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INTEGRATED MANAGEMENT SYSTEMS IN AVIATION: INSIGHTS FROM CASE STUDY RESEARCH

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Abstract. Integrated Management Systems (IMS) have gained increasing attention within the aviation industry as organisations seek to manage multiple, often fragmented, management systems more effectively. Despite this interest, empirical research and regulatory guidance on IMS implementation in aviation remain limited, with much of the existing literature focusing on conceptual models rather than practical application. Recent studies emphasize the importance of incorporating risk as a unifying element within IMS, given its central role across all management systems.

This paper presents a case study evaluating the practical applicability of an IMS model developed by Meeûs, which aims to bridge the gap between theoretical integration frameworks and operational implementation. The model is derived from an analysis of the International Civil Aviation Organization's Safety Management System components and their alignment with various management systems, resulting in a standardized integration "language." This language consists of a shared risk component and two classification mechanisms designed to identify events and underlying causes across multiple systems. The model further introduces the IMS Cube concept, enabling reported events to be reviewed holistically rather than in isolation within individual management systems.

Using empirical data, this study analyses the feasibility of implementing the proposed IMS language and integrated process in an operational aviation context. The findings provide insights into the model's behaviour in practice and contribute empirical evidence to support the advancement of risk-based integrated management systems in aviation.

Keywords: management systems, integrated management systems, interoperability, integrated risk, IMS cube, safety management system, aviation, airline.

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1. Introduction

Integrated Management Systems (IMS) within the aviation industry have gained increasing attention in recent years. This trend is largely driven by the multiple management systems within airlines, which are often implemented in isolation manner and lack effective integration. Despite this growing interest, academic literature and regulatory guidance on IMS in aviation remain limited.

Due to the limited number of articles or studies in the aviation industry, it is valuable to investigate other sectors to see how integrated management systems are developed and to determine if lessons can be learned for implementing such a system in the aviation industry. Examining other industries reveals that most articles focus on ISO standards and their integration into various systems. It is worthwhile to note that articles on ISO standards in the aviation industry are also limited in the literature, particularly for standards such as Occupational Health and Safety or Environmental standards. They might be implemented in an aviation environment but are almost non-existent in the literature. Sources were identified from academic databases, including Web of Science, ResearchGate, and ScienceDirect, as well as industry publications from The International Civil Aviation Organization (ICAO), European Union Aviation Safety Agency (EASA), and International Air Transport Association (IATA). The review employed targeted keywords and combinations, including "interoperability", "integrated", "integrated management system", "SMS", "ISO", and "management systems". Due to the limited availability of publications in the aviation industry, a second search was conducted, with the words "aviation" and "airline" excluded, to ensure capturing publications from various other industries: Figure 1 shows the distribution of the 30 selected articles by methodology. The majority of studies conducted focus on the conceptual methodology, which involves examining the meaning, scope, and interrelationships of concepts to establish definitional precision

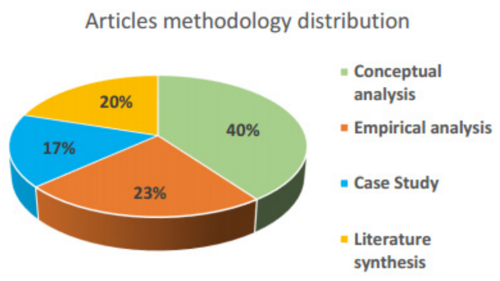

Figure 1. Articles methodology distribution

and theoretical clarity. These concepts form the foundation of empirical work, the second-largest group of articles and studies reviewed. These analyses are helpful because they validate theories and concepts with evidence and can identify correlations for future research. These empirical analyses are often on a low number of interviews, companies used, or within a specific context, for example, surveys on Spanish firms, regardless of the industry or regulatory environment.

The case studies provide an in-depth examination of a single case or a small number of cases within their specific context, highlighting practical challenges. The majority of the case studies analysed are from outside the aviation industry due to the limited number available within it. The literature synthesis provides an overview of the state of knowledge across industries over the years regarding integrated management systems. The key works offering the greatest analytical value are outlined hereafter.

The Appendix (Table A1) provides an overview of all reviewed publications. Blue-shaded rows mark studies specific to the aviation sector, whereas the remaining publications pertain to other industries. The Appendix also specify the scope of each article, including the management systems examined. The key findings from the most relevant articles are presented below.

Historically, prior to the early 21st century, research primarily focused on conceptualizing integration, concluding that integration is defined as a partial integration of various management systems while preserving their individual identities (López-Fresno, 2010; Carvalho et al., 2015; Maier et al., 2015; Nunhes et al., 2019).

Since the turn of the century, academic discussion has shifted toward examining the structural components of integrated systems. A notable contribution was made by Nunhes et al. (2019), who conducted a comprehensive review of literature published between 2006 and 2016 and proposed one of the first IMS models. This model was built upon six foundational pillars derived from various management systems, forming a unified framework. However, the proposed model lacked practical implementation guidelines. More recently, scholars have emphasized the addition of risk as a critical component of IMS design. Risk management is inherent to all management systems, as each system identifies, assesses, and mitigates risks within its domain. Consequently, any integrated model must incorporate risk as a unifying concept (Algheriani et al., 2019; Muzaimi et al., 2017). Although there is strive to define components, including a risk component to develop a model IMS model, there is still a need of more empirical research to evaluate integrated management systems (Chountalas & Lagodimos, 2024; Ispas et al., 2023; Ispas & Mironeasa, 2022; Malakis et al., 2023).

A deep comparison of various concepts and IMS models available has been made by Meeûs (2026) which led to development of his IMS Model. This paper presents a case study based on the IMS model developed by Meeûs et al. (2024), which aims to bridge the gap between theoretical frameworks and practical application. This gap has been identified by Meeûs et al. (2023) identifying the gaps of interoperability amongst various airlines, based on survey data from 77 airlines. The outcome lead to Meeûs' model.

The model is defined through an analysis of the ICAO SMS components (The International Civil Aviation Organization [ICAO], 2018), compared to components of different management systems. This resulted in a model, introducing a standardized "language" for integration, comprising three elements: a risk component and two classification mechanisms designed to define events and their underlying causes across multiple systems. Secondly the model defines a new integrated concept where reported events are no longer isolated within the management system is reported, but review events through the whole spectrum of implemented management systems, providing a holistic view which Meeûs has visualized under the IMS cube.

Given the scarcity of research and regulatory guidance, the proposed model and its associated process represent a different contribution to the field. To evaluate its feasibility, this paper conducts a case study to determine whether the model can be practically implemented or remains a theoretical construct. The demonstration of the model designed by Meeûs necessitates an empirical investigation to comprehend its behaviour.

The paper is organised as follows. Section 2 provides the outline of the case study which comprises of the theoretical framework and methods used for the case study. Section 3 provides the data analysis of the IMS language as defined by Meeûs and section 3.4 analyse the data against the Integrated process of all management systems as one system into the IMS Cube, allowing to interpret the obtained results. The paper is finalised with the conclusions section.

