Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

NLR-CR-2007-961

Safety of ground handling

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Nationaal Lucht- en Ruimtevaartlaboratorium

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Executive summary

Safety of ground handling

Problem area
In the area of commercial aviation, damage from ground-related occurrences implies increased safety risks and economic consequences for all organizations involved.
Initiative has been taken to improve the level of safety at Schiphol Airport, but there is still room for improvement in safety management of ground handling. Elaborating on this initiative, NLR-ATSI has been tasked by the Dutch *Directoraat-Generaal Transport en Luchtvaart* to identify safety issues in the process of ground handling and explore solutions.

Description of work
The ground handling process is mapped and data analysis of past incidents is performed to identify existing risks of aircraft damage. An overall (worldwide) dataset is compared with a dataset of incidents at Schiphol Airport. Additionally, the regulatory framework of ground handling at Schiphol Airport is reviewed.

Results and conclusions
The analysis shows a rate of one ground handling incident with resulting aircraft damage per 5000 flights. Most incidents occur when the aircraft is parked and when interfaces are established between the aircraft and ground handling equipment. Unreported damage poses the highest risk to flight safety.
Safe operation during ground handling is a shared responsibility between operators and airports. Regulations do not require other organisations present on the airport to have an operational safety management system or meet minimum safety standards.

Applicability
The data analysis is applicable to ground handling worldwide. The regulatory framework that is reviewed is only applicable to Schiphol Airport.

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Summary

In the area of commercial aviation worldwide, airlines suffer high costs from damage that results from ground-related occurrences. Apart from the economic consequences, increased safety risks are also of concern to the organisations involved.
In the past, steps have been taken to improve the level of safety at Schiphol Airport by identifying the strengths and weaknesses in current policies, processes, procedures and activities that have an impact on safety at, and around the airport. Safety management of ground handling is one of the issues that requires attention. The main objective of this assignment is to identify safety issues in the process of ground handling and explore solutions.

The ground handling process is reviewed and mapped to identify the existing risks of aircraft damage. To support the data analysis, an overview is established of various actors, their interfaces and their interdependency in terms of time. The purpose of the data analysis is to identify ground handling phases and interfaces in which an increased risk of aircraft damage exists and to investigate causal factors. Data is collected and analysed from past incidents and accidents and the overall dataset (worldwide) is compared with the dataset of Schiphol Airport. Additionally, the current regulatory framework and its applicability to ground handling are reviewed.

The analysis shows a rate of one ground handling incident with resulting aircraft damage per 5000 flights. No significant difference in incident distribution is found between the overall dataset and the Schiphol Airport dataset. Investigation into incident causes reveals that 61% of the incidents are caused when an interface is established between the aircraft and ground handling equipment. Most incidents occur when the aircraft is parked, of which 90% is caused by actors and 10% by the aircraft itself. Damage is most frequently inflicted by actors that attach vehicles or equipment to the aircraft passenger- or cargo door. For a certain amount of cases in which internal damage is found in the aircraft, no cause is specified or found. This kind of ‘unreported’ damage poses the highest risk to flight safety, as the damage has either not been noticed, or otherwise not been reported.

In the current regulatory framework, ground handling safety is a shared responsibility between operators and airports. Regulations do not require organizations present on the airport to have an operational safety management system or meet minimum safety standards. Current developments in mandatory reporting systems may create a good opportunity to identify and assess actual risk levels in the ground handling process, provided that all applicable information is forwarded to the National Aviation Authorities for further analysis.

Contents

Abbreviations

AAS	Amsterdam Airport Schiphol
ADREP	Accident Data REPorting system
ASR	Air Safety Reports
ATC	Air Traffic Control
CAST	Commercial Aviation Safety Team
CICTT	CAST/ICAO Common Taxonomy Team
ECCAIRS	European Co-ordinated Centre for Aviation Incident Reporting Systems
EC	European Commission
EG	Europese Gemeenschap
EU	European Union
FOD	Foreign Object Debris
GCOL	Ground Collision
GHO	Ground Handling Organization
GPU	Ground Power Unit
GSE	Ground Service Equipment
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IVW	Inspectie Verkeer en Waterstaat
JAR-OPS	Joint Aviation Requirements - Operations
NLR	National Aerospace Laboratory NLR
RCL	Regeling Certificering Luchtvaartterreinen
RTL	Regeling Toezicht Luchtvaart
RFF	Rescue and Fire Fighting
SMS	Safety Management System
VACS	Veiligheids Advies Commissie Schiphol
VDGS	Visual Docking Guidance System

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1 Introduction

1.1 Background

In the area of commercial aviation worldwide, airlines suffer approximately US$ 4.000.000.000 from damage that results from ground-related occurrences. Recently an even higher estimate of US$ 10.000.000.000 has been indicated by the Flight Safety Foundation. Added to the economic consequences that result from the damage, increased safety risks are also of concern to the organisations involved.

Concerns about ground safety have also been addressed by several organisations in the Netherlands. Advising organisation KplusV has been tasked in 2005 by the *Veiligheidsadviescommissie Schiphol* (VACS) to conduct a safety survey of Schiphol Airport. According [KplusV, 2005] the purpose of the survey is to contribute to a process of continuing improvement of the level of safety at Schiphol Airport by identifying the strengths and weaknesses in current policies, processes, procedures and activities that have an impact on safety at, and around the airport. The survey has been completed and several advices are included in the final report, which has been issued on August 31st 2005.
In 2006, the VACS has evaluated the follow-up of the advices made by KplusV and has concluded that not all advices have appropriately been addressed by the several actors involved. Issues that still need follow-up are included in [VACS, 2006], which has been issued on December 18th 2006.

Safety management of ground handling is one of the issues that still need follow-up. KplusV has advised both Dutch Government and the aviation sector present at Schiphol Airport to develop projects to promote safety awareness in ground handling and incorporate this in safety management. The following key issues with regard to ground handling at Schiphol Airport have been identified:

- Consolidation of the safety culture;
- Consolidation of the safety management system;
- Improvement of supervision on safety;
- Development and accentuation of requirements to improve safety.

Whereas the aviation sector plays a vital role in consolidation of a safety culture and a safety management system, the role of Government is essential to make both endure. When the consolidated safety culture and safety management system is embedded in policies and standards, a regulatory framework is developed to assure commitment to safety regulations by all actors involved.

1.2 Objective

The main objective of this assignment is to identify safety issues in the process of ground handling and explore solutions.
A further breakdown results in the following underlying objectives:

- Identify and assess the safety risks in ground handling; by
  - Identifying actors involved in ground handling;
  - Investigating the role of the various actors in the accident/incident cause;
- Explore solutions to improve ground safety;
- Investigate the institutional aspects of ground safety.

1.3 Scope

Starting point in defining the scope of this assignment is to define ground handling. For this purpose, the International Air Transport Association (IATA) definition is used:
‘Ground Handling covers the complex series of processes required to separate an aircraft from its load (passengers, baggage, cargo and mail) on arrival and combine it with its load prior to departure’.

As the assignment focuses on risk identification, the scope is further specified by using the definition from the CAST/ICAO Common Taxonomy Team (CICTT) for occurrence categories. CICTT defines ground handling (ramp) as ‘*Occurrences during (or as a result of) ground handling operations*’. The following usage notes are provided by CICTT:

- Includes collisions that occur while servicing, boarding, loading, and deplaning the aircraft.
- Includes propeller/rotor/fan blade strikes.
- Includes pushback/powerback/towing events.
- Includes Jet Blast and Prop/rotor wash ground handling occurrences.
- Includes aircraft external preflight configuration errors (examples: improper loading and improperly secured doors and latches) that lead to subsequent events.
- Includes all parking areas (ramp, gate, tiedowns).
- *Except for powerback events, which are coded here, if a collision occurs while the aircraft is moving under its own power in the gate, ramp, or tiedown area, code it as a ground collision (GCOL).*

The last bullet *(italics)* of the CICTT definition is ignored in this assignment, as this would exclude collisions with ground handling equipment or vehicles when the aircraft is taxiing in, parking on the aircraft stand, or taxiing out. Another motivation to include ground handling incidents during taxiing is that responsibilities of ground handling or maintenance organisations extend to the taxiway (e.g. pushback and removal of the nose gear steering bypass pin). The

various areas in which ground handling operations take place are shown in Appendix A. It should be noted that for the purpose of this assignment any de/anti-icing platform is also considered as aircraft stand.
To set the final scope of the assignment, ground handling occurrences are confined to risks of aircraft damage. Collisions between vehicles/equipment on taxiway or various areas on the aircraft stand are not taken into account.

Only normal operations during ground handling are reviewed. Factors complicating ground handling and possibly increasing risk levels are summarized but not further analyzed.

2 Methodology

This chapter describes the methodology to be used to fulfil the objectives from paragraph 1.2. Firstly the methodology is described to identify risks during ground handling (§ 2.1). Secondly it is described how the regulatory framework applicable to Schiphol Airport is investigated (§ 2.2).

2.1 Risk identification

The first step in the risk identification is a review of the ground handling process. This provides a reference for the data analysis.

2.1.1 Ground handling process

To identify the existing risks during ground handling, the ground handling process is reviewed and mapped. The primary purpose is to establish an overview of various actors and their interfaces during the ground handling process. It also provides an indication about their interdependency in terms of time. The overview of actors and interfaces is used as basis for the data analysis.
The overview of various actors and their equipment that are involved during ground handling of aircraft is compiled from knowledge and literature. After the various actors are defined, their tasks during ground handling are divided by phase. The (sub) phases as defined by CICTT in table 1 are considered relevant for the purpose of this assignment.

Table 1 CICTT phase definitions

Phase	CICTT definition
Taxi from runway	Begins upon exiting the landing runway and terminates upon arrival at the gate, ramp, apron, or parking area, when the aircraft ceases to move under its own power.
Standing	Prior to pushback or taxi, or after arrival, at the gate, ramp, or parking area, while the aircraft is stationary.
Pushback/towing	Aircraft is moving in the gate, ramp, or parking area, assisted by a tow vehicle [tug].
Taxi to runway	Commences when the aircraft begins to move under its own power leaving the gate, ramp, apron, or parking area, and terminates upon reaching the runway.

To accomplish a more detailed analysis, the phase ‘Taxi from runway’ is divided into ‘taxi-in’ and ‘docking’. Docking is defined as the phase when flight crew parks the aircraft on the aircraft stand marking under guidance of a marshaller or visual docking guidance system (VDGS). This phase ends when the aircraft ceases to move under its own power.
Also the phase ‘Pushback/towing’ is divided, in which pushback is defined as aircraft movement *from* the gate, ramp, or parking area, assisted by a tow vehicle. Towing is defined as aircraft movement *to* the gate, ramp, or parking area, and movements from or to the hangar, assisted by a tow vehicle. Table 2 contains the phases and their definitions.

Table 2 Customized phase definitions

Phase	Definition
Taxi-in	Begins upon exiting the landing runway and terminates upon arrival at the gate, ramp, apron, or parking area, when the flight crew is parking the aircraft on the aircraft stand marking under guidance of a marshaller or visual docking guidance system.
Docking	Begins when the flight crew parks the aircraft on the aircraft stand marking under guidance of a marshaller or visual docking guidance system and terminates when the aircraft ceases to move under its own power.
Standing	Prior to pushback or taxi, or after arrival, at the gate, ramp, or parking area, while the aircraft is stationary.
Pushback	Aircraft movement *from* the gate, ramp, or parking area, assisted by a tow vehicle.
Towing	Aircraft movement *to* the gate, ramp, or parking area, and movements from or to the hangar, assisted by a tow vehicle.
Taxi to runway	Commences when the aircraft begins to move under its own power leaving the gate, ramp, apron, or parking area, and terminates upon reaching the runway.

Only normal operations during ground handling are reviewed, as several complicating factors may arise during actual ground handling operations, such as the presence of:

- Security staff
- Cargo specialists (load controllers, dangerous goods specialists, grooms)
- Wingwalkers
- Police
- Ambulance
- Rescue and Fire Fighting (RFF)
- Aviation/Airport Authorities (IVW, AAS, other parties)

2.1.2 Data analysis

The purpose of the data analysis is to:

- Identify phases and interfaces in which an increased risk of aircraft damage exists;
- Investigate causal factors.

Data is collected and analysed from past incidents and accidents. Absolute incident numbers, as well as incident rates are assigned to the various phases and interfaces. The analysis identifies what interfaces (and thus actors) are most frequently involved in aircraft damage and during which phase of the ground handling process aircraft damage is most frequently inflicted.

Data sources

The NLR Air Safety Report database is used to provide a dataset of incidents of aircraft damage inflicted during ground handling. Flight crew report unsafe occurrences they have encountered during operations by means of an Air Safety Report (ASR). The NLR ASR database is compiled from several databases from different European and non-European airlines. It contains data of commercial operations with Western-built aircraft of more than 5.700 kg maximum take-off weight. A number of parameters/descriptors have been included in the database, e.g. date of occurrence, aircraft type, flight phase, a narrative and descriptive factors. Especially the narrative contains relevant information for the review and analysis.

Inclusion criteria – overall dataset

Data is collected according to the following criteria:

- The incident results in aircraft damage;
- The incident takes place in one of the following phases: Taxi-in, Docking, Standing, Pushback, Towing or Taxi to runway;
- Incident data comprises main airports in the United States, Canada, Europe, Australia, Far East and Africa.

Incidents in which damage is inflicted to helicopters during ground handling are excluded from the dataset, because they are considered not relevant in the context of this assignment.

The query results in 2841 incidents. Each record of the data sample is reviewed to identify the phase in which the incident occurs and what interface or actor is involved. The analysis of causal and contributing factors depends on the quality of the ASRs. Many incidents could not be analyzed in more detail because reporters did not report any factors, causes, or did not specify the circumstances in the report.

Inclusion criteria – Schiphol Airport dataset
The same methodology is used to compile a specific dataset for Schiphol Airport. This query results in 378 incidents. The incident distribution in the overall dataset is compared with the Schiphol Airport dataset. A Chi^2 analysis is performed to verify whether there is a significant difference in the incident distribution between the two datasets.

2.2 Regulatory framework
The current regulatory framework and the applicability to ground handling are reviewed by means of a literature review of ICAO documents and an internet search.

3 Results

This chapter describes the results of the risk identification (§ 3.1) and provides the current regulatory framework applicable to Schiphol Airport (§ 3.2).

3.1 Risk identification
To identify existing risks during ground handling, the various actors involved in the ground handling process are listed and an analysis is performed on their involvement in aircraft damage incidents.

3.1.1 Ground handling process
Table 3 describes the actors and equipment involved in ground handling of an aircraft:

Table 3 Actors and equipment

Actor	Equipment
Operator (airline)	Aircraft
Airport	Jetway, visual docking guidance system, marshaller
Ground Handling Organization (GHO)	Aircraft stairs, conveyor belts, baggage carts, cargo loaders, cargo dollies, Ground Service Equipment (GSE), pushback truck
Maintenance	Vehicle, maintenance stairs, maintenance dock, aircraft jacks
Fuel provider	Fuel/hydrant trucks
Catering	Catering trucks
Cleaning	Cleaning trucks
Toilet service	Toilet service truck
Potable water service	Potable water service truck
De/anti-icing	De/anti-icing truck/rig

Note 1: Depending on contract arrangements, several actors may be part of one organisation.

