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APPLICATION OF THE BOW-TIE MODEL IN AIR TRANSPORTATION SAFETY RISK ANALYSIS

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ABSTRACT

To improve aviation safety, effectiveness, one should systematically analyze and assess the risks of aviation errors and determine the possible causes. There are many existing risk management methods for aviation, but nowadays the bow tie method is becoming more popular, also it is becoming one of the commonly used risk management method of airline companies. This article reviews the available literature and identifies the different approaches for risk management assignment that are exist. This applies the bow-tie methodology and is intended to be of interest to those who are new to the technique and experienced users alike. It summarizes the history of the bow-tie method, gives an overview of how to apply it and describes in detail its practical uses and benefits as well as build Bow-Tie method for Pegasus Airline company.

KEYWORDS: Bow-Tie, Risk Management & Aviation Risk Analyze

INTRODUCTION

Air transport is a complex system involving a complicated, interlinking distributed network of human operators, procedures , and technical/technological systems. These factors make the provision of a socially acceptable level of safety difficult [1]. Due to the potentially severe consequences of accidents, safety has always been considered an issue of greatest importance in the sector [2].

Civil aviation is an activity where all types of risk are present. We can define risk in a few different ways. It is possible to define like the probability of occurrence of a hazardous event in a given period. Second, it may be considered as the possibility that an individual or group be impaired through the election of specific actions in a more or less random manner. A practical problem in air transport is how to manage risk and safety. Typically, this has been resolved by investigations of causes of fatal accidents, assessment of their risk and setting-up some risk standards consistent with society's preference function [3].

New management approaches allow to ease the process of risk analysis in air transportation. One of the newest methods for analysis of risk is starting points are from 1980s, yet since 1999 it has been promoted as an organized approach for risk analysis. It is complex and incorporates causal models in the form of fault trees for detecting hazards and estimating the probabilities of related accidents, consequence models in the form of event trees for indicating possible outcomes and their overall risk and safety management models that indicate hierarchically structured measures and interventions aiming at prevention of giving categories of accidents.

In this paper, the application of bow-tie methodology in air transportation is presented. The research aims to introduce given method and show how to use it for air transportation.

Paper is organized as follows: previous works related to trajectory due confection are reviewed in Section II. Elements of the Bow-Tie method explained in section III. Finally, the Bow-Tie model has been built for a Pegasus airline company with elements and definitions in section IV. Section V has the conclusion and the model which is being built for this article can be found in the Appendix section.

LITERATURE REVIEW

Many researchers can be found in the literature study regarding safety risk management. The Purpose of those researchers is to minimize risk which is useful for improving understanding of the causes of accidents and proposing means for avoiding them. This analysis can be restricted to pure statistical analysis based on the available data or it can combine such data with advanced judgement on causes. Also, they can estimate the relative benefits of different interventions aimed at preventing accidents and reduce risk. Some of the methods are used for risk management analysis include the following:

Fault Tree Analysis (FTA) is a development technique for unwavering quality and safety analysis. It has been created by Bell Telephone Laboratories with the idea in 1962 for the US Air Force for use by the Minuteman framework. It was later embraced and widely connected with the Boeing Company. Fault tree analysis is one of numerous representative "analytical logic techniques" found in tasks examine and in system reliability [4]. Any adequately complex framework is liable to failure because of at least one subsystem falling flat. The probability of failure, be that as it may, can regularly be decreased through enhanced framework design. Fault tree analysis maps the connection between faults, subsystems, and excess safety design components by making a rationale graph of the general framework.

Swiss Chess Model (SCM) Reason proposed model which is invented model to show system failure. Each progression in a procedure has the potential for failure, to changing degrees. The perfect framework is undifferentiated from a pile of cuts of Swiss cheese. View the holes as open doors for a procedure to fail, and every one of the cuts as "defensive layers" all the while. A mistake may enable an issue to go through a gap in one layer, yet in the following layer the holes are in better places, and the issue ought to be getting. Each layer is a guard against potential blunder affecting the result.

For a catastrophic error to occur, the holes need to align for each step in the process, allowing all defenses to be defeated and resulting in an error. If the layers are set up with all the holes lined up, this is an inherently flawed system that will allow a problem at the beginning to progress all the way through to adversely affect the outcome. Each slice of cheese is an opportunity to stop an error. The more defenses you put up, the better. Also, the fewer the holes and the smaller the holes, the more likely you are to catch/stop errors that may occur. [12]

Common Cause Failures (CCF) are a technique for distinguishing arrangements of occasions prompting an aircraft accident. It is helpful to remove the basic reasons for a few aircraft accidents and incidents. It "partitions" the aircraft into "zones", suggesting that the framework and segments in each zone are eventually free.

Methods for the analysis of common cause failures have evolved over the past twenty years from simple quantitative models to elaborate systematic methods for data gathering, qualitative engineering analysis, and quantification of the probabilities of CCF events and their impact on risk and reliability measures [5]. US National Aeronautics and Space Administration (NASA) has utilized this strategy for quite a while (since 1987) in spite of the fact that the technique itself is most likely more established than 1975. Likewise, it has been prescribed for evaluation of the danger of failures of aircraft frameworks and gear.

Event tree analysis (ETA) method is utilized for demonstrating arrangements of events emerging from a solitary hazard and depict the earnestness of the results from these events. Estimated time of arrival was created in 1980 and is generally utilized. The hierarchy of displaying a hazard, the succession of events causing failures of the framework segments and their state as far as working and failure speak profoundly of the technique. Subsequently, a tree with branches of events and working and coming up short segments show the probabilities of failures along specific branches. These in a blend with the likelihood of the hazardous event empower evaluation of the likelihood of the framework or part failure. This strategy is relevant in a blend with FTA for every single specialized framework, including aircraft and ATC/ATM segments [6].

