# Pre-Causation Analysis Based on Stochastic Uncertainty to Reduce Tacit Assumption on Mitigation Measurement of Non-Compliance Runway Strip

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**Abstract:** Safety risk assessment and mitigation plan proposed by the aerodrome operator. A review of that documents done by Aerodrome Inspector. The guidance performed as a generic scheme, thus need additional guidelines to make an assessment accurate and objective in the frame of reasonable and practical. Constraint by lack of knowledge and competency, inexperienced and inadequate expertise on safety and risk management, such assessment conducted with the qualitative method and somehow the evaluation result tend to be subjective, multi perception and containing tacit assumption from the personnel. This research revisited the 3M model (Man-Machine-Environment), this model is simple, easy to understand and apply, and meet the reasonable and practical principle. The 3M model incorporated with the level of stochastic uncertainty to make a new model that more advance, clear in guidance, and suitable for a risk assessment and mitigation measures process in evaluation of an aeronautical study.

*Keywords: Runway Strip, Quantitative Risk Assessment, Pre-Causation Analysis, Stochastic Uncertainty*

## 1. INTRODUCTION

The aerodrome is a defined area on land or water (including any buildings, installations, and equipment) intended to be used either wholly or in part for the arrival, departure, and surface movement of aircraft (ICAO, 2018a; Kazda & Caves, 2007). An aerodrome certificate is a certificate issued by the appropriate authority under applicable regulations for the operation of an aerodrome. When an aerodrome is granted a certificate, it signifies to aircraft operators and other organizations operating on the aerodrome that, at the time of certification, the aerodrome meets the specifications regarding the facility and its operation, and that it has, according to the certifying authority, the capability to maintain these specifications for the period of validity of the certificate. As part of the certification process, States shall ensure that an aerodrome manual which will include all pertinent information on the aerodrome site, facilities, services, equipment, operating procedures, organization, and management including a safety management system (ICAO, 2018a).

Compliance with the State’s regulatory requirements is obligatory. However, on some occasions, there might be instances where full compliance is not feasible. In those instances, exemptions or exceptions may be granted by the State. Such measures must be supported by appropriate, robust, and documented safety risk assessments or aeronautical studies and imposition of limitations, conditions or mitigation measures, as appropriate (ICAO, 2017).

On the aerodrome, one facility that shall comply to get a granted certificate is a runway strip. A runway strip is a defined area including the runway and “stopway” if provided, intended to reduce the risk of damage to aircraft running off a runway and to protect aircraft flying over it during take-off or landing operations. (ICAO, 2018a; Kazda & Caves, 2007). It has dimensions (length and width) that shall be complied with within correspond to the code number of the runway (table 1).

Table 1. Required Dimensions of Runway Strip

| Dimension | Runway Code Number | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| **Length**<br>A strip shall extend before the threshold and beyond the end of the runway or stopway for a distance of at least ……… | 60 m (Instrument)<br>30 m (Non-Instrument) | 60 m | 60 m | 60 m |
| **Width**<br>A strip including a precision approach runway shall, wherever practicable, extend laterally to a distance of at least …….., on each side of the centerline of the runway and its extended centerline throughout the length of the strip | 70 m | 70 m | 140 m | 140 m |

Source: Adapted from (ICAO, 2018a)

Many cases of the aerodrome in Indonesia founded that the length and width of the runway strip do not meet the requirement (figure 1). The inadequate dimension of runway strip at many aerodromes in Indonesia is caused by the unavailability of land which can be possessed by aerodrome operator, at some aerodrome the dimension is adequate for a standard runway strip, but it has a slope and/or strength that not meet the safety requirement.

When an aerodrome does not meet the requirement of a standard or practice specified in Annex 14 volume I to the Conventional on International Civil Aviation and the national regulations and practice, the Civil Aviation Authority may determine, after carrying out aeronautical studies, only if and where permitted by the standard and practices, the conditions and procedures that are necessary to ensure a level of safety equivalent to that established by the relevant standard or practice. The Civil Aviation Authority may exempt, in writing, the aerodrome operator from complying. An exemption is subject to the aerodrome operator with conditions and procedures specified by the Civil Aviation Authorities (ICAO, 2001).