Note 2: Depending on time available, contract arrangements and type of operation, not all actors are necessarily involved in actual ground handling

A typical handling arrangement and the various actors involved in ground handling of a large aircraft (Boeing 747-400) are shown in Appendix B. It should be noted that for the purpose of this assignment any de/anti-icing platform is also considered as ground handling area.

Appendix C shows the ground handling process and the specific activities that are performed by the actors involved. Also the interdependency of the several activities is shown, as some of them cannot start before another is completed.

3.1.2 Data analysis

The inclusion criteria provide a specific dataset for ground handling incidents in which damage is inflicted to the aircraft. A total number of 2841 incidents are filtered from the ASR database, which covers 14 million flights. This corresponds with a rate of one incident per 5000 flights.

To put aircraft damage during ground handling into perspective in relation to the total number of incidents (in-flight and ground), the distribution between in-flight incidents and ground incidents is shown in figure 1.

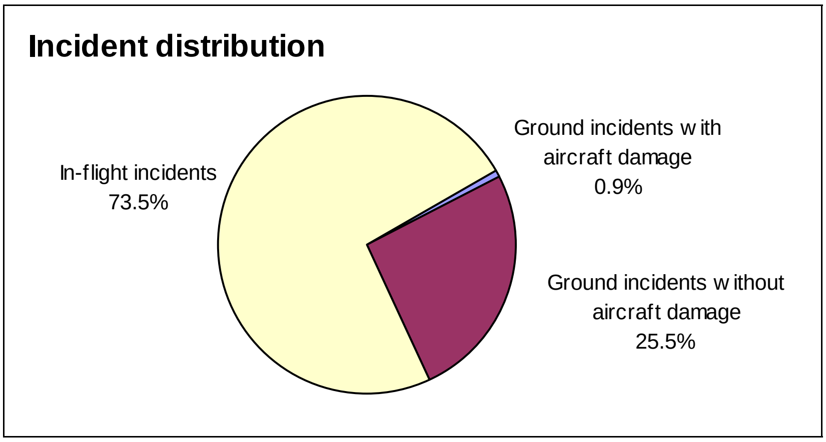

Figure 1 Incident distribution

26.4% of the total number of incidents is categorized as ground incidents. Of this total, 0.9% result in aircraft damage.
Hereafter, ground occurrences that resulted in aircraft damage are referred to as ground incidents.

In the next step the distribution of the ground incidents over the various phases is investigated. Analysis results for the overall dataset are shown in Appendix D. Results for the Schiphol Airport dataset are shown in Appendix E.
The Chi^2 analysis has been performed to verify whether there is a significant difference between the incident distribution in the overall- and Schiphol Airport dataset. In order to perform the analysis, the incidents that occurred at Schiphol Airport are subtracted from the overall dataset, which results in a comparison between a Schiphol Airport dataset and a 'rest of the world' dataset. This analysis shows that there is a 96.7% probability that the incident distribution at Schiphol Airport corresponds with the 'rest of the world' dataset. As no significant differences are found, analysis results of incident distributions are compared in Appendix F and not in this chapter.

Figure 2 shows that the majority (84%) of ground incidents is caused when the aircraft is standing, i.e. when the aircraft is stationary. For Schiphol Airport this percentage is slightly higher (92%).

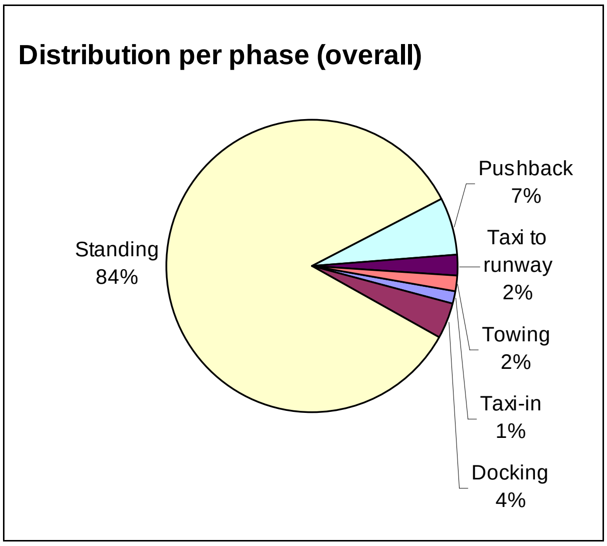

Figure 2 Distribution per phase (overall)

The following interfaces with the aircraft are identified to investigate the role of various actors in ground incidents:

- Jetway
- Stairs
- Conveyor belt
- Baggage truck/cart
- Cargo loader
- Cargo dolly
- GSE (Ground Power Unit (GPU), jet starter, towbar, etc.)
- Fuelling/hydrant truck
- Catering truck
- Cleaning truck
- Maintenance equipment (vehicle/stairs/dock/jack)
- Toilet service truck
- Potable water truck
- De/anti-icing truck/rig
- Unspecified/other vehicle
- Other aircraft (i.e. aircraft – aircraft collision)

As a considerable amount of incidents (39%) cannot be categorized in one of the interfaces mentioned above, these remaining incidents are split into the following groups of other causes:

- Foreign Object Debris (FOD)
- Jet blast
- Environmental (i.e. birdstrikes, weather, collisions with fixed equipment)

- Internal damage during (un)loading
- Damage found – origin not specified

The tables in Appendix D and E also provide a distinction between the interfaces and other causes.

Investigation into the major incident causes in the overall dataset reveals that 61% of the incidents are caused when an interface is established between the aircraft and ground handling equipment (at least one of the actors is moving). The remaining 39% is inflicted by other causes on the airport. In the Schiphol Airport dataset this relation is 69% versus 31% respectively.
As the majority of incidents is caused when interfaces between the aircraft and ground handling equipment are established, the causal factors in the interfaces are investigated first.

Interfaces
To identify the interfaces that most frequently cause aircraft damage, a distinction is made between self-inflicted damage to the aircraft (i.e. aircraft movement caused the damage) and damage inflicted to the aircraft by ground vehicles or equipment, or other aircraft (actors). Figure 3 shows the incident cause per phase from the overall dataset.

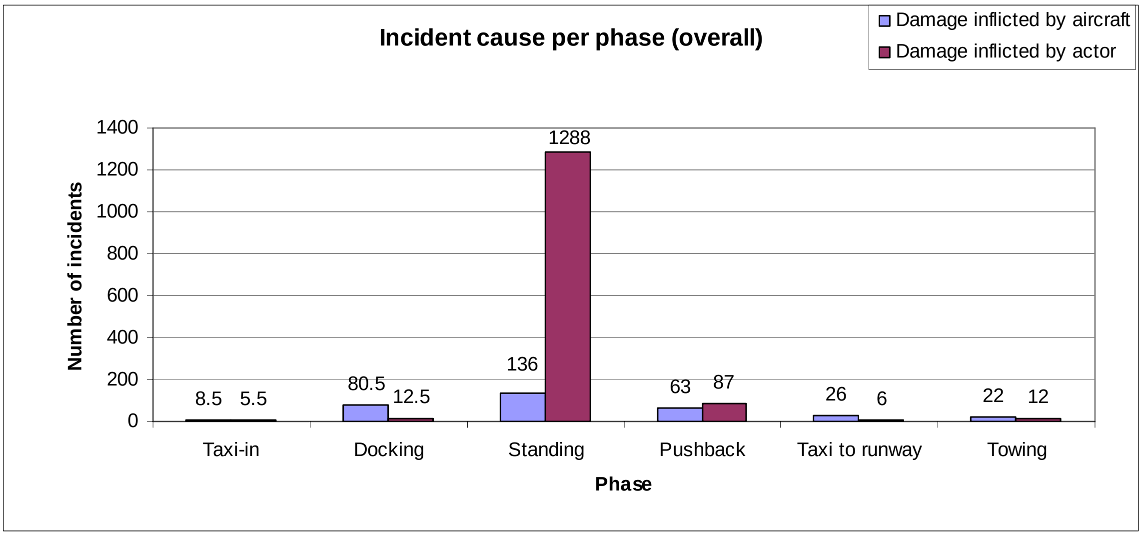

Figure 3 Incident cause per phase (overall)

This confirms that the risk of damage is highest when the aircraft is parked, which is expected due to the numerous activities around the aircraft during this phase. The role of the actors during the phase 'Standing' is significant and needs further investigation. More subtle is the role of the aircraft, which causes damage in all phases, even when the aircraft is stationary.

Figure 4 assigns the incident numbers to the specified interfaces, irrespective of incident cause.

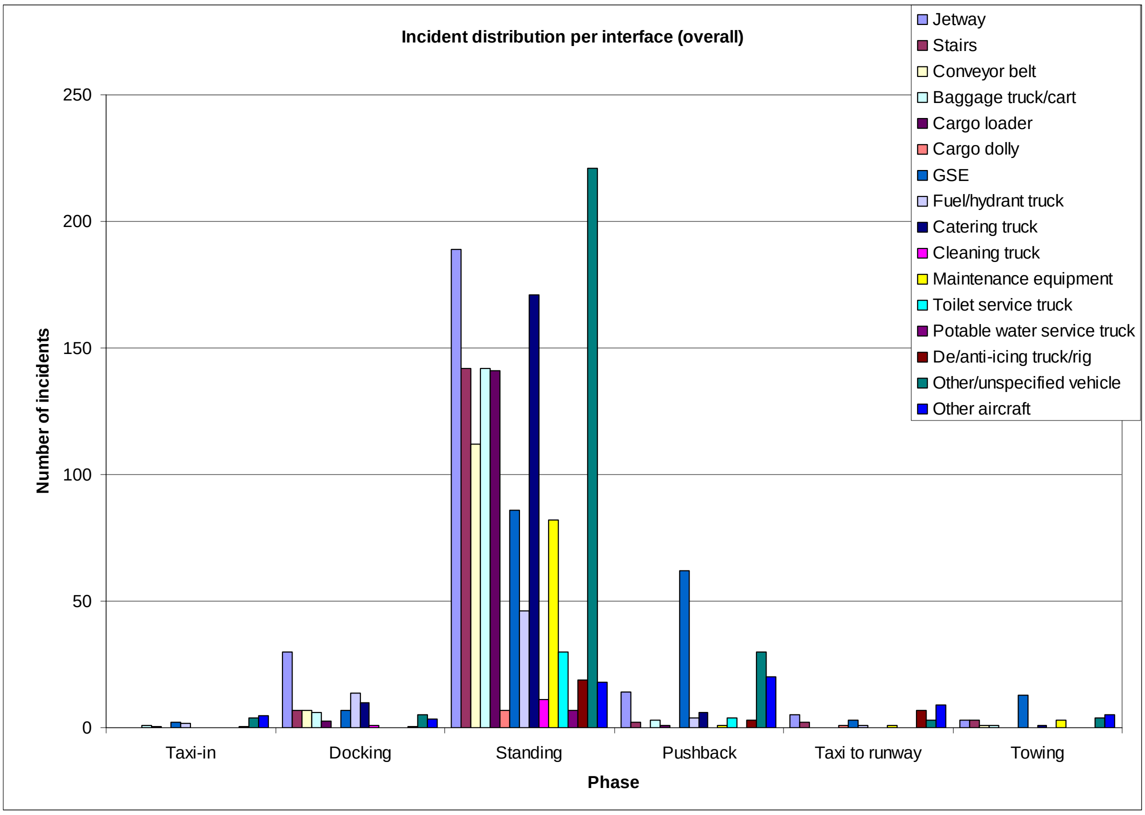

Figure 4 Incident distribution per interface (overall)

The graph provides an indication about what interfaces are most frequently involved when damage is inflicted to the aircraft. Top five interfaces are (summed over all phases):

- Other/unspecified vehicle (15.3% of total incidents)
- Jetway (13.8% of total incidents)
- Catering truck (10.8% of total incidents)
- Ground Service Equipment (9.9% of total incidents)
- Stairs (8.9% of total incidents)

The Schiphol Airport dataset provides some differences in top five interfaces:

- Baggage truck/cart (18.0% of incidents at Schiphol Airport)
- Catering truck (13.4% of incidents at Schiphol Airport)
- Jetway (13.0% of incidents at Schiphol Airport)
- Other/unspecified vehicle (10.3% of incidents at Schiphol Airport)
- Stairs and conveyor belt (both 9.6% of incidents at Schiphol Airport)

To enhance the transparency in incident distribution, separate figures are created for each phase, specifying which interfaces are involved in the incident and whether the incident is caused by the actor or aircraft. Figure 5 shows the incident distribution during taxi-in.

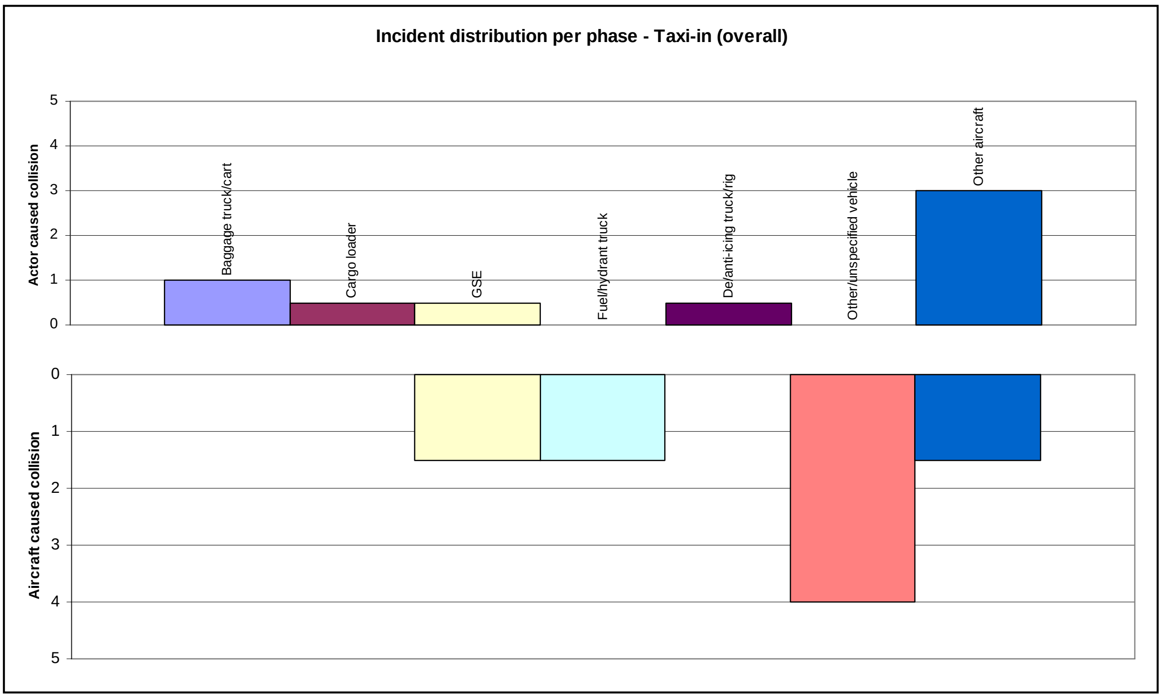

Figure 5 Incident distribution per phase – Taxi-in (overall)

When compared to the other phases that were reviewed, the number of incidents in which damage was inflicted to the aircraft is lowest during taxi-in (see Figure 2). This number corresponds with 0.0027 ground incidents per 1000 flights.
Also a small amount of interfaces is involved (7), which may be caused by the fact that taxi-in not necessarily takes place in the confined space of the ramp area, making the traffic density less than when the aircraft is parked on the aircraft stand. Additionally, during taxi-in no interfaces with any actor in the ground handling process should exist, since the aircraft is taxiing on its own power and actors have no responsibilities with regard to establishing aircraft interfaces during taxi-in (see Appendix C).

