannot do anything about. Other common problems are pilots or vehicle drivers that are not familiar with the airport and its layout. At all airports visited, the problem with a lot of snow clearing vehicle present around and on the runway is also mentioned as a potential risk. Table 2 shows a summary of the main findings after the study visits and interviews with ATC.

*Table 2. Summary of the main ATC findings.*
Despite any technical aids or working methodology, the human factor is still one part of the system that sometimes causes an incident or accident. From an ATCO perspective, tiredness, complacency and fatigue are considered to be contributing factors that need to be taken into account.

9.2 Pilot findings
When looking at the pilot perspective, it is clear that some problems and risks for the pilots are the same as for the ATCOs. For example, some weather is making it harder for pilots to see signs and markings thus increasing the risk for a RWYI. Table 3 shows the findings from the inquiry sheets sent to the pilots.

*Table 3. Summary of pilot findings.*

<table>
<thead>
<tr>
<th>Airline Pilots</th>
<th>GA pilots</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risks</strong></td>
<td><strong>Risks</strong></td>
</tr>
<tr>
<td>• Darkness, heavy precipitation and poor visibility</td>
<td>• Poor visibility and heavy precipitation</td>
</tr>
<tr>
<td>• Wet taxiways</td>
<td>• Snow covering markings and signage</td>
</tr>
<tr>
<td>• Snow covering markings and signage</td>
<td>• Confusing lights during darkness</td>
</tr>
<tr>
<td>• De-icing procedures that requires much focus</td>
<td></td>
</tr>
<tr>
<td>• Complacency, tiredness and stress</td>
<td></td>
</tr>
<tr>
<td><strong>RGL opinion</strong></td>
<td><strong>RGL opinion</strong></td>
</tr>
<tr>
<td>• Should be in line with holding point</td>
<td>• Should be in line with holding point</td>
</tr>
<tr>
<td><strong>Suggested improvements</strong></td>
<td><strong>Suggested improvements</strong></td>
</tr>
<tr>
<td>• Introduce a SOP regarding communication procedures between each other.</td>
<td>• Stop bars mandatory</td>
</tr>
<tr>
<td>• Stop bars mandatory</td>
<td>• Reduce workload by facilitate taxi clearance</td>
</tr>
<tr>
<td>• Study visits</td>
<td>• Implement standardized taxi system</td>
</tr>
<tr>
<td>• Simply taxi instructions</td>
<td></td>
</tr>
</tbody>
</table>

As shown in Table 3, both airline pilots and GA pilots think that the RGL should be placed aligned with the holding point. This is to avoid misunderstanding when instructed to hold at the holding point.

9.3 Airport findings
The airport, which involves the personnel operating at the maneuvering area, signs, markings and lights, is also a part of the problem with RWYI. It has not been mentioned that there are any problems with the maintenance of the signs, markings or lights. However, they are sometimes, especially during winter, covered or blocked by snow, ice or other contamination.

The biggest problem for the airport is, according to the ATCOs, vehicle drivers that are unfamiliar with the movement area and the rules and regulations on it. For example, snow clearing personnel
might be seasonal employees and it may be a big turnover of staff leading to many novice employees.

9.4 The Swedish Transport Agency findings

The national safety authority is, according to our investigation, not directly contributing to the RWYI problem. They fulfill their purpose of regulating what is required from both an airport perspective as well as what knowledge is needed to hold a pilot license.

The location of the RGL which, according to the pilots, sometimes may be confusing is regulated by the Swedish Transport Agency to a certain extent (Transportstyrelsen, 2013). They regulate the minimum distance that the RGLs can be placed from the runway centerline. It is however the airports decision to give the RGLs their exact location and whether they should be co-located with the holding point or not.
10. Conclusion

This chapter describes our conclusion from the investigation made about RWYI. Sub-chapter 10.1 brings up our suggested improvements. Even though a lot of work is being done to prevent RWYI, our investigation shows that even more work can be done by some of the different stakeholders.

Arlanda is the biggest airport in Sweden. The ATC tower has a well-developed system with stop-bars, electronic FPB and SMR. Therefore, Arlanda might not have the same need for improvements regarding technical aids in the tower as the other airports visited. However, systems presented in chapter 8 are applicable to all airports in Sweden since RWYI still occurs, no matter the size or the traffic amount at airports.

The fact that GA pilots do not consider the human factor part to be a risk might be because that they are not operating on a daily basis. They might not have the same pressure as the airline pilots to always be on time, spend the least amount of fuel and operate for long days.