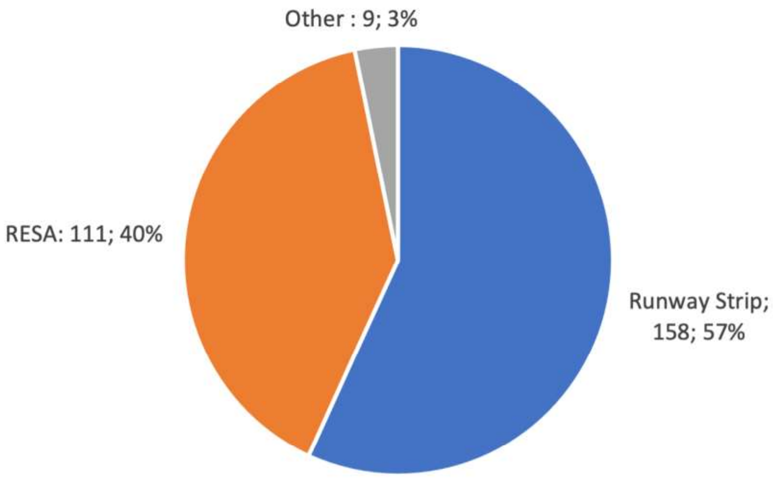


Figure 1. Number and Percentage of Issuance an Exemption in Indonesia
(source: DGCA Database September 2020)

An aeronautical study should be developed by the aerodrome operator to demonstrate whether an equivalent level of safety or an alternative acceptable means of compliance can be achieved. Review and acceptance of such an assessment or study should be performed by the Civil Aviation Authority at the appropriate level. The regulator also needs to assess, before granting an exception or exemption, the issuance of exceptions or exemptions that are not supported by safety risk assessments or aeronautical studies and by thorough reviews by the competent authority is *not acceptable* (ICAO, 2017).

The safety risk assessment and mitigation plan proposed by an aerodrome operator. A review of that documents is doing by Aerodrome Inspector. Aerodrome Inspector is personnel that has a credential from the state to evaluate such a document or study result, following the guidance that was published by the International Civil Aviation. In the fact of the guidance is performed as a generic scheme, thus needed additional guidelines to make an assessment accurate and objective in the frame of reasonable and practical. Constraint by lack of knowledge and competency, inexperienced and inadequate expertise on safety and risk management, such assessment conducted with a qualitative method and somehow the evaluation result tend to be subjective, multi perception and, contain tacit assumption from the personnel. In this condition, is important to find a supplementary method to reduce such tendency and get the output of the assessment from a quantitative way.

Another crucial thing is to find a method or process guidance for mitigation measures that needed to get a rapid, suitable, effective and sustainable output might be achieved in the best effort and way but keep on valid, reasonable, and practical context, instead of rigid procedural and long iteration from the generic guidance. At the rest, the evaluation result could be used as a valid and logical reference for decision-making of exemption granted for the aerodrome operator which has a non-compliance with the regulation.

## 2. LITERATURE REVIEW

### 2.1 Generic Safety (Risk) Assessment Method

The aerodrome operator shall develop and maintain a process that ensures analysis, assessment, and control of the safety risks associated with identified hazards (ICAO, 2016; Stolzer, Halford, & Goglia, 2015). "Aerodrome operators shall identify the hazards, decide who may be harmful and how to evaluate risks and, decide whether the existing control measures are adequate or whether more should be done. The aerodrome operator shall submit a safety assessment to the competent civil aviation authority which should evaluate the conclusion to ensure compliance with the relevant requirements for the operator. Risk assessments are necessary at the initial request of issuing certificate" (Moretti, Di Mascio, Nichele, & Cokorilo, 2018)

An occurrence considered foreseeable if any reasonable person could have expected the kind of occurrence to have happened under the same circumstances. Identification of every conceivable or theoretically possible hazard is not possible. Therefore, good judgment is required to determine an appropriate level of detail in hazard identification. Aerodrome operators should exercise due diligence when identifying significant and reasonably foreseeable hazards related to their product or service. Should be noted, regarding product design, the term "foreseeable" is intended to be consistent with its use in airworthiness regulations, policy, and guidance (ICAO, 2018b). ICAO noted that States shall establish and maintain a process to identify hazards from collected safety data and States shall develop and maintain a process that ensures the assessment of safety risks associated with identified hazards (ICAO, 2016; Stolzer et al., 2015).

