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# IMS CUBE, A NEW RISK MODEL FOR INTEGRATED MANAGEMENT SYSTEMS IN AVIATION

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**Abstract.** Airlines have implemented various management systems to avoid different risks but without considering interoperability or integration. This results in a lack of a holistic view and a counterproductive and isolated approach to managing different risks. Therefore, this article proposes a newly designed model to have an integrated system for airlines to ensure interoperability and demonstrate the added value of such a model. The model is based on a survey outcome which confirmed the need for interoperability amongst different management systems. The developed model creates a language for key processes in different management systems, enabling different management systems to create interoperability. The language consists of 3 components used by the different systems. Adding a process to integrate all the different systems provides a holistic view of how each management system works together by providing focus points for the different risks airlines face. Together with the concept of the IMS cube, a new practical model is developed and provides new insights into the different management systems, which remain undetected when looking at management systems individually. It is concluded that a holistic risk profile assists airlines in making decisions which impact multiple management systems rather than individual management systems.

**Keywords:** management systems, integrated management systems, interoperability, integrated risk, IMS cube.

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## 1. Introduction

Integrated management systems for the aviation industry have gained interest over the past years, as more management systems are implemented within airlines but in a siloed manner and lacking integration amongst them. Although there are limited articles and studies, and even lacking in aviation regulations, due to its gaining interest, the focus has been shifting over the years. Before the change of the 21st century, the focus was mainly on defining what integration means, which was concluded that integration means a partial integration of different management systems, respecting the identity of each system (López-Fresno, 2010; Carvalho et al., 2015; Maier et al., 2015; Nunhes et al., 2019).

Since the 21st century, more interest has been set on the different components of an integrated system. A review was conducted in 2019 by Nunhes (Nunhes et al., 2019), who reviewed the different literature between 2006 and 2016 and provided one of the first a model for an integrated management system based on his 10-year timeframe review. The concept was based on a foundation of different management systems, which have six different pillars, which resulted in one integrated system. Yet, it was missing a practical implementation of this model.

Recently, an additional factor called "risk" has been considered. This component gains interest as every management system, which is part of an integrated system, will keep a certain identity. One characteristic of management systems is to identify risks and assess and mitigate them. When defining a model, the different risks defined by each management system should be considered as an integrated concept (Algheriani et al., 2019; Muzaimi et al., 2018).

In this paper, the concept of integrated management system from Meeûs was followed (Meeûs et al., 2023). The concept is based on a foundation which comprises certain building blocks like hazard identification, risk assessments, change management, risk matrix, taxonomies and others, on which different management systems are built. This results in coordinated processes and approvals, which work together in an integrated manner. The building blocks are defined through an analysis of the ICAO SMS components (International Civil Aviation Organization, 2018), which are compared with components of different management systems. The concept starts from the ICAO SMS elements to ensure the basis is compliant with international regulations. These components have been set off against other management systems, which resulted in a correlation of some elements between the different management systems analysed. Some management systems were implemented due to aviation regulations, while others were implemented due to local regulations or the need to implement additional management systems, like OHS (Occupational Health System) and EMS (Environment Management Systems). The survey provided an understanding of which management systems are currently implemented and how their interoperability works based on those common components and processes.

In this paper, it is built on the results of this survey outcome, which contains a unique dataset on how management systems are currently implemented in the aviation industry. The complete data set of this survey and defining a model that could be used in the airline industry are being considered. It also provides a better understanding and a practical approach to how interoperability could work by defining an integrated process and a language which could be applied to all management systems to work together in an integrated manner. The language created consists of three components: a risk component and two classifications to understand what is happening and why certain events are happening in each management system. The components of the language, the risk matrix and classifications, are chosen in function of risk, as the different blocks of the IMS model, the different processes are about risk, which is the core of existence for each management system. A process is defined when this language is developed to facilitate the different foundation blocks to work together as an integrated system. Due to the limited research and regulations, the designed model with its process is unique in its kind as no practical models exist to connect different management system into one integrated system.

The paper is organised as follows. Section 2 explains the model setup as the ICAO SMS is based on Dr. Reason's Swiss model, where an enhanced model is developed for an integrated management system. The IMS language, which consists of different characteristics, is included in Section 3. Section 4 explains the Integrated process of all management systems and how this enhanced Swiss Cheese model and language come together into the newly developed IMS Cube, followed by the conclusion in Section 5.

## 2. Model setup

The Risk Management process of the ICAO Safety Management System is based on Dr. James Reasons (Reason, 1990, 1997) Swiss Cheese model. The model still stands today for SMS, as it looks at systematic errors deeply rooted in the organisation.

The Reason model, developed in the 1990s, looks at specific risks with a specific accident outcome. Today, airlines are complex organisations facing different risks that might not be visible at first glance or even hidden. Secondly, the outcome is not always an accident outcome, and different consequences could harm an organisation in one way or another, originating from a risk. Hence, the word undesirable outcome is chosen as not all risks end up in an accident but rather into outcomes that are unacceptable to an organisation.

An integrated management system looks at different risks simultaneously from the different management systems. Therefore, an enhanced model needed to be developed to include the different risks an IMS is exchanging with (Figure 1). The difference lies in the complexity of incidents that airlines are facing, which does not always result in a straight line from the failure to the undesired state.

As with Reason, the slices represent the different barriers, safeguards, and defences in place to prevent a risk from escalating to an undesirable outcome. The slices could represent training, procedures, documentation, supervision, inspections etc. These are not perfect, and sometimes procedures and training are inadequate for an event (latent failures). Secondly, human errors could come

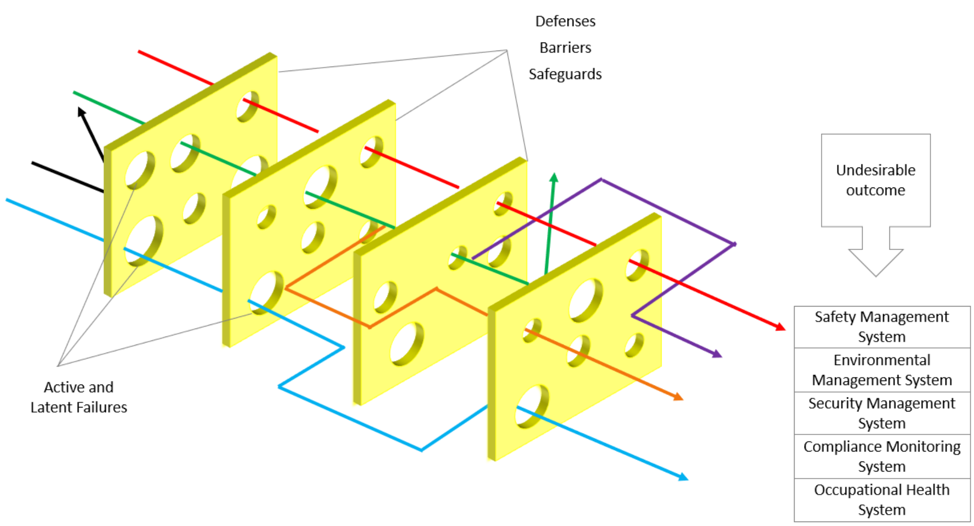


**Figure 1.** Enhanced Swiss Cheese model (source: created by the author)

into place (slip, lapse, mistake etc.), which are called active failures.