The improvements suggested by the pilots are in some or another way related to increasing the situation awareness or reducing workload. A high level of situation awareness is important when operating on an airport to avoid confusion, misunderstandings and stress. Reducing the workload is a vital part so extra capacity can be spared to unexpected events and attention directed to the most important tasks.

As mentioned in chapter 9, the Swedish Transport Agency is not directly contributing to the problem with RWYI according to the investigation. We believe they should continue their work with follow-ups as they do now to make sure the involved stakeholders follow the rules and regulations.

Findings regarding the airport as a stakeholder is based on the interviews made with the ATCOs and the inquire sheets to pilots. The focus on the investigation has been on ATC and pilots and therefore vehicle drivers and service personnel operating on airports were not approached. The result regarding the airport may have differed if they were included. Furthermore, if we would have made the investigation based on reports instead of interviews and opinions, the result might have differed. However, compilation of recent reports in Sweden has already been made and we also wanted to look at the problem in a proactive way instead of reactive.

The result of the investigation regarding RWYI from an ATCO perspective was expected. The weather factors are known and it is obvious that bad visibility not only is a problem at some, but at all airports. However, the technical aids are different depending on the size of the airport and amount of traffic. At both Bromma and SAAB/Linköping airport, ATCOs suggested additional technical aids to assist them in their work to prevent RWYI. At Arlanda, the technical aids are considered to be sufficient from an ATCO perspective and there is a concern that further systems perhaps would perplex their work instead of helping them. Adding additional technical aids often comes with a high cost, and this is considered before implementing.
At most of the airports in Sweden, it is the airport itself that is the owner of the equipment the ATCOs are working with. Even if the ATCOs want improvements it might be the airport that bears the costs. We believe this type of fragmentation makes it hard to implement new equipment or upgrade an old one. It might be the fact that an accident is necessary before not only the ATCOs, but also the airport, sees the problem with equipment not sufficient to perform safe ATC. We think this fragmentation is a widely spread problem over the whole aviation industry because of the many involved stakeholders. A closer cooperation between all of the stakeholders would be preferable to achieve one of the goals that are common for every one; Increased safety. With respect to safety, it is often a lot better to be proactive instead of reactive. As it is now, most of the improvements are made using reports, of incidents or accidents, as a basis. With our investigation, the purpose was to be proactive by looking at what stakeholders consider to be risks and if they have any suggestion to improvements.

Statistics in table 1 shows that pilots and vehicle drivers are the most frequent contributing stakeholders for RWYIs. Due to this fact, more attention should be directed to them and what they consider important to reduce the risk of a RWYI. Even though it is a big cost, the implementation of stop bars is considered to be the most essential improvement since one of the biggest risks for a RWYI to happen are, according to the pilots, reduced visibility. Because of the fact that pilots and vehicle drivers are the most contributing stakeholders, the major part of our improvements in chapter 10.1 are addressed to them or for them.

The systems that are presented in chapter 8 are all systems that include lights. They are chosen since the majority of the risks involve reduced visibility and darkness. All systems, except the TSMS, are designed in a way so that none of them require any human input to function. They are visual or audible warnings to pilots, vehicle drivers and ATCOs if anyone makes a mistake and the systems serves as an extra safety net.

A discussion that has been going on for some time in Sweden is the location of the RGLs. A lot of RWYIs occurred due to pilots taxiing beyond the holding point to the RGL, believing the holding point was co-located with the RGL. Even though these RWYIs had no immediate impact on safety they are still added to the statistics. Where misunderstandings occurred, most RGLs have been re-located to avoid the confusion. However, as they were placed before, they worked as an extra safety net in case the pilot or vehicle driver would not stop at the holding point. When re-located to the holding point, there is no extra safety net if the holding point/RGL is missed. RGLs aligned with holding point might lead to fewer RWYIs in the statistics. However, the severity may increase since pilots and vehicle drivers could taxi/drive all the way to the runway without any final warning.
10.1 Suggested improvements

With the help of the result from the investigation, and opinions gathered from the different stakeholders, we have come up with some improvements to the current system. The cost for implementation differs and has not been considered since it is up to each stakeholder to decide how much money they are willing to spend on improvements. The improvements below are considered to increase runway safety for airports in Sweden and are not specifically addressed to the ones visited;

