ATR AIRCRAFT OVERALL SAFETY REPORT

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Glossary

ATR	Avions de Transport Régional
DHC	De Havilland Canada
EASA	European Authority for Aviation Safety
ETOPS	Extended-range Twin-engine Operation Performance Standards
FOD	Foreign Object Debris/Damage
STOL	Short Take-Off and Landing
SM	Safety Management

1 Introduction

This paper is a technical article that shall research and evaluate the ATR aircraft models. More specifically, this paper shall focus on safety aspects, and determine whether the ATR42 and ATR72 aircraft models are indeed safe to fly. The methodologies employed for the research and analysis are technical ones, based on factualness and statistical evaluations. The report is not directed towards or against any entity and is intended to objectively assess the overall safety of the mentioned aircraft models through accident data analysis and comparison to industry standards.

A presentation of the aircraft type will introduce the discussion, which will be followed by an overview of airlines and state actors (ie. Military branches) operating ATR aircraft. All documented accidents are listed and some of the most serious ones are studied in further detail. SM (Safety Management) tools are employed to define and process the causes leading to these accidents, with the aim of highlighting recurrent patterns, trends, and deficiencies around the aircraft model. Eventually the accident statistic is thoroughly compared to industry standards, to assess the safety of ATR aircraft in detail. This precise evaluation shall allow a clear assessment and a final verdict about the aircraft's safety.

2 ATR42 and -72 aircraft models and their purpose

ATR is a Franco-Italian aircraft manufacturer headquartered in Blagnac, France, a suburb of Toulouse. It was founded in 1981 as a joint venture between Aérospatiale of France and Aeritalia of Italy, known today as Airbus and Leonardo, respectively. The company first introduced the -42 version in 1985, which is the basis for the stretched ATR 72 (Figure 2 .1), introduced in October 1989. The turboprop regional airliner is designed for short-haul flights. The aircraft seats 42 passengers in its -42 variant, and 70-75 in the -72 variant and is powered by two turboprop Pratt & Whitney Canada PW120 engines. Later variants are upgraded with new avionics, glass cockpit, and newer engine versions, including six-bladed propellers instead of the original four-bladed ones [5].

Figure 2.1: ATR72-600

ATR aircraft find their primary use in connecting remote places of the world, where poor infrastructure, as well as short runways render flight operations complicated for other aircraft. These aircraft have been designed with the aim of facilitating the operations on short and unpaved runways, such as dirt- or even gravel-runways. Its advanced STOL capabilities translate into a minimum required runway dimension of 800x14 metres. Its propellers are much more resistant to FOD than turbo-fan engines, its high-wing configuration further reduces the risk of FOD-related engine damages by considerably increasing the propellers' ground clearing distance. The aircraft is moreover ETOPS-certified for up to 120 minutes. Because of these key characteristics, ATRs are ideal for operations in countries with extensive rainforests, where small rural communities exist completely isolated from each other and where the sole connection to the outer world is provided by charter air operation with small propeller aircraft. Such geographies are typical of south-east Asian countries and Latin American countries within the Amazonas, as well as African countries; most notably Indonesia and Brazil (but also Botswana, Kenya, Malawi, Mozambique, etc.), where short and unpaved runways are widely spread in the remote rural communities around the rainforests.

The aircraft's rectangular wing generates lift at much lower speeds than swept wings, allowing the aircraft to take-off at lower speeds, ultimately reducing the aircraft's required take-off distance all the way down to 800 meters (ATR42-600S, Figure 2 .2). However, these advantages come with the price of reduced cruise-speed and ceiling altitude (11.000 ft) as well as increased noise levels and vibrations inside the cabin, all of which are common limitation of turboprop aircraft, when compared to turbofan aircraft [6].

Figure 2.2: ATR 42-600S

The ATR's main competitor is the De Havilland Canada DHC-8 Series, commonly known as "Dash-8 series" and up to 2019 part of Bombardier, before being sold back to De Havilland Canada. The Dash-8 series comprises the Dash 8-100, -200, -300, -400 and most notably the updated Dash-8 Q-Series (Q for "quiet"; a modernized DHC-8-series fitted with active noise control system) aircraft models. While having some design and structure differences, the ATR and DHC models are largely similar and essentially serve the same purpose and thus compete directly against each other for the same market niche. Other, less widespread competitors are the Fokker-50 and the Saab-2000 (and -340).

ATR claims the title of world's largest maker of regional turboprop planes.

> "As the world's number one regional aircraft manufacturer, and the most eco-responsible commercial aircraft, we connect people and places in a sustainable and modern way, no matter how remote they are. From the world's largest cities to our planet's most remote regions, our purpose is to deliver air travel to people, communities, and businesses in an innovative, sustainable, and modern way. […] Responsible flying is in our DNA, which is why we deliver the most advanced and efficient solutions to our customers, allowing travelers to pursue their passions and get into the very heart of life." [9]

These statements, however, are challenged by some unfavorable statistics regarding safety and reliability. In fact, these very statistics have pinned to the ATR 42 and ATR 72 the title of "most dangerous modern airliner worldwide". While this bold statement might be a speculation, there are a few statistics that support to a certain extent such statements. This report's purpose is to analyze the available data and elaborate an objective and fact-based evaluation of the ATR 42 and -72's safety record and overall reliability.