The black arrow demonstrates that the risk was blocked as sufficient barriers are in place to prevent a different outcome.

The red arrow represents an example where all barriers failed and, in this example, results in an unacceptable safety risk.

The Enhanced Swiss Cheese model shows that sometimes slices are missing for certain risks. An event might result in an unacceptable risk for an Occupational Health Management System (example of the blue arrow). Sometimes some barriers are in place, like procedures and training, but other barriers are not existing, for example, the slice of supervision is missing, which results in an undesirable outcome.

Another difference in the enhanced model is the green arrow, which is an example of where many barriers are in place. However, the arrow is split, and side arrows appears (orange and purple arrows). This event includes other risks for which some barriers do not exist, creating other risks. Traditionally, when having a safety management system, these risks would not be spotted as only safety risks are considered. Moreover, other systems would not even know that these events occurred in an organisation. An Integrated Management System is there to be able to spot other risks, whereas individual management only looks at the risk related to their identity. It emphasize the need for an unique language for an integrated management system.

## 3. IMS language

### 3.1. Risk matrix

The first part of the IMS language is the understanding of risk. The Meeûs' survey pointed out that the most common matrix used is the ICAO matrix, consisting of five probability and five severity levels. In addition, if custom-made matrices were used, it was also indicated that those use a scaling of 5*5, so by far, this is the most used scaling. Many risk matrices exist in various industries with different scaling levels, colours, and values. Even within one airline, multiple matrices are used, as identified from the survey result.

In this model, one risk matrix is designed to be used by different management systems. It was demonstrated that many risk matrices exist in an organization, negatively affecting the alignment of similar processes of different management systems, resulting in limited interoperability. On the other hand, it has a negative effect on the holistic risk approach. Furthermore, as the model should fulfil the ICAO and local regulations like EASA, FAA, risk is always defined as a combination of probability and severity. In order to ensure the development of a model compliant with the current rule settings in aviation, this needs to be respected.

It can be questioned whether risk matrices are the best assessment tools. Cox (2008) and Peace (2017) both argue that this tool is so embedded in risk management frameworks (and even software packages provided) that it is likely to stay. The researcher tends to agree. Additionally, it is a widely praised tool during risk management training and consultancy. It is an easy way to create risk appetite and risk culture, as a coloured matrix is easy to understand.

In order to develop a risk matrix, the purpose of the risk matrix needs to be clear. A risk matrix is only a tool to assist in graphically representing the risk level. The visualisation helps decision makers to distinguish between higher and lower risk events, to prioritise and secondly to make adequate decisions to accept (or not) the identified risk level (Cox, 2008; Duijm, 2015). It is to be understood that for decision-makers, the end result is plotted on the risk matrix, which leads to an action. Bao (Bao et al., 2022) refers to it as a tool that measures the perception of risk, the researcher would instead refer to it as a tool to measure risk tolerability. It can be seen further that how to get to a specific coordinate on a matrix, is more for Subject Matter Experts (SMEs). Therefore, matrices must be designed by and for the organisation, and a copy-paste from other organisations or industries will not work (Peace, 2017). The "look-and-feel" of the risk matrix might be similar (number of levels, colour coding) to organisations, however, as it can be seen further on, the matrix's calibration is crucial to be an efficient tool. It depends on the scope of activity, even within the same organisation.

As a starting point, the ICAO matrix (Figure 2), as the most used one, is analysed and adopted where needed to make it functional for many other management systems. The matrix consists of five levels of probability and five levels of severity. In this research, the same nomenclature is being kept. Probability is sometimes phrased as frequency (Cox, 2008; Krisper, 2021) or likelihood (Allen, 2013; Bao et al., 2017, 2021; Peace, 2017) and severity as consequences (Bao et al., 2017, 2021; Duijm, 2015; Thomas et al., 2013). The matrix holds different colours, which is being called the risk tolerability level. It indicates which risks are more or less urgent rather than just a random decision-making process.

The ICAO matrix is counterintuitive, as the probability scale goes from low to high (bottom to top) while the severity scale goes from high to low (left to right). Both scales should be increasingly orientated.

This results in reversed risk outcomes, so the highest risk is to the top left and the lowest risk to the bottom

| *Safety Risk* | | *Severity* | | | | |
|---|---|---|---|---|---|---|
| *Probability* | | *Catastrophic A* | *Hazardous B* | *Major C* | *Minor D* | *Negligible E* |
| Frequent | 5 | 5A | 5B | 5C | 5D | 5E |
| Occasional | 4 | 4A | 4B | 4C | 4D | 4E |
| Remote | 3 | 3A | 3B | 3C | 3D | 3E |
| Improbable | 2 | 2A | 2B | 2C | 2D | 2E |
| Extremely improbable | 1 | 1A | 1B | 1C | 1D | 1E |

**Figure 2.** ICAO SMS risk matrix (source: International Civil Aviation Organization, 2018)

right (Bao et al., 2021). The natural intuiting is that risk increases from bottom left to upper right. Duijm (2015) refers to the monotonous character of risk mapping, where an increase in probability and severity should be intuitively visible.

The scales are defined as letters and codes. Risk is often defined as a product of probability and severity, which means that the letters could be replaced by numbers, and by calculating the product, there would be values in the risk cells. In the example below (Figure 3), the severity scale was replaced with logically numeric values. This results in similar risk values (in this example, value 18) appearing in different colours, having different risk tolerability. This conflicts with the first axiom from Cox (2008), one of the first authors to make critical assessments on risk matrices. The weak colouring axiom defines equal risk as having the same colour.

The second axiom from Cox refers to weak consistency, meaning that hazards in a higher red category should always represent a higher quantitative risk than those in a lower coloured field. In the example, this is conflicting. The risk value of 15 in the orange field (high-risk colour, so lower risk tolerability) is lower than the risk value of 18 in the green field (lower risk colour, higher risk tolerability).

No matter how the product changes, by changing the values of the severity or probability scale (by linear or non-linear values) in the ICAO matrix, it is always a conflict with one or both axioms as defined by COX unless the risk tolerability of certain cells is also changed.

When developing the model further on, to see risk as a product of severity and probability is wrong, as it is to be understood that risk is a combination of probability and severity. Multiplying numbers to arrive to a certain risk value is a wrong concept. A quantitative approach to risk has its value, but not as a mathematical product of two factors (for example Risk = probability x severity).

The risk matrix does fulfil the third axiom from Cox, called betweenness. It ensures that every jump in the next risk colour always passes through the same risk colour. In order to go from green to red, the yellow risk tolerance is always being passed, and there is nowhere to move from green directly to red.