Figure 6 shows the incident distribution during docking.

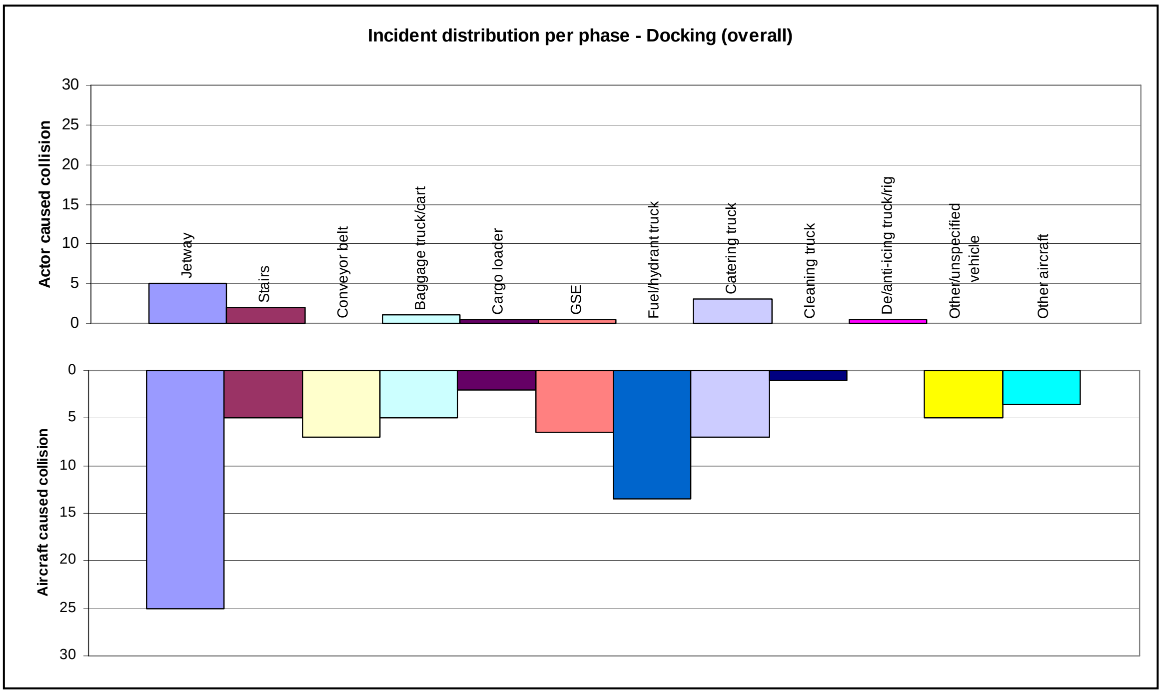

Figure 6 Incident distribution per phase – Docking (overall)

When the aircraft crosses the aircraft stand clearance line, traffic density likely increases due to the various actors moving and parking on, or near, the confined area of the aircraft stand. This increase is also shown in the number of incident causes, as more interfaces (12) are involved during docking than during taxi-in of the aircraft. However, no interfaces with actors should be present yet, as the aircraft is still moving on its own power and is parked by the flight crew either under guidance of a marshaller or a VDGS.

The incident rate of aircraft damage during docking is 0.0078 per 1000 flights and represents 4% of the ground incidents that caused aircraft damage. It is noticed that 87% of the collisions is caused by movement of the aircraft itself. Primary cause is insufficient clearance during marshalling. Peaks are noticed for jetway contact and contact with fuel/hydrant trucks.

Figure 7 shows the incident distribution when the aircraft is stationary on the aircraft stand.

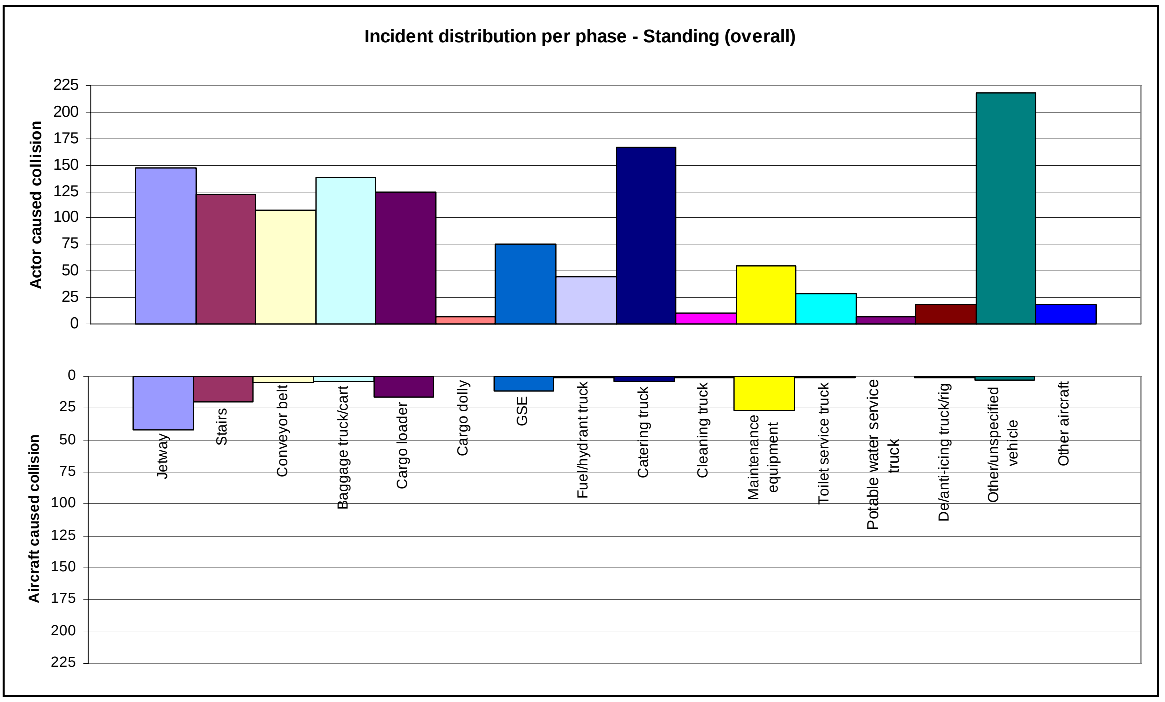

Figure 7 Incident distribution per phase – Standing (overall)

When the aircraft is parked on the aircraft stand and is stationary, all actors that have been identified (16) start servicing the aircraft at some stage. As a result of the high number of actors in the confined space of the aircraft stand, all defined actors are represented in the incident causes. Of the total amount of ground incidents with aircraft damage as result, 84% is caused when the aircraft is stationary, which corresponds with a rate of 0.1714 incidents per 1000 flights.

It is noted that, although the highest number of incidents is caused by actors (90%), still 10% is caused by the aircraft. The main cause that accounts for these 10% is that the aircraft settles during fuelling, passenger (dis)embarkation and (un)loading. Although the aircraft is stationary, it may still move in the vertical pane when mass is added or removed. When required clearances with the aircraft doors or fuselage are not kept, settling of the aircraft may cause aircraft damage.

Specific interfaces that make the aircraft vulnerable for damage caused by settling can be identified. Damage to aircraft exits (doors) is caused when the aircraft settles on the jetway or stairs. Damage to the fuselage is inflicted when the aircraft settles on ground handling equipment that is positioned underneath the aircraft fuselage (maintenance equipment and GSE). Also in some occasions (cargo) doors are opened without sufficient clearance with the jetway, ground vehicles or equipment.

When the actor ‘other/unspecified vehicle’ is excluded, 5 of the top 6 interfaces attach vehicles or equipment to the aircraft passenger or cargo doors. The remaining interface in the top 6 is the interface with baggage trucks/carts. The Schiphol Airport dataset shows a similar pattern, although baggage trucks and carts most frequently inflict damage to the aircraft.
A high number of damages inflicted by catering trucks is noticed, but it should be taken into consideration that even smaller commercial aircraft are serviced with two catering trucks at once, thereby increasing the traffic density on the aircraft stand. The same applies to cargo loaders and baggage trucks/carts.

Figure 8 shows the incident distribution during the pushback.

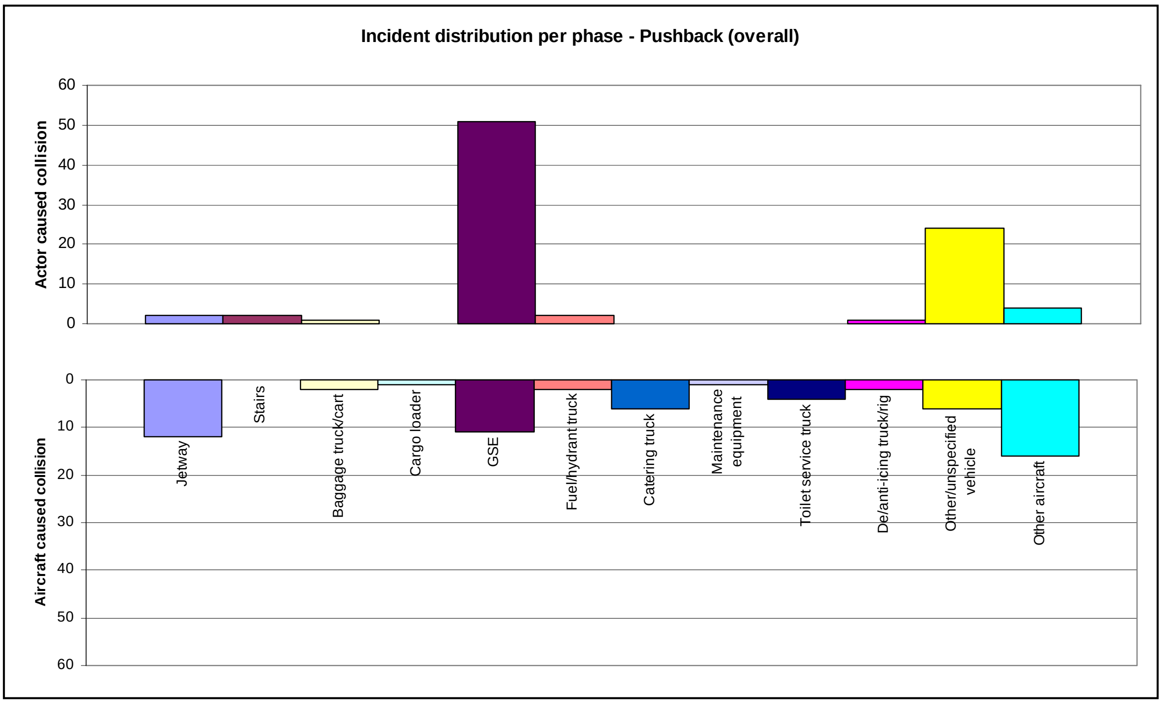

Figure 8 Incident distribution per phase – Pushback (overall)

Of the total amount of ground incidents with aircraft damage as result, 7% is caused during the pushback, which corresponds with a rate of 0.0134 incidents per 1000 flights. Although the causes are more or less evenly spread between aircraft (42%) and actors (58%), it should be noticed that the aircraft is not moved by its own power, but by a pushback truck. Therefore, most damage caused by the aircraft is in fact caused by incorrect manoeuvring of the pushback truck. For example, the jetway or toilet service truck may still be attached to the aircraft when the pushback is started. Underlying causes may be miscommunication, impaired vision or insufficient clearance from other actors’ vehicles or equipment.

A total amount of 12 interfaces are involved with regard to aircraft damage during the pushback, but peaks are shown for interfaces with GSE and other/unspecified vehicles. Many incidents relate to failing towbars with resulting aircraft damage, or to collisions with the pushback truck due to incorrect use of the aircraft parking brake. The interfaces of the aircraft with the towbar and pushback truck should be the only existing interfaces during the pushback.
Pushback operations consist of a complex set of procedures, responsibilities and moving hardware interfaces (aircraft – towbar – pushback truck). Additionally, staff of several organizations is involved (flight crew, GHO, maintenance). Complicating factors, such as a slippery ramp surface or impaired vision may result in an uncontrolled pushback and an increased risk of collision.

Figure 9 shows the incident distribution during taxi to runway.

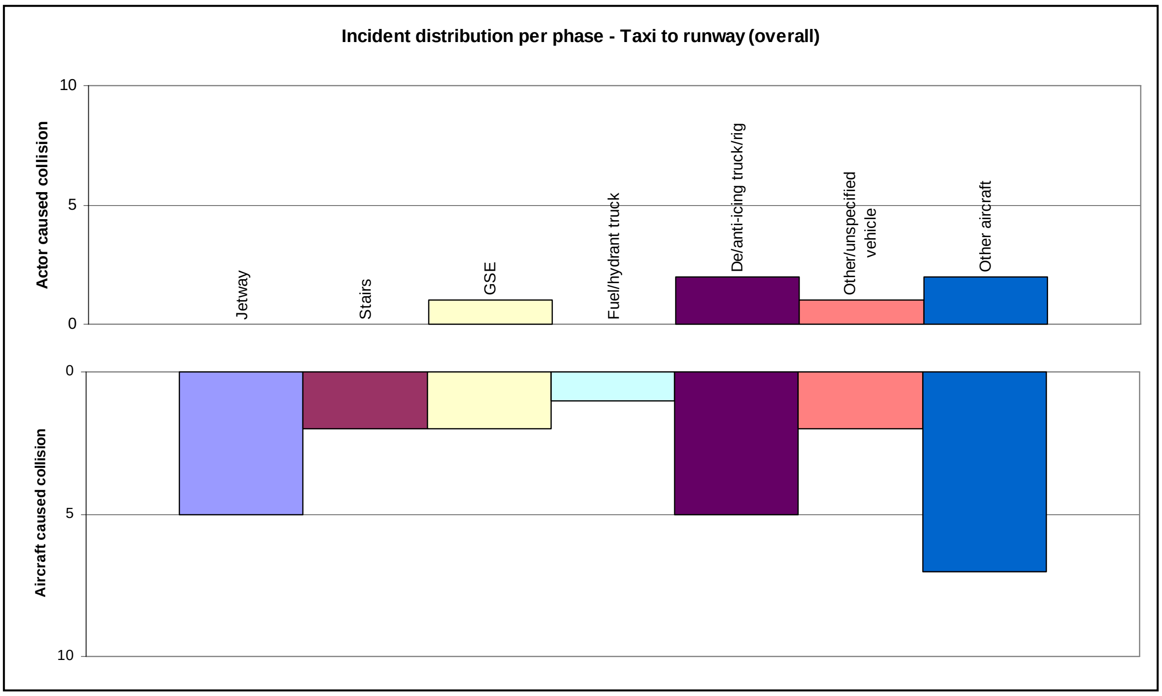

Figure 9 Incident distribution per phase – Taxi to runway (overall)

The incident rate of aircraft damage during taxi to runway is 0.0042 per 1000 flights and represents 2% of the ground incidents that cause aircraft damage. It is noticed that 81% of the collisions is caused by movement of the aircraft itself. No interfaces with other vehicles or equipment should exist during taxi to runway.
When compared to the taxi-in phase, it is noticed that the same amount of interfaces (7) are involved in incident causes, of which 5 cause damage in both phases. The major difference in the remaining 2 interfaces is that during taxi to runway, damage to jetways and stairs is only

caused by the aircraft itself, whereas these 2 interfaces are not represented as incident cause during taxi-in.