3 Airlines that operate ATR aircraft

The aircraft first entered service in 1989, with its launching airline Finnair, and remains in production to this day. In total 2297 aircraft have been built so far, 1800 ATR-72 and 497 ATR-42. As of July 2019, 775 ATR 72s and 232 ATR 42s were in airline service, with over 200 aircraft still on order. Dozens more are employed by multiple militaries and governments worldwide, such as but not limited to:

Table 3.1: Military branches operating ATR aircraft (exact fleet count unknown)

Military branch and Nation	Type operated
Italian coastal guard	ATR 42; ATR 72
Italian financial police	ATR 42; ATR 72
Pakistan navy	ATR 72
Turkish navy	ATR 72
Philippine air force	ATR 72
Nigerian air force	ATR 42
Senegalese air force	ATR 42

Some of the main ATR airline operators (as of September 2022) include:

Table 3.2: Airlines operating ATR aircraft

Airline Operators	No. operated
Wings Air (Lion Group)	70 ATR 72
IndiGo	40 ATR 72
Azul	36 ATR 72
Air New Zealand	29 ATR 72
Fedex	29 ATR 72; 17 ATR 42
Easyfly	14 ATR 42
Canadian North	13 ATR 42
Empire Airlines	11 ATR 42

4 Severe accident history of ATR aircraft

The ATR aircraft have made a name for themselves for allegedly being “unsafe”. This reputation finds its roots within the aircraft’s dubious safety record. In fact, since its entry into service in 1989, a total of 113 accidents and incidents have occurred, of which 74 were so-called “hull losses”, ie. The accidents were so severe, that the aircraft were irrecoverably damaged and had to be written off. 74 Hull-losses correspond to a staggering 3.22% of all ATR built so far. A total of 746 souls were claimed in connection to the 113 ATR-accidents. Variant-specifically, the ATR 42 has been involved in 47 accidents and incidents including 34 hull losses, resulting in 276 fatalities. The ATR 72 has been involved in 66 accidents and incidents, including 40 hull losses, resulting in 470 fatalities [4].

Figure 4.1: TransAsia Airways 235 collision with Keelung bridge, Taipei, ROC

In the following paragraph, a closer look is paid at so-called “severe accidents”, ie. accidents that involved any loss of human-life. In sum, 24 such “severe accidents” have occurred, evenly divided between ATR 42 (12 accidents) and ATR 72 (also 12 accidents). The following table lists these occurrences chronologically. Note how the severe accident count is evenly spread between variants, even though there exist trice as many ATR72s than ATR42s.

Table 4.1: Severe accidents history of ATR aircraft [4]

Date	Flight	Fat	Surv	Location	Event	Variant
15 Oct 1987	**Aero Trasporti Italiani 460**	**37**	**0**	**Italy, Conca di Crezzo**	**Crashed due to icing.**	**ATR 42**
21 Aug 1994	Royal Air Maroc 630	44	0	Morocco, Atlas Mountains	CFIT, suicide by pilot	ATR 42

31 Oct 1994	**American Eagle 4184**	**68**	**0**	**United States, Roselawn, IN**	**Crashed due to icing.**	**ATR 72**
30 Jan 1995	TransAsia 510A	4	0	Taiwan, near Taipei	CFIT due to pilot error; non-adherence to standard operating procedures	ATR 72
30 Jul 1997	Air Littoral 701	1	16	Italy, Peretola Airport, Florence	Runway overrun due to human error (unstable approach), aircraft hull-loss.	ATR 42
11 Oct 1999	Air Botswana	1	0	Botswana	Captain stole an empty aircraft, suicide by pilot, crashed into and destroyed 2 further ATR 42s.	ATR 42
12 Nov 1999	Si Fly 3275	24	0	Kosovo, Mitrovica	A UN-operated flight, CFIT due to crew error, ATC failure, GPWS malfunction, airline deficiencies.	ATR 42
14 Sep 2002	**Total Linhas Aereas 5561**	**2**	**0**	**Brazil, Sao Paolo**	**Pitch-trim control system failure, loss of control.**	**ATR 42**
21 Dec 2002	TransAsia 791	2	0	Taiwan, near Makung City	Crashed due to icing, both crew died.	ATR 72
6 Aug 2005	Tuninter 1153	16	23	Italy, near Palermo	Ditch due to fuel exhaustion caused by inappropriate indicators.	ATR 72
21 Feb 2008	Santa Barbara Airlines 518	46	0	Venezuela, Mérida	CFIT due to pilot error and navigational error.	ATR 42
4 Aug 2009	Bangkok Airways 266	1	71	Thailand, Koh Samui Airport	Skid into a disused tower, killing the captain.	ATR 72
13 Sep 2010	Conviasa 2350	17	34	Venezuela, Ciudad Guayana	Crash on approach due to severe pilot error.	ATR 42
4 Nov 2010	Aero Caribbean 883	68	0	Cuba, near Guasimal	Crashed due to icing and bad crew decisions.	ATR 72
2 Apr 2012	UTair 120	33	10	Russia, Tyumen Airport	Crashed soon after takeoff. Incorrect deicing procedures.	ATR 72
16 Oct 2013	Lao Airlines 301	49	0	Laos, near Pakse Airport	Crash into the Mekong while on approach.	ATR 72
23 Jul 2014	**TransAsia 222**	**48**	**10**	**Taiwan near Magong Airport**	**Crash while landing.**	**ATR 72**
4 Feb 2015	TransAsia 235	43	15	Taiwan, Keelungne ar Taipei	Engine failed after takeoff, crashed into water upside down after remaining engine shut down by accident.	ATR 72
16 Aug 2015	**Trigana Air Service 267**	**54**	**0**	**Indonesia, West Papua**	**CFIT, attributed to lacking safety culture within airline.**	**ATR 42**
7 Dec 2016	PIA 661	47	0	Pakistan, Havelian	Loss of control due to maintenance error.	ATR 42
13 Dec 2017	West Wind Aviation 280	1	24	Canada, Fond-du-Lac, Saskatchewan	Crashed after takeoff due to icing conditions and because of airline operational control system deficiencies.	ATR 42
18 Feb 2018	Iran Aseman 3704	66	0	Iran, near Yasuj Airport	Crash into Mount Dena.	ATR 72
6 Nov 2022	Precision Air 494	19	24	Tanzania, Lake Victoria	Crashed on approach due to bad weather and pilot error.	ATR 42
15 Jan	Yeti Airlines	72	0	Nepal, Pokhara	Stalled during approach due to	ATR 72

2023	691				accidental feathering of propellers, pilot error.	

A few hand-picked accidents are described in further detail below.