In addition to Cox axioms, Duijm identified another component to consider called risk aversion, which is to be understood as "the attitude that a low probability-high severity event is assigned higher risk value than a high probability-low severity event, even when the expected loss for both events is the same" (page 15). If a risk matrix is risk-neutral, the rating of the two risks is the same (low probability-high severity versus high probability-low severity). The higher probability rate would play a more important role in a risk-averse matrix, resulting in a high-risk outcome. Depending on the scaling selected, which affects the product outcome to define the scores, this risk aversion is not always respected in the above matrix.

| Probability \ Severity | 15 | 12 | 9 | 6 | 3 |
|---|---|---|---|---|---|
| 5 | 75 | 60 | 45 | 30 | 15 |
| 4 | 60 | 48 | 36 | 24 | 12 |
| 3 | 45 | 36 | 27 | 18 | 9 |
| 2 | 30 | 24 | 18 | 12 | 6 |
| 1 | 15 | 12 | 9 | 6 | 3 |

**Figure 3.** Example of weak colouring axiom matrix (source: created by the author)

A final factor is the range compression factor, as defined by Cox and Thomas. It defines that the different risk scores should reflect the real distance between the risks. In the example above under Figure 3, is the risk difference from the cell with risk value 18 really half of the risk of the cell with risk value 36? Range compression is important in developing a risk matrix. It needs to follow a certain logic going from one risk cell to another. The representation of numbers in a matrix should be proportionally chosen to avoid graphical distortion and ambiguity.

A variation of the range compression is Tufte's (1983) "Lie factor". The factor calculates what is visualised in a risk matrix against the actual data. Although the factor could help in designing a risk matrix, it implies that for each event occurring in the aviation industry, or any industry for that matter, that data should always be available to calculate the Lie factor. In reality, data is not always available for each event occurring in management systems. Therefore, some risks must be set qualitative rather than quantitative, and the lie factor would not be a meaningful ratio. After x amount of years, when an organisation receives sufficient data, it would be useful to review if the values chosen in the risk matrix are accurate by comparing events versus the geographical visualisation to get the Lie factor close to one, to minimise the difference between visualisation and reality. For the design of this matrix, the range compression factor definition by Cox and Thomas remains.

To develop a matrix, all these criteria need to be considered to have a working matrix. As the most common risk matrix used is a 5*5 matrix, the same matrix size is used in this design. Due to the various management systems, an additional risk colour is added to ensure sufficient diversification in the risk tolerability levels due to the many different risks in this integrated model. Peace also mentions this granularity to ensure sufficient risk tolerability levels are available for the different management systems. The following matrix has been designed (Figure 4).

The first difference is that the scales of severity and probability are in increasing sequence, which is more intuitive to use. The lowest risk is situated on the bottom left side and increases towards the top right side of the matrix.

It has to be noted that risk is not considered here as a product of probability and severity, but the risk is a combination/ function of both components, which leads to a certain number. It means that the values of the x and y axes cannot be multiplied to have the risk value in a specific cell. The risk values are chosen depending on a different concept, which is explained further.

| | | Risk Probability | | | | |
|---|---|---|---|---|---|---|
| | | highly improbable | improbable | remote | occasional | frequent |
| Risk Severity | catastrophic | 400 | 500 | 1.000 | 1.500 | 2.000 [1] |
| | hazardous | 50 | 200 | 500 | 1.000 | 1.500 |
| | major | 10 | 50 | 200 | 500 | 1.000 [2] |
| | minor | 2 | 10 | 50 | 200 | 500 [4] |
| | negligible | 1 [2000] | 2 [1000] | 10 [200] | 50 [40] | 200 [10] |

**Figure 4.** IMS risk matrix with iso-risk line & event values (source: created by the author)

The matrix respects the three axioms defined by COX. Each risk value corresponds to a similar colour, so there is no weak colouring as defined in that axiom. There is also no risk of weak consistency, meaning that a higher risk always has a higher value than a lower risk. Finally, the matrix respects the betweenness axiom, meaning that moving from one coloured risk into another passes through the same colour. Moving from a yellow risk into a red risk, you would always need to pass the orange one, regardless of the chosen direction.

The risk matrix is neutral, meaning that if iso-contours are drawn on the matrix, identifying the same risk value (blue dotted lines on Figure 4), the diagonals go straight from top left to bottom right. This avoids risk aversion, where the severity weight would be higher than the probability weight. So low severity/high probability has an equal risk value than high severity/lower probability.

There is one exception made for the highly improbable but catastrophic events. Although this risk cell is coloured yellow, a higher value was chosen in this cell. When such rare events occur, they need a certain attention, although the risk tolerability rates it lower. For example, events where there are fatalities, cyberattacks that create a complete blackout, bomb attacks, etc., are lucky events that are very rare. However, when they happen, actions need to be taken due to the catastrophic severity. It was decided to increase the value to demonstrate this on a risk matrix. Another option is to lower the tolerability, meaning making this field an orange field, but then it would have more impact on the risk matrix. For example, some other cells would also need to change colour to avoid "jumping" colours to ensure it comforms to the axioms.

These highly improbably surprising events are often referred to as black Swans, which are by nature defined as unpredictable, a concept that has existed for a long time in risk management. Nisula (2018) reviewed this concept from different authors between 2007 and 2018 as part of his research. The major takeaways are explained here as black Swans are a subject on itself in risk management.

Black Swans can be defined in three categories (Aven, 2015; Aven & Krohn, 2014):

- Unknown unknowns: Completely unknown events to persons or the industry. Examples are design faults of aircraft which touch the surface many years later. The global impact on aviation due to COVID-19, where all traffic was stopped for a few years.
- Unknown knowns: unknown events to certain individuals, especially those involved in risk management, but known to others in the organisation. For example, the space shuttle Challenger crash was related to faulty O-rings, which engineers knew, but this knowledge did not reach the risk decision makers to assess this risk.
- Knowns negligible: Events that are known but considered highly improbable and therefore assumed that they do not occur.

Black swans are solely defined by probability levels, and risk matrices can help tackle them as severity and tolerability levels are added to the quotation. A risk matrix is a tool to visualize the risk for better decision-making and prioritization, but it cannot remove all the defined black Swans types.

The knowns negligible can be addressed by creating a higher risk value to the top left cell of the matrix (or adapting the risk tolerability). The unknown knowns could be tackled by better risk assessment and management of change processes to ensure all involved people are included in these assessments. The risk matrix is the tool to be used in these processes, but the risk matrix in itself, cannot avoid these events. In aviation, precursor monitoring is an often-used technique for tracking defined indicators, which could lead to specific events. This technique could also help against the unknown knows and knowns negligible cases.

The unknown unknowns are very difficult to tackle as per definition, they are not known. The risk could be reduced by knowledge sharing of events which happened to others. However, when unknown unknows events occur, they have mostly a reactive character, as the result of the unforeseen event creates some indicators to prevent re-occurrence. It also means that each unknown unknown event is unique in its kind.

The risk values are not the result of the product of the probability and severity scale. The risk value is chosen using a different approach, keeping in mind the range compression, to ensure that the values amongst them reflect the real risk difference.