Figure 10 shows the incident distribution during towing.

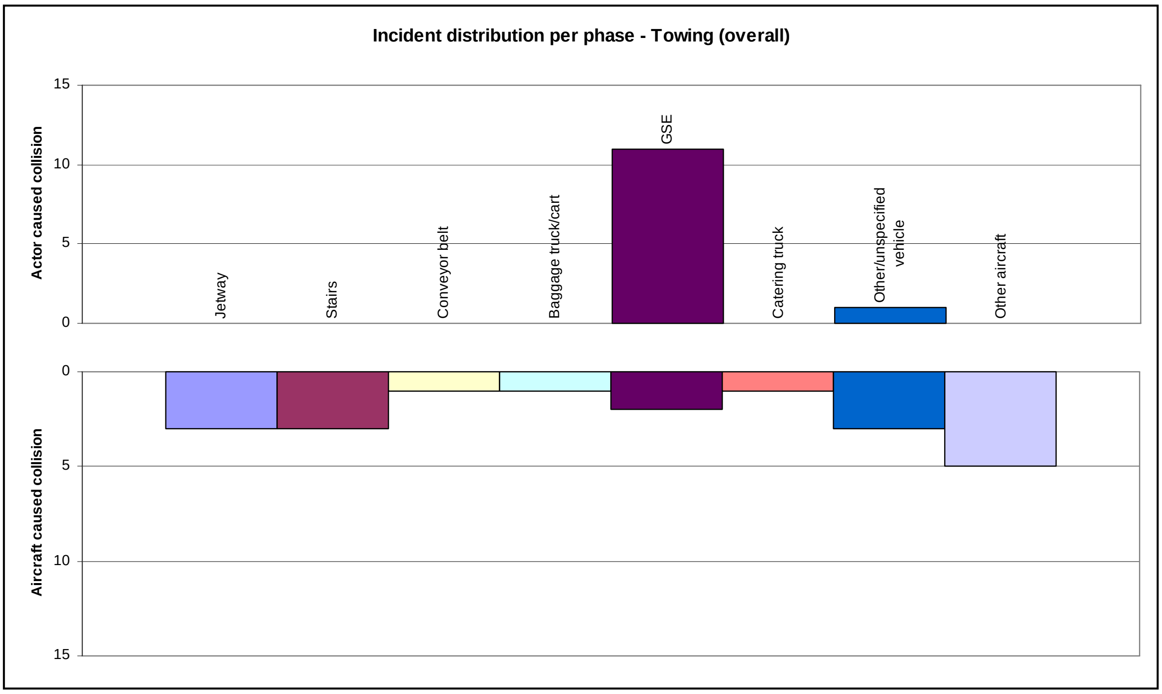

Figure 10 Incident distribution per phase – Towing (overall)

Of the total amount of ground incidents with aircraft damage as result, 2% is caused when the aircraft is being towed. This corresponds with a rate of 0.0035 incidents per 1000 flights. Similar as during pushback operations, it should be noticed that the aircraft is not moved on its own power, but by a tow truck. A total number of 8 interfaces are identified as incident causes. Of the incidents, 65% is caused by the aircraft, whereas the other 35% is primarily caused by GSE. As already has been noticed during the pushback phase, many incidents relate to failing towbars with resulting aircraft damage.

Other

Striking numbers in the other causes of aircraft damage are the incidents in which damage is found but its origin not specified (27% of total incidents), and damage that is caused during (un)loading (7% of total incidents). The Schiphol Airport dataset provides more or less similar results of 20% and 9% respectively.

Reasons for the high number of damages for which its origin has not been specified may be that:

- The original report was provided without sufficient details to specify the origin of the damage; or
- The damage was found by another party, which implies that the original damage had not been noticed or reported.

Damage to the aircraft interior caused during (un)loading may have several causes:
- Pallets were built-up outside contours;
- Shifting cargo/baggage; or
- Rough cargo/baggage handling.

It should be noted that when damage is found inside the cargo holds or main cargo deck before (un)loading, the original damage may not have been noticed or reported by the personnel responsible for loading the previous flight(s).

3.2 Regulatory framework

With regard to the ground handling process an international regulatory framework exists, but this has particularly been developed for operators and airports.

Table 4 describes the regulation framework applicable to the ground handling process and which interfaces are affected by the regulations.

Table 4 Regulatory framework ground handling

Actor	Regulation	Description	Related interfaces
Operator	JAR-OPS 1.035	Quality system	All
	JAR-OPS 1.037	Accident prevention and flight safety programme	All
	JAR-OPS 1.120	Endangering safety	All
	JAR-OPS 1.175	General rules for Air Operator Certification	All
	JAR-OPS 1.205	Competence of Operations personnel	All
	JAR-OPS 1.210	Establishment of procedures	All
	JAR-OPS 1.305	Refuelling/defuelling with passengers embarking, on board or disembarking	Fuel provider, Airport, GHO, Catering, Cleaning (clear areas)
	JAR-OPS 1.307	Refuelling/defuelling with wide-cut fuel	Fuel provider
	JAR-OPS 1.308	Pushback and towing	GHO, Maintenance, Airport
	JAR-OPS 1.345	Ice and other contaminants – ground procedures	De/anti-icing, Airport
	JAR-OPS subpart J	Mass and balance	GHO
	JAR-OPS 1.1040	General rules for Operations Manuals	All
	JAR-OPS 1.1045	Operations Manual – structure and contents	All
	JAR-OPS subpart R	Transport of Dangerous Goods by air	GHO
	JAR-OPS subpart S	Security	All
Airport	ICAO Annex 14	Volume 1 Aerodrome design and operations	All
	RCL	Regeling Certificering Luchthaventerreinen	All

Safe operation during ground handling is desired by all organizations involved. However, from a regulatory point of view, safe operation is a shared responsibility of only two of the actors: the operators and the airport.

Operators are partially responsible for safe operation during ground handling, since JAR-OPS 1 requires that procedures for ground staff have to be established, ground staff have to be trained and that no person endangers the aircraft or occupants. The operator also has to appoint a nominated postholder who is responsible for management and supervision of ground operations. The operator's quality system should assure compliance with, and adequacy of, procedures required to ensure safe operational practices. Some procedures are more specifically described, like fuelling, pushback/towing, de/anti-icing and loading of the aircraft. Means to monitor safe operational practices are the by JAR-OPS 1 required accident prevention and flight safety programme, and the occurrence reporting system.
As the aircraft is the focal point of all ground handling activities, the operator is involved in all interfaces with ground handling vehicles and equipment. JAR-OPS 1 has to be used as basic principle for developing specified procedures for ground handling activities, which have to be embedded in contract arrangements with the contracted parties. Contract arrangements should also include arrangements for (recurrent) training of ground handling staff.

The airport is also partially responsible for safe operations during ground handling, as it has to comply with regulations set out in ICAO Annex 14. Although ICAO Annex 14 primarily concerns airport facilities, some operating procedures are included with regard to driving on the apron. An overlap with JAR-OPS 1 regulations is noticed in procedures for fuelling with passengers on board.
ICAO Annex 14 paragraph 1.4 requires that as per 27th November 2003, States shall certify aerodromes used for international operations in accordance with the specifications contained in the Annex, as well as other relevant ICAO specifications through an appropriate regulatory framework. The Dutch *Ministerie van Verkeer en Waterstaat* has adopted this regulation in the *Regeling certificering luchtvaartterreinen (RCL)*, which states that aerodromes should have an operational Safety Management System (SMS) as per 25th November 2005. Based on the *Regeling Toezicht Luchtvaart (RTL)*, certification of aerodromes is currently done on a voluntary basis. Schiphol Airport has initially been certified in accordance with RCL in 2004 and on 4th July 2007 the certificate has been extended for another three years.
RCL applies only to the airport proprietor, so it requires that *internal* company processes are established in such a way that they assure safe operations. It states that airports are not responsible for safe operations of other organizations present on the airport. However, airports are authorized by means of the *Algemeen Luchthavenreglement* to enforce additional

requirements with regard to discipline and safety. Non-adherence to the *Algemeen Luchthavenreglement* by organizations present on the airport is an offence and sanctions may be imposed on the organization that commits the offence. Compliance with regulations should be included in contract arrangements with contracted parties.
The regulatory framework and contract arrangements applicable to the ground handling process are shown in Appendix G.

Regulations on security and occurrence reporting enclose all organizations in the aviation sector, i.e.:

- EC 2320/2002 (Common rules in the field of civil aviation security);
- *Richtlijn 2003/42/EG (Melding van voorvallen in de burgerluchtvaart).*

Although not directly related to the ground handling process, security regulations may influence ground handling activities. On-board security checks may have to be performed, which have to be accommodated in the ground handling process. To make the turnaround time as short as possible, certain security tasks may be assigned to other organizations like cleaning- or ground handling staff.
The objective of *Richtlijn 2003/42/EG* is to contribute to safety improvement in the aviation industry by collecting, storing, protecting and distributing safety information. The *Richtlijn* requires operators, airports, maintenance companies, Air Traffic Control (ATC) and ground handling organizations to report occurrences that could affect flight safety to the National Aviation Authorities. Organizations that provide catering, cleaning, toilet service and potable water service are not specifically mentioned, but according the *Algemeen Luchthavenreglement* these organizations should report such occurrences to the airport proprietor. Required reporting of occurrences by all actors involved in ground handling may improve safety awareness and provide a basis for safety improvement.
It is, however, noticed that several options to report occurrences are present for organizations involved in ground handling. Since operators at Schiphol Airport manage their own occurrence reporting system, contract arrangements with other parties may include a clause which requires that occurrences are reported to the operator. Organizations present at Schiphol Airport have to adhere to the *Algemeen Luchthavenreglement*, which already contains a clause which requires that occurrences are reported to the Airport Authorities. Apart from these two reporting lines, there is always the option for organizations to report directly to the National Aviation Authorities. The various reporting lines may lead to scattered information present at either the operator, Airport Authorities or National Aviation Authorities. Additionally, several (different) reporting filters may be applied by operators or airports before occurrences are reported to the National Aviation Authorities. When no clear reporting standards on what to report are

established and agreed upon by all actors involved, valuable information is denied to the National Aviation Authorities, which have the means and authority to implement measures to improve safety.

4 Findings and conclusions

The analysis shows a rate of one ground handling incident with resulting aircraft damage per 5000 flights. Most incidents occur when the aircraft is parked.

Except from the fact that no incidents during the taxi-in phase are reported in the Schiphol Airport dataset, no specific differences in incident distribution between the overall dataset and the Schiphol Airport dataset is found.

Investigation into the major incident causes in the overall dataset reveals that 61% of the incidents are caused when an interface is established between the aircraft and ground handling equipment. The remaining 39% is inflicted by other causes on the airport. In the Schiphol Airport dataset this relation is 69% versus 31% respectively.

Of the incidents when the aircraft is parked, 90% is caused by actors and 10% by the aircraft itself. Damage is most frequently inflicted by actors that attach vehicles or equipment to the aircraft passenger- or cargo doors. High incident rates for catering trucks, baggage trucks/carts and cargo loaders may be explained by the fact that these actors usually service the aircraft with more vehicles at a time.

During pushback and towing, ground service equipment causes most frequently damage to the aircraft. This is probably caused by the several interfaces (aircraft – towbar – pushback truck) and organizations (operator – GHO – maintenance) involved.

In 27% of the aircraft damage incidents the origin is not specified. This is either caused by the fact that the original report contains insufficient information, or that the cause of the damage has not been found. Another 7% of the incidents consists of internal damage found on, or inflicted to the aircraft. For a number of incidents included in this percentage, the damage cause is not specified or found. This kind of ‘unreported’ damage (over one-third of the incidents) poses the highest risk to flight safety, as the damage has either not been noticed, or otherwise not been reported.

In the current regulatory framework, ground handling safety is a shared responsibility between operators and the airport. JAR-OPS 1 requires operators to establish a quality system, accident prevention and flight safety programme, and an occurrence reporting system. ICAO Annex 14 requires airports to establish a safety management system. Regulations do not require other organizations present on the airport to have an operational safety management system or meet minimum (safety) standards like IATA recommended industry standards.

Richtlijn 2003/42/EG provides a good opportunity to identify and assess actual risk levels in the ground handling process. However, there are various reporting lines, which may lead to scattered information present at either the operator, Airport Authorities or National Aviation Authorities. Additionally, several reporting filters may be applied by operators or airports before occurrences are reported to the National Aviation Authorities. When no clear reporting standards on what to report are established and agreed upon by all actors involved, valuable information is denied to the National Aviation Authorities, with which safety at the airport could have been improved.

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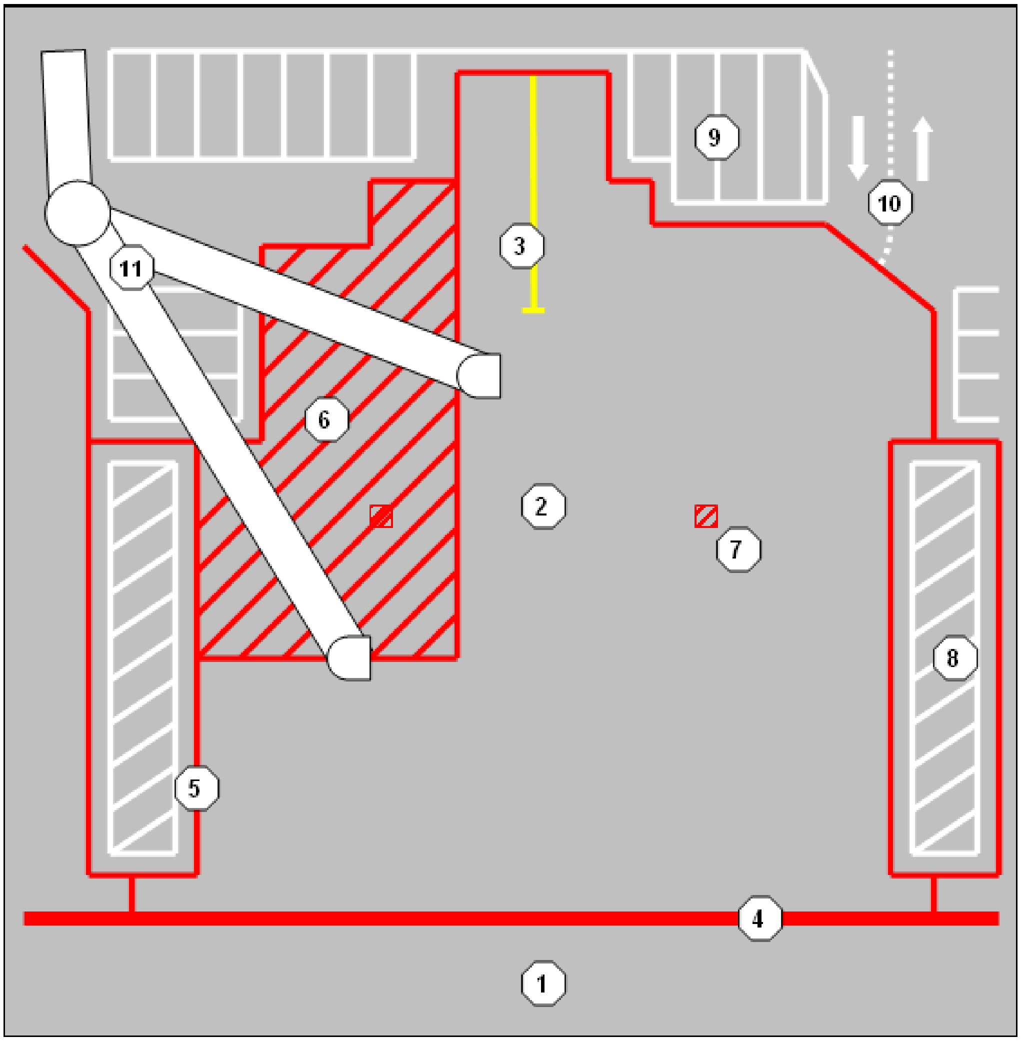
Appendix A Ground handling areas