- **Gas-cannons** – These are situated close to the runway to complement or replace a bird control car. The benefits are that they are remotely controlled from the ATC tower, do not require a lot of maintenance and reduces the movements on the runway thus reducing the risk for a RWYI. Another benefit, not RWYI related, is the short time interval from when birds are spotted until the ATCO can scare them away.
- **TSMS** – The system used to assist pilots, vehicle drivers and ATCOs could be useful to especially larger airports in Sweden. The system is further described in 8.4.
- **Stop bars** – To reduce the risks for a RWYI, stop bars should be implemented and used even during conditions when it is not mandatory. They help to increase the situational awareness for pilots and vehicle drivers. In addition to that, some stop bars have the function that they alert ATCOs when being passed by aircraft or vehicle drivers, chapter 8.3.
- **Location of RGL** – RGLs should, according to the pilots included in the report, be located in line with the markings and signs for the holding points to avoid any confusion.
- **SOPs** – Implement a SOP for airlines (pilots) and, when applicable, vehicle drivers. The SOP should consist of a crosscheck between the pilots or vehicle personnel that a clearance is received to enter the runway even though it is obvious that the clearance is received.
- **Maps** – It should be mandatory for every vehicle with permission to be on the maneuvering area to have clear and simple maps covering the movement area, and where a clearance from the ATC is needed.
- **Guide** – In addition to the map, all vehicles should be equipped with an easy understandable guide to airport signs and markings.
- **Additional aid** – If vehicle drivers or service personnel on the airside are not 100% comfortable when performing work on the maneuvering area, they should have someone who is experienced accompanying them.
- **De-fragmentize** – The stakeholders should have a closer cooperation and be aware of each others work to enhance the understanding and problems that different stakeholders have regarding RWYI. For example through study visits.

In addition to our suggestions above, all technical systems in chapter 8 are considered to decrease the risk for a RWYI. Furthermore, it is important to always follow the rules and regulations for any stakeholder operating at an airport.
References


ICAO. (2007a). *DOC 4444 Procedures for air navigation services*. ICAO.
LFV. (2013). *LFVs kundrapport 2012*. LFV.
Stockholm - Bromma. (2010, 6 29). LFV.
Appendix A – Bromma intervjuer

1. Vad görs från ett flygledarperspektiv och vilka medel använder man för att motverka en RWYI? Är detta tillräckligt?

Sandra Vinberg (SV), flygledare: Man använder posanger för både fordon och flygplan som läggs under RWY posangen. När det gäller fordon så skrivs det på en lapp vilket fordon det är som är ute och åker. Man är även noggrann med att få en tillbakaläsning och att banan är fri innan man tar bort posangen ur FPBt. Man tittar alltid ner i FPBt och bekräftar att banan är fri innan man ger en klarering in på banan. Detta systemet anser jag vara tillräckligt.

Christian Sjölin-Olsson (CSO), flygledare: Man använder FPBt, har tydlighet i rösten och rättar eventuella fel i tillbakaläsningar. Detta system är tillräckligt även om en sensor som känner av om någon passerat en stopbar vore bra.

2. Används alla system för att indikerar en bana som är blockerad?

SV: Ja
CSO: Ja

3. Är det nuvarande arbetssättet för flygledare tillräckligt för att motverka en RWYI?

SV: Ja
CSO: Ja, piloter och fordonsförare frågar dessutom om något verkar konstigt.

4. Anser du att du har fått tillräcklig utbildning i systemet och arbetssättet som finns för att motverka en RWYI?

SV: Ja
CSO: Ja

5. Litar du till 100% på systemet som används?

Notering: Endast för Arlanda.

6. Är det något tillstånd hos involverade parter som du anser kan vara extra bidragande till att en incident eller olycka inträffar?

SV: Ja, när det blir lite att göra efter en peak (när man har haft mycket att göra). Complacency.
CSO: Ja, complacency. Även fordon som arbetar länge på samma ställe kan lätt glömmas bort.


7. Under vilka yttre förutsättningar anser du att det är mest ansträngande att jobba?

SV: Snöövänder på grund av mängden fordon som behöver tillträde till banan och taxibanorna men även väder med dålig sikt.
CSO: Solsken som bländar, då man kan bli ”blind” åt vissa håll. FPB blir extra noga då. Mörker försvarar också då mängden lampor på och utanför flygplatsen kan göra det förvirrande.
JA: Snö och mörker är de största problemen.

8. Under vilka förhållanden anser du att risken för en RWYI ökar?
SV: Snöröjning då det är många fordon ute och kör.
CSO: Förhållanden då sikten försämras från tornet.
JA: Så länge man följer bestämmelser så ska det inte bli något problem.