A value for the highest risk of 2000 has been arbitrarily chosen, deliberately an even number for this model. Krisper (2021) mentions that even numbers are not neutral, while uneven numbers could lead to neutral assessments. Even numbers, therefore, always guide you in a direction (higher/lower) and help you avoid remaining in the middle. This also counters the effect of centring bias, where people tend to avoid extreme positions and therefore remain with the middle uneven number (Hubbard, 2009; Hubbard & Evans, 2010; Moors et al., 2014). These concepts are applied through the risk matrix design, except for the lowest value, the uneven number 1. These risks are so negligible and highly improbable that it might even be questioned if this is a risk at all, even at the lowest level. However, number 1 was chosen to ensure it could be tracked and used in big data analysis.

Risk values have no unity, like kilograms or centimetres. They are abstract numbers given as a result of a risk assessment made. What does a risk value of 2000 mean compared to a risk value in another organisation of 10.000? The values only make sense within an organisation working with these specific values set up for their integrated system.

What is more important is the relationship between the different values throughout the risk matrix and the range compression set-up.

Based on the value of 2000, iso-risks contours are created to ensure a risk-neutral matrix. For each iso-contour, to have a meaningful set-up, it was defined how many events an organisation can accept for each combination of probability and severity, to arrive to the same highest value (Figure 4). As an example, an organisation can have 10 of the same yellow events, with the same probability and severity levels, which would be unacceptable to have as the cumulative risk of all these individual yellow events (10 times value 200), in a given timespan, would be the same risk value as that one event in the red cell

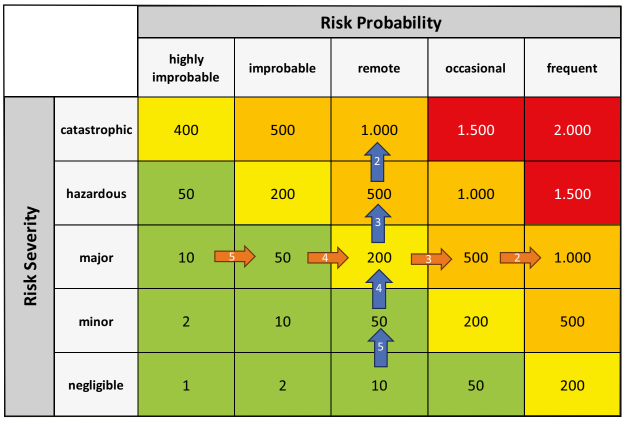


**Figure 5.** IMS Risk matrix with moving events (source: created by the author)

(value 2000). This logic has been applied throughout the matrix except for the left top yellow cell value, as explained above.

Another approach to look at the range compression is to look at an individual cell and, depending on how the events are moving, either through an increase in probability or severity, how much of the same events are needed to start moving from one cell to another. In the Figure 5 below, this is plotted. By increasing one of the scale levels, for example, the green risk cell with a value of 10, five equal events are needed to make an equal risk event in the next cell (risk value of 50). The more we go up into the scaling, the less risk can be accepted. When going up into the scaling, events become more serious, either by severity or increasing probability they are occurring, and therefore less accepted. Hence, the number of the same events, which equals a higher risk, decreases when the scales increase.

ICAO defined three risk tolerability levels in their risk matrix. This design increased it to four tolerability levels to ensure enough diversification for all the different management systems. The risk value obtained from the risk matrix is translated to a tolerability level that narratively describes an organisation's tolerability criteria. Table 1 is the risk tolerability table linked to the designed risk matrix. Risk tolerability tables could be extended by defining the response period for action, who the decision makers are, escalation levels, etc. for each defined risk colour/tolerability level. In this design it is limited to the tolerability level and actions to be taken. These risk tolerability levels provide the necessary visualisation tool for the decision-makers to take action on certain risk events.

The risk matrix is now designed, but it needs to be ensured that each management system can use it. To ensure that each management system is able to use this matrix, the different severity and probability scaling needs to be defined for each management system, which is called the calibration of the scale and a fundamental step.

The scale calibration is crucial and needs to be as detailed as possible for two reasons: to ensure that different people can select for the same event, the same categories of probability and severity points, to ensure the same

**Table 1.** IMS risk tolerability level (source: created by the author)

| Risk Score Range | | Tolerability Level | Actions |
|---|---|---|---|
| 1500 | 2000 | STOP – Intolerable | Take immediate action to mitigate the risk or stop the activity. Perform priority risk mitigation to ensure additional or enhanced preventative controls are in place to bring down the risk level to an acceptable level. |
| 500 | 1000 | WARNING – Tolerable | Can be tolerated based on the risk mitigation. It may require management's decision to accept or lower the risk. |
| 200 | 200 | Caution – Tolerable | Can be tolerated based on the risk mitigation. It may require management decision to accept the risk. |
| 1 | 50 | Monitor – Acceptable | Acceptable as is. No further risk mitigation required. |

selection is obtained (Zhao et al., 2016). The second reason is to ensure that the different points chosen to obtain the risk level at a particular time are assessed similarly at different times (Environmental Protection Agency, 2021; Barnard, 2018). Bao (Bao et al., 2022) added that this is important to ensure that when designing a risk matrix, the calibration needs to be transparent to avoid misconceptions between the designer and users. The researcher agrees but, in addition, would add the different users, which are not limited to experts who assess the risk. It is equally important that other users, like the decision makers, understand how the risk values and tolerability levels are defined. As stipulated many times, a risk matrix is a tool decision-makers use to prioritise and mitigate. Therefore, clarity is crucial to ensure the risk is well understood by all users in an organisation.

This tool is to be used for different management systems, different risks are assessed, and multiple calibration scales are needed. What is essential is that the scales are aligned. The highest risk determined by one management system should be the highest risk of other management systems and not considered a lower risk on the matrix. For example a bomb treat and an aircraft crash should be both on the highest severity level. And the same for the lowest risk. The challenge lies in the intermediate levels, but there needs to be consistency among the different management systems. Matrix scales often use words like frequent, improbable, major, and minor and Budescu (Masuin & Latief, 2019; Budescu et al., 2009) argues that it is not real communication but rather creating an illusion of communication. Indeed, the terms in the matrix can be used to group different levels in some way. However, clear guidance is required on what is meant, for example, by major severity in a safety management system versus a Security Management System. The clarity on the scales will also limits the effect of subjective bias when assessing risk (Hubbard & Evans, 2010; Duijm, 2015; Krisper, 2021; Peace, 2017). On the other hand, each management system still has its own identity, which is reflected in the calibration.

An example of such a severity scale is provided in Table 2.

