FINAL REPORT

B737-800, REGISTRATION 9V-MGM
PUSHBACK INCIDENT

6 December 2015

AIB/AAI/CAS.118

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

27 April 2017

The Transport Safety Investigation Bureau

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> *"The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability."*

Accordingly, it is inappropriate that TSIB reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

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GLOSSARY OF ABBREVIATIONS

AIP	:	Aeronautical Information Publication
ATC	:	Air Traffic Control
CVR	:	Cockpit Voice Recorder
EOT	:	End-of-Tow
EPM	:	Engineering Procedures Manual
FCTM	:	Flight Crew Training Manual
FDR	:	Flight Data Recorder
GOSM	:	Ground Operations Safety Manual
GSP	:	Ground Service Provider

SYNOPSIS

On 6 December 2015, a B737-800 parked at Bay F41 in Singapore Changi Airport was ready for departure. A ground operation crew pushed back the aircraft from the bay using an airtug and a towbar. The aircraft was to be positioned on Taxiway C2 facing south-east. It began raining during the pushback.

The aircraft's right engine was started as the aircraft was being pushed back from Bay F41. After completion of the pushback, the aircraft was pulled forward to an End-of-Tow line that was marked on the ground. During the forward pull, the aircraft's left engine was started. Following that the airtug driver experienced difficulty in controlling the moving aircraft. He sensed that the aircraft was pushing the airtug and causing the airtug to accelerate. The airtug also tended to drift to the left. The airtug driver tried to slow down the aircraft by applying brakes gradually, but the airtug continued to drift to the left. He then applied full brakes to stop the aircraft before reaching the End-of-Tow line. As a consequence, the towbar broke. The airtug swung to the left, 180° anti-clockwise, and hit the left side of the aircraft which had surged forward after the towbar had broken off, resulting in damage to the lower left side of the aircraft fuselage just behind the radome. There were no injuries to any person.

The occurrence was classified as a serious incident.

AIRCRAFT DETAILS

Aircraft type	:	Boeing 737-800
Operator	:	SilkAir
Registration	:	9V-MGM
Engine details	:	2 x CFM 56-7
Date and time of occurrence	:	6 December 2015, 13:20 hours local time
Location of occurrence	:	Singapore Changi Airport
Type of flight	:	Scheduled passenger flight
Persons on board	:	153

1 FACTUAL INFORMATION

All times used in this report are in Singapore Local Time. Singapore Local Time is eight hours ahead of Coordinated Universal Time.

1.1 Sequence of events

1.1.1 On 6 December 2015, a B737-800 aircraft was departing for Phuket from Singapore Changi Airport. The aircraft was parked at Bay F41. A ground operation crew from a ground service provider (GSP) of the airport was to push back[1] the aircraft using an airtug (see **Figure 1**). The airtug was connected to the aircraft's nose wheel with a towbar. One end of the towbar (with a lunette ring) was hooked up to the airtug's tow hitch (see **Figure 2**).

Figure 1: Airtug (typical)

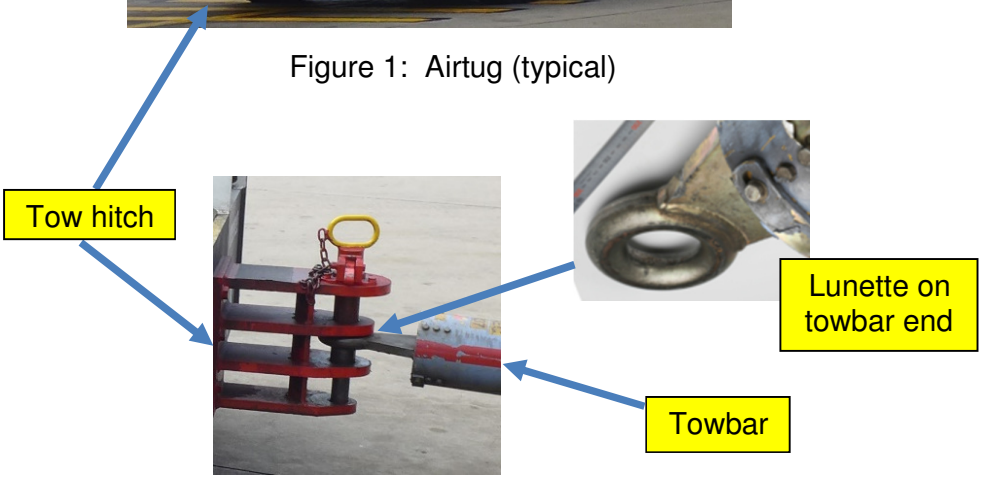

Figure 2: Towbar - tow hitch connection (typical)