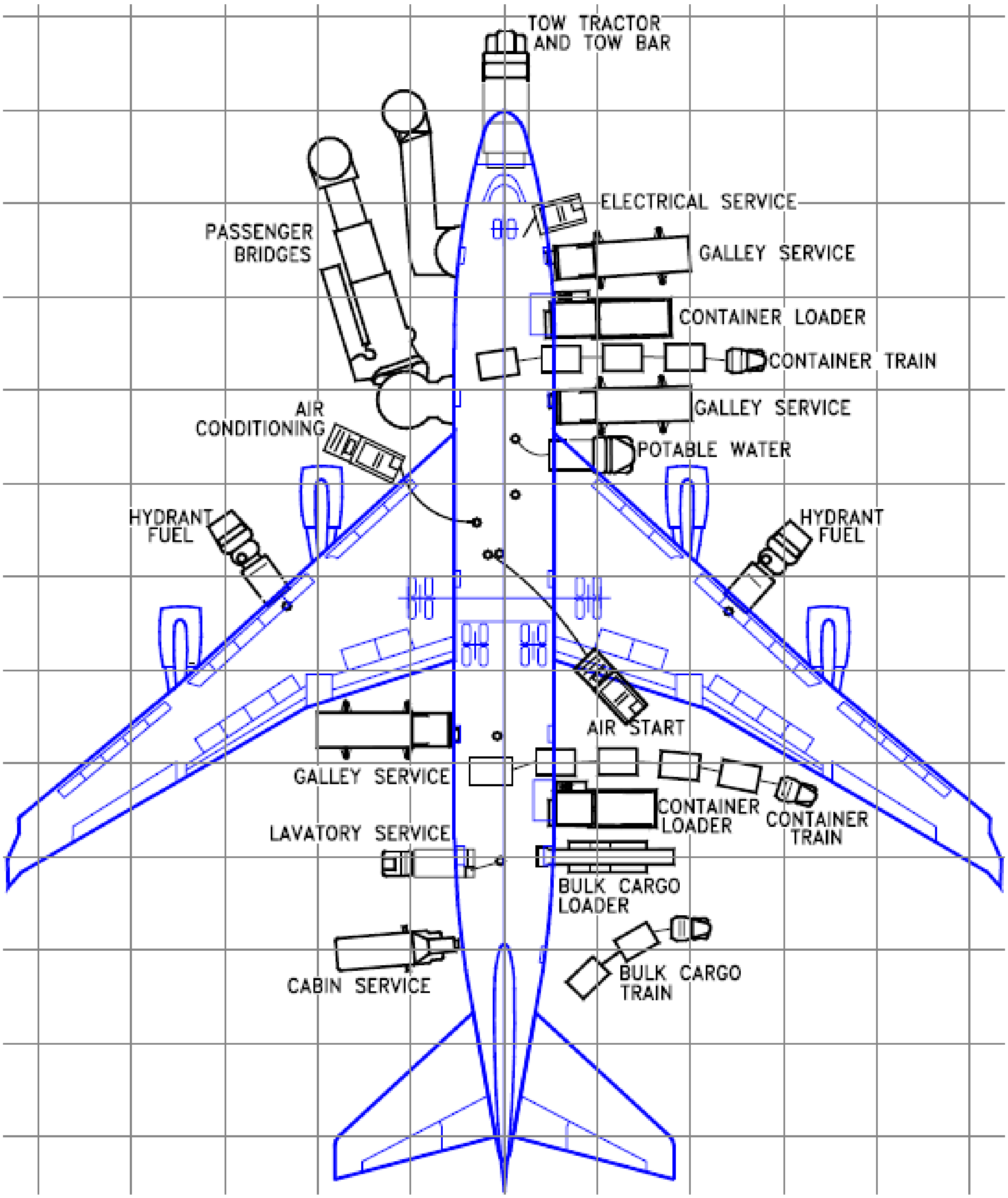


Legend:

1) Taxiway
2) Aircraft stand
3) Aircraft stand marking
4) Aircraft stand clearance line
5) Aircraft clearance line
6) Movement area jetway
7) Fuel hydrant pit
8) Parking space ground handling equipment with height restriction
9) Parking space ground handling equipment
10) Access/exit
11) Jetway

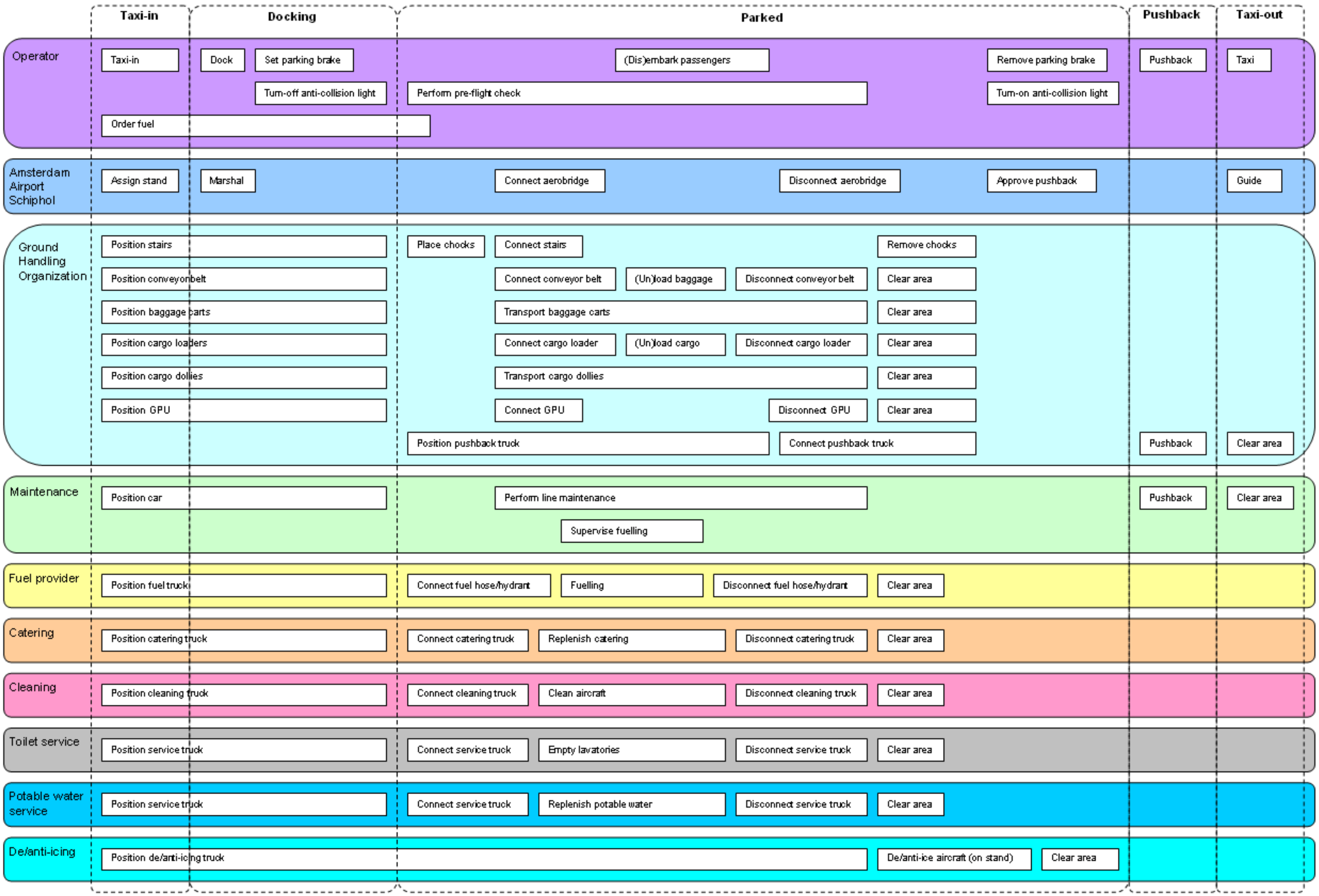
Source: Adapted from Zakboek Veiligheid Airside, Amsterdam Airport Schiphol

Appendix B Typical handling arrangement 747-400 passenger configuration



Source: www.boeing.com

Appendix C Typical ground handling process



Appendix D Analysis results overall dataset

Interfaces / *Phase*	*= sum*	*Taxi-in*	*Docking*	*Standing*	*Pushback*	*Taxi to runway*	*Towing*	*Plower*	*Pmean*	*Pupper*
Aircraft causes collision to:										
Jetway	*87*		25	42	12	5	3	2.46E-02	**3.06E-02**	3.76E-02
Stairs	*30*		5	20		2	3	7.14E-03	**1.06E-02**	1.50E-02
Conveyor belt	*13*		7	5			1	2.44E-03	**4.58E-03**	7.81E-03
Baggage truck/cart	*12*		5	4	2		1	2.18E-03	**4.22E-03**	7.37E-03
Cargo loader	*19*		2	16	1			4.03E-03	**6.69E-03**	1.04E-02
Cargo dolly	*1*					1		8.91E-06	**3.52E-04**	1.96E-03
GSE	*34*	1.5	6.5	11	11	2	2	8.30E-03	**1.20E-02**	1.67E-02
Fuel/hydrant truck	*19*	1.5	13.5	1	2	1		4.03E-03	**6.69E-03**	1.04E-02
Catering truck	*18*		7	4	6		1	3.76E-03	**6.34E-03**	9.99E-03
Cleaning truck	*2*		1	1				8.53E-05	**7.04E-04**	2.54E-03
Maintenance equipment	*32*			27	1	1	3	7.72E-03	**1.13E-02**	1.59E-02
Toilet service truck	*5*			1	4			5.72E-04	**1.76E-03**	4.10E-03
Potable water truck	*0*							none	**0.00E+00**	1.30E-03
De/anti-icing truck/rig	*8*			1	2	5		1.22E-03	**2.82E-03**	5.54E-03
Unspecified/other vehicle	*23*	4	5	3	6	2	3	5.14E-03	**8.10E-03**	1.21E-02
Other aircraft	*33*	1.5	3.5		16	7	5	8.01E-03	**1.16E-02**	1.63E-02
Total	***336***	**8.5**	**80.5**	**136**	**63**	**26**	**22**	1.07E-01	**1.18E-01**	1.31E-01
Aircraft collision is caused by:										
Jetway	*154*		5	147	2			4.62E-02	**5.42E-02**	6.32E-02
Stairs	*126*		2	122	2			3.71E-02	**4.44E-02**	5.26E-02
Conveyor belt	*107*			107				3.10E-02	**3.77E-02**	4.53E-02
Baggage truck/cart	*141*	1	1	138	1			4.19E-02	**4.96E-02**	5.83E-02
Cargo loader	*126*	0.5	0.5	125				3.71E-02	**4.44E-02**	5.26E-02
Cargo dolly	*7*			7				9.91E-04	**2.46E-03**	5.07E-03
GSE	*139*	0.5	0.5	75	51	1	11	4.13E-02	**4.89E-02**	5.75E-02
Fuel/hydrant truck	*47*			45	2			1.22E-02	**1.65E-02**	2.19E-02
Catering truck	*170*		3	167				5.14E-02	**5.98E-02**	6.92E-02
Cleaning truck	*10*			10				1.69E-03	**3.52E-03**	6.46E-03
Maintenance equipment	*55*			55				1.46E-02	**1.94E-02**	2.51E-02
Toilet service truck	*29*			29				6.85E-03	**1.02E-02**	1.46E-02
Potable water truck	*7*			7				9.91E-04	**2.46E-03**	5.07E-03
De/anti-icing truck/rig	*22*	0.5	0.5	18	1	2		4.86E-03	**7.74E-03**	1.17E-02
Unspecified/other vehicle	*244*			218	24	1	1	7.58E-02	**8.59E-02**	9.68E-02
Other aircraft	*27*	3		18	4	2		6.27E-03	**9.50E-03**	1.38E-02
Total	***1411***	**5.5**	**12.5**	**1288**	**87**	**6**	**12**	4.78E-01	**4.97E-01**	5.15E-01
Total all interfaces	***1747***	***14***	***93***	***1424***	***150***	***32***	***34***	5.97E-01	**6.15E-01**	6.33E-01
Other										
FOD	*43*	4.5	4.5	22	6	6		1.10E-02	**1.51E-02**	2.03E-02
Jet blast	*26*	3.5	1.5	17		4		5.99E-03	**9.15E-03**	1.34E-02
Environmental	*66*	8.5	5.5	33	4	9	6	1.80E-02	**2.32E-02**	2.95E-02
Internal damage during (un)loading	*198*			198				6.06E-02	**6.97E-02**	7.97E-02
Damage found - origin not specified	*761*	7.5	4.5	705	27	8	9	2.52E-01	**2.68E-01**	2.85E-01
Total other	***1094***	**24**	**16**	**975**	**37**	**27**	**15**	3.67E-01	**3.85E-01**	4.03E-01
Total ground damage incidents	***2841***	***38***	***109***	***2399***	***187***	***59***	***49***	9.99E-01	**1.00E+00**	none
	Plower	9.48E-03	3.16E-02	8.31E-01	5.70E-02	1.58E-02	1.28E-02			
	Pmean	**1.34E-02**	**3.84E-02**	**8.44E-01**	**6.58E-02**	**2.08E-02**	**1.72E-02**			
	Pupper	1.83E-02	4.61E-02	8.58E-01	7.56E-02	2.67E-02	2.27E-02			

Pmean = Probability of incident occurring as part of the total number of ground damage incidents
Plower = Probability reliability – lower limit
Pupper = Probability reliability – upper limit

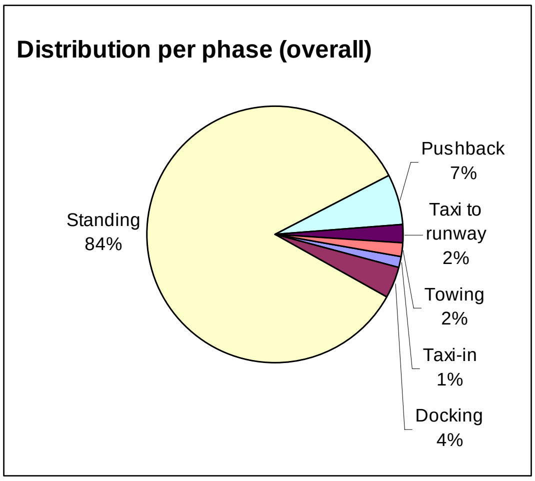
Appendix E Analysis results Schiphol Airport dataset