**Table 2.** IMS severity level example (source: created by the author)

| | OHS | CMS | SeMS | SMS | | | EMS |
|---|---|---|---|---|---|---|---|
| | | | | Flight Crew | Cabin Crew | Operational | |
| catastrophic | Permanent disability/ death / Multiple fatalities | Non-compliance which lead to financial penalties or limitations on operations Loss of approvals/certifications Settlements/ Fees/ Penalties > 10M | Bomb Threat/ Hijacks/ loss of property unscreened cargo/ bagagge Attempt ot breach the flight deck | Conditions preventing safe continuation of flight Uncontained engine fire/ in-flight collision, RWY excursion | Fatalities or fatal injury to passenger(s) | Irreversible Equipment, Component, tool damage. Structural damage CG out of envelope/ potential early rotation, tail strike AC (or fleet type) grounded for more then 2 days. Safety impact on a global scale | Environment contaminated, not recoverable or remediation longer than 5 years, threats to life (human/organisms) Hazmat spillage which result in AC evacuation and/or fire |
| hazardous | Disabling injury/ recovering requires more than 6 weeks/ Permanent injury/ Multiple people involved | Non-compliance to regulations leading to a negative impact on Safety, Security, OHS etc. process not followed Settlements/ Fees/ Penalties 1M–10M | Life-threatening with a weapon, Cargo Pilferage above XX unscreened cargo/ bagagge | Near mid air collision / crew to follow emergency procedures as per AFM / Pilot incapacitation / process not followed / runway collisions | Serious injury to passenger(s) | Heavy reverssible damage to equipment Loadsheet issued with wrong weights and/or distribution, outside the CG, wrong ULD weights AC (or fleet type) grounded for up to 2 days. Safety impact on a whole continent | Immediate emergency response to contamination, 1–5 years for clean-up, harmful to human or organisms Hazmat spilleage which results in Facilities evacuation |
| major | External medical treatment / temporary injury / One or more injuries | Non-compliance to regulations with no impact on operations missing procedures/ outdated documentation majority of process not followed Settlements/ Fees/ Penalties 500K–1M | Physical abuse/ unauthorized access by unknowns or personnel Cargo Pilferage above XX | majority of processes not followed | Physical distress on passengers (e.g. abrupt evasive action; severe turbulence causing unexpected aircraft movements), or Minor injury to greater than 10% of passengers | Light repearable damage to equipment Loadsheet issued with wrong weights and/or distribution, within the CG AC (or fleet type) grounded/ delayed between 04–48hrs. Impact on a region of stations | Short to medium term effects, clean-up between 06–12 months/ Hazmat spilleage with no evacuation but requires local rescue services for clean-up |

*End of Table 2*

| | OHS | CMS | SeMS | SMS | | | EMS |
|---|---|---|---|---|---|---|---|
| | | | | Flight Crew | Cabin Crew | Operational | |
| minor | First aid on site, temporary discomfort | Non-compliance against company procedures/ policies Continguous steps of process not followed Settlements/ Fees/ Penalties 100–500K | Suspicious or threating behaviour unauthorized access by visitors | Contiguous steps of processes not followed | Physical discomfort to passenger(s) (e.g. extreme braking action; clear air turbulence causing unexpected movement of aircraft causing injuries to one or two passengers out of their seats) Minor injury to greater than zero to less than or equal to 10% of passengers | Hidden/undeclared DG AC (or fleet type) grounded delayed up to 4 hrs. Safety impact on multiple stations | Short effect, clean-up between 0–6 months, slight disturbance or discomfort Hazmat spilleage which does not requires local resecu services for clean-up |
| negligible | No injury | Recommendation for improvements single steps of processes not followed Settlements/ Fees/ Penalties <100K | No Security Impact | single steps of processes not followed | Minimal injury or discomfort to passenger(s) | Safety impact on an isolated station | Immediate clean-up with no consequence, little impact |

This example provides some nomenclature for the different risks which are assigned to five management systems. If an organisation implements more or other management systems, additional columns must be added and calibrated. Some systems could be split up into scopes. For example, the SMS is split up between Flight Crew/Cabin Crew and the operations. There is no limit in defining the calibration, but the most important is that the different risks are aligned, contain a certain logic, and use terms that are known to the organisation. The calibration details should be such that the general concept of the severity of risk is grasped. It is impossible to identify all possible risks and map them into the different severity levels. Users would get lost in the level of detail. The scaling should guide users to where certain occurrences are situated. In addition, even if all occurrences could be mapped out in this scaling, there is always the context of the event, which would justify why an occurrence is classified in one way or another.

Scales should always be adapted to the kind of operations, cargo airlines face other risks than passenger airlines and business jet operators. Long-haul operations are different than short-haul, and even the area of operations could impose other risks. Operating on the African continent could impose other risks than operating on the Asian continent as the area is different, and different regulations and local requirements are applicable.

A probability scale is provided under Table 3 for the same management systems. Also, sub-divisions could be made to target particular organisational scopes if needed. Probability scales can vary between each other. Some management systems are implemented longer and are well-mature in organisations, while newly added systems are less mature. It results in some events not being spotted or less frequently occurring as they are unknown to the new system/organisation and still need to be included in change management processes and assessments. For example, the highest level of probability, "frequent", is defined as an occurrence which could happen every day for OHS, while the same level of probability is defined under SeMS as an event which could happen more than two times per quarter.

Probability scales also highly depend on the organisation. An airline with 300 flights per day would have a different meaning of probability than an airline with ten flights per week.

In addition, probability nomenclature can take many forms compared to severity scales, which are more general terms applicable to that organisation to have a general concept of each level. Probability can be expressed in multiple facets. It can be defined in percentage, number of flights, number of sectors, number of manhours, number of reported events, etc. As with the severity scales, probability needs to be defined, used and understood by all users to represent the organisation's needs.

Probability and Severity scales are calibrated. This implies that the scales are to be reviewed to ensure that

**Table 3.** IMS severity level example (source: created by the author)

| | | extremely improbable | improbable | remote | occasional | frequent |
|---|---|---|---|---|---|---|
| OHS | | Expected to occur every 5 years | expected to occur every year | expected to occur every month | expected to occur every week | expected to occur every day |
| CMS | | in 1 audit scope, 1 or 2 findings (lower findings level) | in 1 audit scope, 3 to 4 findings (lower finding levels) or 1 repetitve finding | in 1 audit scope, more then 4 lower level findings or at 1 higher level finding. Mulitple repetitive findings | in 1 audit scope, more then 4 lower level findings or multiple higher level finding. Mulitple repetitive findings | in 1 audit scope, majority of higher level findings |
| SeMS | | Expected to occur every 5 years | expected to occur every 3–5 years | expected to occur every year | expected to occure 1–2 times per quarter | expected to occur more then 2 times per quarter |
| SMS | Flight Crew | expected to occur once every 5 years | expected to occur several flights per year | expected to occur numerous flights per month | expected to occur on multiple flights per week | expected to occur every flight |
| | Cabin Crew | expected to occur once every 5 years | expected to occur several flights per year | expected to occur numerous flights per month | expected to occur on multiple flights per week | expected to occur every flight |
| | Operational | Expected to occur once every 5 years Expect to occur every X hours expect to occur 1–5% | expected to occur several times per year Expect to occur every X hours expect to occur 5–25% | expected to occur numerous times per month Expect to occur every X hours expect to occur 25–50% | expected to occur on multiple flights per week Expect to occur every X hours expect to occur 50–75% | expected to occur every flight Expect to occur every X hours expect to occur > 75% |
| EMS | | Expected to occur every 5 years | expected to occur every year | expected to occur every month | expected to occur every week | expected to occur every day |