9. Utöver yttre förhållanden som kan påverka, vilken skulle du anse vara den största risken för att en RWYI skulle inträffa?

SV: Fordon som under en hel dag får samma klarering som efter ett tag får en ny, annan klarering. Deras tillbakaläsning kan vara korrekt, men de följer samma rörelsemönster som tidigare under dagen.
CSO: Onormala procedurer med VFR och helikoptrar samt även då det är snöröjning då det är många fordon ute och kör. Den absolut största risken är däremot om man har yttre aktörer på flygplatsen och arbetar som inte arbetar där i vanliga fall. Det kan bero på att de har mindre kunskap och förståelse om vad som gäller på flygplatsen.

10. Är det något flygbolag eller någon typ av piloter som behöver extra/mindre uppsyn och behandling?

SV: Utländska piloter/VFR piloter som låter osäkra på klareringar och tillbakaläsningar får extra uppmärksamhet.
CSO: Skolflyg då eleverna flyger ensam men även sällanflygare får extra uppsikt.
JA: Man känner av läget. De som låter osäkra får lite extra uppmärksamhet.

11. Är det någon speciell bankombination som du anser ger ökad risk för en RWYI?

Notering: Endast för Arlanda.

12. Anser du att alla aktörer som rör sig på manöverområdet gör tillräckligt för att motverka RWYI?

CSO: De gör tillräckligt, förutom yttre aktörer som kan vara väldigt osäkra.

13. Finns det enligt dig brister i radiokommunikationen mellan flygledare och piloter eller servicefordon? Vilka är dessa i så fall?

SV: Nej.


SV: Nej
CSO: Arbetssättet är bra.
JA: Arbetssättet är tillräckligt bra.

15. Anser du att det på Bromma skulle behövas ytterligare tekniska system? Vad i så fall?

SV: Nuvarande system är tillräckligt.
CSO: Markrader skulle hjälpa. Även stopbars med sensorer som reagerar om ett flygplan eller fordon skulle taxa förbi.
16. Vad för sorts uppföljning sker vid en eventuell RWYI? Fortsätter driften som vanligt?

**SV:** Man skriver en DA (rapport) samt ber den som var inblandad att ringa tornet för att reda ut vad som hände. Man fortsätter driften som vanligt om det går.

**CSO:** Man skriver en rapport vid en händelse. Det finns också avlösningsrutiner vid allvarligare incidenter. Man ber även de inblandade ringa till tornet för att prata om det som hänt.
Appendix B – Arlanda Intervju

1. Vad görs från ett flygledarperspektiv och vilka medel använder man för att motverka en RWYI? Är detta tillräckligt?

Maria Karlstedt (MK), flygledare: Man använder posanger i det elektroniska FPBt. Banan kan även bli blockerad/stängd på markradarn och det markeras genom röda kryss över den banan som är blockerad. Om det är mixed-ops så har man två kolumner i FPBt, en för avgående och en för ankommande och då placera man två posanger där. En i varje kolumn. Detta för att inte misa att ett fordon befinner sig på banan. Det här systemet är tillräckligt.

2. Ansöks alla system för att indikera en bana som är blockerad?

MK: Det finns ett varningssystem i markradarn som inte används för att det inte är installerat, men annars ja.

3. Är det nuvarande arbetssättet för flygledare tillräckligt för att motverka en RWYI?

MK: Ja

4. Anser du att du har fått tillräcklig utbildning i systemet och arbetssättet som finns för att motverka en RWYI?

MK: Ja, framförallt fraseologin.

5. Litar du till 100% på systemet som används?


6. Är det något tillstånd hos involverade parter som du anser kan vara extra bidragande till att en incident eller olycka inträffar?

MK: Om man som flygledare inte är på topp finns det alltid en potentiell risk, fatigue. Medvetenheten om sin egen kapacitet för stunden är viktig då man kan anpassa sitt arbetssätt efter hur man känner sig.

7. Under vilka yttre förutsättningar anser du att det är mest ansträngande att jobba?

MK: Mörker, det bidrar till trötthet. Snö gör att det blir extra mycket jobb och prat på frekvensen. Ljudnivån i tornet kan bli högre då vilket kan störa. Även dimma kan göra det ansträngande.

8. Under vilka förhållanden anser du att risken för en RWYI ökar?

Notering: Se fråga 7.

9. Utöver yttre förhållanden som kan påverka, vilken skulle du anse vara den största risken för att en RWYI skulle inträffa?
MK: Enbaneoperationer (mixed operations), framförallt då piloter på Arlanda inte är vana vid detta och att de ibland då har tidspress på sig vid start.