Table 2 presents a typical safety risk probability classification table. It includes five categories to denote the probability related to an unsafe event or condition, the description of each category, and an assignment of a value to each category. This example uses qualitative terms; quantitative terms could be defined to provide a more accurate assessment. This will depend on the availability of appropriate safety data and the sophistication of the organization and operation (ICAO, 2018b).

Table 2. Safety Risk Probability

| *Likelihood* | *Meaning* | *Value* |
|---|---|---|
| Frequent | Likely to occur many times (has occurred frequently) | 5 |
| Occasional | Likely to occur sometimes (has occurred infrequently) | 4 |
| Remote | Unlikely to occur, but possible (has occurred rarely) | 3 |
| Improbable | Very unlikely to occur (not known to have occurred) | 2 |
| Extremely improbable | Almost inconceivable that the event will occur | 1 |

Once the probability assessment has been completed, the next step is to assess the severity, taking into account the potential consequences related to the hazard. Safety risk severity is defined as the extent of harm that might reasonably be expected to occur as a consequence or outcome of the identified hazard. The severity assessment should consider all possible consequences related to a hazard, taking into account the worst foreseeable situation. Table 3 presents a typical safety risk severity table. It includes five categories to denote the level of severity, the description of each category, and the assignment of a value to each category. As with the safety risk probability table, this table is an example only (ICAO, 2018b).

Table 3. Safety Risk Severity

| *Severity* | *Meaning* | *Value* |
|---|---|---|
| Catastrophic | • Aircraft / equipment destroyed<br>• Multiple deaths | A |
| Hazardous | • A large reduction in safety margins, physical distress or a workload such that operational personnel cannot be relied upon to perform their tasks accurately or completely<br>• Serious injury<br>• Major equipment damage | B |
| Major | • A significant reduction in safety margins, a reduction in the ability of operational personnel to cope with adverse operating conditions as a result of an increase in workload or as a result of conditions impairing their efficiency<br>• Serious incident<br>• Injury to persons | C |
| Minor | • Nuisance<br>• Operating limitations<br>• Use of emergency procedures<br>• Minor incident | D |
| Negligible | • Few consequences | E |

The safety risk index rating was created by combining the results of the probability and severity scores. In the example above, it is an alphanumeric designator. The respective severity/probability combinations are presented in the safety risk assessment matrix in table 4. The safety risk assessment matrix is used to determine safety risk tolerability (ICAO, 2018b).

Table 4. Example Safety Risk Matrix

| *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 |

Safety risks are conceptually assessed as acceptable, tolerable, or intolerable. Safety risks assessed as initially falling in the intolerable region are unacceptable under any circumstances. The probability and/or severity of the consequences of the hazards are of such a magnitude, and the damaging potential of the hazard poses such a threat to safety, that mitigation action is required or activities are stopped (ICAO, 2018b).

Table 5. Example Safety Risk Tolerability

| *Safety Risk Index Range* | *Safety Risk Description* | *Recommended Action* |
|---|---|---|
| 5A, 5B, 5C, 4A, 4B, 3A | INTOLERABLE | Take immediate action to mitigate the risk or stop the activity. Perform priority safety risk mitigation to ensure additional or enhanced preventative controls are in place to bring down the safety risk index to tolerable. |
| 5D, 5E, 4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C, 1A | TOLERABLE | Can be tolerated based on the safety risk mitigation. It may require management decision to accept the risk. |
| 3E, 2D, 2E, 1B, 1C, 1D, 1E | ACCEPTABLE | Acceptable as is. No further safety risk mitigation required. |

ICAO state a note (ICAO, 2018b), that is an example only. The level of detail and complexity of tables and matrices should be adapted to the particular needs and complexities of each organization. It should also be noted that organizations might include both qualitative and quantitative criteria.