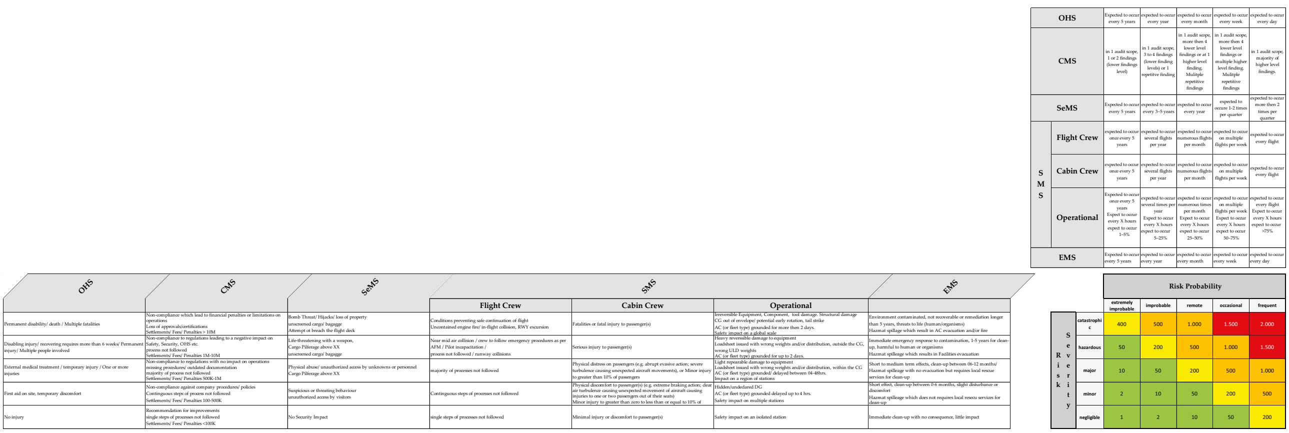


**Figure 6.** IMS risk matrix with calibrated scales (source: created by the author)

the calibration is still adequate. Management systems evolve and mature, new risks are surfacing the horizons, the organisation itself is evolving, and external factors are changing. For these reasons, recalibration is needed to adjust and finetune the scales to ensure they reflect reality. Training is key when recalibration is done. It ensures that similar occurrences lead to similar assessments, avoiding human bias to over/underestimate probabilities and severities (Hubbard, 2008; Duijm, 2015; Krisper, 2021). Training of risk assessors as well as the decision-makers on the calibration of scales, is an added value as the increased knowledge of the risk matrix and its scales will only contributes to the calibration of it.

Finally, it must be emphasised that when looking at a risk matrix, it is not just about the risk matrix, its colours and numbers. The holistic view of the matrix and its scales needs to be looked at together as per Figure 6. It is only by looking at the matrix and calibrated scales together that it makes sense, as they are all connected. Looking individually at one of the components de-calibrates the risk matrix.

### 3.2. Classification – "Events"

The second pillar of the language design is the event classification to be used by each system. The Meeûs survey concluded that most participants are using their custom-made classification, linked or not to industry taxonomies like ECCAIRS (European Co-ordination Center for Accident and Incident Reporting Systems) and ADREP (ICAO Accident/Incident Data Reporting). Own classifications made by organisations are challenging to reproduce. ADREP and ECCAIRS are complex classifications as they consist of various attributes and entities, each with its taxonomy, which results in a couple of thousands of combinations. Such a classification is not a very straightforward taxonomy, which requires a deep understanding of how this taxonomy is to be used to ensure the correct output from the data can be received. It might be the reason why most airlines develop their own taxonomy and try to link it to ADREP/ECCAIRS through software systems.

The industry standard taxonomy available is the IDX, which is less used but is a more straightforward taxonomy which would be more approachable for this research. It consists of 4 levels, of which the following are the first level in the taxonomy:

- Air Traffic Management
- Airport Management
- Cabin Safety
- Common
- Engineering/ Maintenance
- Flight Operations
- Ground
- Occupational Health and Safety
- Security
- Why

This taxonomy distinguishes events from management systems like SMS, OHS and Security. Although limited, the taxonomy's Level 1 descriptor "common" includes some fatigue events and non-compliance events. The "why" descriptors of the IDX are more related to root causes, so they will be removed from our model as root causes have a separate taxonomy. If classifications need to be added, when other management systems are implemented, they can easily be added to the level 1 of the tree. In addition, if more granularity is required in the other levels, this can be easily complemented to the needs of an organisation. As with custom classification trees, it is possible to map the above tree to an ADREP/ECCAIRS classification if needed. For this research and model, only the adjusted IDX tree is used; how to map this classification to other taxonomies is not part of the research.

### 3.3. Classification – "Root Causes"

Out of the survey result, there is a more uniform use of a standard classification, the Human Factors Analysis and Classification System (HFACS), to understand why events are happening and determine the root causes of the issues. Also, the survey pointed out that the different systems use custom classification trees, which is difficult to reproduce. As the HFACS is an international standard used in many industries, with many options in the taxonomy, a reduced taxonomy is developed to facilitate the different management systems using the same concept so the nomenclature can be aligned.

The HFACS layer structure is based on Reason's Swiss Cheese model, where HFACS tries to define the active and latent failures of the holes in the cheese. The same philosophy can be applied to the enhanced Swiss Cheese model (see Figure 1), where different management systems come together as it attempts to do the same but on an integrated level.

HFACS is a 4-level structure created to understand and determine the apparent reasons for events, but in addition, it looks for the underlying causes of events.

The four main categories consist of:

- Unsafe Acts: descriptions of what did not go according to plan. It consists of actions, intentional deviations from procedures and practises defined by the organisation, but the real reason why, is not uncovered. Correction on this level can be re-training, blame, but as the real reason is not uncovered, the correction will work until the next occurrence.
- Preconditions for Unsafe Acts: describes factors and conditions which affect human performance or contribute to the actions of the layer "Acts". This level will lead to prevention and countermeasures of a more structural nature.
- Supervisory Factors: describes how the organisation is working. Actions in these levels result in other types of supervision, leadership, and change of procedures to avoid workarounds and working arrangements.
- Organizational Influences: Lowest level and describes influences of the organisation, internal and external (demands, competition). It defines the organisation's culture and focuses on values and norms to ensure a sustainable environment. Actions on this level are to be seen in changes to policies, resources, staffing adjustments and even organisational changes.

Each category is further defined in sublevels (Figure 7), which are further split into different items. The lowest level of the classification, level 4, is called the Nano-codes level. It describes other possible causes even further in high detail, but is not described in this paper.

HFACS is used in different industries, and as with other taxonomies, there is a great level of detail available in the tree. Each organisation needs to define what applies to their organisation, and if needed, can even define more detail in the tree. It is possible to add additional definitions for each category, even up to the lowest level, nano-code level, if an organisation desires. As the complete taxonomy is already so detailed on the lowest level, it is questionable what the added value could potentially be for an organisation if additional definitions are created. Therefore, for the model, a tree of up to 3 levels is used, for which the meaning of each classification is defined.