1.1.2 The GSP crew consisted of a headset man and an airtug driver. The headset man was the leader of the GSP crew. The crew had to push the

[1] Pushback means the movement of an aircraft from a nose-in parking stand using the power of a specialised ground vehicle attached to the nose landing gear.

aircraft tail out onto Taxiway C2 (and, in so doing, turning the aircraft tail out to the right). Thereafter, the crew had to pull the aircraft forward to a stop point marked as EOT[2] 4 on Taxiway C2 (see **Figure 3**). In the course of the forward pull, the crew would have to steer as necessary to align the aircraft with the centreline of Taxiway C2.

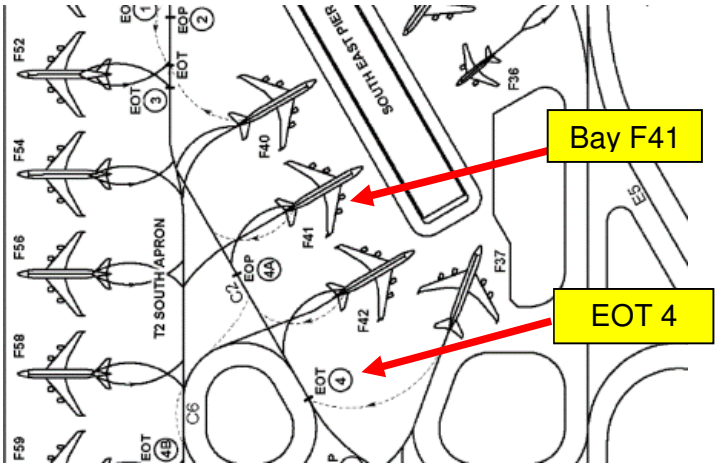

Figure 3: Location of Bay F41 and EOT 4

1.1.3 At 1318:13 hours, the flight crew received clearance from the Air Traffic Control (ATC) for pushback. At 1318:38, the GSP crew commenced the pushback. The flight crew started the aircraft's right engine during the pushback.

1.1.4 It began raining during the pushback. The asphalt surface of Taxiway C2 was wet but not waterlogged.

1.1.5 At 1319:55 hours, the aircraft reached the end of the pushback on Taxiway C2, but was off the taxiway centerline to the right. The airtug driver had to bring the aircraft to the taxiway centerline during the subsequent pull forward to EOT 4. The tug driver endeavoured to align the airtug and towbar with the aircraft fuselage when coming to the final few metres before EOT 4 and ensure that the aircraft was on the centreline of the taxiway.

1.1.6 The right engine reached idling thrust soon after the pull forward had begun. While the aircraft was being pulled forward towards EOT 4, the flight crew started the aircraft's left engine with the permission of the GSP crew.

1.1.7 According to the airtug driver, he experienced difficulty in controlling the movement of the aircraft. He sensed that the aircraft was pushing the airtug and causing the airtug to accelerate. The airtug also tended to drift to the left. The airtug driver tried to slow down the aircraft by applying brakes gradually, but the airtug continued to drift to the left. He then

[2] EOT stands for End-of-Tow.

applied full brakes to stop the aircraft before reaching EOT 4.

1.1.8 As a consequence, the towbar broke near the end that was connected to the airtug's tow hitch. The airtug swung to the left, 180° anti-clockwise, and hit the left side of the aircraft which had surged forward after the towbar had broken off. The sound of the collision was captured by the cockpit voice recorder (CVR) at 1320:36 hours. Data from the flight data recorder (FDR) showed that the aircraft came to rest at 1320:41.

1.1.9 The FDR data showed that the left engine was still in the process of spooling up at the time of the collision and that it reached the idle speed at 1320:56 hours.

1.1.10 After the collision, the headset man informed the flight crew that the towbar had broken and the aircraft had sustained damage. The flight crew applied the parking brakes. At the same time, the airtug driver moved the airtug to a safe distance from the aircraft for safety reason, as the aircraft engines were still running. The flight crew eventually shut down the engines.