10. Är det något flygbolag eller någon typ av piloter som behöver extra/mindre uppsyn och behandling?

MK: Ovan och ”nya” piloter på Arlanda kan vara en risk då det skiljer sig ganska mycket att operera på Arlanda gentemot andra svenska flygplatser.

11. Är det någon speciell bankombination som du anser ger ökad risk för en RWYI?

MK: Framförallt mixed operation då det är lite annorlunda för piloterna. Annars kan bana 08 för start och 01R för landning innebära en risk vid eventuellt pådrag för landande på 01R.

12. Anser du att alla aktörer som rör sig på manöverområdet gör tillräckligt för att motverka RWYI?

MK: Ja, men ovana aktörer är osäkrare. Exempelvis personer som inte brukar vara på Arlanda eller säsongsarbetande snöröjare.

13. Finns det enligt dig brister i radiokommunikationen mellan flygledare och piloter eller servicefordon? Vilka är dessa i så fall?

MK: Nej.


MK: Nej. Arbetssättet är bra och alla arbetar likadant vilket är viktigt.

15. Anser du att det på Arlanda skulle behövas ytterligare tekniska system? Vad i så fall?

MK: Nej, det finns redan många olika komplexa system och dessa räcker. Ytterligare system skulle potentiellt kunna bli för mycket.

16. Vad för sorts uppföljning sker vid en eventuell RWYI? Fortsätter driften som vanligt?

Appendix C – SAAB/Linköping intervjuer

One of the interviewees wanted to be anonymous and therefore the two interviewees are only referred to as “SAAB1” and “SAAB2” in the answers below. Some of the questions were answered during a tour in the tower by the mentor for the thesis, Axel Magnestrand, and those questions are therefore referred to him.

1. Vad görs från ett flygledarspektiv och vilka medel använder man för att motverka en RWYI? Är detta tillräckligt?

Axel Magnestrand (AM), flygledare: Man använder posanger i FPBt. Dels en stor fordonsposang som täcker både ankomst och avgångskolumnen. Man lägger även en fordonsens specific posang i FPBt för att markera vilket specifikt fordon som är på banan.

2. Används alla system för att indikera en bana som är blockerad?

AM: Ja

3. Är det nuvarande arbetssättet för flygledare tillräckligt för att motverka en RWYI?

SAAB1: Egentligen inte eftersom att det sker RWYI:s.
SAAB2: Ja, baserat på tidigare händelser så sker hela tiden förbättringar rörande arbetssätt. Man tar bort gråzoner och pratar om händelser direkt på möten.

4. Anser du att du har fått tillräcklig utbildning i systemet och arbetssättet som finns för att motverka en RWYI?

SAAB1: Ja.
SAAB2: Ja.

5. Litar du till 100% på systemet som används?

Notering: Endast Arlanda.

6. Är det något tillstånd hos involverade parter som du anser kan vara extra bidragande till att en incident eller olycka inträffar?

SAAB1: Slentriannässigt beteende kan leda till att man glömmer.
SAAB2: Slentriannässigt beteende. Oftast samma klarering till fordon.

7. Under vilka yttre förutsättningar anser du att det är mest ansträngande att jobba?

SAAB1: Riktigt dåligt väder eller då det är beläggning på kamerorna. Även mörker och dimma.
SAAB2: Det kan bli problem vid mörker tillsammans med regn. Då RGL tidigare var felplacerad körde ”många” fram till RGL istället för att stanna vid holding point.

8. Under vilka förhållanden anser du att risken för en RWYI ökar?

SAAB1: Under snöröjning då det är mycket fordon ute och kör.

9. Utöver yttre förhållanden som kan påverka, vilken skulle du anse vara den största risken för att en RWYI skulle inträffa?
Notering: Se fråga 7.

10. Är det något flygbolag eller någon typ av piloter som behöver extra/mindre uppsyn och behandling?

SAAB1: GA piloter får extra uppsyn. Kamerorna används då som ett hjälpmedel för att följa flygplanet när det taxar.


11. Är det någon speciell bankombination som du anser ger ökad risk för en RWYI?

Notering: Endast för Arlanda.

12. Anser du att alla aktörer som rör sig på manöverområdet gör tillräckligt för att motverka RWYI?

SAAB1: "Sällankörare" är inte tillräckligt utbildade.


13. Finns det enligt dig brister i radiokommunikationen mellan flygledare och piloter eller servicefordon? Vilka är dessa i så fall?