Aero Trasporti Italiani Flight 460 was a tragic accident that occurred on **15 October 1987**. The flight was a scheduled passenger service between Milan Linate Airport in Milan, Italy, and Cologne Bonn Airport in Cologne, Germany. The aircraft involved was an ATR-42 turboprop. The aircraft took off from Milan-Linate airport at 7.13 pm, 53 minutes later than scheduled due to traffic and poor weather conditions. Fifteen minutes after takeoff, while climbing through FL147 (14,700 feet) in IAS hold mode (constant speed set at 133 knots), the aircraft began to roll left and right. It crashed nose down into Mount Crezzo, near Lake Como, following an uncontrolled descent. All **37 people on board**, including 34 passengers and 3 crew members, were **killed** in the crash. The main cause of the crash was disputed. The aircraft manufacturer, ATR, attributed the accident to pilot error. However, investigators pointed to **icing conditions and a design flaw** as contributing factors. The aircraft had encountered icing conditions at the time of the accident. The icing, combined with the aircraft's design, may have led to the uncontrolled descent and subsequent crash [4].

American Eagle Flight 4184 was a scheduled domestic passenger flight from Indianapolis, Indiana, to Chicago, Illinois. On **October 31, 1994**, the ATR 72 performing this route encountered severe icing conditions, lost control, and crashed into a soybean field near Roselawn, Indiana. All **68 people on board**, including 64 passengers and 4 crew members, were **killed** in the crash. The main cause of the crash was determined to be the **accumulation of ice** on the wings of the aircraft, which disrupted the airflow and caused a sudden loss of lift. This accident was the second deadliest involving an ATR 72 and led to significant changes in the procedures for de-icing aircraft surfaces. The National Transportation Safety Board (NTSB) investigation concluded that the ATR 72's wings lost lift due to ice accumulation in a manner that was **not** predicted by the wing's designers (**design flaw**). The NTSB also cited the lack of procedures to ensure timely use of deicing systems as a contributing factor. There are multiple air-crashes of ATR42s and -72s that occurred as a result of design flaws which caused ice accumulation in situations not predicted by the constructor. Some of these, but not limited to, are: TransAsia 791 (21 Dec 2002), Air Carrebean 883 (04 Nov 2010), UTair 120 (2 Apr 2012) [4].

Figure 4.2: American Eagle Flight 4184 crash scene

Total Linhas Aéreas Flight 5561 was a domestic cargo flight from São Paulo, Brazil to Londrina, Brazil. On 14 September 2002, the ATR 42-300 involved in the flight crashed near Paranapanema, 47 minutes after takeoff. Both crew members on board were killed in the accident. The main cause of the crash was determined to be a pitch trim control system failure (**design flaw**). The crew lost control of the aircraft's pitch and were unable to recover. The **crew was not trained** for a "runaway trim" scenario and no procedure for dealing with this were found in the manuals written by the aircraft manufacturer. This may have been a factor in the cause of the accident. Examination of the ATR 42's history shows several reports of trim control concerns that the Federal Aviation Administration issued Airworthiness Directive(s) (AD) for. An incident in 2001 led the Civil Aviation of France to issue an AD for ATR 42 type aircraft as well. The investigating bureau stated in part that problems involving system relays, switches, wires, and connectors was "considered the most likely to have occurred, giving rise to the firing of the elevator compensator (pitch trim system)". Also stated in the report was that the "systems (pitch trim) normal and reserve (stand by) were not independent, and the system had low error tolerance" [4].

Trigana Air Flight 267 was a scheduled domestic passenger flight from Sentani Airport, Jayapura to Oksibil Airport in the eastern Indonesian province of Papua. On **16 August 2015**, the ATR 42-300 twin-turboprop operating this route crashed near its destination, killing all **54 people on board**. The main cause of the crash was determined to be **pilot error** in challenging weather conditions. The investigation by Indonesia's National Transportation Safety Committee (NTSC) found that the pilots lost situational awareness and inadvertently flew into a mountainous area while trying to navigate through a cloud-covered valley. The NTSC also noted that the airline's lack of a system to monitor its flights in real-time and provide information to the crew about potentially hazardous conditions (**lack of safety culture**) was a contributing factor. The analysis of the causes leading to the crash suggests that a safety management system within the airline could have prevented such a disaster from happening.

This accident is the **deadliest involving an ATR 42** aircraft. It led to calls for improved safety standards and better oversight of airlines in Indonesia, which has a history of aviation accidents. The Indonesian government subsequently introduced several measures to improve aviation safety, including stricter regulations and increased inspections of airlines. Other air-crashes directly linked to missing or severely flawed safety management within the airline are Pakistan International Airlines 661 (7 Dec 2016), and West Wind Aviation 280 (13 Dec 2017) [4].

Figure 4.3: Trigana Air Flight 267 crash scene

TransAsia Airways Flight 222 was a scheduled domestic passenger flight from Kaohsiung International Airport to Magong Airport on **23 July 2014**. The ATR 72-500 twin turboprop operating the route crashed into buildings during approach to land in bad weather at Magong Airport. Among the **58 people on board**, of which 54 passengers and 4 crew members. Only **10 survived**. The main cause of the crash was determined to be **pilot error**. An investigation by the Taiwanese Aviation Safety Council found that the pilots intentionally descended below the minimum descent altitude and that the captain was overconfident. The crash occurred during a heavy storm near Magong Airport on Taiwan’s Penghu Island. The plane crashed while it was trying to land. The weather at Magong Airport was inclement and visibility was poor, making it difficult for the pilots to see the runway [4].

Figure 4.4: TransAsia Airways Flight 222 crash scene

5 Leading causes of severe accidents

Following, the leading causes of all severe accident listed in Table 4 .1 are presented, following the "M-Method", a SM tool, which can be employed to assess the main causes of accidents, according to the **5-M principle**. The 5-M's used by this principle are: **Man** (refers to human error), **Machine** (refers to design flaws, aircraft issues), **Medium** (refers to climate, weather conditions and phenomena), **Mission** (refers to dangerous maneuvers, procedures, etc.), and **Management** (refers to company policies, safety culture, etc.). On top of this, a second tool is used to further investigate the type of human-error. In fact, the "Man" cause, is broken down in further 5 categories, as can be seen from Table 5 .2.