2. Outline of the case study

A first approach was to involve the ECCAIRS Database, the European Central Repository for Accident and Incident Reported events. European Regulation 376/2014 (European Parliament, 2014), under Article 10, allows interested parties, including universities, to access this database, as per Annexe II of the regulation. However, a strict protocol must be followed to obtain this data. Upon reviewing the database, several constraints were identified. The ECCAIRS database records approximately 230.000 events annually from various European airlines. Despite implementing a standard taxonomy, numerous free-text fields are available, and different risk assessment methods are used by various airlines. This process revealed a significant issue. The data is often stored in the national language of the respective airline, rather than in English, adding complexity to data utilisation. Robust Artificial Intelligence (AI) tools would be necessary to analyse and translate the data into "aviation" English. Given airlines' extensive use of abbreviations and specific terminology, translating this information into "aviation" English using an online tool would be highly challenging. An AI tool would be required, which would also need time to learn all the abbreviations and terms used in aviation and distinguish between word abbreviations and airport codes, for example. Furthermore, it was unclear how the 230.000 events could be exported from the database. Consequently, using this data for the case studies was deemed impractical.

A second approach was to reach out to various airlines, to explain the case study objectives and to present the model during online meetings. Follow-up meetings were conducted to address any additional queries. The primary aim was to engage different airlines in the case study by utilising their data to observe the behaviour within the model. The requested data encompassed information from their diverse management systems, including details such as the title of the event, a text narrative, the risk classification of the event, any taxonomy used for data clustering, and corrective actions taken in response to specific events.

Another challenge raised the surface as the requested information is considered safety-critical, and airlines are reluctant to share it. Even those willing to share faced opposition from their legal departments, data protection departments, and unions. Although tools such as Data Protection Agreements and Non-Disclosure Agreements exist to facilitate this, obtaining the requested data proved to be very difficult.

Despite the challenges, participation in the study was undertaken by an airline to validate the model and assess its behavior. For the purposes of this case study, the airline has been de-identified and renamed "Lambda" or "Lambda Airlines." It operates worldwide on a long-haul network to numerous destinations and has a significant fleet of wide-body aircraft. Lambda Airlines can be considered a mature airline, operating for a few decades worldwide, an European airline with a flees size smaller than 50 aircraft, IATA Operational Safety Audit (IOSA) certified and categorised as a Pax-cargo carrier.

Lambda has implemented multiple management systems over the years, although in a siloed approach. The data came from the following different management systems implemented by the airline:

- Safety Management System
- Occupational Health and Safety Management System
- Security Management System

The airline has implemented more systems, but the data from those systems (fatigue management system, compliance monitoring system, and Environmental Management System) could not be shared to test the model. The data provided was only related to the reporting system; no data from Change Management and/or Risk assessment processes were shared. Lambda is a mature airline with a good reporting culture, which results in a high number of reports received.

The above management systems provided the following data fields through their reporting system:

- Report Title
- Report Text narrative
- Company event classification and ADREP classification
- Report Risk rating
- Closure notes of the report.

This article was obliged to adopt an exploratory single-case study design. Due to the sensitive nature of safety and risk data in aviation, access was limited to a partial reporting dataset from a single airline group. Data selection was therefore conducted using a structured, expert-driven screening procedure consistent with qualitative case study research

The dataset contained report data from January 1, 2023, to September 30, 2024. The total report data consisted of 6387 events. At the time of the case study, the industry was heavily affected by GPS jamming and spoofing events, which was also the case for Lamba Airlines. Therefore, the 876 reported events related to this issue were filtered from the dataset, as the problem of GPS jamming and spoofing is a global concern, and the airline itself has no direct impact on resolving this issue. The airline also has an interlink between its maintenance software and its reporting system, which records defects, allowing for automatically triggering of events in the reporting system. These 942 events were also filtered out because those events are routine maintenance events which are inserted in the reporting system to comply with the regulatory requirements as laid down in EU regulation 376/2014 (European Parliament, 2014) and are managed through the maintenance organisation to rectify the defects and therefore have a limited impact on the different management systems.

This resulted in a total data set of 4569 events. The reported events originated from all layers in the organisation. All these events have been reviewed through the report text to identify possible impact on multiple management systems when the narrative indicated credible implications beyond the originally assigned system (e.g., safety, compliance, occupational health, environmental, or security domains). For example, if a safety report event demonstrated as well a non-compliance or impact on the safety of staff (occupational health), or if a non-compliance event as well indicates a safety impact or a security impact, such events would be selected for the second filtering. If the report text consisted of a single sentence, it was not considered. It resulted in an initial selection of 447 reports (9.78% of the reports). A third filtering was conducted focusing on event complexity. Complexity was defined qualitatively as events involving multiple contributing factors, cross functional operational impacts, or interactions between various domains. Based on these criteria, 235 reports were retained for detailed review (5.14%). It is worth mentioning that it is based only on the de-identified narrative report text, which varies between reports, and can be limited or extensive. The airline did not disclose all the steps between the reception of reports by Lambda and the time the reports are closed, which often makes it difficult to understand the impact and complexity of certain reported events. The final sample of 235 events was selected to represent the most information rich and analytically relevant cases for demonstrating the behaviour of the Integrated Management System model. All screening and classification steps were conducted by a domain expert with extensive experience in aviation safety and management systems.

No formal inter coder agreement was applied, and no independent coding was performed. This represents a methodological limitation and introduces potential expert bias; however, the approach is appropriate for the exploratory purpose of this case study, which aims to demonstrate model behaviour rather than to produce statistically generalizable findings. Therefor, the selected 235 events are considered sufficient data to conduct the exploratory case study for its purpose and to understand the model's behaviour.

3. Result of the analysis

To understand the results of the analysis, a brief description is provided of Meeûs model. The model features 3 new elements for achieving interoperability to create a single integrated system. The first element is a unique language, to ensure that each system can communicate with each other. To achieve that, the language consists of 3 elements. The first element is a unique event taxonomy that must be applied to all management systems. Secondly, a new risk matrix was defined, including calibration scales for each management system and a risk tolerability table. This ensured that when a risk is assigned to one or more management systems, there is a correlation between all the risk levels of each system. The final element of the language is the unique root-cause classification method. Meeûs has used an adapted HFACS (Human Factors Analysis and Classification Scheme) to enable cross-divisional use across various management systems. A second element of his model is an integrated process to ensure that events do not remain isolated in either management system, but that there is interoperability amongst them. And the last element is the holistic visualisation of all the elements into a Cube, which visualises all these risks holistically as well as per individual systems, the top events and root causes analysis across various systems, to ensure that risks are under control for each management system, which will result in better decision making to manage any risk. Further details of each element, such as the taxonomies used, calibration scales across the various systems, and risk evaluation, can be found under the Meeûs model in order to reproduce the below results.

3.1. Language – risk

The first pillar of the Meeûs' IMS Model is uniform way of looking at risk by all the systems implemented by Lambda Airline. The selected data was distributed among the different management systems (MS) as shown in Table 1 below. Due to the airline's mature reporting system and to reflect its different divisions and complexity, the data from the safety management system is split up between Flight Operations, Ground Operations, and Maintenance Operations. This is standard practice as airlines have different reporting templates and strive to direct their respective staff to report on the corresponding templates within their domain.

The selected reports were analysed with respect to the risk ratings assigned by Lambda Airlines. As the operator applies a 5×5 risk matrix, it was possible to establish a clear correspondence between its internal risk-assessment framework and the matrix proposed by Meeûs in the IMS Model, using the definitions of the severity and probability scales defined for each management system. Based on this alignment, all identified events were systematically remapped and assigned a severity and probability value specific to the relevant management system. This ensured methodological consistency and enabled a transparent comparison between the Lamba risk matrix and the IMS Matrix from Meeûs for the various events and systems.