SAAB1: Ja, ibland används ej fastställd fraseologi med t.ex. fordonstalare.

SAAB2: Vissa fordonssradio har dålig kvalitet men oftast används korrekt fraseologi.


SAAB1: Möjligtvis, men allt har ett pris.

SAAB2: Arbetssättet är tillräckligt bra. Åtgärder tas direkt när en incident inträffar.

15. Anser du att det på SAAB/Linköping skulle behövas ytterligare tekniska system? Vad i så fall?

SAAB1: Nej.

SAAB2: Man skulle kunna utrusta alla fordon med GPS för att kunna följa deras rörelser på en skärm i tornet.

16. Vad för sorts uppföljning sker vid en eventuell RWYI? Fortsätter driften som vanligt?

SAAB1: Man får avlösning direkt om det är allvarligt följt av krishantering och rapporter som ska skrivas. Man kan även vid mindre allvarliga händelser be de inblandade att ringa till tornet eller komma upp till tornet för att diskutera det som hänt.

SAAB2: Man blir löst direkt om man är två i tornet. Man skriver direkt ner vad som skett och pratar med de inblandade för att tala om att en rapport kommer skrivas.
Appendix D – General Aviation inquire sheet

1. Anser du skyltningen och markeringar för runway är tillräckligt synligt?


Petter Naef (PN): Ja

2. Under vilka yttre förhållanden anser du att det är störst risk att missa en skylt under taxation? (väder, trafik, mörker etc.)

JT: Självklart svårast under mörker och dålig sikt, trafiksituationen brukar inte påverka just detta.

PN: Vid dålig sikt, kraftig nederbörd eller mycket snö som kan bygga snövallar som skymmer skyltarna.

3. Under vilket tillstånd anser du att det är störst risk att det skulle inträffa en runway incursion? (trötthet, stress, complacency etc)

JT: Som med allt måste många missar sammanfalla för att det ska ske, åtminstone i en flerpilotcockpit. Jag har mest varit med om situationer i skolningen där det är mycket trafik i varvet och ATC tappar kontrollen och ger line up trots att någon är på kort final eller klart landa efter han gett någon line up etc. I dessa fall har det varit bra väder och ingen verklig fara.

PN: -

4. Anser du att utbildning/uppföljning för piloter angående skyltning/markeringar och dess betydelse är tillräcklig?

JT: Nej, å andra sidan anser jag inte att det går att fel tolka betydelsen av skyltar och markeringar så pass att fara uppstå, med nuvarande kunskapsnivåer.

PN: Ja

5. Vad är din åsikt angående placeringen av Runway Guard Lights (de orange blinkade lamporna som varnar för runway ahead)? Tycker du att det är lämpligt att de är placerade efter väntplats eller är det förvirrande?

JT: Som jag nämnde ovan är det ett problem att de inte är konsekvent uppställda i höjd med stopplinjen. Särskilt på vintern såklart då linjen kan vara helt täckt av snö/is.

PN: De är lämpligt placerade, och jag har aldrig upplevt att de inte befinner sig på ett bra avstånd från RWY.

6. Anser du att något kan göras bättre för att motverka runway incursion av flygledare, piloter, LFV, flygplatsen eller markpersonal som arbetar på manöverområdet?

JT: Arbetssättet i tornet har jag inte så stor koll på, men man bör ju ha ett arbetssätt som inte möjliggör att man ställer upp någon som står kvar på banan medan annan trafik får klart landa etc. flygplatserna bör sträva efter användning av stopbars och TS för att dessa ska användas kontinuerligt.
**PN:** Det är pilotens ansvar, och han ska vara noga med hur han taxar. En markradar kan vara till nytta, men det är inte ekonomiskt genomförbart på alla flygplatser. Min erfarenhet är att TWR på ESMS har exemplariskt god uppsikt över både taxande flygplan och de som startar och landar. Det är inte speciellt svårt att se de gula lamporna, och taxibanans form bidrar till att man förstår att man närmar sig RWY.

7. **Vad görs från ett pilotperspektiv för att motverka runway incursion? Ex. Arbetssätt, rutiner etc.**

**JT:** På senaste OPC var markeringar/skyltningar ett tema på teoretiska provet efter att det kommit in några ORar kring rwy incursions. Arbetsbördan bör planeras så att båge piloterna tittar ut och navigerar under taxningen så länge det inte är väldigt självklart vart man ska (ofta finns ju checklistor som ska göras under taxning tex). Varje pilot måste själv läsa på och förbereda sig för flygplatser med komplexare taxning.