Table 5.1: Leading causes of severe accidents

Flight	Fat.	Surv.	Event	Cause (M-Method)	Type of *Man* Cause
Aero Trasporti Italiani 460	37	0	Crashed due to icing.	Machine, Medium	-
Royal Air Maroc 630	44	0	CFIT, suicide by pilot	Man	Intended Violation
American Eagle 4184	68	0	Crashed due to icing.	Medium, Machine	-
TransAsia 510A	4	0	CFIT due to pilot error; non-adherence to standard operating procedures	Man	intended mistake - knowledge
Air Littoral 701	1	16	Runway overrun due to human error (unstable approach), aircraft hull-loss.	Man	intended mistake - knowledge
Air Botswana	1	0	Captain stole an empty aircraft, suicide by pilot, crashed into and destroyed 2 further ATR 42s.	Man	Intended Violation
Si Fly 3275	24	0	A UN-operated flight, CFIT due to crew error, ATC failure, GPWS malfunction, airline deficiencies.	Man, Machine, Management	Intended Mistake - knowledge
Total Linhas Aereas 5561	2	0	Pitch-trim control system failure, loss of control.	Machine	-
TransAsia 791	2	0	Crashed due to icing exceeding type certification limit, both crew died.	Medium, Machine, Man	Intended mistake - knowledge
Tuninter 1153	16	23	Ditch due to fuel exhaustion caused by inappropriate indicators.	Man, Management	Unintended lapse error
Santa Barbara Airlines 518	46	0	CFIT due to pilot error and navigational error.	Man, Machine	Intended Violation
Bangkok Airways 266	1	71	Skid into a disused tower, killing the captain.	Mission, Medium	-
Conviasa 2350	17	34	Crash on approach due to severe pilot error.	Man, Machine	Intended mistake - knowledge
Aero Caribbean 883	68	0	Crashed due to icing and bad crew decisions.	Machine, Medium, Man	intended mistake - knowledge
UTair 120	33	10	Crashed soon after takeoff. Incorrect deicing procedures and airline's deficient safety and training procedures.	Man, Medium, Management	intended violation
Lao Airlines 301	49	0	Crash into the Mekong while on approach.	Man, Mission	unintended lapse error
TransAsia 222	48	10	CFIT due to pilot error whilst landing. Deficient airline safety policy, pilot overconfidence, harsh weather.	Man, Management, Medium	intended violation

TransAsia 235	43	15	Engine failed after takeoff, crashed into water after remaining engine shut down by accident.	Man, Machine	unintended lapse
Trigana Air Service 267	54	0	CFIT, attributed to lacking safety culture within airline.	Man, Management	Intended violation
Pakistan International Airlines 661	47	0	Loss of control due to maintenance error.	Management, Machine	-
West Wind Aviation 280	1	24	Crashed after takeoff due to icing conditions and because of airline operational control system deficiencies.	Medium, Management, Man, Machine	Intended violation
Iran Aseman 3704	66	0	Crash into Mount Dena, due to violation of minimum FL and lacking CRM.	Man, Medium	Intended violation
Precision Air 494	19	24	Crashed on approach due to bad weather and pilot error (disregard EGPWS warnings and visual approach in IMC)	Man, Medium	Intended violation
Yeti Airlines 691	72	0	Stalled and crashed during approach due to accidental feathering of propellers, pilot error.	Man	Intended Mistake - knowledge

5.1 Analysis of the accident causes

From an analysis of the Table 5 .2 above, some common denominators emerge. First of all, on top of all the accident causes is ice formation. Icing is probably the main weakness of this aircraft, directly causing, or at the very least, playing a role, in most of the listed accidents.

It is concerning how part of the icing problem resides directly within the aircraft itself. The de- and anti-ice systems the ATR is equipped with have been subject of criticism multiple times [1][2]. Technically, the system is not an anti-ice system, since it does not prevent ice formation through heating, or other active ice prevention methods. Instead, the system relies on de-ice boots (inflatable cushions) installed along the leading edge of the aircraft's wings and flight surfaces that mitigate ice build-up. The rubber de-ice boot is inflated via a pneumatic system. As the de-ice boot expands, it cracks and loosens any ice buildup along the leading edges. The ice then blows away into the airflow. In theory, ice should be allowed to form up to a certain extent, and before it reaches a critical stage, at which the ice formation would begin to disrupt the airflow to the point that stable flight isn't possible anymore, the de-ice system should be activated. There are many problems with this principle [1][2]: It relies on the continuous manual activation and deactivation by the pilot, and on top of this, entrusts him to do it just before the icing reaches a critical state. Here's the dilemma: If the pilot continuously operates the system prematurely, it's not only ineffective, but it may lead to ice building up on these leading surfaces while the cushions are inflated. If enough ice builds up with inflated cushions, it will oftentimes not break when these are deflated again. So, pilots may end up in a situation where there's a gap between the ice layer and the inflatable cushions, a gap that cannot even be overcome by the inflated cushions. On the other hand, obviously, if the pilot waits to long to activate the de-ice system, excessive ice will build up and the aircraft might stall. This problem represents a serious system design flaw, which has proven to be deadly on various occasions.

Apart from ice formation, engine loss also seems to be a serious danger. In fact, the ATR doesn't feature good single-engine performance SEP, actually they are considerably worse than its main competitor the Dash-8. Human error in the form of pilot error is an additional recurrent cause of accident among the analysed occurrences. Instances such as CFIT (Controlled flight into terrain), pilot suicide, pilot overconfidence, and failed SOP compliance are some of the main manifestations of pilot error. While it might be a main cause of accidents, it has not been found to be the case that pilot errors occur disproportionally often and thus would represent a statistical outlier case. In the same way as pilot error are one of the main causes of accidents for every other aircraft model, it is also the case for the ATR aircraft. The high number of pilot errors might rather be attributed to the popularity of the aircraft in "unsafe" countries in terms of aviation safety, as described in the following paragraph. Still, the fact that aircraft- or producer-related accident causes play a significant role, persists.