This is necessary to ensure that the same risk matrix can be used consistently throughout the model demonstration process and that all subsequent risk ratings utilise a single standard matrix. It resulted in a higher cumulative risk value for all management systems (Table 2). The increase in the Security and Occupational Health and Safety

Table 1. Distribution of data amongst the various MS

System	SMS			SeMS	OHS
	Ground	Flight	Maintenance		
Number of reports	1300	1061	1664	212	332
Selected reports	54	52	117	8	4
%	4.15	4.90	7.03	3.77	1.20

Table 2. Difference in cumulative risk between Lambda and IMS model

System	SMS			SeMS	OHS
	Ground	Flight	Maintenance		
Lambda risk value	2666	707	2337	610	400
IMS risk value	3825	978	3627	1204	800

Table 3. Comparison of Lambda vs IMS events and associated risk

System	SMS			SeMS	OHS	EMS	CMS	FRMS
	Ground	Flight	Maintenance					
Lambda event	54	52	117	8	4	0	0	0
Lambda risk	3825	978	3627	1204	800	0	0	0
IMS events	98	77	145	15	51	17	111	4
IMS risk	4496	1458	3849	1290	1876	456	1317	152
Δ events	44	25	28	7	47	17	111	4
Δ Risk	671	480	322	86	1076	456	1317	152
Δ Risk %	15.25	19.20	11.50	12.29	22.89	26.82	11.86	38.00

(OHS) system's values is explained by the low number of reports received and the higher risk attributed by the risk matrix from the IMS model compared to the risk matrix from Lambda Airlines.

In the IMS Model, no event belongs to an individual system; it belongs to the integrated management system. This means that all events must be assessed against the various systems implemented in the airline, as defined by Meeûs' IMS Process.

Therefore, all 235 events are reviewed in detail, and if a potential risk could be associated with one or more systems, a risk is associated with that additional management system. If a ground event were reported with Lambda, it would only be seen through the SMS-Ground system. If the review of this event indicates an additional risk, for example, to SMS-Maintenance or OHS, it would also receive a risk rating related to those systems.

In addition, when reviewing these events, some risks were identified that could impact other management systems, although data was not provided for that specific management system. For example, some events could pose a potential risk for the compliance monitoring system, and therefore, a risk was associated with them. It resulted in three additional management systems, which received a risk rating as well. However, no data from these systems were made available for the case study by the airline:

- Environmental Management System (EMS)
- Compliance Monitoring System (CMS)
- Fatigue Risk Management System (FRMS)

This is seen as a positive evolution, as the IMS model was developed to take a holistic view beyond individual systems, resulting in the following risk ratings. Table 3 present the total initial identified events, along with their associated total risk, as assessed by Lambda Airlines through the IMS risk matrix (first two rows). The following two rows show the events and associated total risk after review by the IMS model. The events provided by Lambda are isolated and, therefore, only appear in one or another system. It also explains the zero for the 3 other systems.

The IMS model indicates that events impact multiple systems, even those that may not be visible to the airline. For example, from the events provided by Lambda, 17 events also impacted the EMS system, with a total associated risk of 456.

The following row, which shows the difference between Lambda and IMS model's output in terms of the number of events that impact other systems (absolute numbers). The IMS examines and studies the impact of all systems; events reported in one system can affect other systems. Under the SMS-Ground, 44 events reported in various other systems are additionally associated with this SMS-Ground. Or from all the reviewed events, 111 events are also associated with the CMS system.

The last two rows illustrate the effects on additional risk in absolute and percentage differences.

The IMS model changes the weight of each system in the organisation. The total risk has increased from 10434 (total Lambda risk) to 14994 (total IMS risk), representing a 42% increase. This means that the real risk impact, when considering all systems together, is higher because more events have an additional risk defined that impacts other systems, consequently, the "weight" of all the systems is changing (Figure 2 – rounded numbers).

Lambda Airline's views on the events are 72% related to the SMS management system for Ground and Maintenance. In the integrated model, they are still the main contributing systems but only represent 56%. OHS plays a more prominent role in the organisation's overall risk, and SeMS plays a more minor role. On the systems for which no data was received by Lambda but triggered by the IMS model, many events have a compliance risk identified, and some risks are also related to EMS and FRMS.

The results demonstrate that the outcome behaves as defined by the model (Figure 2). It demonstrated the risk picture is indeed changing. The IMS Model provides

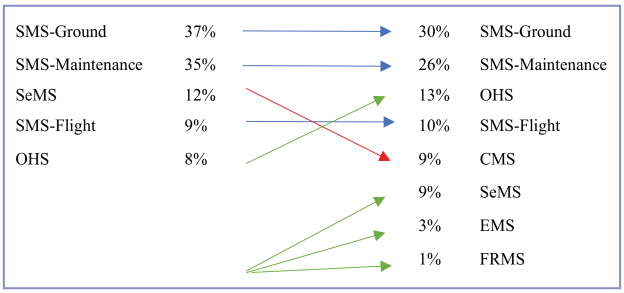

Figure 2. Comparison of the weight of MS between Lambda and IMS

a comprehensive perspective on the various management systems in relation to the overall risk that the airline is facing, but remains to have the possibility to view individual management risks.

3.2. Analysis of IMS language – what descriptors

The second pillar of the IMS language is to understand what is happening. The data received from Lambda contained both their company classification and the ADREP classification. The company classification consisted of a 4-level taxonomy and was well structured. With the combination of the report text, Lambda taxonomy, and provided ADREP, it was possible to map all these events to the classification used by the IMS Model, which is IDX based, for the selected 235 Events.

All the events could be clustered into 60 unique categories. Some categories had only one datapoint (i.e., single event). The top 15 clustered events, which represent 71% of the 235 selected events, were used to validate the model and understand its behaviour, resulting in the following classifications and number of datapoints (Table 4).

The category "fuel errors" relate to wrong fuel figures, wrong uploads, wrong distribution, wrong refuelling, etc. The cluster "ramp" is related to a variety of items like manoeuvring area issues, broken ramp equipment, items falling of ramp equipment, pushback issues etc. The category "Fuelling" relates to fuelling servicing (Deadman switch, leaking hoses, fuel caps etc). All other cluster items are self-explanatory. For example all events reported related to documentation could be classified under the element "Documentation/Records" of the IMS model taxonomy. Same for the pushback and towing events to name another one. The IMS model taxonomy was detailed enough to able to remap all the filtered events, even when the initial Lambda classification was a custom-made taxonomy.

Table 4. IMS top 15 clustered events

Maintenance information system (entry or update)	36
Documentation/Records	17
Fuel errors (fuel figures/distribution)	15
Aircraft Damage	13
Fuel Spillage	12
Incapacitation	11
Maintenance task not correctly documented	11
Ramp	11
Certification error	8
Production of Load sheet and/or Load instruction report	7
Miscommunication	7
Unapproved data	6
Pushback and Towing	5
Fuelling	4
Tooling	4

Secondly, as described in the previous paragraph, all events associated with each clustered category have been re-assessed through the various management systems. Table 5 below provides a detailed view of the top 15 clustered events. Additionally, all management systems identified by the IMS model are listed. On the left side, all clustered classifications are shown. The column "lambda vs IMS events" indicates the difference between what Lambda Airlines sees with the isolated view of the different systems and the result of the IMS model. The cluster classification "Maintenance information system (entry or update)" shows that 36 events were reported in the different Lambda Airline systems (blue highlighted numbers). In contrast, the IMS model shows that these same events are identified 73 times in the different systems, as they impact other systems.