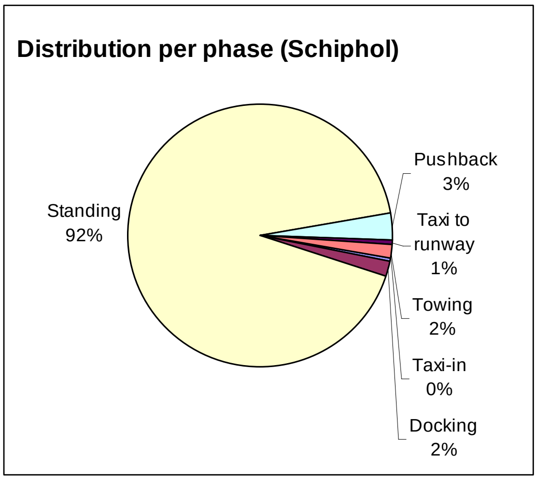
Interfaces / *Phase*	= *sum*	*Taxi-in*	*Docking*	*Standing*	*Pushback*	*Taxi to runway*	*Towing*	*Plower*	*Pmean*	*Pupper*
Aircraft causes collision to:										
Jetway	*10*		3	7				1.28E-02	**2.65E-02**	0.00E+00
Stairs	*6*		1	4			1	5.85E-03	**1.59E-02**	0.00E+00
Conveyor belt	*0*							none	**0.00E+00**	0.00E+00
Baggage truck/cart	*1*		1					6.70E-05	**2.65E-03**	0.00E+00
Cargo loader	*2*			2				6.41E-04	**5.29E-03**	0.00E+00
Cargo dolly	*0*							none	**0.00E+00**	0.00E+00
GSE	*4*		1	3				2.89E-03	**1.06E-02**	0.00E+00
Fuel/hydrant truck	*0*							none	**0.00E+00**	0.00E+00
Catering truck	*1*			1				6.70E-05	**2.65E-03**	0.00E+00
Cleaning truck	*0*							none	**0.00E+00**	0.00E+00
Maintenance equipment	*8*			7			1	9.18E-03	**2.12E-02**	0.00E+00
Toilet service truck	*1*			1				6.70E-05	**2.65E-03**	0.00E+00
Potable water truck	*0*							none	**0.00E+00**	0.00E+00
De/anti-icing truck/rig	*0*							none	**0.00E+00**	0.00E+00
Unspecified/other vehicle	*3*			1	2			1.64E-03	**7.94E-03**	0.00E+00
Other aircraft	*2*				2			6.41E-04	**5.29E-03**	0.00E+00
Total	***38***	**0**	**6**	**26**	**4**	**0**	**2**	7.21E-02	**1.01E-01**	0.00E+00
Aircraft collision is caused by:										
Jetway	*24*			24				4.11E-02	**6.35E-02**	0.00E+00
Stairs	*19*			19				3.05E-02	**5.03E-02**	0.00E+00
Conveyor belt	*25*			25				4.33E-02	**6.61E-02**	0.00E+00
Baggage truck/cart	*46*			46				9.05E-02	**1.22E-01**	0.00E+00
Cargo loader	*22*			22				3.68E-02	**5.82E-02**	0.00E+00
Cargo dolly	*1*			1				6.70E-05	**2.65E-03**	0.00E+00
GSE	*11*			8	1	1	1	1.46E-02	**2.91E-02**	0.00E+00
Fuel/hydrant truck	*1*			1				6.70E-05	**2.65E-03**	0.00E+00
Catering truck	*34*			34				6.31E-02	**8.99E-02**	0.00E+00
Cleaning truck	*5*			5				4.31E-03	**1.32E-02**	0.00E+00
Maintenance equipment	*2*			2				6.41E-04	**5.29E-03**	0.00E+00
Toilet service truck	*1*			1				6.70E-05	**2.65E-03**	0.00E+00
Potable water truck	*2*			2				6.41E-04	**5.29E-03**	0.00E+00
De/anti-icing truck/rig	*5*			4	1			4.31E-03	**1.32E-02**	0.00E+00
Unspecified/other vehicle	*24*			20	3		1	4.11E-02	**6.35E-02**	0.00E+00
Other aircraft	*1*			1				6.70E-05	**2.65E-03**	0.00E+00
Total	***223***	**0**	**0**	**215**	**5**	**1**	**2**	5.38E-01	**5.90E-01**	0.00E+00
Total all interfaces	***261***	***0***	***6***	***241***	***9***	***1***	***4***	6.41E-01	**6.90E-01**	0.00E+00
Other										
FOD	*1*			1				6.70E-05	**2.65E-03**	0.00E+00
Jet blast	*2*	1	1					6.41E-04	**5.29E-03**	0.00E+00
Environmental	*4*			2			2	2.89E-03	**1.06E-02**	0.00E+00
Internal damage during (un)loading	*33*			33				6.09E-02	**8.73E-02**	0.00E+00
Damage found - origin not specified	*77*			72	4	1		1.64E-01	**2.04E-01**	0.00E+00
Total other	***117***	**1**	**1**	**108**	**4**	**1**	**2**	2.63E-01	**3.10E-01**	0.00E+00
Total ground damage incidents	***378***	***1***	***7***	***349***	***13***	***2***	***6***	9.90E-01	**1.00E+00**	none
	Plower	6.70E-05	7.48E-03	8.92E-01	1.84E-02	6.41E-04	5.85E-03			
	Pmean	***2.26E-03***	***1.85E-02***	***9.23E-01***	***3.44E-02***	***5.29E-03***	***1.59E-02***			
	Pupper	1.46E-02	3.78E-02	9.48E-01	5.81E-02	1.90E-02	3.42E-02			

Pmean = Probability of incident occurring as part of the total number of ground damage incidents
Plower = Probability reliability – lower limit
Pupper = Probability reliability – upper limit

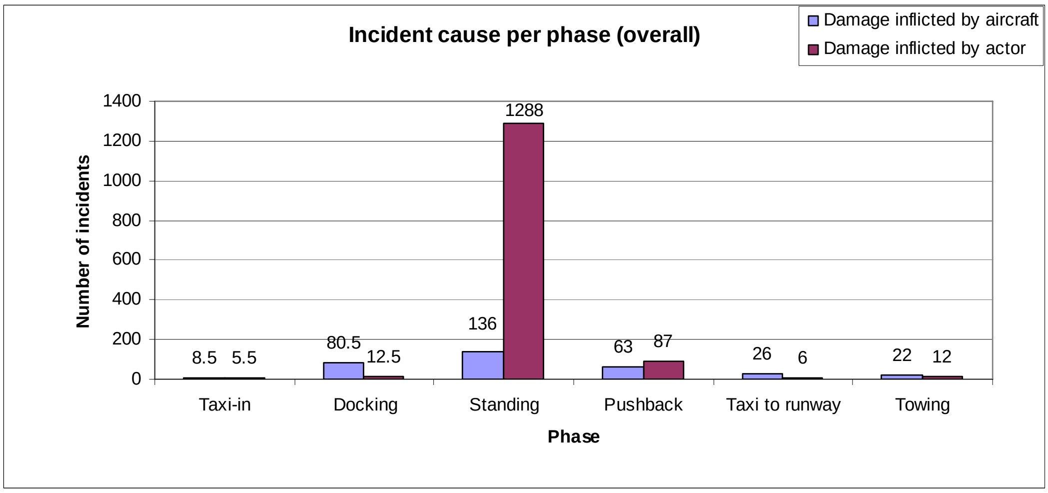
Appendix F Comparison of analysis results