A factor worth noting is the popularity of ATR aircraft in world areas such as South-East Asia, South America, or Africa; areas in which the presence of airlines formerly or currently blacklisted (EU Air Safety List, Annex A) or restricted (EU Air Safety List, Annex B) by the EU is particularly high [7]. It is also the case that some of these very EU-blacklisted air-carriers have once operated or are presently operating ATR aircraft. The mentioned regions present either particular natural/geographic features, unstable governments, and weak state institutions, and/or lacking safety cultures, due to which the probability of severe air accidents is acutely negatively impacted for all aircraft types. The ATR is thus statistically more exposed to poor maintenance, poor pilot training, weak airline safety records, flawed safety cultures and mishandling, leading to more and severer accidents happening. A notorious example of an accident happened due to one or more of the reasons explained in this paragraph is Pakistani International Airlines PIA Flight 661, which occurred on December 7, 2016. Onboard the ATR42 were 47 people, when the aircraft crashed into the ground in Havelian, Pakistan leaving no survivors. It was later determined that a series of very unusual technical failures led to the sudden appearance of huge amount of drag on the left side, which rendered the aircraft uncontrollable. The investigation further revealed that faulty maintenance practices within PIA were to blame for such failures and the issue had been allowed to happen by weak oversight from the company and the nation's aviation regulatory body [8].

Moving on to a more pragmatic analysis approach, the accident causes have been evaluated according to the M-Method (See Table 5 .1). Additionally, the human error (Man) cause has been further broken down in a subsequent step, which is presented below. The analysis has yielded following results.

Table 5.2: Accident causes according to the M-Method

M-Cause	Main cause	Concurring cause
Man	13	8
Machine	3	8
Medium	2	8
Mission	0	2
Management	5	2

Table 5.3: Breakdown of accident cause "Man"

Cause Type	Frequency
1. Unintended Slip Error	0
2. Unintended Lapse Error	3
3. Intended Mistake Rule based	0
4. Intend-ed Mistake knowledge based	7
5. IntendedViolation	9

6 Aircraft safety comparison within the industry

The ATR's aircraft safety record shall now be compared to the industry benchmark and a clear conclusion about its performance with regards to the set benchmark shall be drawn [3].

To statistically evaluate the aircraft's safety following metrics will be analysed:

- Fatalities
- Accidents per aircraft-built
- Hull-losses (in absolute and relative terms)
- Fatalities per aircraft built
- Standardised fatality rate (fatalities per lifetime-seats)

6.1 Fatalities

Figure 6 .1 and Figure 6 .2 show an industry safety benchmark (blue curve). This benchmark has been drawn as an approximating line, following the least-squares-method, and should represent an industry-wide average ratio between number of aircraft built against fatalities occurred. For this benchmark, only data from the displayed aircraft models has been used. The chosen aircraft should be most representative of the ATR's segment and direct competition. An extension of this segment has been made by including the Airbus A320 Family and Boeing B737-800 aircraft, which are generally seen as some of the safest and most affirmed passenger aircraft ever built. The graph highlights the ATR42 and ATR72 data sets and allows initial conclusions to be drawn. The ATR42 presents far higher-than-average fatalities for the number of aircraft built. The fatalities occurred aboard ATR42s are as much as 6 times higher than the benchmark. Comparable competitors such as the DHC-8-400 (Dash-8) caused only 100 fatalities, corresponding to one third of the fatalities caused by the ATR42, whereby the number of DHC-8-400 built is higher than the number of ATR 42s by almost 100 units. This graph unambiguously highlights a disproportionate number of fatalities for the number of ATR42 aircraft built, however, it does not give account of the accident-causes. In other words, this graph proves that the fatalities are above-average, but it does not by itself prove the reason for being above-average.

Comparing the data sets to the industry-benchmark (blue curve) some interesting learnings can be derived.

- While the ATR42 is critically unsafer than the benchmark, interestingly the ATR 72 is not. In fact, the ATR72 sits precisely on the benchmark. And ATR as a whole, if the single models are combined, also sits approximately on the benchmark, as there are considerably more ATR72s than -42s, and thus ATR72s have a greater weight in combined statistic.
- The DHC-8 Family positions itself slightly above-benchmark and thus is marginally better positioned than its main competitor, ATR.
- The undisputed worst-performer is the Fokker 50 (See Figure 6 .2).