To understand which events identified multiple impacts on other systems which Lambda did not see, these numbers are listed under the different management systems. The numbers highlighted in blue represent the events that Lambda initially assigned to the management system before running through the IMS Model. For example, the event classification cluster "Fuel errors (fuel figures/distribution)" contains 15 events according to Lambda; nine events are assigned to the SMS–Ground and six events are assigned to the SMS-Flight. The respective risk rating for these events is always shown next to it, which is the sum of the risk rating related to these nine events (total risk of 50) and six events (total risk of 68). By running the same events through the IMS Process, the 15 events from Lambda are returning 44 times under different systems, SMS-Ground, SMS-Flight and the CMS, indicating multiple impacts (and a higher risk value) on other systems. The events appear to be recorded in various management systems by applying the IMS Process, meaning that it does not depend on a single management system, but rather on a combination of all systems implemented.

In other words, when looking at the clustering of events, the blue numbers represent how Lambda has assessed the events and through which management system. The uncoloured numbers represent additional information beyond how the IMS has modelled these events. The last column is added to demonstrate the total risk seen by the IMS versus what Lambda is seeing.

This information allows us to understand how the different events behave and compare before and after the IMS process.

Figure 3 presents the top 15 events and their respective total risk, listed in order from highest to lowest risk. The left side of the table represents the events and respective risks from Lambda Airline's perspective. The events and risks assessed after using the IMS model are displayed on the right side. Blue arrows in Figure 3 indicate no change in the ranking, green indicates an increase in the IMS model, while red indicates a decrease.

Events are starting to move in the IMS Model. Looking at Lambda, the concern about various ground issues (Fuel

Table 5. Top 15 events outcome by IMS

Classification	Lambda vs IMS events	SMS- Ground		SMS - Flight		SMS- Maintenance		SeMS		OHS		EMS		CMS		Lamda vs IMS Risk
		nr of events	total risk	nr of events	total risk	nr of events	total risk	nr of events	total risk	nr of events	total risk	nr of events	total risk	nr of events	total risk	
Maintenance information system (entry or update)	36					36	1344									1344
	73					36	1344			1	2			36	264	1610
Documentation/Records	17					17	490									490
	34			1	2	17	490							16	112	604
Fuel errors (fuel figures/distribution)	15	9	50	6	68											118
	44	15	150	15	438									14	412	1000
Aircraft Damage	13	13	570													570
	28	13	570	1	2	13	137			1	10					719
Fuel Spillage	12	4	80	4	63	2	20			2	400					563
	28	6	100	4	63	5	42			2	400	11	390			995
Incapacitation	11			11	254											254
	22			11	254					11	110					364
Maintenance task not correctly documented	11					11	261									261
	23	1	50			11	261	1	2	1	10			9	34	357
Ramp	11	2	210	9	34											244
	24	11	348	9	34					3	70			1	10	462
Certification error	8					8	135									135
	17			1	2	8	135							8	24	161
Miscommunication	7					7	86									86
	14	6	132			7	86			1	2					220
Production of LS and/or LIR	7	2	250	5	232											482
	21	7	364	7	292	2	100							5	170	926
Unapproved data	6					6	272									272
	12					6	272	1	10					5	58	340
Pushback and Towing	5	5	352													352
	10	5	352	1	2	1	10			3	110					474
Fuelling	4	2	210	1	2	1	50									262
	11	3	212	2	12	1	50			1	2	2	52	2	60	388
Tooling	4					4	40									40
	8	1	50			4	40			3	30					120

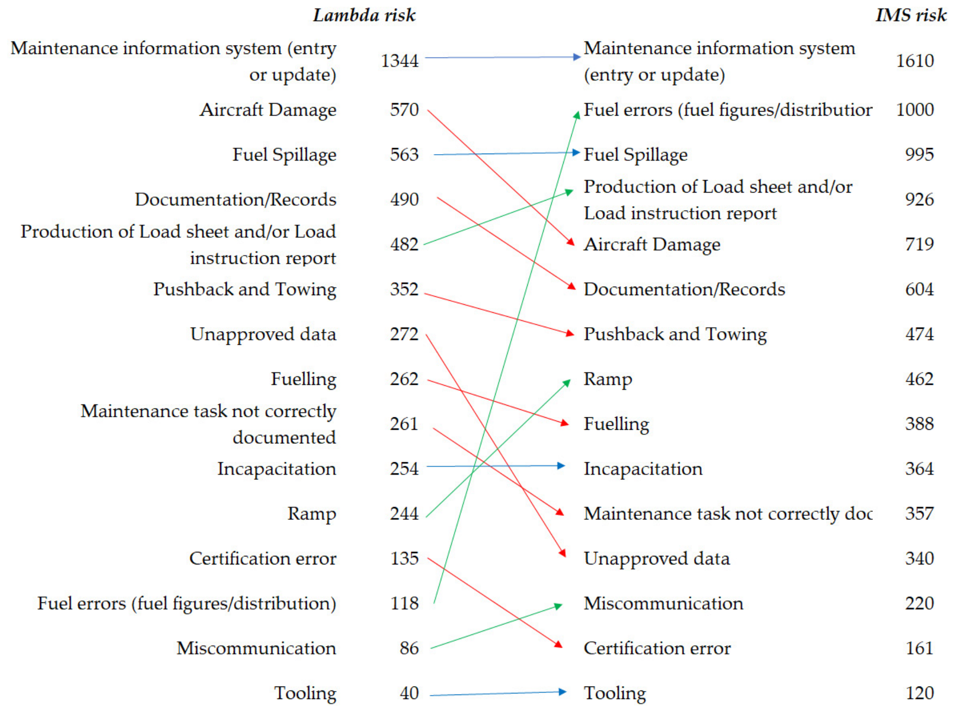

Figure 3. Shifting weight top 15 events between Lambda and IMS

errors, ramp handling, load sheets) is not a high priority. Compared to the IMS model, all these categories are rated higher and are moving up the list. This is understandable as handling ground issues involves many actors around the aircraft (ground handlers, maintenance staff, and pilots), and each is affected by ground issues in their own way and has a different risk. With Lambda Airlines, these events are mostly reported through the SMS-Ground system and remain isolated. The risk is assessed from the perspective of purely ground operations. The IMS model considers multiple other factors, and therefore, it is moving up the priority list. The fuel errors, for example, no longer belong to an individual system although reported through the SMS-Ground. The IMS model assesses the potential impact and risk of these events on other management systems, regardless of the channels through which they are reported, making it independent of any single system, as the topic belongs to the IMS system.

The opposite trend is also valid. Events related to documentation "unapproved data", "maintenance task not correctly documented", and "certification error" have a higher ranking under the Lambda approach. The IMS model also considers the CMS, among others, as shown in Figure 3 above, which breaks down these events by management system. In the IMS model, all these events have a higher total risk value than the Lambda risk perspective. This means it adds additional risks to the organisation. Still, in the overall picture, compared to other risks within the organisation the IMS assesses, it remains on the lower side.