## 2.2. Another Safety (Risk) Assessment Method

Considering some risk assessment methods, Simona Verga proposes a taxonomic scheme that partitions the All-Hazards Risk Domain into major event categories based on the nature of the risk sources. The taxonomy enables an architecture approach for an all-hazards risk model, in support of harmonized planning across levels of government and different organizations. Provided that the classifications are aligned with the areas of expertise of various departments/agencies, a framework can be developed and used to assign portions of the risk domain to those organizations with the relevant authority. But it remains methodologically and conceptually difficult, due to the inherent complexity of the domain and limited ability to represent it adequately (Verga, 2008)

A paradigm for Risk Management Process (RMP) proposed by Sperandio (Sperandio, Robin, & Girard, 2008), then illustrated via an industrial case. Such an RMP includes the tasks of establishing the context, identifying, analyzing, evaluating, treating, monitoring, and communicating risks resulting from design system dysfunctions. It also takes into account risks caused by the domino-effect of design system dysfunctions and completes risk management methodologies provided by companies that do not consider this aspect. To identify and manage relationships between global factors influencing the performance of the design process, they propose to use product, process, and organizational models. The application of such a decomposition to the global and local factors of the design system is proposed hereafter to three criteria: The occurrence scale (O) is defined by the appearance frequency of a dysfunction. The gravity scale (G) considers the sum of the quotations obtained for the criteria organization, process, and product. and the risk of its non-detection (*D*) measures the ‘‘probability’’ of not detecting a potential failure when the cause exists But the term ‘‘probability’’ used is not standard, since the values corresponding to these probabilities are not contained between 0 and 1. Criteria weighting results from the expertise of leaders and/or analysts and/or operators, based on an experiment (Sperandio et al., 2008).

Experience with accidents in different branches of industry, also in railways companies and the nuclear industry, has shown the importance of safe operation management. Methods of evaluating safety culture can be divided into two main groups: the approach is mainly based on interviews with plant management and staff to get direct information about the plant safety culture and an approach that uses information derived from plant operation, incidents, and accidents. The regulatory authorities should make sure that the licensees have and continually use a self-assessment system that addresses organizational and personnel aspects. The review of this system for appropriateness should ensure that the self-assessment tools, e.g. questionnaires and work-study techniques meet acceptable quality criteria and that they are implemented correctly. But The authorities' involvement should not be too prescriptive to avoid interfering with the responsibility of the licensee since the regulatory process itself can influence the licensee’s safety culture (Berg, 2008).

“The risk management process is a structured approach to identify, evaluate, and prioritize potential risks. Risk management at airports is different from other organizations because these infrastructures have significant potentials for risks and their risks are not only related to technical aspects. Therefore, it is necessary to implement a risk management process in the airport to identify available risks, to focus on factors that exacerbate risks, and to reduce human and financial losses and other risks by adopting necessary solutions” (Rezaee & Yousefi, 2018).

### 2.3 Assessment Safety (Risk) by Accident Causation Model

“Causal models of assessment of risk and safety of aircraft and ATM/ATC operations establish the theoretical framework of causes that might lead to aircraft accidents. They can be qualitative or quantitative, with the former providing a diagrammatic or hierarchical description of the factors that might cause accidents, which is useful for improving understanding of causes of accidents and proposing means for avoiding them. The latter estimate the probability of occurrence of each cause and thus estimates the risk of an accident. This can be restricted to pure statistical analysis based on the available data or it can combine such data with expert judgment on causes" (Netjasov & Janic, 2008). Most studies conducted on risk management in the airline industry have not considered cause-effect relationships between risks (Rezaee & Yousefi, 2018).

Reason, J., Hollnagel, E., Paries, J., 2006 (as cited in (Larouzee & Le Coze, 2020)) said: "the vertical orientation does not suggest causality, but a rather structuralist vision of hierarchical relations between different levels of an organization". This version was quickly abandoned, it has not been quoted or used in any publication referencing or drawing upon Reason's work (Larouzee & Le Coze, 2020).

The International Civil Aviation adopts the Swiss Cheese (or Reason) Model (SCM) as content in the sub-chapter Accident Causation of Safety Management Manual. It's mean that causation is an important matter that should be considered in doing safety management further risk assessment process. Accident causation models could answer at least two questions: (i) why does an accident occur, and (ii) how does it occur?. For safety science, these models were the most important theoretical basis that could provide an important method for accident analysis and prevention (Fu et al., 2020).

One concept of accident causation is a 3M model known as man, machine, and media model. 3M model comes from the epidemiological accident model, that had been a certain advanced nature. This theory has infiltrated the understanding of the single factor of accident causation and the simple causal relationship. From a system perspective, a 3M model considered the relationships among the causal factors, but the theory lacks clear guidance (Fu et al., 2020).