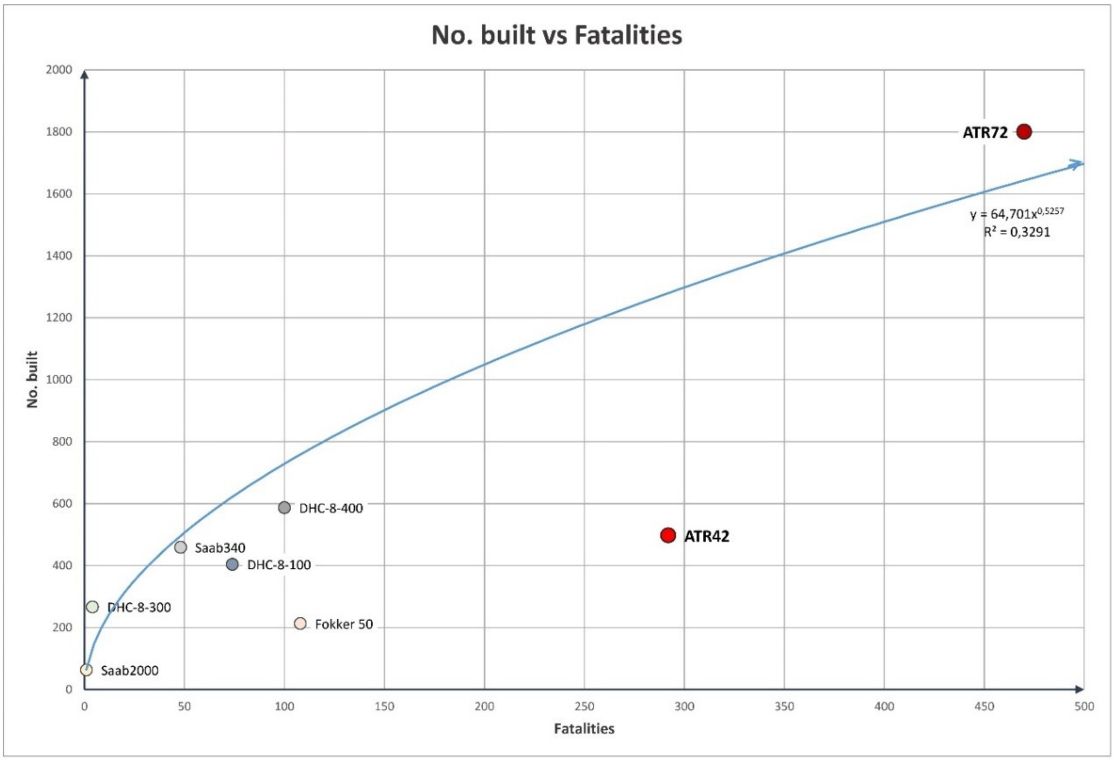

Figure 6.1: Fatalities industry benchmark; linear scaling

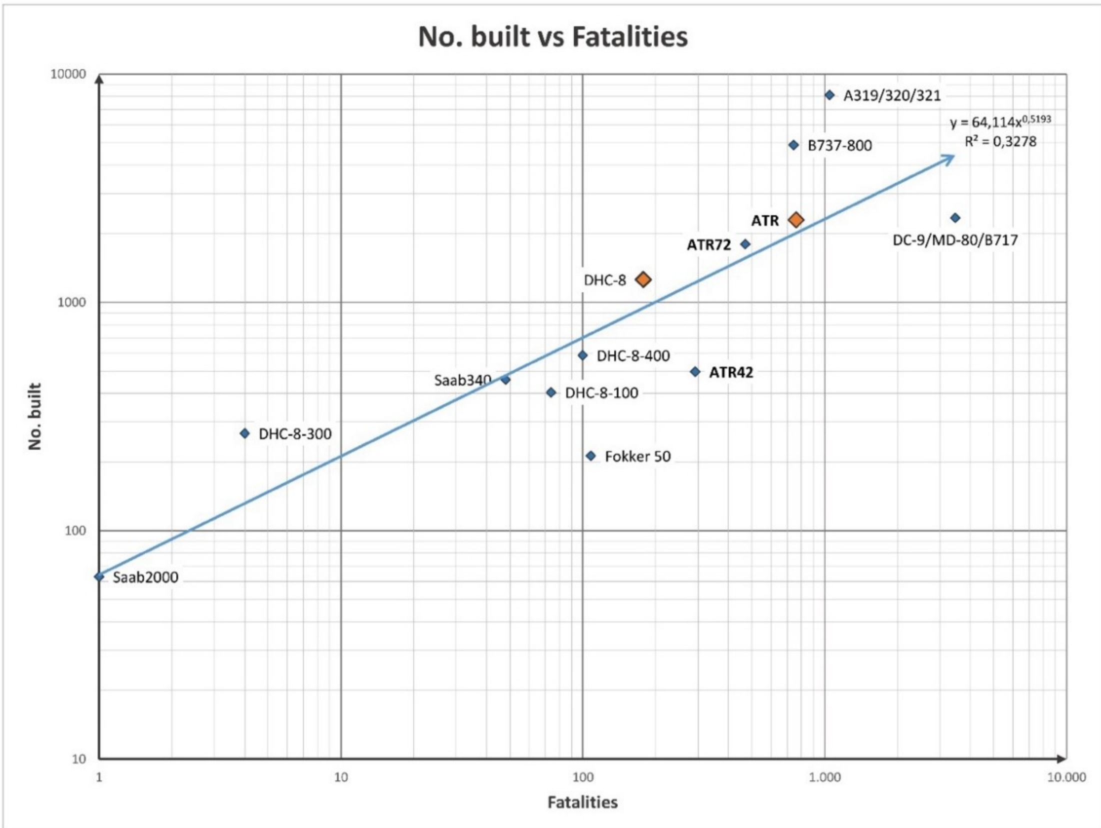

Figure 6.2: Fatalities industry benchmark; logarithmic scaling

6.2 Accidents and hull-losses

A different statistic is shown in Figure 6 .3, where two other metrics are evaluated: accidents occurred, and hull-losses compared to the number of aircraft built. The data shows a relatively wide data range, where hull-losses account for 0.5% to 9.5% of all aircraft ever built, while accidents per aircraft built range from 0.02 to 0.16 for the displayed models. ATR's data combined does not stand out negatively initially. The ATR42's hull-losses however total 8.2% of all aircraft ever built, while the accidents per aircraft-built reach 0.11. In other words, more than 1 out of 10 aircraft experiences an accident during his entire operational life. The ATR72's performance is again conspicuously better, surpassing its counterpart, the DHC-8-400.