Taking this into account, if Lambda uses the IMS model, the focus should be more on aircraft handling, particularly fuelling and ramp topics. There is a higher combined risk for the organisation at this time than focusing on maintenance issues. It demonstrates that due to the unique taxonomy used, cross divisional over all the management systems, the IMS model enables events to be clustered and therefore the associated risk is cumulated which provides other priorities compared to looking at taxonomies which are different amongst the various systems.

3.3. Analysis of IMS language – why descriptors

The last pillar of the IMS language is understanding "Why" events are happening with the different management systems. It is only by understanding those that recurrence can be avoided, but at the same time, it is the most difficult pillar to define.

Unlike the two other pillars, "why" analysis, also known as root cause analysis, is more challenging. Every report entered into a reporting system must be risk-rated and classified, in accordance with various regulations and standards. To understand "what" is happening, there are ADREP and ECCAIRS in Europe, as well as other taxonomies in the industry. Risk ratings are always evaluated against an airline's implemented risk matrix. Root causes are different from that perspective. No standard exists to classify root causes in regulations or industry standards.

The data from Lambda also demonstrates this: there is not always a classification of root causes used, or a root cause analysis conducted at all. Most of the time, causes are free text, and limited analysis is reported in the closure notes of the events, which were obtained from Lambda. Still, not all interactions between receiving the event and closing the event were made available, which could help identify and classify the root causes.

The Lambda data contained only 29 events with a root cause classification reflected in the closure note. These causes have been remapped to the root cause classification defined by Meeûs IMS model to establish a standardised approach throughout the demonstration process. It is acknowledged that the number of available causes is a methodological limitation. However, the resulting root causes classification should be interpreted as pattern explorations under conservative attribution assumptions aimed at avoiding underestimation of potential systemic involvement.

Of the 29 events, 60 causes were identified across 14 categories. Most of these events had either 1 or 2 different causes assigned (Figure 4), and a few outlines had more causes identified. As Lambda reviews its events through a single management system, the identified causes are unique to the system to which they are assigned.

Through the IMS model, all events are evaluated and classified. Based on the report text and Lambda's closure notes, all 235 events could, using a high-level approach, be assigned to one or more cause descriptions from the IMS model.

First, as the IMS model categorises all events, it identifies many more potential causes. For all 235 events, 353 causes were identified across 19 categories. Secondly, many more events have multiple causes identified, and a significant number of events have multiple causes assigned (Figure 5). The IMS model is compelled to provide more detail about the events. If all data were made available from Lambda, for example, the details of all actions taken between the occurrence and closure of the events, even more granularities would be observed.

The number of causes recognised by the IMS model provides a more holistic overview, as it identifies where all the causes are located on the IMS causes tree. This will help the organisation understand why specific issues occur

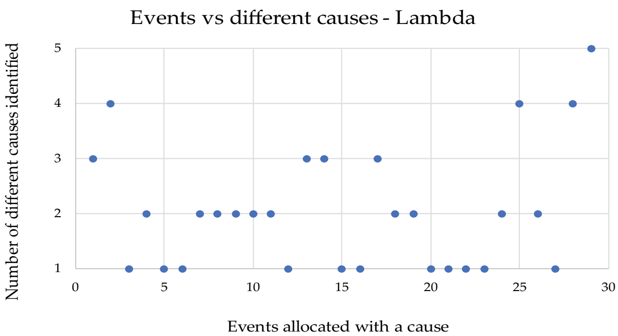

Figure 4. Events vs different causes by Lambda

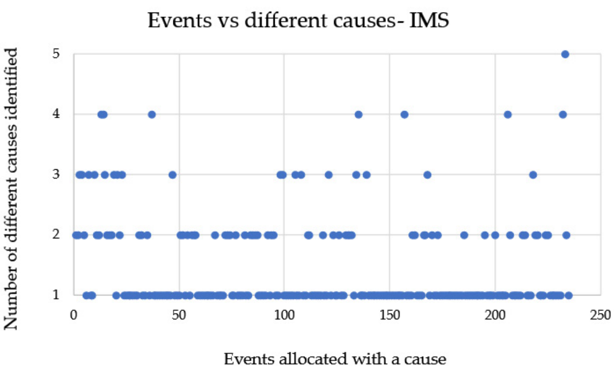

Figure 5. Events vs different causes – IMS

and where to look to avoid recurrence. Figure 6 presents the IMS cause tree, including the 60 Lambda-identified causes at various levels and the 353 IMS-identified causes. The number of IMS-identified causes represents the total of all identified causes across all management systems.

By reviewing Figure 6, one can conclude that Lambda identified the cause of all events as skill-based errors (slips, lapses, checklist errors, etc.), as represented by the blue number in the table and with the most hits in the causes tree. Lambda could focus on skill-based errors to reduce them, as on the other levels of the causes tree, a low number of causes is identified first. Secondly, they are scattered throughout the different categories of causes. A limited number of hotspots can be identified.

The IMS model, however, has more data points and goes deeper into the analysis. It shows a higher number of skill-based errors, which is normal as more reports have been analysed, and the level of "unsafe Acts" is the apparent surface cause that can be identified. It is also observed that, at other levels, clusters are formed (red numbers) that extend deeper into the organisation. This suggests that Lambda Airlines should not only examine skill-based errors but also assess factors related to communication, coordination, supervision, and operational processes. These are the causes that are most frequently identified when examining all events together. Under the "preconditions for unsafe acts" level, it also highlights technical equipment factors and environmental causes that contribute to event occurrence.

The above causes are for the total of events reported, and the numbers will change if the organisation looks for the top 15 clustered events (Figure 7). According to Lambda data, only a limited number of events have received a causal classification, as evidenced by the top 15 events. Only six of the top 15 clustered events have one or more causes identified. In addition, not all events within the cluster are reviewed by Lambda. For example, the cluster "ramp" consists of 11 events, but Lambda has not analysed all 11 events to define one or more causes. As data are clustered, this results in a greater variety of causal

	unsafe Acts				
	Errors			violations	
	Decision Errors	Skill-based Errors	Perceptual Error	Routine	Exceptional
Lambda	1	20	2	1	0
IMS	12	100	14	5	2

	Preconditions for unsafe acts						
	Situational Factors		Conditions of Operations			Personnel Factors	
	Physical Environment	Technology Environment	Mental State	Physio-Behavioral State	Physical/ Mental Limitations	Communication, Coordination & Planning	Personal Readiness
Lambda	6	8	3	0	4	3	1
IMS	21	42	8	1	6	34	17

	Supervisory factors			
	Inadequate Supervision	Planned Inappropriate Operations	Failure to Correct Known Problem	Supervisory Violation
Lambda	3	3	0	0
IMS	40	8	10	3

	Organizational Influences		
	Organizational Culture	Operational Process	Resource Management
Lambda	1	0	4
IMS	1	22	7