Man-machine-environment system engineering is a developing synthesis of frontier science. It analyses three factors for man, machine, and environment of the system and the relationship among them to make the system become "safety, cost-effective and highly efficient" (Xiaoyan & Zhongpeng, 2014).

From the aspect of operator, the behaviour pattern of man was indicated as S-O-R, meaning stimulus-organism-response, from the perspective of production, there are three reasons for it, man's error in sensing the environment information, the wrong decisions when the human's brain dealing with information and action organs failing to complete assigned action. The statistic shows that in all system failures, about 70% to 90% of it is directly or indirectly from human error. Man's unsafe behavior is the most important factor for the failure of the man-machine-environment system, so prevention man's error to improve man-machine-environment system safety is very important (Xiaoyan & Zhongpeng, 2014).

The unsafe state of the machine is the mechanical state which had caused or may cause accidents. It is the direct cause of accidents. People are the determinant and machine is the key factor in the system of man-machine-environment. So, it is greatly significant to deeply analyze the relationship between machine and accident to enhance the safety of the system. The environment of the workplace makes a great influence on the worker's operant habit. A favourable environment can create a comfortable working atmosphere. It's good for safety production. Poor environment cause physiological, pathological, efficient and mental human body effect. It affects the worker's health and working efficiency, even endangers people's life. There are high temperature, high humidity, low pressure, oscillation, noise, dust, and some harmful gases, besides flood, fire, gas explosion, and various environmental factors (nature, factitious, normal, and abnormal). In the man-machine-environment system, the environment is another important factor in affecting system safety. It also is the soil to causes man's unsafe behavior and machine's unsafe state (Xiaoyan & Zhongpeng, 2014).

## 2.4 Relation of Risk and Uncertainty

“The situations of uncertainty are dealt with all risk assessments, and risk assessment assumptions are commonly made in the face of epistemic uncertainty, i.e., when there is a lack of knowledge. An assumption may also be made in the face of aleatory uncertainty, i.e., when there is variation in the phenomena involved. The explicit assumptions made are often conservative, meaning that they lead to a higher level of described risk, compared to ‘best estimate’ or ‘best judgment’ assumptions. It probably understands ‘best judgment’ assumptions as reflecting the strongest beliefs of the risk analyst. A conservative assumption can, however, also be given a justification (albeit possibly weaker than the best judgment one) and can thus be considered a justified belief, in line with how assumptions are conceptualized. Tacit assumptions, on the other hand, are understood as assumptions that are not acknowledged, or at least not openly stated (documented), can be seen as justified beliefs. Consider a probability judgment based on some knowledge. If the probability judgment is based on a belief about how a system works, and this belief is not stated, then this belief can be considered a tacit assumption. The belief may be very strong, at least if held sub-consciously or if it was considered unnecessary to document that the probability judgment was made under that condition” (Flage & Askeland, 2020).

“The probability and resulting risk metrics are conditional on this knowledge including these assumptions, and the strength of this knowledge and the ‘risk’ related to potential deviations from these assumptions need attention. Assumptions are made in all risk assessments, making these a foundational issue of relevance across different application areas. Being able to formally relate risk assessment assumptions to the background knowledge of the risk description, and, in the next step, to distinguish between assumptions that are acknowledged and stated openly and assumptions that are ‘hidden in the background knowledge’ and thus represent a potentially unacknowledged ‘risk’ related to deviations, gives a sharper conceptual basis for the thinking and discussion about risk assessment assumptions” (Flage & Askeland, 2020).

Risk relates strongly to uncertainty. “The price of uncertainty”, the proverbial crocodile appeared. The reader should be aware that there are several aspects to the overall regulatory side of risk management which warrant further discussion. As so often, “the truth” of what constitutes good and proper supervision will no doubt be somewhere between the more extreme views. The Basel process has a very laudable aspect that constructive criticism is taken seriously (McNeil, Frey, & Embrechts, 2015). Each knowledge element has been evaluated in terms of its impact on the risk assessment, but the evaluated impact could be a good or poor prediction of the real (unknown) impact. To be in line with fundamental principles of risk management, such as the cautionary principle, needed to be aware of these uncertainties. stochastic uncertainty is understood as a reflection of variation, in the sense that high (low) stochastic uncertainty is used when the population of a certain knowledge element has high (low) variation. (Langdalen, Abrahamsen, & Abrahamsen, 2020).