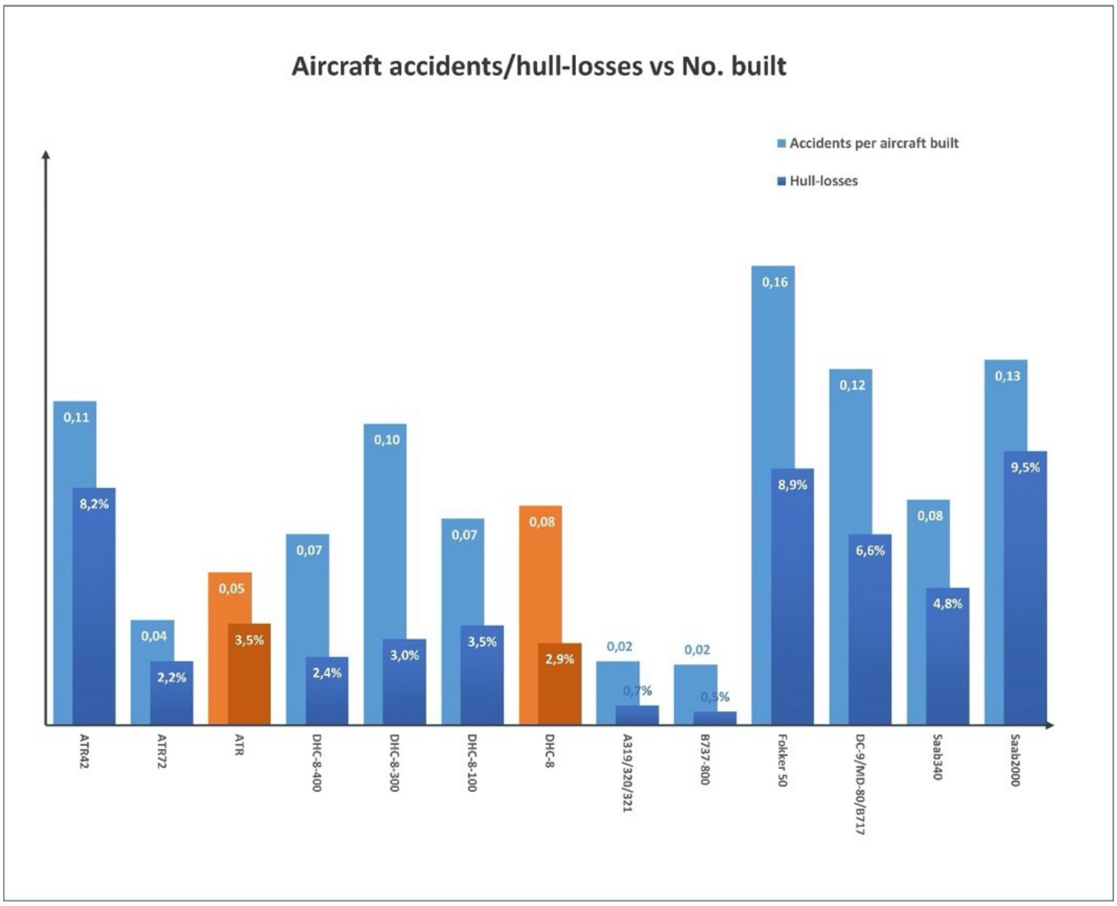

Figure 6.3: Accidents per aircraft built and hull losses

6.3 Standardized Fatality Rate

A limitation of the statistics in Figure 6 .1 and Figure 6 .2 is that they do not consider the size difference between the various aircraft models. Meaning, a smaller aircraft than an ATR, like a DHC-Q-100 will be less negatively affected by one crash, than an ATR, since less fatalities will arise from a smaller aircraft. Therefrom arises a need to standardise these statistics further, to make them fully comparable between aircraft models. The statistics must be made independent from aircraft-size and shall be projected upon a standardised seat-contingent. Figure 6 .4 presents a standardised statistic with data projected on a 100-seat basis. This statistic shows the average fatalities occurred every 100 lifetime-seats. The unit lifetime-seats refers to the total amount of fatalities that statistically occur for every 100 seats over these seats' entire operating life. In other words, the fatalities that would have occurred statistically if these aircraft had exactly 100 seats.

This graph ultimately compares the fatality rate of aircraft one-to-one, and clearly shows what aircraft model performs better in relation. In this graph, the ATR data (comprising both models) is highlighted in orange, to allow easier comparison to the DHC-8 Family, also highlighted in orange. The cumulative data shows that the DHC-8 aircraft have in fact a much lower fatality rate than ATR has. Looking at the single aircraft models the divergence between ATR42 and ATR72 is once again very wide. The ATR42 scores as most dangerous aircraft following this metric. No other aircraft has a fatality per 100 lifetime-seats as high as 1.18; not even the notorious DC-9, which ranks 2nd with a fatality per 100 lifetime-seats of 1.11. The ATR72 however performs much better, which is unexpected since the ATR72 is merely a stretched version of the ATR42. On the other hand, this disproportion could have been expected since, as described in Section 4, the severe accident count is equally spread between the two variants (12 severe accidents occurred aboard an ATR42, and 12 occurred aboard an ATR72), even though there exist trice as many ATR72s than ATR42s, hence, the disproportion. While performing better than the ATR42, the ATR72 still has higher fatalities than its direct competitor, the DHC-8-400. Comparison to industry leaders such as the Airbus A320 or the Boeing B737 further highlights the existing safety gap.