Figure 6. Causes tree Lambda compared to IMS

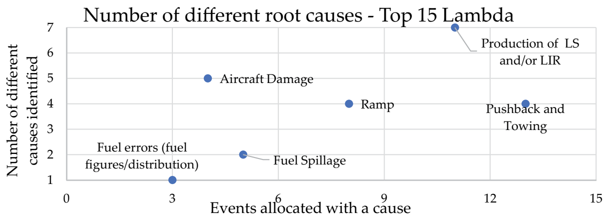

Figure 7. Top 15 different root causes seen by Lambda

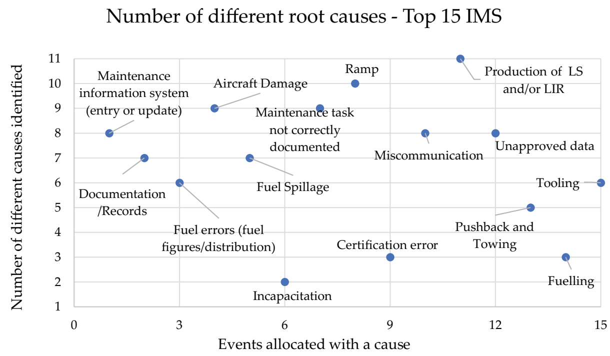

Figure 8. Top 15 different root causes seen by IMS

outcomes. One event could have three causes allocated to it. In contrast, another event in the same cluster will have three additional identified causes, resulting in six different causes identified. Every event is different, and the reasons they occur are as well.

If the top 15 events are analysed through the model, each event within the cluster is analysed, meaning all 15 clustered events are returning on Figure 8. Every event has more than one cause; the majority have six or more.

The IMS model examines events from various perspectives. If an event occurs and creates a potential risk to any of the management systems implemented in an organisation, each of those systems is to review it. This results in many more root causes being identified, as each management system views the event from its own perspective. The analysis of why an event occurred may yield different outcomes depending on the system used.

Looking at which causes have the greatest effect on the top 15 events, the same behaviour is observed when considering all events together (Figure 9). From Lambda's perspective, they will identify skill-based errors (blue number) as the primary reason these top events are occurring. The IMS reveals different hotspots (red numbers), more hotspots, and a deeper level of root cause within the organisation. It is more likely that when Lambda works on the deeper causes, the risk of recurrence of those events will decrease, rather than working on the surface cause of skill-based errors. These skill-based errors are also high under the IMS Model, but it shows that additional underlying causes also affect why these events occur.

The IMS model can identify these items as the main hazards for Lamba and items to focus on for the organisation. As these causes are more fundamental and deeply rooted in the organisation, they will provide another in-

	unsafe Acts				
	Errors			violations	
	Decision Errors	Skill-based Errors	Perceptual Error	Routine	Exceptional
Lambda	1	13	2	0	0
IMS	10	76	10	3	0

	Preconditions for unsafe acts						
	Situational Factors		Conditions of Operations			Personnel Factors	
	Physical Environment	Technology Environment	Mental State	Physio-Behavioral State	Physical/ Mental Limitations	Communication, Coordination & Planning	Personal Readiness
Lambda	3	6	2	0	2	3	1
IMS	12	31	6	0	4	24	13

	Supervisory factors			
	Inadequate Supervision	Planned Inappropriate Operations	Failure to Correct Known Problem	Supervisory Violation
Lambda	1	3	0	0
IMS	22	7	7	1

	Organizational Influences		
	Organizational Culture	Operational Process	Resource Management
Lambda	1	0	2
IMS	1	12	5

Figure 9. Top 15 causes tree Lambda compared to IMS

sight for Lambda when using the IMS Model, to understand why these events are occurring and for other fields to review to prevent recurrence, not just by examining skill-based errors.

3.4. Analysis of IMS cube

The previous paragraphs described how the IMS model behaves through its IMS process and the different components of the IMS language. It showed the result when looking at all the events together or through the top 15 selected grouped events.

To understand which specific events, such as "fuelling" or "pushback", are occurring, how the different risks associated with the various systems are analysed, and the underlying causes, see the IMS Cube in more detail.

The IMS Cube represents the integration of all these components of the IMS language and IMS process into one, at the level of each individual system.

The analysis results, as seen by Lambda Airline, have been plotted on the IMS cube to demonstrate the advantages of the IMS model.

The first cube (Figure 10) shows the top 15 events seen by Lambda. It is generated by translating the Lambda data into the IMS language, encompassing the "what" and "why" taxonomies and the IMS risk matrix, but without the IMS process to ensure it can be compared with the cube generated through the entire IMS process (Figure 11).

All Lambda events are reviewed by a single management system. Some events, like "Fuel errors" and "Ramp", are displayed differently across systems, but they are clustered under the same terminology. Some of these events have been allocated to the Lambda SMS-Ground, while other events have been allocated to other systems; however, they are still grouped together. Events are isolated in one system or another. As Lambda is not consistently assessing the causes of each event, the number of causes is low, as explained in the previous paragraph.

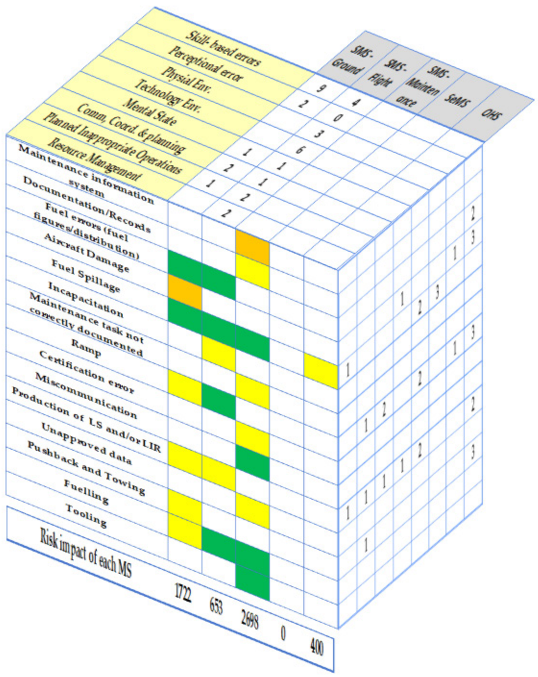

Figure 10. 15 IMS Cube top 15 events viewed by Lambda

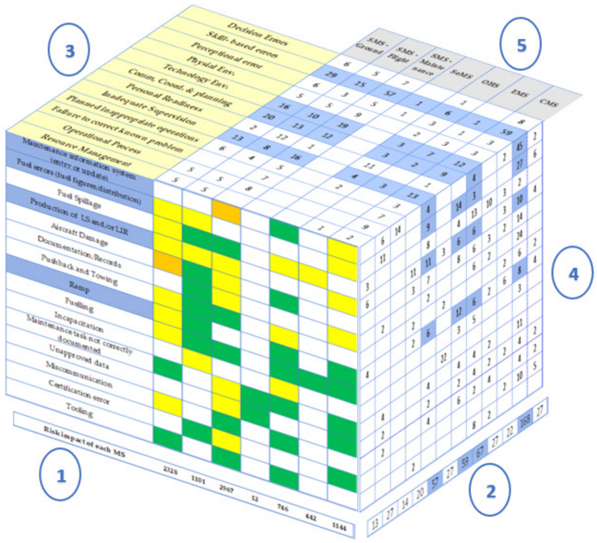

Figure 11. IMS cube top 15 events viewed by IMS model

By comparing it with the IMS Cube generated by Lambda's data through the IMS model, the differences become clear between the traditional approach, where each event belongs to a single management system, and the IMS approach, where all events are reviewed by each system, which has an impact. The result is plotted on the cube below (Figure 11). The cube contains more colours, representing the same events seen through the different management systems.