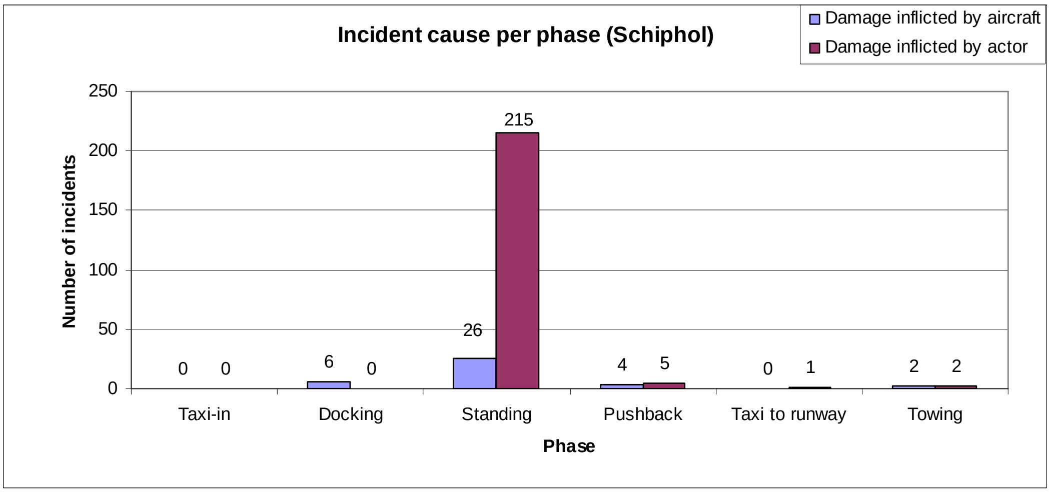
1. Comparison distribution by phase



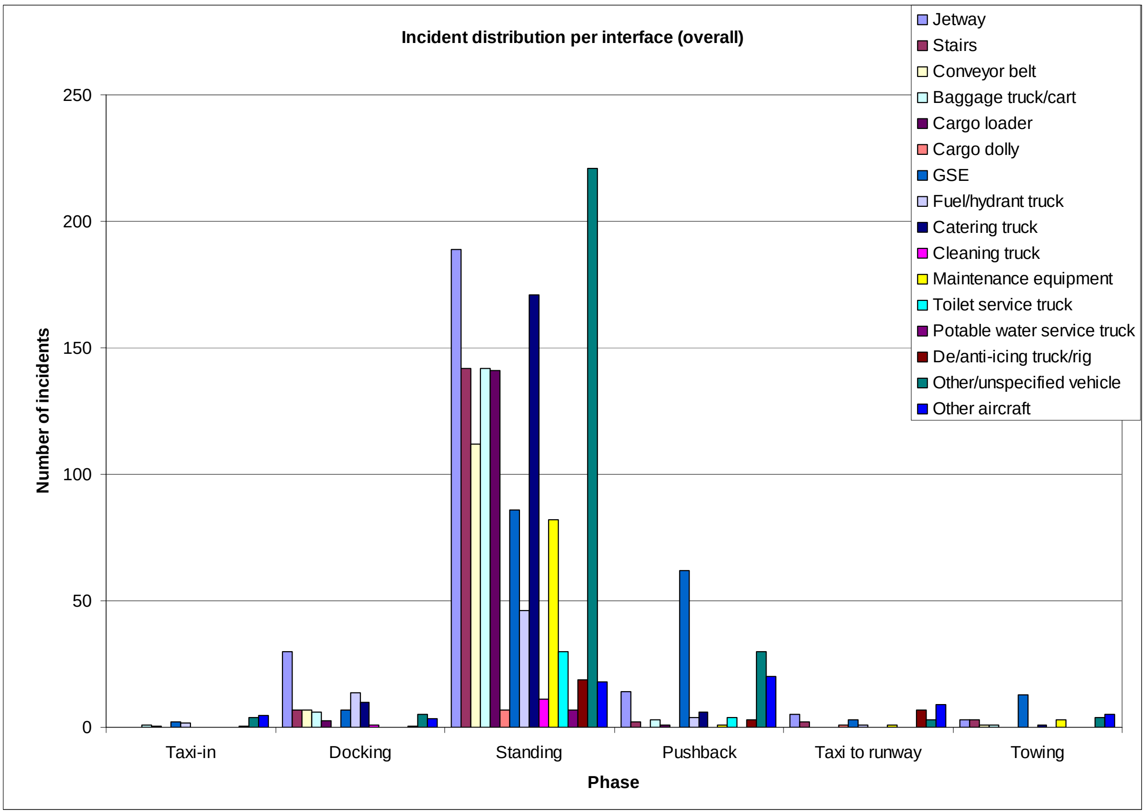


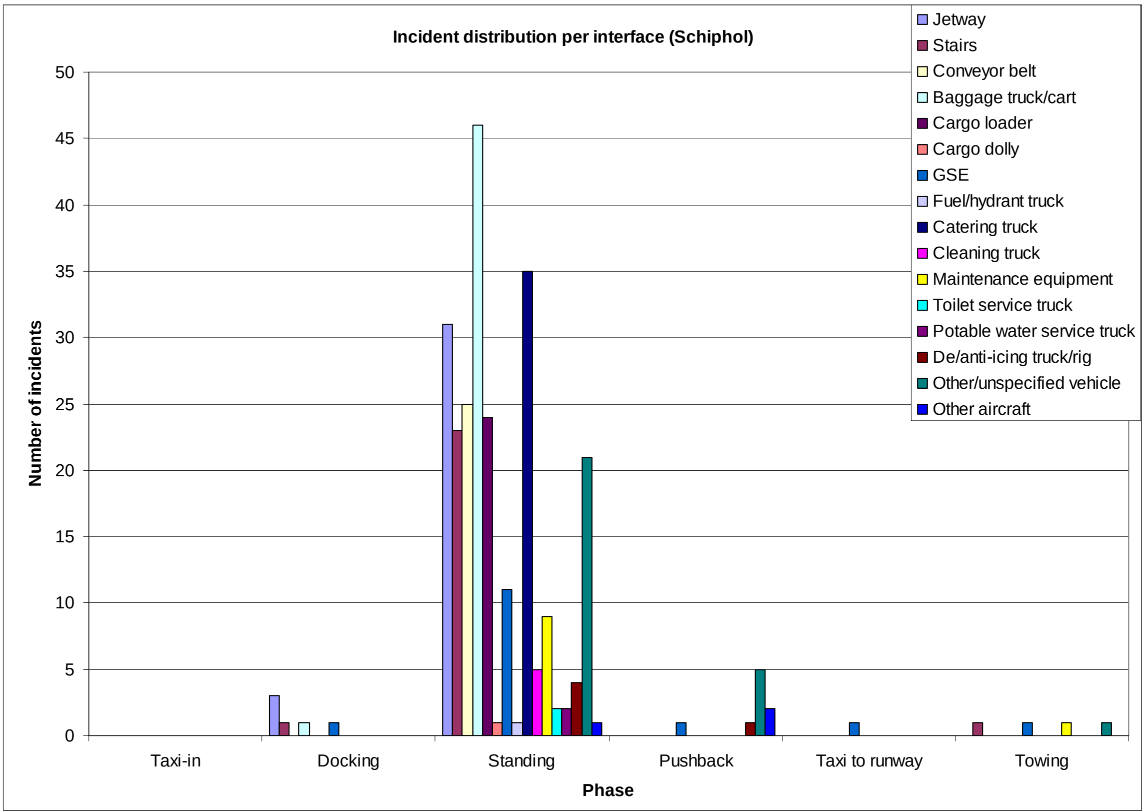
2. Comparison incident cause by phase



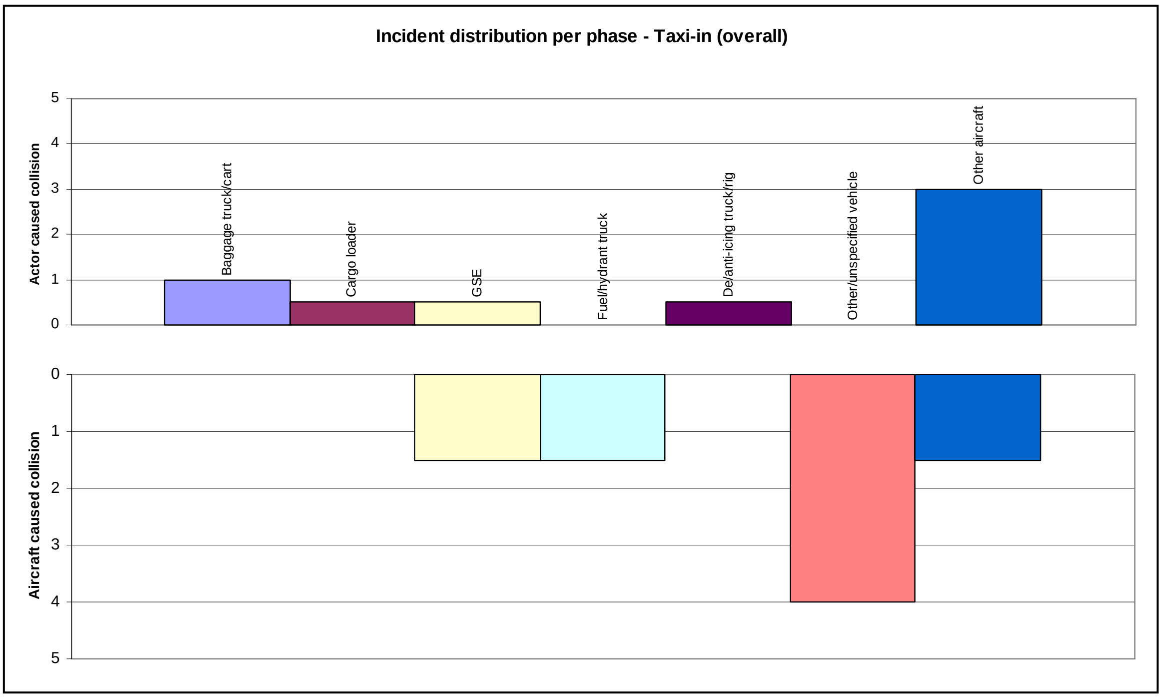


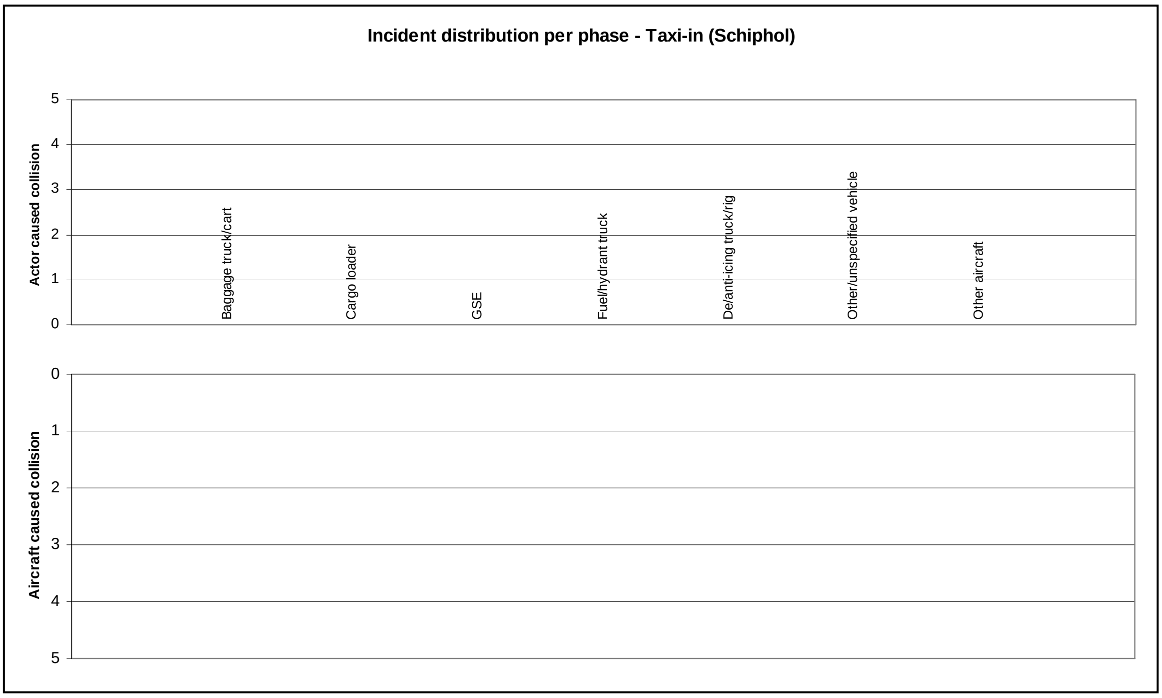
3. Comparison incident distribution per interface



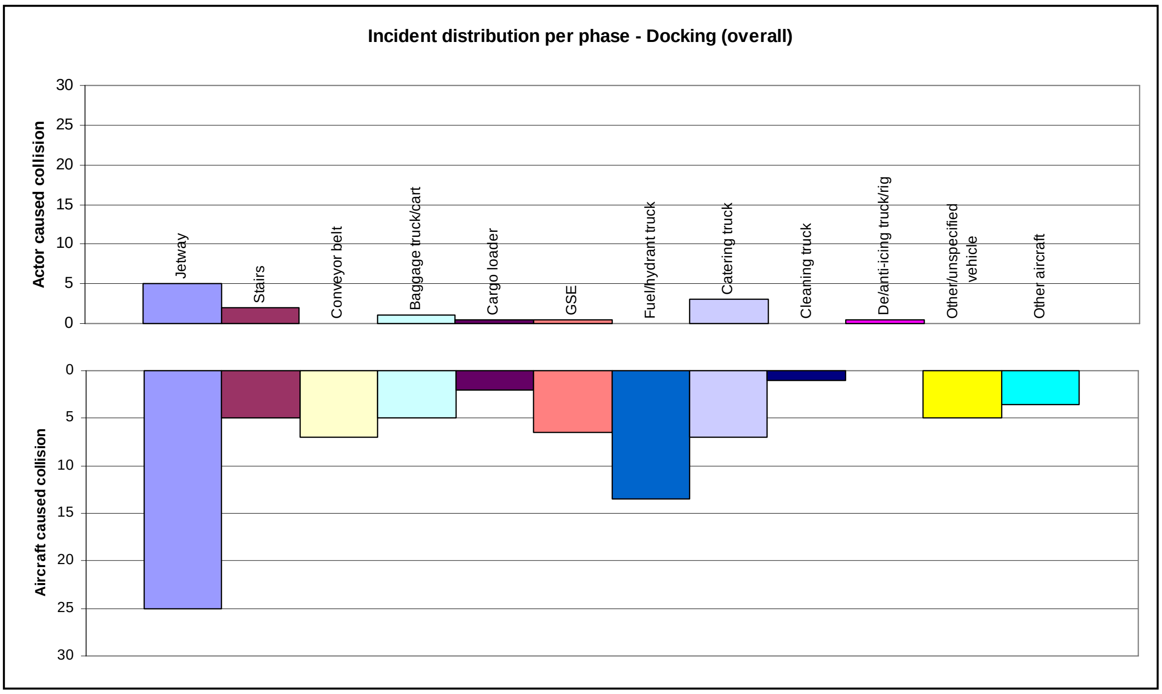


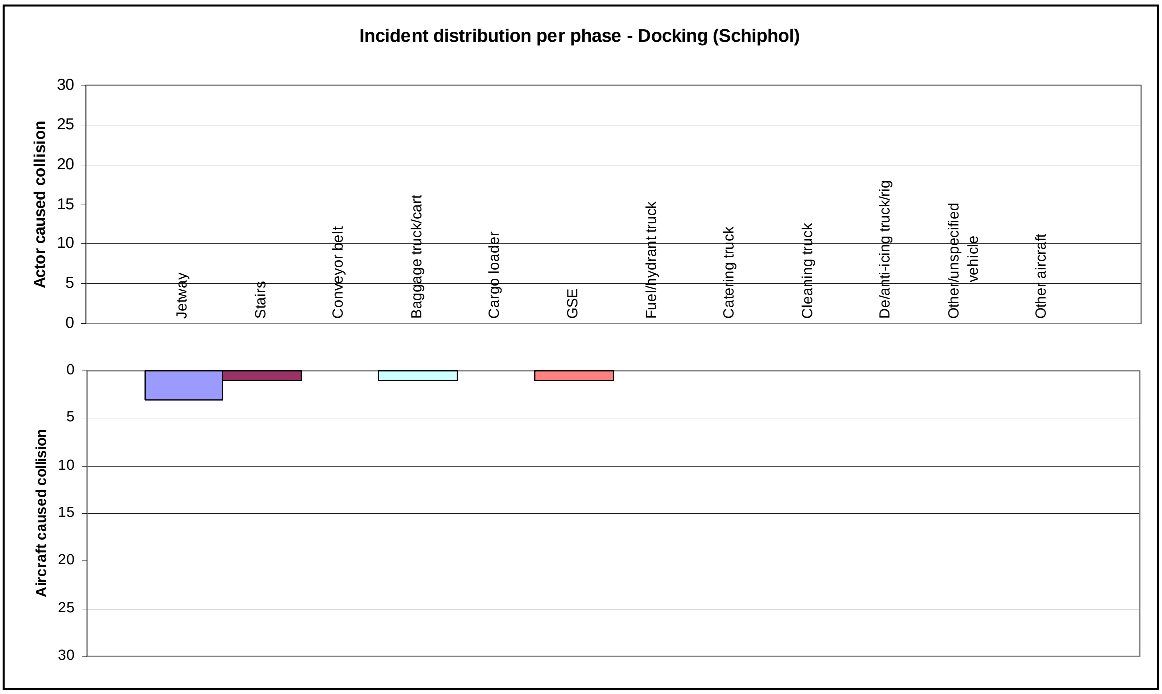
4. Comparison incident distribution per phase – Taxi-in



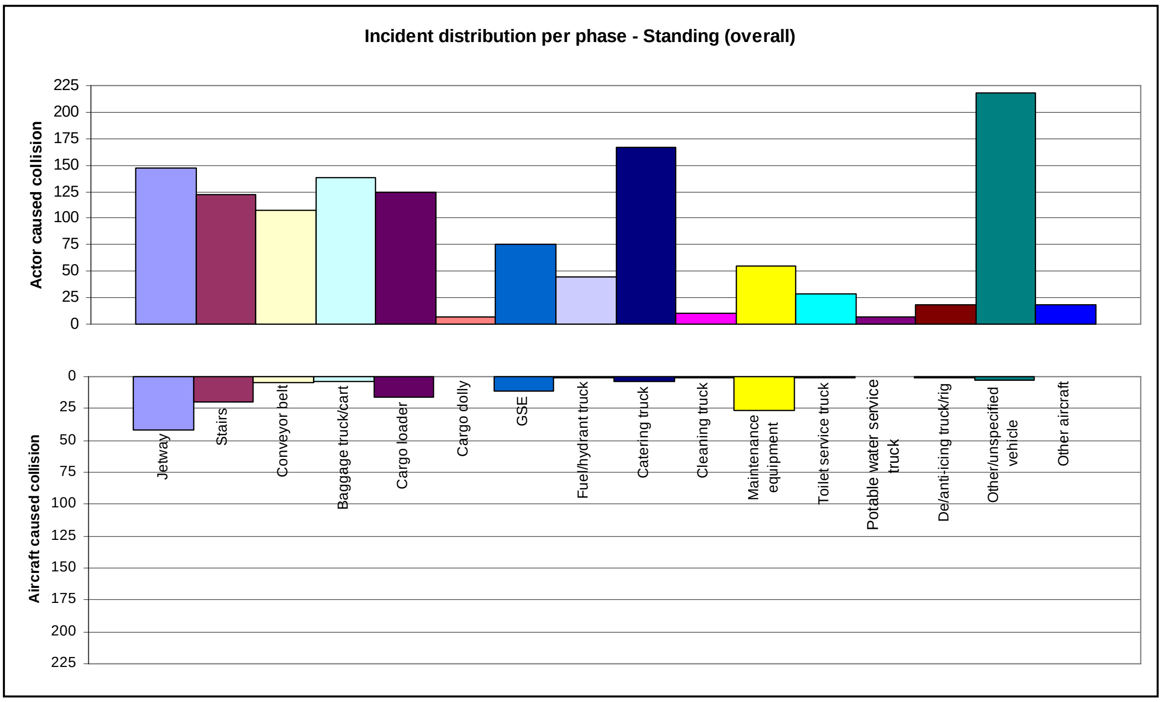


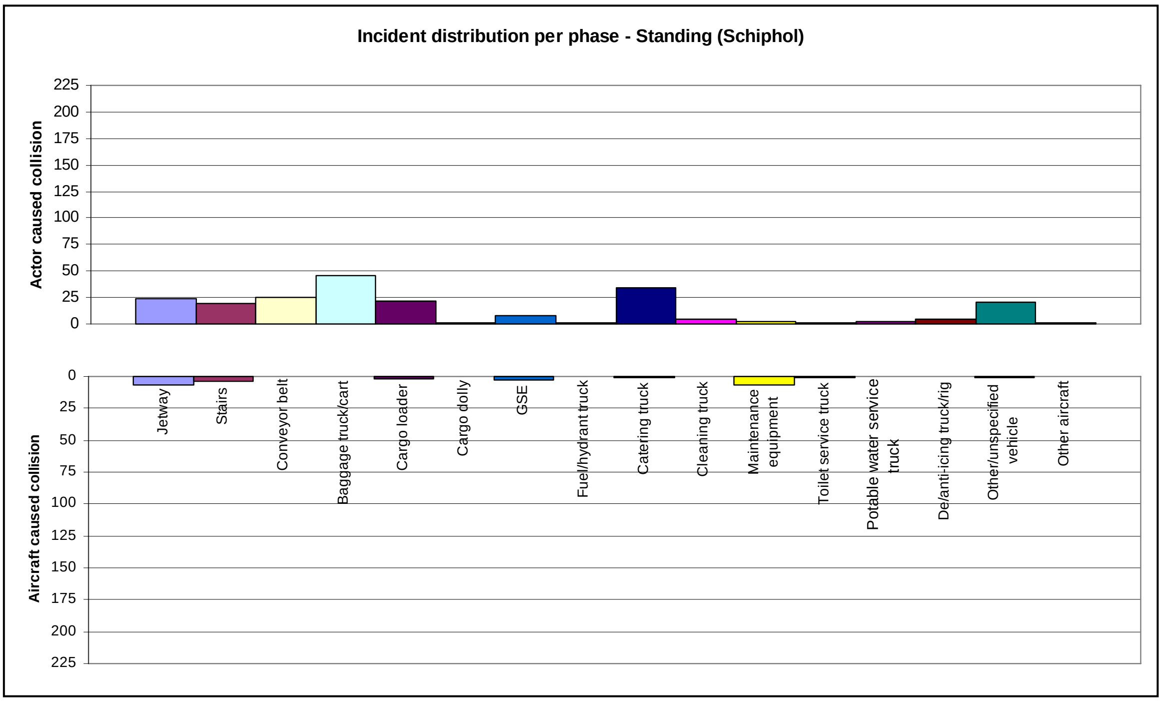
5. Comparison incident distribution per phase – Docking