1.1.11 After the ground maintenance engineer had completed the visual inspection and assessment of the damage to the aircraft, the aircraft was towed back to F41 by another airtug. Passengers disembarked and were transferred to another aircraft for their flight to Phuket. There were no injuries to any person.

1.2 Damage to aircraft

1.2.1 The aircraft sustained structural damage to an area of about 280cm by 60cm on the lower left front fuselage just behind the radome (see **Figure 4**).

Figure 4: Damage to the lower left front fuselage

1.3 Damage to towbar and airtug

1.3.1 The towbar broke near the end that was connected to the airtug's tow hitch

(see **Figure 5**).

Figure 5: Damage to towbar

1.3.2 The airtug sustained damage to its right door (dents and scratches) and its right hand side mirror (broken off) (see **Figure 6**). The stop plate[3] in the airtug's tow hitch sustained an indentation (see **Figure 7**).

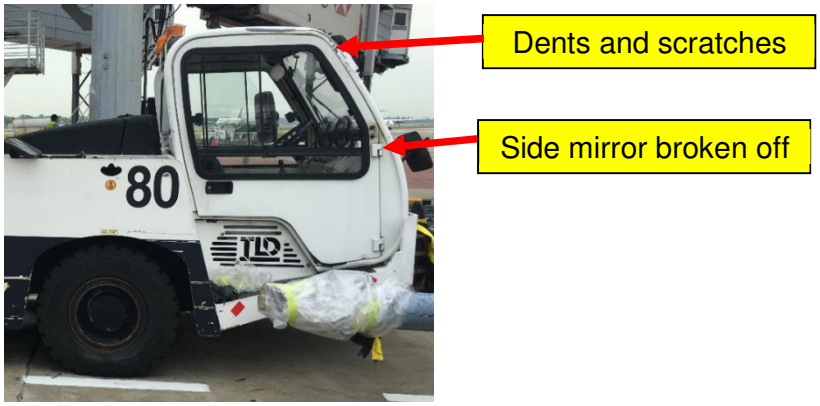

Figure 6: Damage to airtug

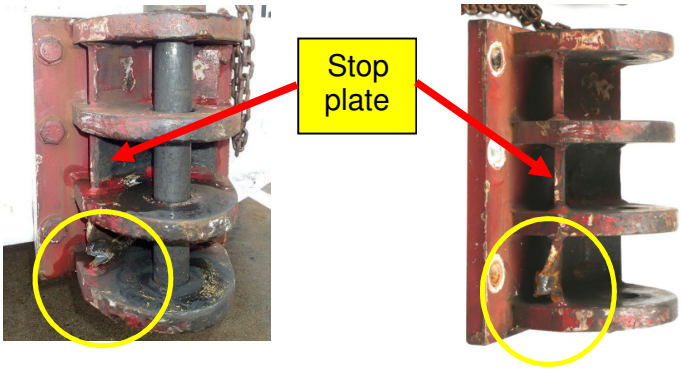

Figure 7: Indentation on tow hitch

[3] The stop plate set was angled at 60° on either side of the centerline of the airtug.

1.3.3 The indentation was a result of pressing by the lunette mount flat (see **Figure 8**) when the latter had turned and reached the stop plate.