Not a single event is isolated; all events pose a risk to one or more systems (Figure 11, number 1). The events that pose a risk to other systems are analysed through the model, and causes are identified. In addition, it provides associated risks for systems for which Lambda did not provide the data, such as Environment or Compliance Monitoring Management Systems. The IMS cube has ordered the events from the system with the highest cumulative risk to the lowest. Additionally, it will indicate which system has the highest weight in the integrated system, namely SMS-Maintenance, followed by SMS-Ground. Under Figure 3, it was identified that risks related to "Fuel" (fuel errors, load sheet productions and ramp) and "maintenance entry or update" are higher in the IMS Cube, and these events have been highlighted in blue, as well their respective causes related to those events.

There are also many more root causes. Each event has been identified as a potential risk to one or more management systems. With the information provided by Lambda, most occurring root causes could be identified (number 2). As not all the data were provided by Lambda, it was not possible to identify, for each system associated with the events, the causes within each management system. If causes could be identified for one system, the same causes have been assigned for the other systems affected by the event. This means that if an event was allocated to 3 different management systems, the root causes identified for one system, for example, skill-based errors, were allocated to all three systems as a cause for the event, so skill-based errors were identified three times. This manipulation was needed because not all data were provided to identify the individual causes of the event across the different systems. However, it will not impact the model's behaviour as it is a more conservative approach, but is a methodological limitation. If all data were made available, the causes of an event identified by one management system might differ from those identified by the other systems. When all data are available, the output of the causes might shift as more distinct causes are identified, compared to the more conservative approach. It will not result in fewer causes; rather, a more diverse landscape of causes will emerge.

The IMS cube presents the results of the most common causes identified: "skill-based errors", "technology environment", "communication, coordination & planning", and "inadequate supervision". Compared to the Lambda model, these are more in-depth as Lambda can only see a few skill-based causes for a few events, as seen on the Lambda cube.

As the various events have been risk-rated through the applicable systems and analysed for root cause classification, the impact on each management system can be seen (number 3). It will display which contributing factors impact one or more management systems. For example, skill-based errors affect all systems, but resource management is not a cause of events in most systems, and when it does contribute, it is seen as a limited factor.

The IMS cube can break this down to the individual event level (number 4). The highest-rated event (maintenance information system) affects three systems and, according to analysis, is mainly due to skill-based errors and a supervisory cause, as the problem appears to be known but not corrected. Looking at the other three highlighted events, they have a more diverse root cause landscape, and to prevent those from happening within Lambda, some more in-depth mitigations are required. If those events are only looked at through the contributor's "skill-based errors", it will not avoid the recurrence of these events. Fuel errors also have a high cause called "operational process", which could indicate that the process is unclear to everyone involved. The "production of load sheets" events also include improperly planned operations as a factor. Events are complex, involve many stakeholders and risks, and, to better understand them, these defined causes will help prevent recurrence.

The IMS Cube can also examine an individual system (number 5). For example, the EMS can be identified with only a few events, which have low risk and low "impact-weight" on the IMS. The SMS-ground has a greater impact, as it identifies risk in the majority of events it spots. If it focuses on the most identified causes, it will be more likely to prevent the events from recurring. However, the OHS should focus more on "personal readiness" to prevent the events from happening.

The IMS Cube enables an organisation to assess all global risks while examining individual systems that may seem insignificant in the overall picture but are still important enough to address. As stated, the IMS reviews the risk of all systems together but respects each system's individual identity.

4. Discussions and lessons learnt

Lambda Airlines is a major airline with multiple management systems implemented, though in a siloed approach, resulting in limited interoperability among the systems. The limitation of the case study is in the unique data received. For the reasons explained in the first chapter, airlines are reluctant to share this type of data which is considered safety critical data for many airlines. Furthermore partial data was received, not the complete data of each event. Some data from other management systems within Lambda could not be shared for the research. The provided data was limited to the reporting system, and data from change management processes and risk assessments were not made available. This limitation is acknowledge throughout the manuscript, nevertheless, sufficient data was received to transfer the data into the IMS model and to understand the behaviours and benefits. Firstly, this case study's findings suggested a unique event taxonomy. Lambda has isolated management systems, and each event belongs to a single system with no interactions. This can already be seen in how events are classified, where the same type of events are classified differently. One example would be ramp issues. In Lambda's data, this could be classified either as "Ground Handling Report/ Aircraft Pushback/towing", "Air Safety report/ airport management", "Maintenance safety report/ ground handling", and many more options are available. Because Lambda management systems work in isolation, events are treated as such; therefore, the total "ramp" events, for example, are not detected by the airline, as there is no interoperability. The IMS model features a unique event classification, in which all events are grouped under a single event name. This avoid that similar events are classified in divergent ways, obscuring cross-system patterns. The IMS model overcome this inconsistencies and provides a more holistic view and a more accurate picture of which events are occurring most frequently. Lambda would benefit from a unique event taxonomy throughout its various management systems.

Secondly, the case study demonstrated the advantage of the IMS process, in which each event is reviewed by each system, and a potential risk is identified. Lambda already use a single matrix, which could be transferred to the IMS matrix in this study. However, as events are isolated, the risk is also reviewed by an isolated system. Using the IMS process, we demonstrated that each event affects multiple management systems and that no event remains confined to a single system. In addition, the associated risks to each event are changing, which provides Lambda with other insights and which events to tackle with a higher priority compared to the isolated approach from the airline. Additionally, risks associated with certain events are highlighted in the IMS model, but are currently not visible in Lambda's individual approach. The added analytical power of the IMS process highlight the importance of cross-domain risk visibility, leading to more effective decision making.

Thirdly, based on the Lamba Airlines case study, it is suggested that a root cause taxonomy be implemented. Lambda's current approach is both limited and inconsistent. It is limited as the identification is conducted based on the system in which the event is occurring. It is inconsistent because some events utilise a root cause taxonomy within the same system, while others do not. If Lamba were to implement such a taxonomy, it would be beneficial to Lamba to understand why these events are occurring and prevent their recurrence.

Fourthly, the case study compared the current Lamba model to the IMS model, in which all data are brought together through the IMS cube. It demonstrated that Lambda would be provided with a more holistic approach. Adopting the IMS model in Lamba is believed to help better understand company-wide risks, why they occur, and their impact on different systems. Such an approach would create value by reducing the volatility of their operation due to better strategy settings to tackle the different events. Reducing volatility would decrease recurring events, leading to more efficient operations and mitigating their consequences, such as disruptions and associated costs.

Fifthly, the case study reveals a practical challenge: the substantial workload associated with manually integrating events into the IMS mode. Scaling the model to real-world data volumes will require advanced digital tools, potentially AI-enabled, to automate classification and cross-domain analysis. The absence of such tools in current industry practice further reinforces the relevance of the IMS model, even in technologically mature environments. Such a tool is currently not known to the author.

Finally, given the single-case design and the limited dataset, broader validation is required. Future research should include large-scale applications within a single airline or comparative studies across multiple airlines. Only through multiple independent demonstrations can the model be benchmarked, refined, and fully validated. Additionally, to support further research, improvements in ECCAIRS accessibility and multilingual processing are recommended to support more efficient data analysis.