The two key types of uncertainty can be described as *aleatory uncertainty* and *epistemic uncertainty*. Aleatory uncertainty refers to uncertainty about a value or an outcome in which the variability is inherent due to randomness in the environment or the system and which cannot be reduced by obtaining further data. The epistemic uncertainty refers to uncertainty about a value or an outcome due to a lack of knowledge about the object or system; thus, data can be used to reduce the uncertainty. In a decision with uncertainty, a decision-maker will consider the range of possible outcomes for every alternative. “The precautionary principle is the ethical principle that, if the consequences of an action (especially the use of technology) are subject to scientific uncertainty. Although uncertainty is acknowledged as an important factor in decision making, there are many different ways to describe and model uncertainty" (Herrmann, 2015).

## 3. METHOD

This research revisited the 3M model, this model is simple, easy to understand and apply and meet the reasonable and practical principle. To make that model more advance, clear in guidance, and suitable for a risk assessment and mitigation measures process in the aeronautical study, the relationships among the causal factors is should be considered. We modified the origin by adding a factor of exponential for the element of a subset (circle). There were 3 factors, (i) exponent 1 (^1) for the cause which categorized as an element of a single subset (circle), (ii) exponent 2 (^2) for the cause which categorized as an element of slice from two subsets (circle), and (iii) exponent 3 (^3) for the cause which categorized as an element of centre slice from three subsets (circle). Placement cause in a subset or slice of a circle based on the hazard identification. All processes in a modified 3M model we say as "Pre-Causation Analysis" as presented in figure 2.

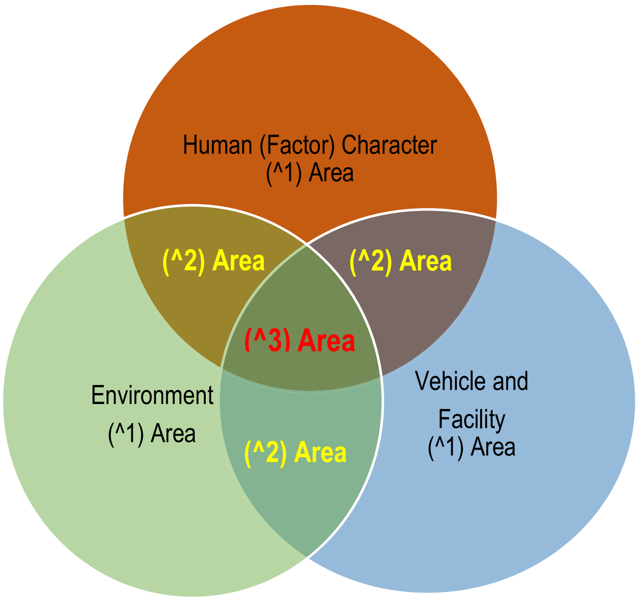


Figure 2. "Modified 3M Pre-Causation Model"

In the second step, this research formulated an uncertainty as stochastic (epistemic) uncertainty, using the level of high, medium, or low, as a variation of a condition such knowledge and data that coming from the aeronautical study. The uncertainty categorized as "**low**" if knowledge and data relatively could give a description WHEN (Time Frame) and HOW the risk may cause an accident/incident, The uncertainty categorized as "**medium**" if knowledge and data relatively could not give one of description about WHEN (Time Frame) or HOW the risk may cause an accident/incident, and The uncertainty categorized as "**high**" if knowledge and data relatively could not give both of description about WHEN (Time Frame) or HOW the risk may cause an accident/incident.

## 4. RESULT (INTERIM)

The research took a step of incorporation of a modified 3M pre-causation model with the level of stochastic uncertainty as described in table 6.