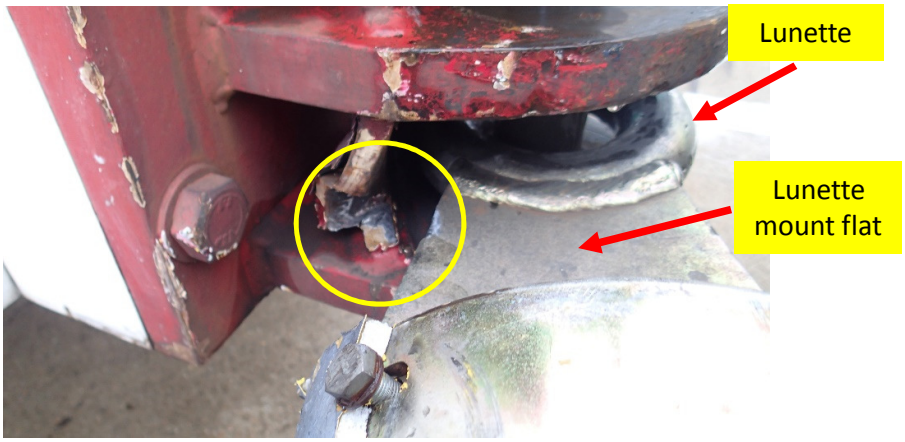

Figure 8: Cause of the indentation

1.4 Personnel information

1.4.1 The headset man was a technician who joined the GSP in 2007. He qualified as a headset man in the GSP in 2012.

1.4.2 The airtug driver had been with the GSP for 37 years and had been working as an airtug driver for 25 years.

1.4.3 According to the headset man and airtug driver, their work schedule on the day of the incident was normal and they were not in hurry to complete the pushback from Bay 41.

1.5 Recorded data

1.5.1 Pertinent recordings were recovered from the cockpit voice recorder (CVR) and flight data recorder (FDR) of the aircraft, as well as from the in-vehicle recording device (IVRD) that was installed on the airtug.

1.5.2 The airport's surveillance cameras also provided useful footages.

1.5.3 Data from the airtug's IVRD showed that the airtug speed was increasing during the pull forward and attained 11 km/h about 23 seconds before the impact occurrence. There were no more IVRD speed data beyond this point. This airtug speed of 11 km/h is comparable to the aircraft speed of 10.2 km/h recorded by the FDR at about the same moment. Data from the FDR revealed that, thereafter, the aircraft speed gradually increased to and then remained at 13 km/h prior to the impact occurrence. These data

suggests that the airtug speed during the 23 seconds prior to the impact occurrence was at least 11 km/h.

1.6 Tests and research

1.6.1 Taxiway C2

1.6.1.1 The gradient of the stretch of Taxiway C2 between the end of the pushback and EOT 4 was about 0.18%[4], sloping downward towards EOT 4.

1.6.2 Airtug

1.6.2.1 The airtug weighed about 12 tonnes. It was last serviced on 3 December 2015 in accordance with GSP's maintenance schedule. The airtug and its tyres did not have operation-related defects before the incident. An examination by a vehicle inspection centre of the airtug (covering the mechanical and air brake system, engine and transmission system, steering wheel system, wheels and tyres, and drive shaft) did not reveal any defect that could have contributed to the incident.

1.6.3 Towbar

1.6.3.1 The towbar broke near the end that was connected to the airtug's tow hitch. The broken towbar (including the lunette ring end that had broken off) and the airtug's tow hitch were sent to an outhouse laboratory for examination. The examination showed the following:

(a) The material of the towbar tube conformed to specifications.
(b) The towbar tube had no material defects, corrosion or fatigue.
(c) The towbar tube had turned about 96° with respect to the centerline of the airtug and cause the lunette mount flat to make contact with and dent the stop plate in the airtug's tow hitch.
(d) The failure of the towbar was due to overloading and the tube material fractured in a ductile[5] manner.

1.7 Aircraft pushback and pull forward

1.7.1 The Aeronautical Information Publication (AIP)[6] listed the parking bays, including F41, where aircraft engine may be started and powered up to idle thrust during aircraft pushback[7]. However, the AIP did not prescribe

[4] The aviation regulatory authority has a standard that taxiway gradient shall not be more than 1.5%.
[5] Ductility is a solid material's ability to be stretched into a wire. It characterises the material's ability to deform under tensile stress.
[6] AIP is a publication issued by a State and contains aeronautical information essential to air navigation in the particular country to which it relates.
[7] At other bays, engine start was not permitted until the aircraft was at the EOT point where it could then move on its own power.

how many engines may be started during the pushback. The AIP also did not prescribe any speed limit for pushback, or pushback with pull forward.

1.7.2 The aerodrome operator had a Ground Operations Safety Manual (GOSM) which defined the ground handling safety standards for the GSPs. The GOSM prescribed that aircraft should not be pushed back at more than 5 km/h and that the aircraft should be pushed back even more slowly if the ground surface condition is wet or bad, but did not specify if the speed limit was also applicable to pushback followed by a pull forward. The GOSM was also silent on the number of engines that could be started during pushback.