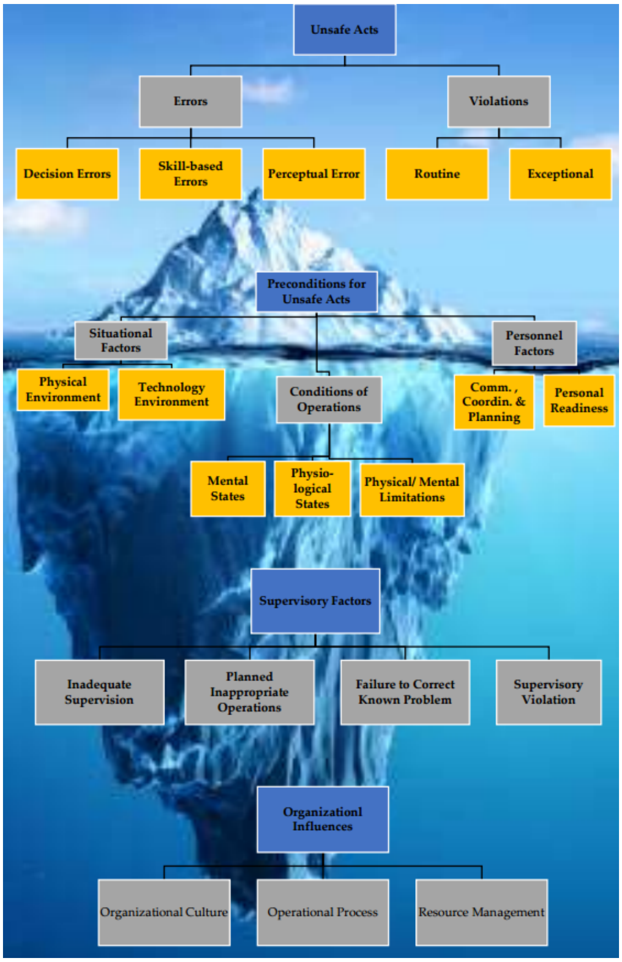


Figure 7. IMS why taxonomy (source: created by the author)

## 4. IMS process & IMS cube

The management systems today work individually, with sometimes common procedures, but they are not fully integrated and can be summarized and visually represented as per Figure 8.

As a result of the survey, it was revealed that the different management systems are implemented independently. Consequently, as no policy is defined that systems must work together, they also work independently (Plan). Occurrences are identified, either through a change in the organisation (for example the integration of a new aircraft type), an external change (a pandemic, change of regulatory environment, incidents with other operators) or through the internal reporting system. These occurrences are addressed by one or the other management system. Depending to which management system the occurrence is allocated to, it goes through different classifications and risk matrices, or in some organisations, some management systems do not use a classification or a matrix to assess the event (Do). These assessments are performed individually, not coordinated with other systems. Following the assessments, actions are taken (or not taken) to mitigate the risk through setting up, measuring and monitoring performance indicators, the "Check" stage of the PDCA cycle. Finally, some systems conduct evaluations to ensure a cycle of continuous improvement (Act). However, these evaluations are not shared or participated with other management systems.

The researchers' concept on which the model is based, defines foundation blocks, where all systems implemented in an organisation can work as interoperable as possible to have a holistic, integrated manner to look at all management systems together. The survey pointed out that different taxonomies and risk methods are used. In this model, the same classifications and risk methods are to be used, developed in the above chapters, to do the assessment, regardless of the nature of the management system. This unique language in the IMS Model is another contribution to a holistic approach.

The six building blocks that are defined for the data capture of the survey, the IMS foundation, are presented in the Figure 9 below, to demonstrate how these should work together (green arrow boxes).

The first block from the foundation is Management Commitment. In an IMS, another management system can only be implemented if the policies and objectives are aligned to avoid goal settings which could work against each other rather than with each other. One example is

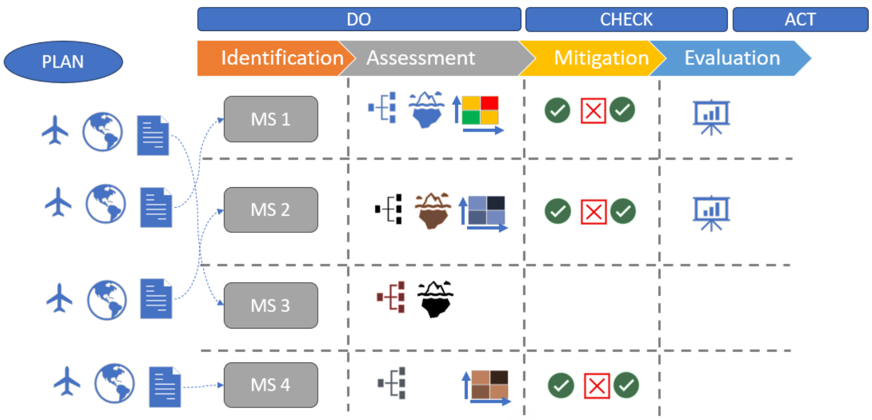


Figure 8. Process of individual management systems (source: created by the author)

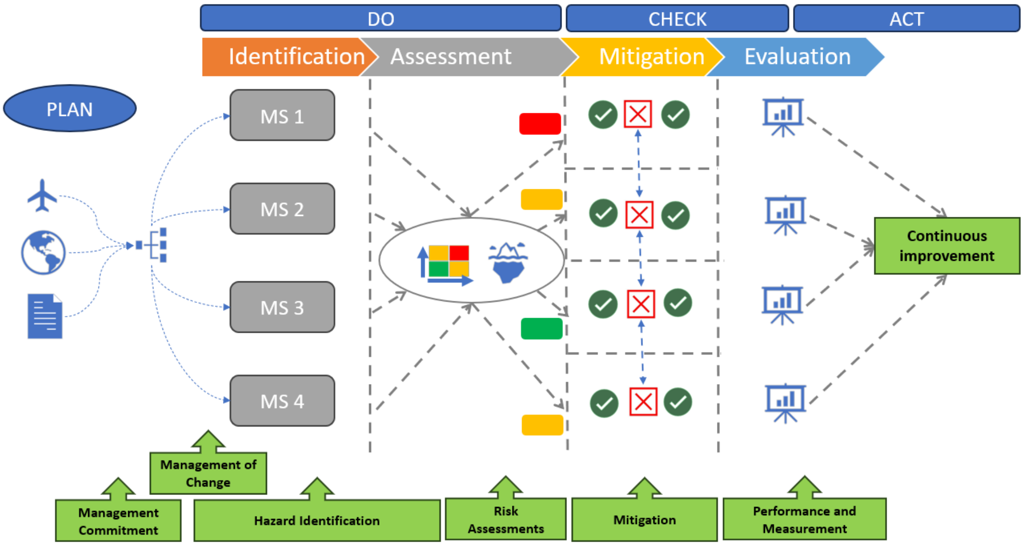


**Figure 9.** IMS process (source: created by the author)

where reducing emissions by saving fuel, could have an adverse effect on other systems like SMS, where minimum fuel is required to operate safely. In this model, this is the first criteria to set up when new management systems need to be integrated within an organisation, to define objectives in line with other management systems.