Table 6. Incorporation of pre-causation analysis and the level of stochastic uncertainty

| Degree | Area of Causation | Level of Stochastic Uncertainty |
|---|---|---|
| 1 | Exponent 1 (^1) Cause categorized as an element of a single subset (circle) | The uncertainty is categorized as "**low**" if knowledge and data relatively could give a description WHEN (Time Frame) and HOW the risk may cause an accident/incident. |
| 2 | | The uncertainty categorized as "**medium**" if knowledge and data relatively could not give one description about WHEN (Time Frame) or HOW the risk may cause an accident/incident |
| 3 | | The uncertainty categorized as "**high**" if knowledge and data relatively could not give both descriptions about WHEN (Time Frame) or HOW the risk may cause an accident/incident |
| 4 | Exponent 2 (^2) Cause categorized as an element of slice from two subsets (circle) | The uncertainty is categorized as "**low**" if knowledge and data relatively could give a description WHEN (Time Frame) and HOW the risk may cause an accident/incident. |
| 5 | | The uncertainty categorized as "**medium**" if knowledge and data relatively could not give one description about WHEN (Time Frame) or HOW the risk may cause an accident/incident |
| 6 | | The uncertainty categorized as "**high**" if knowledge and data relatively could not give both descriptions about WHEN (Time Frame) or HOW the risk may cause an accident/incident |
| 7 | Exponent 3 (^3) a cause which categorized as an element of slice from three subsets (circle) | The uncertainty is categorized as "**low**" if knowledge and data relatively could give a description WHEN (Time Frame) and HOW the risk may cause an accident/incident. |
| 8 | | The uncertainty categorized as "**medium**" if knowledge and data relatively could not give one description about WHEN (Time Frame) or HOW the risk may cause an accident/incident |
| 9 | | The uncertainty categorized as "**high**" if knowledge and data relatively could not give both descriptions about WHEN (Time Frame) or HOW the risk may cause an accident/incident |

The incorporation process rendered that each area of causation has a degree associated with its level of stochastic uncertainty. All of the areas of causation split into 9 degrees that more clearly as figure 3. The degree indicated a complexity of causation that coming from mixed original matter which contains uncertainties. Degree 1 indicated the less complexity of causation and the increased number of degrees indicate more complexity of the causation matter.

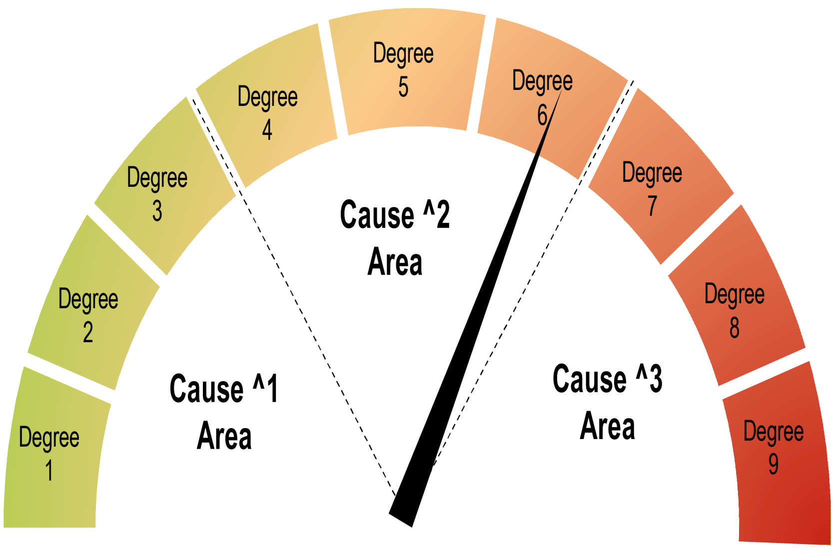


Figure 3. Degree of Causation by Stochastic Uncertainty

## 5. DISCUSSION

This model of modified 3M pre-causation analysis incorporated with the level of stochastic uncertainty that generates a degree of causation by stochastic uncertainty is experimental. A non-compliance runway strip is taken as a hazard that needs to mitigate. Mitigation is starting from put in a cause of non-compliance runway strip in a scheme of Modified 3M Pre-Causation Model. A cause was reviewed by considering a relationship among causal factors. In this case, the appearance of a single causal factor may need reconsideration.

In the next step, the researcher would test a model with the real case using the data from an aeronautical study. On a test process, a researcher expected that model could be a rapid, suitable, effective, and sustainable method for conducting the risk assessment and mitigation measures in evaluating the risk of non-compliance at an aerodrome.

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