**PN:** -

8. **Väkommen med ytterligare kommentarer angående runway incursion ifall du har några!**

**JT:** RWY incursion är såklart det potentiellt farligaste vad gäller detta, men också där man kommit längst med motmedel i form av stop bars, alarm till ATC om man kör för långt, tydliga unika skyltar etc. Det som normalt upplevs som störst arbetsbelastning är navigeringen under taxningen, skyltar och belysning kan vara väldigt förvirrande och det är lätt att ta fel, särskilt när man kommer ut på ett "torg" från vilket det finns flera avfarter. Taxning bör standardiseras internationellt, t.ex. arlandas clockwise taxning. Det smartaste jag hört tror jag var ett experiment ICAO gjorde på Bryssel, där man vid alla RWY exits inte bara har en gul taxilinje, utan även en blå, en röd, en grön etc. Sen ges inte klareringen "taxi to stand 56" (vilekt förutsätter att man läst på ordentligt om hur de vill att man taxar), eller "taxi to stand 56 via right turn on to Y, left on UG onto U and left on ZM” etc, utan bara "follow blue line". Supersmart!

**PN:** -
Appendix E – Airline pilot inquire sheet

1. Anser du skyltningen och markeringar för runway är tillräckligt synligt?

Magnus Ögren (MÖ): Generellt sett tycker jag skyltningar kring banor är tydliga och klart synliga och jag har personligen aldrig upplevt att en skylt varit dold av något annat. Problem som dock kan uppstå är att väntplats för en bana ibland inte är där den ”förväntas” vara vilket mycket väl kan leda till misstag. Finns flygplatser som exempelvis Uleåborg (OUL) i Finland där vanlig väntplats CAT1 är där den ”förväntas” vara men CAT2 är långt innan pga för smalt mellan bana och taxiväg. Missas detta av crew vid briefing samt att fokus ligger på något annat vid taxi ut råder risk för incursion.

Emma Renström (ER): Ja, i stort sett. Under vinterhalvåret är det i regel svårare att se dem på grund av snö/is på taxibanor och höga plogvallar/snöhögar.

Patrik Högman (PH): Det skiljer sig en hel del mellan olika flygplatser men på det stora hela tycker jag att det är bra.

2. Under vilka yttre förhållanden anser du att det är störst risk att missa en skylt under taxning? (väder, trafik, mörker etc.)

MÖ: Man kan simpelt säga att risken för att missa markeringar ökar med att vädet blir sämre. Kraftig nederbörd kan minska sikten ordentligt plus att sämre väder kan leda till bl.a. avisning som i sin tur gör att andra procedurer ska följas och således minskar fokus på exempelvis skyltar. Blöt taxiväg påverkar i sig inte möjligheterna att se skyltar men kan göra det klart svårare att se målade linjer på taxibanor/väntplats på de flygplatser som saknar belysning på dessa områden vilket gör att det blir extra viktigt att det är tydligt skytat.


PH: Dimma under dagtid, det är svårare att se ljus från skyltarna.

3. Under vilket tillstånd anser du att det är störst risk att det skulle inträffa en runway incursion? (trötthet, stress, complacency etc)

MÖ: Jag tror alla ovan nämnda faktorer skulle kunna vara boven i dramat och jag skulle själv säga att stress eller complacency är störst risk. Att behöva komma iväg snabbt säger sig själv att det kan gå lite för fort och därmed kan något gå snett. Complacency på flygplatser där man förväntas göra på ett vis(ex lina upp direkt) kan också bli riskfyllt om man inte har fullt fokus på det man borde ha.
ER: Stress och trötthet är nog de största bidragande orsakerna, men självklart ökar risken om det dessutom är dåligt väder, mörkt och man inte känner till flygplatsen så bra. Dåligt fungerande CRM i cockpit är nog också en bidragande orsak, fungerar inte samarbetet mellan piloterna ökar risken att något ska gå snett.

PH: Här tror jag att de flesta tillstånd har lika stor påverkan. På Arlanda är det vanligt att när man ropar upp tower freq så får man ”line up in sequence” direkt även fast man är nr 6 i kön för start. Skulle man inte få den klareringen finns säkert en risk för complacency och att man ställer upp ändå.

4. **Anser du att utbildning/uppföljning för piloter angående skyltning/markeringar och dess betydelse är tillräcklig?**

MÖ: Utbildning av det här ser jag som klart tillräkligt, när det har inträffat incursions har jag svårt att tro att det har haft med bristande utbildning att göra. Uppföljning ang skyltning är däremot något jag aldrig upplevt mer än att vi arbetar regelbundet och på så sätt hela tiden bygger upp större erfarenhet inom området.