5. Conclusions

This study validated the Meeûs Integrated Management System (IMS) model through a practical demonstration using a real-world airline case. The findings clearly show that an integrated approach to risk analysis provides substantial added value. By consolidating event information across organisational domains, the IMS model reveals risks and interactions that remain hidden within siloed systems. Events previously considered low-priority become more visible once their cross-system impact is understood, enabling more informed and proactive decision-making. The model therefore offers a truly holistic view of risk, including the identification of risks that are acceptable only when assessed from multiple perspectives.

The case study also highlights a significant operational challenge: no existing software solution is currently capable of supporting the full functionality of the IMS model at scale. Given the volume of events processed by large airlines, practical implementation will require advanced digital AI tools to automate classification and detect cross-domain interactions.

The IMS Model is dynamic and adaptive. As mitigations are implemented and conditions evolve, the model's outputs will change accordingly, allowing organisations to monitor the effectiveness of interventions over time. This dynamic capability strengthens its relevance as a decision-support tool.

Overall, the case study demonstrates that the proposed IMS model offers a promising and conceptually robust solution to long-standing interoperability challenges in aviation risk management. It provides a strong foundation for further empirical research, broader validation across multiple airlines, and future development of supporting digital tools.

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Author contributions

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Disclosure statement

The authors declare no conflict of interest, there is none competing financial, professional, or personal interests from other parties.

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APPENDIX

Table A1. Overview IMS articles in various industries

Author(s), Year	Title	Methodology	Scope	Reviewed Management Systems					
				SMS	ISO 9001	ISO 14001	ISO 18001	ISO 27001	Others
Abad et al., 2014	Taxonomic proposal for integration levels of management systems based on empirical evidence and derived corporate benefits	Empirical analysis	Spanish firms operating in manufacturing, construction and service sectors. (110 observations)		X	X	X		
Algheriani et al., 2019	Risk model for integrated management system	Conceptual analysis	model to integrate ISO standards based on PDCA cycle		X	X	X	X	X
Almeida et al., 2014	Different perspectives on management systems integration	Case Study	4 organisations in Portuguese mines and mining, wholesale trade and civil construction		X	X	X		
Bernardo et al., 2010	Integration of standardized management systems: Does the implementation order matter?	Empirical analysis	435 Spanish companies, no defined industry		X	X	X		X
Bugdol & Jedynak, 2015	Integrated management systems	Conceptual analysis	Management concepts which use integration as a key tool of management processes		X	X	X	X	X
Chountalas & Lagodimos, 2024	Integrated management systems: a content and bibliometric analysis	Literature synthesis	Review of 846 publications between the period 1995 to 2023 into 3 future ISM research themes		X	X	X	X	X
Daneshjo et al., 2021	Integrated Management System and Corporate Risk Management	Conceptual analysis	IMS concept in comparison to corporate risks types						
De Oliveira, 2013	Guidelines for the integration of certifiable management systems in industrial companies	Case Study	Case studies on 14 Brazilian Industrial companies		X	X	X		
Fernandez et al., 2021	Conceptual classification of leading indicators for the dynamic analysis of emerging risks in integrated management systems	Conceptual analysis	Defining IMS indicators		X	X	X		
Garvin, 1991	How the Baldrige Award really works	Conceptual analysis	Concept - Total Quality Management						
Ispas & Mironeasa, 2022	The Identification of Common Models Applied for the Integration of Management Systems: A Review	Literature synthesis	synthesis of strategies, benefits, and barriers in IMS, review of 103 publications between the period 2019 to 2020						
Ispas et al., 2023	Risk-Based Approach in the Implementation of Integrated Management Systems: A Systematic Literature Review	Literature synthesis	A risk-based approach that can manifest in IMS, review of 190 publications between the period 2022 to 2023						
Karapetrovic & Willborn, 1998	Integration of quality and environmental management systems	Conceptual analysis	Concepts of a system of systems, addressing interrelations and integration.		X	X			
Karapetrovic, 2003	Musings on integrated management systems	Conceptual analysis	Provides a foundation for and guide to construct an IMS		X	X	X		
Lahuta et al., 2021	Integrated Risk Management System in Transport	Conceptual analysis	Concepts based on an ISO survey in 2020 outcome on European Transport companies		X	X			

Author(s), Year	Title	Methodology	Scope	Reviewed Management Systems					
				SMS	ISO 9001	ISO 14001	ISO 18001	ISO 27001	Others
Leopoulos et al., 2010	Integrated management systems: Moving from function to organisation/ decision view	Case Study	Case study to integrate two management systems within Chemical Industry compnay through using an Analytic Network Process		X	X			
López-Fresno, 2010	Implementation of an integrated management system in an airline: A case study	Case Study	Case study on the second largest airline in Spain in 1986, the model resulted in a number of quantifiable and unquantifiable benefits resulting from integration	X	X	X			
Carvalho et al., 2015	Benefits in the Implementation of Safety, Health, Environmental and Quality Integrated System	Case study	Case Study in three units of a large steel industry in Brazil		X	X	X		
Maier et al., 2015	Innovation as a part of an existing integrated management system	Conceptual analysis	Proposed some recommendations regarding innovation management and its implementation as a part of an integrated management system.						
Malakis et al., 2023	A pragmatic approach to the limitations of safety management systems in aviation	Empirical analysis	Group discussion across 4 European airline to define limitations of SMS and need for intergration models	X					
Marinello & Dinicolò, 2019	Integrated management systems between evolutionary routes and management process	Conceptual analysis	technical and conceptual tools to highlight the most critical aspects for an integrated t system						
Misiura, 2015	Enterprise Risk Management in the Airline Industry -Risk Management Structures and Practices	Empirical analysis	Field study and case study with 10 airlines to investigate structures and practices of entreprise risk management within airlines						
Muzaimi et al., 2017	Integrated management system: The integration of ISO 9001, ISO 14001, OHSAS 18001 and ISO 31000	Empirical analysis	Five interviews with senior managers from an manufacturing of solar cell, to define components for an IMS		X	X	X		X
Muzaimi et al., 2018	Integrated Management System for quality management system accreditation	Empirical analysis	Five interviews with senior managers from an manufacturing of solar cell to define implementation strategies		X	X	X		
Nunes, 2014	Holistic Risk Management in Commercial Air Transport	Empirical analysis	Study on implementing ISO 31000 within airlines						X
Nunhes et al., 2019	Guiding principles of integrated management systems: Towards unifying a starting point for researchers and practitioners	Literature synthesis	Atarting point towards the establishment of the IMS theory.						
Nunhes et al., 2017	Identification and analysis of the elements and functions integrable in integrated management systems	Literature synthesis	Review of the 30 most cited articles in Integrated Management Systems from 2006 to 2016 to define IMS elements						
Seghezzi, 1997	Business concept redesign	Conceptual analysis	General framework for an integrated conept which supports the integration of all existing partial management systems		X	X	X		
Singh, 2009	Establishing an Integrated Management System (ISO 9001, ISO 14001, OHSAS 18001) within Typical Manufacturing Industry	Conceptual analysis	Analysis of various ISO systems and components for integration models		X	X	X		
Yatim, 2004	A review on integration of ISO14001 and OHSAS 18001 Management system in an organisation	Literature synthesis	Review the integration of two Management systems and their challenges in the organisation.			X	X		