1.7.3 The airline operator's B737 Flight Crew Operations Manual stated that engine start procedure may be carried out during pushback, or pushback with pull forward. Thus, other than the restrictions imposed by the AIP, the flight crews may carry out engine start during pushback operation (including pull forward) but permission must be sought from the GSP crew[8].

1.7.4 In its Engineering Procedures Manual (EPM), the GSP allowed the start-up of a second engine during the pull forward for the airline operator's B737/A319/A320[9]. The EPM did not prescribe any speed limit for aircraft movement during pushback/pull forward other than that the pull forward speed was limited to 10 km/h under certain conditions for other aircraft types[10].

1.7.5 The GSP did not have a checklist for performing aircraft pushback operation for departure, but it had a "General Aircraft Towing Process Form" that had a detailed list of actions which must be performed for aircraft towing[11]. Included in the list was the briefing by the towing-in-charge to all members of the towing team. Under the heading "Airtug driver duties", the form stated that the speed should not exceed 10 km/h when a conventional airtug with towbar was used.

[8] The GSP crew has to ensure that there is no hazard when the aircraft is starting an engine.

[9] The airline operator operated only B737/A319/A320.

[10] The GSP expected its crews to, if any engine in excess of the limit during the pull forward phase had been started, exercise extreme caution and limit the pull forward speed to 10 km/h. And in wet and/or slippery conditions, the GSP crews would be expected to request for the appropriate engine(s) to be shut down if pulling forward in that situation was considered hazardous.

[11] The term 'aircraft towing' refers to the movement of an aircraft, usually with engines off, other than pushback operations, using an airtug.

2 DISCUSSION

2.1 Towbar failure

2.1.1 The airtug swung around to the left, 180° anti-clockwise, and hit the left side of the aircraft. The investigation team believed that the sequence of the airtug's swinging around was likely to be as follows:

- The airtug was left of the aircraft at some stage during its manoeuvre to bring the aircraft in line with the taxiway centerline during the pull forward.
- However, when the centres of gravity of the airtug, towbar and aircraft were not in line, the forward momentum of the aircraft created a turning moment and forced the airtug, through the towbar, to turn further to the left.
- The angle between the centerline of the airtug and the centerline of the towbar increased. When the angle reached 60°, the lunette mount flat came into contact with the stop plate in the tow hitch. Further turning, however, caused the lunette mount flat to press on the stop plate and dent it. By the time the lunette mount flat became stuck in the tow hitch, the angle had reached about 96° (see paragraph 1.3.3 and Figure 8).
- After this, the airtug and towbar were, together, pushed further to the left by the momentum of the aircraft.
- The "folding over" (or "jack knife" effect) of the airtug against the end of the tow bar caused the skin on the left side of the towbar tube just after the lunette mount flat to tear, thus sending the airtug swinging further anti-clockwise.
- The complete disconnection of the towbar from the airtug also caused the aircraft to surge forward and collide with the airtug which was swinging back towards it.

2.1.2 As mentioned in paragraph 1.1.7, the airtug driver sensed that the aircraft was pushing the airtug. The investigation team believed that this sensation of being pushed by the aircraft could be related to the brake applications. That the aircraft was being towed by the airtug at a relatively high speed, i.e. 11 km/h or more (see paragraph 1.5.3), could make the sensation more pronounced.

2.1.3 The investigation team also believed that it is unlikely that the second engine could have contributed to the airtug driver's sensation of the airtug being pushed by the aircraft as, at the time of the incident, the second engine's power was still well below idle thrust.

2.2 Use of checklist for aircraft pushback

2.2.1 Empty or out-of-service aircraft may be towed forward, engine power off, from one point in an aerodrome to another (e.g. towing to the hangar for

maintenance). The GSP had a checklist “General Aircraft Towing Process Form” for such towing operation. The checklist helped in the prevention of mishaps.

2.2.2 For a passenger flight, safety during a pushback operation should deserve consideration of having a pushback checklist. The checklist could help ensure pushback operations are safely, efficiently, and consistently accomplished.

3 SAFETY ACTIONS

During the course of the investigation and through discussions with the investigation team, the following safety actions were initiated by the airline operator, the GSP and the aerodrome operator.