ER: Nej, man lägger rätt lite vikt vid detta under utbildningen, och det finns i princip ingen uppföljande utbildning på området.

PH: Ja.

5. **Vad är din åsikt angående placeringen av Runway Guard Lights (de orange blinkade lamporna som varnar för runway ahead)? Tycker du att det är lämpligt att de är placerade efter väntplats eller är det förvirrande?**


ER: Tycker det borde vara självklart att de ska sitta i jämhöjd med väntplatsen, allt annat kan vara onödigt förvirrande.

PH: Guard lights står väl alltid vid sista väntplatsen innan banan hade jag jag för mig? Jag tycker deras placering är bra, som ett sista led i att förhindra runway incursions.

6. **Anser du att något kan göras bättre för att motverka runway incursion av flygledare, piloter, LFV, flygplatsen eller markpersonal som arbetar på manöverområdet?**

**ER:** Flygbolagen skulle i större utsträckning kunna utveckla procedurer för att förhindra detta, genom callouts och så vidare.


Under mörker på Heathrow får man exempelvis klareringen ”follow the greens, hold at satun” Så tänds centerline lights på taxibanorna och man följer bara dessa till man kommer fram till en stop bar. Systemet fungerar utmärkt, i alla fall från en pilots perspektiv. Det gör det väldigt svårt att taxa fel.

Jag tror att om man eliminerar risken för att taxa fel, minskar man också risken för stress, att man tappar bort sig och att man mitt i allt detta skulle råka ställa upp eller korsa en bana som man inte hade klarering för.

7. **Vad görs från ett pilotperspektiv för att motverka runway incursion? Ex. Arbetssätt, rutiner etc.**

**MÖ:** I mitt nuvarande bolag finns ingen skriven procedur kring det här. Dock sker ofta att vi muntligt bekräftar med varandra att vi har klarering innan vi passerar väntplats etc.

I mitt förra bolag fanns proceduren att kapten ALLTID innan en bana äntrades konfirmerade med styrman att klarering erhållits. Detta oavsett om det var helt uppenbart eller ej. (I stil med ”Confirm we’re cleared to line up/cross rwy XX” med svar Affirm/negativ, We’re (not) cleared to line up/cross rwy XX”).

**ER:** Framför allt genom CRM, rutiner och callouts. Piloten som mottagit klarering ser till att skriva ner den, och piloten som taxar ser till att repetera klareringen så att båda har samma bild av vad man blivit klarerad. Innan man taxar ut på en aktiv bana tittar kaptenen till vänster för att se att banan/finalen är fri, och styrmanen gör det samma till höger och bekräftar detta högt. Aldrig chansa utan dubbelkolla om man är osäker.

**PH:** Personligen brukar jag alltid skriva upp i scratchpaden på CDU:n att vi har fått klarering för att ställa upp. Olika flygbolag har självklar olika rutiner, men jag skulle tro och hoppas att de flesta har någon form av SOP där man – innan man ställer upp på banan – konfirmerar med den andra piloten om man verkligen har fått klareringen.
8. Väkommen med ytterligare kommenterar angående runway incursion ifall du har några!

MÖ: Skulle jag gissa är det viktigaste för att minska antalet incursions att flygbolag tillämpar någon form av procedur vid ännandet då jag skulle tro att det oftast är ett misstag från cockpit som leder till en incursion. Skyllningar ser jag inga problem med utan det är kommunikation mellan kapten - styrman samt mellan flygledare – crew som i min mening är det viktigaste att fokusera på. Ges en klarering likt ”behind landing tfc....behind” måste det vara tydliga instruktioner samt tydliga svar. Har själv upplevt missförstånd som i sista stund räddats från runway incursion så fokus på kommunikation är a och o i det här ämnet.

ER: Jag tror att stress är en stor bov i fråga om runway incursions. Stressen kan komma från flera olika håll, bland annat så har många piloter osäkra anställningsvillkor och hög press uppifrån på att vara i tid, spara bränsle och undvika förseningar, vilket alla naturligtvis strävar efter, men det får inte gå ut över flygsäkerheten. Sedan tror jag att flygledare och piloter borde få mer insyn i varandras arbete redan under utbildningarna, med tanke på hur nära vi jobbar i verkligheten är det konstigt att vi inte vet mer om varandras arbeten.

PH: -