The second foundation block, hazard identification, consists of different aspects. One was the identification of hazards, which is ingested in the different systems through the same reporting system, which is a positive observation from the survey. In proposed model, it means that each reported event goes through each management system. The event is not "owned" by one system. It is shared with all systems. This implies that one of the language pillars, the "what" descriptors, is defined when the event occurs, and afterwards, it goes through the different systems rather than assigning an event to a management system and then starting the classification as these might not be aligned.

Each management system then assesses the risk about the scope of their system/identity and define root causes that could explain why this event is a risk for their management system.

The foundation block Risk assessments are also made interoperable. Risk assessments are detailed analyses and should follow the same risk method and classifications as for any other event. It ensures no difference is made by the methods used depending on the events that occurred or the assessment done for these events. These assessments would always involve different management systems, but this is currently not the case per the survey outcome.

The outcome of why events are occurring or the outcome of risk assessments leads to different mitigations. Each MS has its own identity and should keep this as they have been developed and implemented in organisations for a specific need. It also requires an action to mitigate depending on that need. As with the management commitment, these mitigations would need to be coordinated and aligned to ensure those actions are not counterproductive or even create a new risk for another MS, hence dotted blue arrows between the individual mitigation actions to visualise this coordination.

The "Management of Change" follows, as for any assessment or identified hazard, the same language and process flow. A change in an organisation is identified and assessed by the different systems, like any other occurrence. It leads to different coordinating mitigation actions to lower the risk when the change is implemented.

The "Performance and Measurement" block is the trend of each system and should be established for each system individually, as each system has its specifications. This is crucial in order to be able to build the last block called "Continuous improvement".

The final building block, continuous improvement, demonstrates the real advantage of the IMS Model. All the identified building blocks contributes to this last one. Each MS is based on the same process, and they are able to "communicate" with each other. This enabler provides added value for the organisation, which can be seen under the IMS Cube (Figure 10).

The IMS Cube provide different views of how management systems impact the organisation. Thanks to the interoperability created, additional information can be extracted, useful for the decision-makers:

1. It can be easily discovered which events impact the organisation most. Two things can be easily identified by calculating the cumulated risk of events (occurrence, change management outcome, risk assessment outcome). On the one hand, which event has the most impact on the different management systems can be seen. In Figure 10, this would be occurrence 1, as it has the highest cumulated risk of the different systems together. In other words, this event has a significant impact throughout the

organisation. Secondly, the impact of each event on each system can be "compared".

2. Another benefit is that it can be identified which management system is the most affected by all the events occurring in the organisation. It detects to see if the overall events have the most impact on compliance, safety, and security or if any other system is implemented.
3. The most assigned causes of events within the organisation to be improved. If root cause number 4 is, for example, the cause of "inadequate supervision", it would mean that this affects mainly the safety management systems and has a lower impact on other systems. However, when looking at root cause number 8, it has a more significant effect on all the systems together. This can then be translated to prioritise on those causes, either targeted on one system or combined overall systems. Is the reason for events occurring related to one system, or is it related to a company-wide problem affecting the different management systems together?
4. In one system, it can be seen which causes occurred the most for all the events affecting that system. So a focus could be made to tackle the root cause 8 first as this would have the most effect on the all the events triggered in this system
5. Provides an overview of which causes has an effect on which events individually. It could also provide an indication of the complexity of certain events as they trigger more root causes, within different systems or not.

An additional dimension could be further developed if, for example, during the process, the financial impact of these events on the different systems is calculated, providing an additional ranking. However, not all events are easy to translate into figures, reputational loss, the "value" of causalities, to name a few, are difficult to calculate. A better option could be to add a dimensions on consequence. These could be interpreted as hours of delay, working shift not covered, cancellations of flights, diversions etc.

## 5. Conclusions

The paper defined a new IMS model based on the full dataset from the survey conducted by Meeûs in 2023. A language is developed to ensure that different management systems can communicate when implemented as one integrated management system. The developed language consists of three components: a risk component and two classification components. It creates a standard approach to assess risk and how events should be classified to understand what and why they occur.

A new process is defined for an integrated management system to define how this language is used and applied to ensure interoperability between the different systems. This interoperability is demonstrated through the different building blocks defined by the survey data points and used as the foundation of an integrated management system. This foundation and its interoperability ensures that new individual systems can be added easily to an integrated system.

Finally, the benefit of this model is described through the design of the IMS cube, which provides an overview for decision-makers to identify the strong and weak points throughout the different management systems and the impact of events on these systems individually or as a whole. Looking holistically to all management systems together, would not only make the organization more robust towards different risks, it could also reduce costs. Different occurrence could impact different systems and by acting on those, improvements could affect the different systems at once which might reduce cost to implement this improvements with a more holistic impact.

The introduction also highlighted the lack and need for an integrated management system model. There is a need for an integrated system, but the question of how to implement this still needs to be defined in the different regulations and requirements and even in recent studies (Bao et al., 2022; Ispas & Mironeasa, 2022; Malakis et al., 2023).

A model always has its benefits and limitations as it is designed for a specific purpose and framework. In order

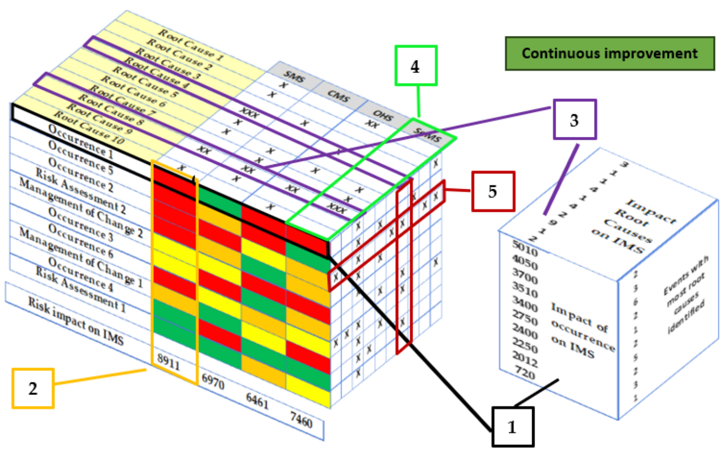


Figure 10. IMS cube (source: created by the author)

to know the pros and cons of this model, the model needs to be tested through case studies to see how the model is behaving, perceived by airlines, to either validate the model or provide some insights for further improvements to ensure that the model does not remain a theoretical model, but a practical approach for airlines to use the model.

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## Author contributions

Conceptualisation, J. M.; methodology, J. M.; software, J. M.; validation, J. M.; formal analysis, J. M.; investigation, J. M.; resources, J. M.; data curation, J. M.; writing – original draft preparation, J. M.; writing – review and editing, J. M., W. D. and R. M.; visualisation, J. M.; supervision, W. D. and R. M.; project administration, J. M.; funding acquisition, J. M.

## Disclosure statement

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