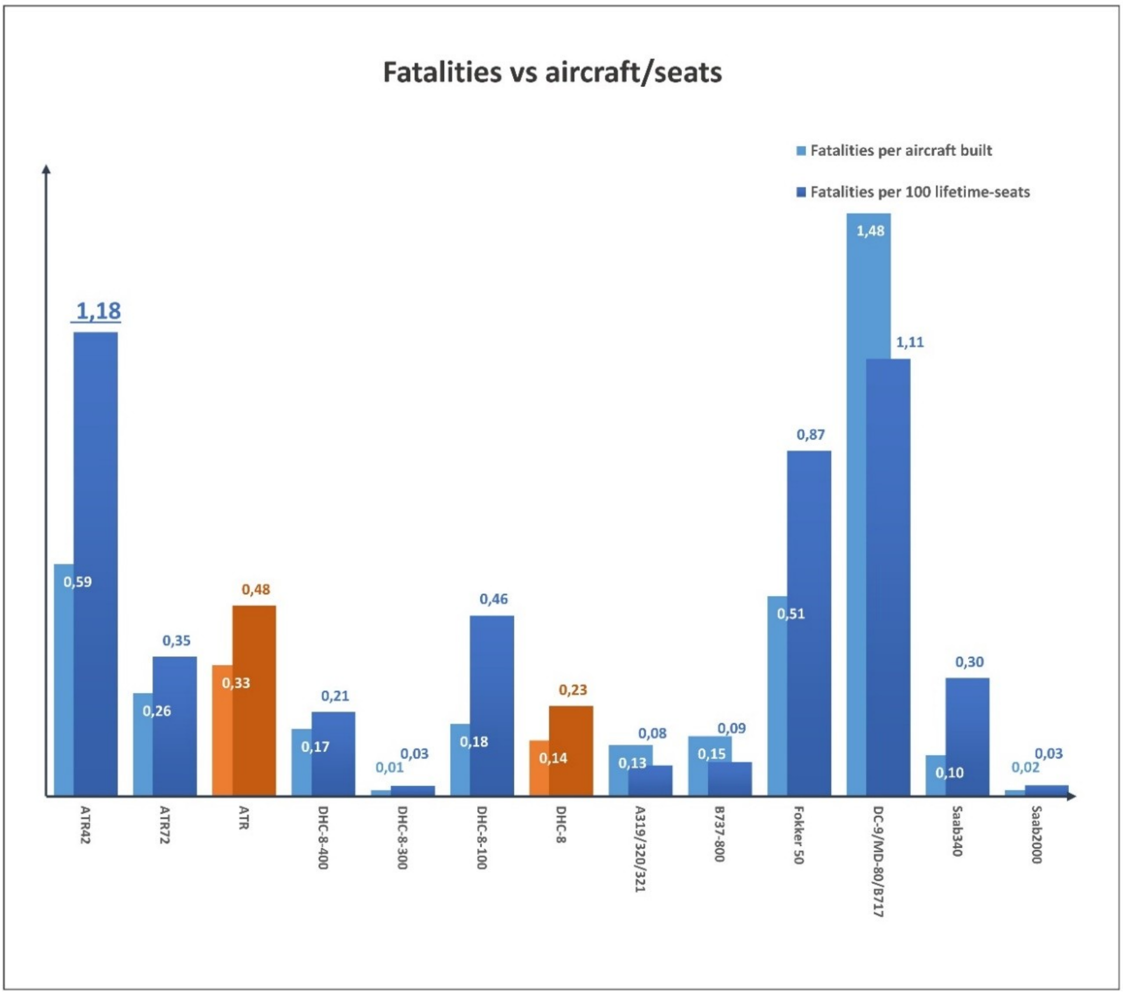

Figure 6.4: Fatalities per aircraft built and per lifetime-seats

7 Conclusion

The topic of aircraft safety is a complex one, in which the interplay of many external factors ultimately determines the aircraft's safety. Some of the most pressing factors have been analysed by this report, while the totality of relevant factors cannot possibly be analysed inside a single report.

To conclude, the evaluation of the main accidents shows how the constructor has repeatedly failed over the course of the years to detect flaws in the design of the aircraft and also critically failed to define emergency procedures in the event of emergencies caused by such design flaws. The aircraft's design flaws primarily concern ice accumulation on the aerodynamic surfaces of the aircraft coupled with inadequate onboard anti-ice systems. On top of this, the aircraft's trim control system was also found to be concerningly defective, along with problems involving system relays, switches, wires, and connections.

On the other side, the different scores between the two ATR aircraft models in all analysed metrics suggests the influence of external factors, not directly linked to the producer or the aircraft themselves. Factors, such as the extensive use of ATR42s in EASA-blacklisted airlines carrying flawed safety records and severely limited safety management systems, especially in airlines from regions such as Southeast-Asia, Africa, and South America may be a contributing factor to the negative footprint of the ATR42.

Nevertheless, while the ATR42 statistics might be negatively influenced by certain unfortunate coincidences, serious concerns with regards to design flaws and lack of proper documentation by the constructor, specifically regarding emergency procedures and abnormal operations persists. This report believes that a different approach by the constructor, such as increased scrutiny in the definition of emergency handling procedures and in the forecast of possible failures, as well as the implementation of multiple safety redundancies could have had a major positive impact on the safety record of ATR aircraft. The ATR aircraft family is hence found to have critical safety concerns of various kind and severity and represents an increased risk for passengers flying aboard these aircraft.

Decisive action by the constructor to tackle every single design flaw that was determined so far, as well as to tackle any suspected failure-prone aircraft part, is demanded. The constructor shall furthermore thoroughly restructure the aircraft's QRH and define any missing abnormal situation procedure as well as emergency procedures. The aircraft's weaknesses and vulnerabilities need to be clearly defined and communicated by the constructor and proper handling procedures to cope with the aircraft's vulnerabilities, for both pilots and mechanics, need to be created. In the meantime a serious aircraft-redesign shall take place, through modification and updates shall eliminate all persisting design flaws. The constructor shall demonstrate it is doing everything in his power to minimise fatalities caused by its aircraft.

8 References

[1] Article; FAA endorses de-icing boot change to overcome ATR 42/72 difficulties https://www.flightglobal.com/faa-endorses-de-icing-boot-change-to-overcome-atr-42/72-difficulties/16813.article

[2] Article; FAA Bans ATR Flights in Icy Conditions: Safety: Order comes six weeks after fatal crash in Midwest. Manufacturer provides new information about possible hazards in bad weather. https://www.latimes.com/archives/la-xpm-1994-12-10-mn-7325-story.html

[3] Website; Aviation Safety Network (accidents statistics per aircraft model) https://aviation-safety.net/

[4] Website; General information about specific accidents, such as date, location, fatalities, occurrence, findings of investigation, etc. https://en.wikipedia.org/

[5] Website; General information about the ATR72 https://en.wikipedia.org/wiki/ATR_72#Accidents_and_incidents

[6] General information about the ATR42 https://en.wikipedia.org/wiki/ATR_42

[7] Article; "Community list of air carriers which are subject to an operating ban within the Community acc. to Regulation (EC) No 2111/2005" (ie. EU Air Safety List) https://transport.ec.europa.eu/transport-themes/eu-air-safety-list_en

[8] Article; "FINAL INVESTIGATION REPORT INTO ACCIDENT OF PIA FLIGHT PK-661 ATR42-500 REG NO AP-BHO CRASHED NEAR HAVELLIAN ON 07-12-2016" (PDF). Aircraft Accident Investigation Board of Pakistan, Pakistan Civil Aviation Authority. 18 November 2020.

[9] Website; ATR own website, Mission Statement, aircraft's purpose. https://www.atr-aircraft.com/about/who-we-are/