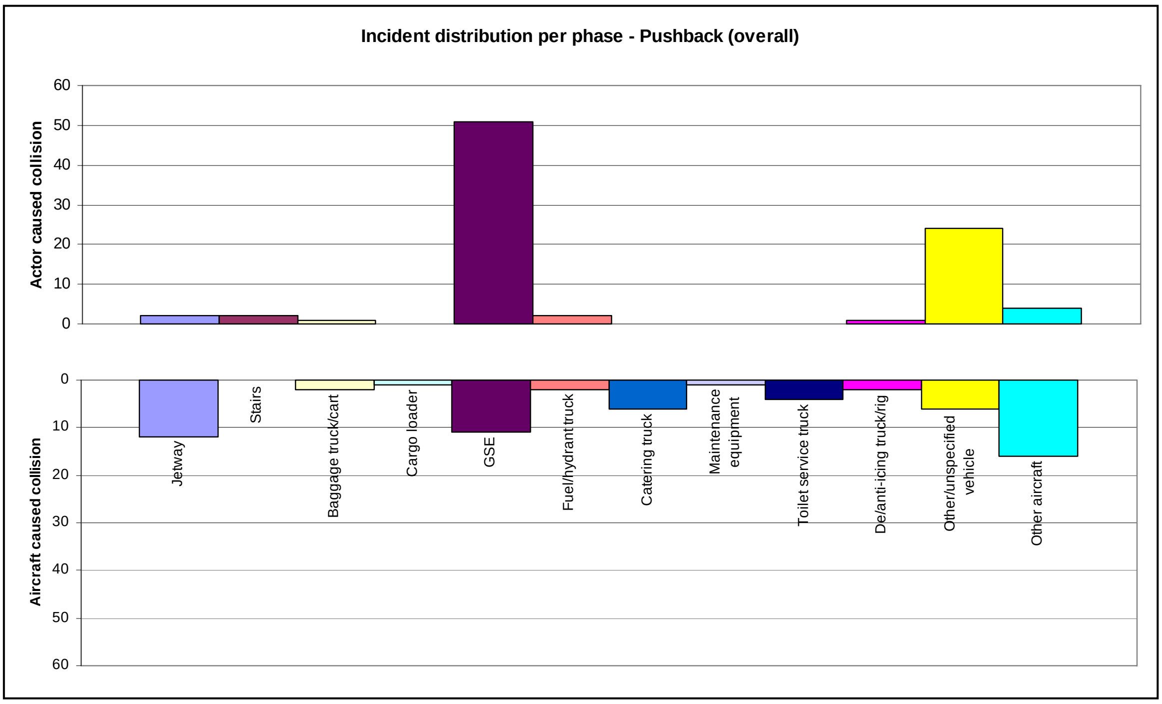


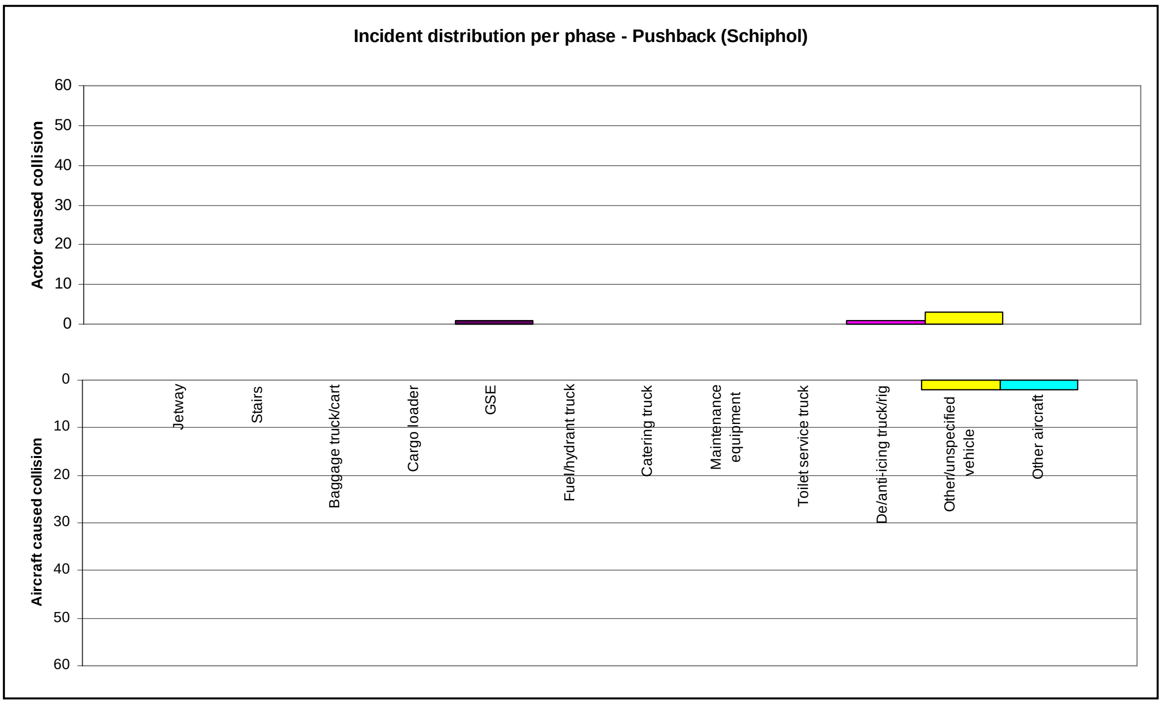
6. Incident distribution per phase – Standing



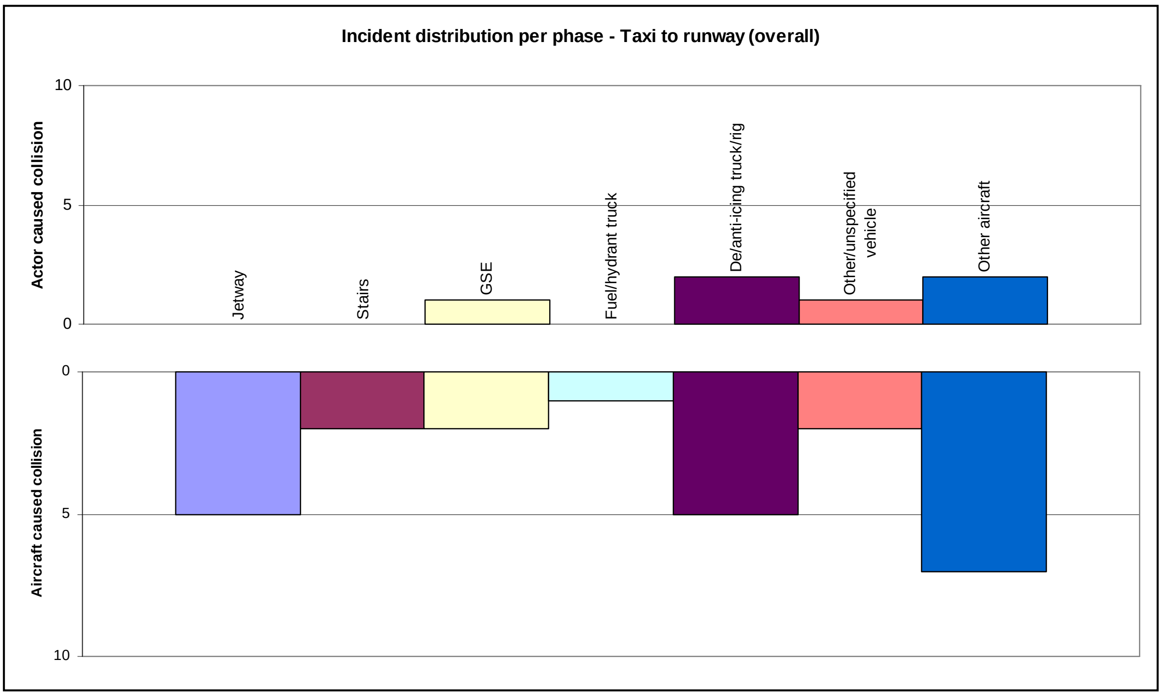


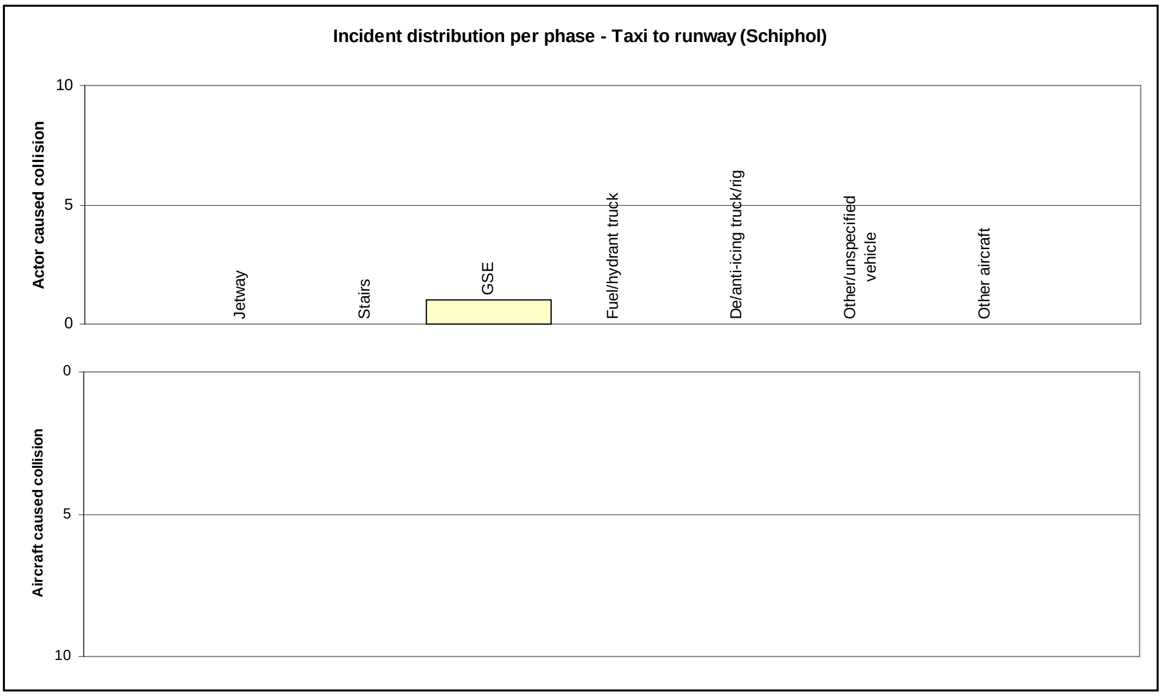
7. Incident distribution per phase – Pushback



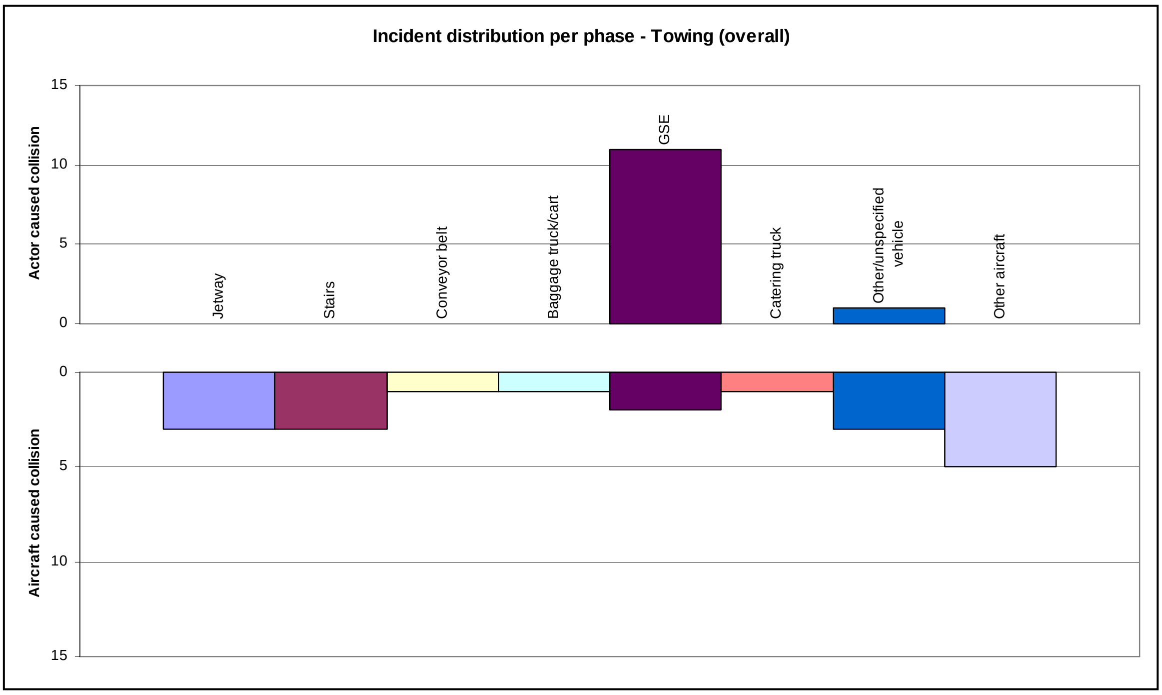


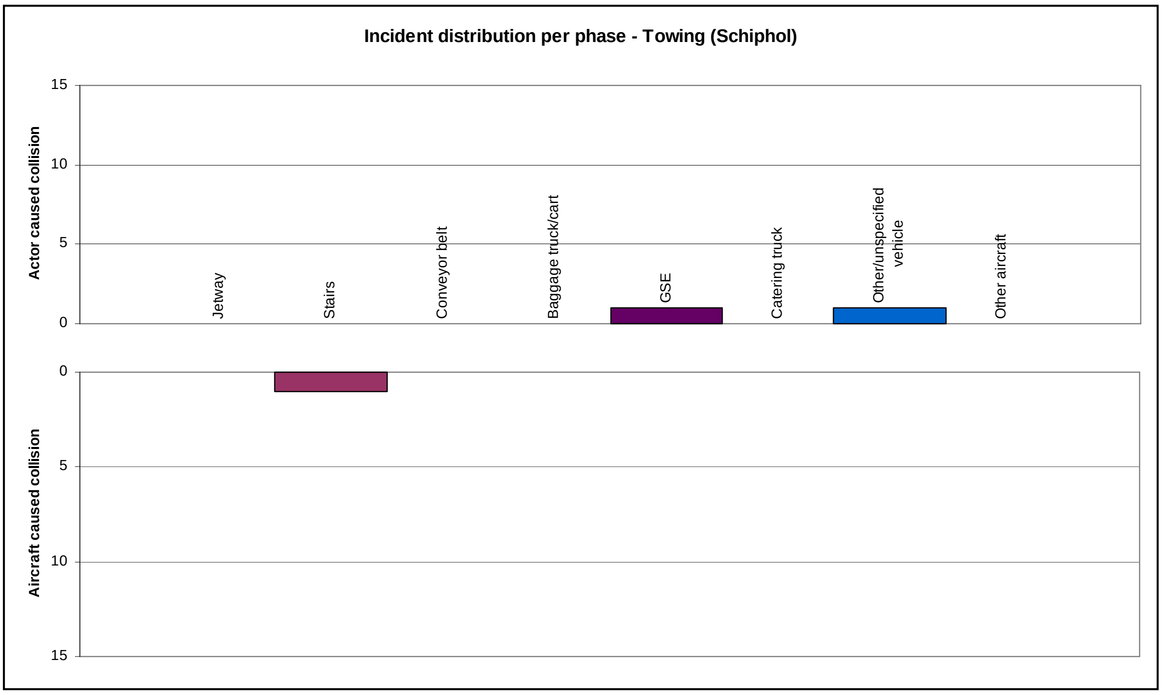
8. Incident distribution per phase – Taxi to runway





9. Incident distribution per phase – Towing





Appendix G Regulatory framework ground handling process