3.1 Safety actions taken by the airline operator

3.1.1 As an interim measure after the incident, pulling forward the aircraft with engines running was stopped immediately (which meant that the practice of starting one engine during pushback, where allowed, was also suspended). This action was taken as a precaution pending an investigation by the airline operator into the incident. Subsequently, the airline operator reviewed its aircraft pushback procedures and implemented a procedure whereby no more than one engine of its twin-engined aircraft should be operating during a pull forward.

3.2 Safety actions taken by the GSP

3.2.1 The GSP reviewed its pushback procedures and set the following limit on the number of engines that could be started for a pushback / pull-forward operation:

Aircraft Type	Without Pull Forward	With Pull Forward
Aircraft with 2 engines	Allow to start all 2 engines during pushback	Allow to start only 1 engine during pushback
Aircraft with 4 engines	Allow to start all 4 engines during pushback	Allow to start up to 2 engines during pushback

3.2.2 The GSP also reviewed the pushback and pull forward speed limits for airtugs and set the limits as follows:

Pushback	Walking speed, not to exceed 5km/h in all circumstances
Pull forward (after pushback)	Not to exceed 10km/h, and not to exceed 5 km/h in wet or slippery conditions

3.2.3 The GSP prepared a “Quality and Safety Briefing Sheet” on the pushback incident, shared the learning points and the revised procedures on aircraft engine start and pushback with staff. All operational personnel were briefed on these changes and the lessons learnt. The briefings to staff were completed on 21 July 2016.

3.2.4 The changes were also incorporated in the training notes on Aircraft Handling and Aircraft Towing courses carried out by the GSP.

3.2.5 The GSP reiterated the following driving techniques as recommended by the aerodrome operator (arising from this latter’s own investigation of the incident):

- Low deceleration
  Airtug drivers should spread out the braking process over as long a distance as possible, brake lightly and progressively while reducing speed as gradually as possible. Ground crews should plan the route beforehand, be alert, anticipate the path ahead, and avoid abrupt braking.

- Steering
  Airtug drivers should avoid abrupt turning of the steering wheel as this is a skid trigger, and should observe gentle and gradual steering at all times during towing.

- Avoid braking or slowing down in a turn (or on a curve)
  During towing, airtug drivers should not brake during turning or when navigating a curved path, and should instead decelerate gradually while still on the straight path in anticipation of the turn (or curve) ahead. Airtug drivers should slow down sufficiently before the turn (or curve) and release brakes before going into the turn (curve). They may apply a little power as they enter the turn in order to have better control of the vehicle.

- Recovery from skid (regaining traction)
  Airtug drivers should remain calm, and carry out the appropriate counter-intuitive measures of releasing brakes and steering into the direction of the skid to regain traction. After traction is restored, and having regained control of the airtug, drivers should then add power and drive off so as to avoid "jack-knifing".

The GSP also included these driving techniques in its initial and recurrent training curriculum for airtug drivers.

3.3 Safety actions taken by the aerodrome operator

3.3.1 Following the incident, the aerodrome operator issued an Airside Safety Notice (ASN) on 8 December 2015 to remind all airtug drivers of the following before commencing pushback operation:

- To ensure the correct tow bar is used;
- To check that all equipment (airtug, tow bar etc.) are in good working condition; and
- To read the pushback procedures and ensure they are followed strictly.

3.3.2 The ASN also reminded airtug drivers of the following:

- To maintain a slow speed during pushback operation;
- To observe all towing angle limitations; and
- To stop only when the airtug, tow bar and aircraft nose wheel are

aligned on the End-of-Tow line.

4 SAFETY RECOMMENDATIONS

A safety recommendation is for the purpose of preventive action and shall in no case create a presumption of blame or liability.

Aerodrome operator

4.1 It is recommended that the aerodrome operator provides comprehensive guidelines for pushback operations covering pushback hazards and accident prevention for use by the GSPs to develop operational practices accordingly. [TSIB Recommendation RA-2017-25]

Ground service provider

4.2 It is recommended that the ground service provider include the following additional topics in the initial and recurrent training curriculum:

- Effects on pushing aircraft with engines operating
- Effects of aircraft weight and too high a towing speed on aircraft pushback.

[TSIB Recommendation RA-2017-26]

4.3 It is recommended that the ground service provider develop a checklist for aircraft pushback operation so that the ground operation activities are safely, efficiently, and consistently accomplished. [TSIB Recommendation RA-2017-27]