Bayesian Belief Networks (BBN) depend on likelihood theory and has been produced to enhance comprehension of the effects of various reasons for the risk. Started in the mid1980s, the technique was connected to the start of the 2000s in the US in the parsing of the aviation system risk display (ASRM) created by the Federal Aviation Administration (FAA) and the NASA. ASRM has been utilized to give a systematic, organized approach for understanding the air ship mishap causality and playing out the appraisals of new aviation safety items created through NASA's Aviation Safety and Security Program. For CFIT and LOC mishaps, runway incursion, and engine failures, 20 particular BBN techniques have been created utilizing contextual analyses combined with the master information. Causal elements have been distinguished from mischance reports [7].

Bow-tie Method is a technique that hard to define when exactly appeared, but earliest mention is from 1979 by University of Queensland. Undoubtedly, the Royal Dutch/Shell Group was the first major company to integrate fully the total bow-tie methodology into its business practices and is credited with developing the technique which is widely in use today. The bow tie method combines a Common Cause Failures Diagram and merges it with barriers into a single diagram. Although it seems straightforward, there are differences in how this diagram has been put together.

ELEMENTS OF THE BOW-TIE MODEL

Figure 1: Bow-Tie

Bow tie is one of many barrier risk models available to assist the identification and management of risk and it is this particular model have found (and are still finding) useful by many companies and civil aviation authorities. We will be using BowTie XP software to demonstrate and build the modelling.

The bow tie model consists of different elements that build up the risk picture. The risk picture revolves around the hazard (something in, around or part of an organization or activity which has the potential to cause damage or harm) and the top event (the release or loss of control over a hazard known as the undesired system state). Consideration is then turned to the threats (a possible direct cause of the top event), consequences (results of the top event directly ending in loss or damage) and the controls (any measure taken which acts against some undesirable force or intention).

Left side the model shows preventative measures which dispose of the threat completely or prevent the threat from causing the top event recuperation and right side of the model shows measures which diminish the probability of the result infer-able from the top event being "live" or relieve the seriousness of the outcome. The Bow-Tie model investigates the escalation factors (the thinking to why a control may not be vanquished or less successful) of all controls permitting the portion of escalation factor controls. These prevent the escalation factors affecting the prevention or recuperation controls. Additionally, properties, for example, control effectiveness or critical can be dispensed to the bow tie model to assess the risk picture as a component of a viable SMS.

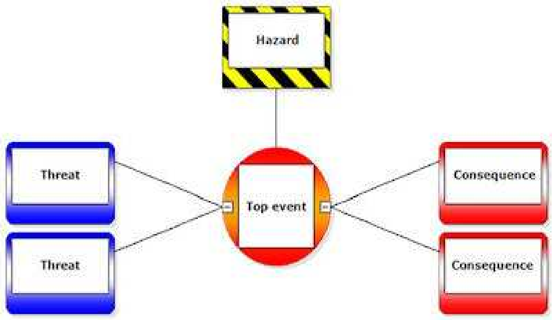

Figure 2: Bow-Tie Model

The Bow-Tie model can be used for a variety of tasks such as SMS (Safety Management System) while identifying hazards and threats in safety system, qualitative assessments of control, risk mitigation and identify and monitor safety assurance measure success of the actions. Also, assisting safety event reporting and identify high level controls to allocate risk [8].

Regardless of whether you are building or deciphering a bow tie, the place to begin is with the hazard. This depicts the potential wellspring of damage under thought. It will regularly portray an 'ordinary' angle inside the operating environment and sets the unique circumstance and extent of the bow tie, for instance, take off in a rainy day this is a movement where risks are available. Hazards are regularly part of typical business exercises and not really something that can or ought to be killed. There is likewise the likelihood to have in excess of one top event from one hazard as there would be various hazard events related in taking off in a bad weather.

All bow ties merge in a central event which is generally characterized as the minute control is lost. In figure 2 connecting all relevant causes and consequences it may be found that the paths from several independent clauses to their consequences, have a ‘‘common node” in the form of a certain event beyond which the graphs are identical. This means that it may be more expedient as a starting point to postulate a certain event, related to the node, that may be a result of many independent causes, and that calls for actions from the same accident-anticipating/limiting systems. This event may be considered as a ‘‘critical event” from which a consequence searching as well as a case-searching analysis may be performed.

This means that a top event is an event that is shared by multiple possible scenarios. It is not critical in the sense that it is the worst event that can occur. It is critical in the sense that it can lead to many negative events. Usually, this means the top event happens just before the various final consequences occur. Classical examples include ‘Loss of containment’ in oil and gas and ‘Loss of separation’ in aviation [9].

Threats can depict as events that may cause a risky state if not made do with preventative controls. Consider the top event and make the inquiry 'why' or 'how' could this happen. These causes are the threats and should be 'immediate'. There ought to be a sensible circumstances and end results connection between the danger and the top event. The reader ought to have the capacity to comprehend this relationship in light of the danger description.

Another fundamental element is the utilization of prevention barriers in the graph. Any measure was taken which acts against some bothersome power or goal, keeping in mind the end goal to keep up a coveted state. On both sides of the central loss of control, barriers are placed which try to eliminate or prevent the loss of control on the left side and try to recover from or mitigate the loss of control on the right side. Barriers can also call as a control. More often than not there will as of now be various manners by which you try to prevent the top event from happening. The expansion of these controls to the bow-tie is the subsequent stage. The controls would take a gander at two parts of danger administration. To start with, disposing of the risk totally, along these lines ensuring the danger is absent and preventing the risk of forming into a top event if the danger becomes "live".

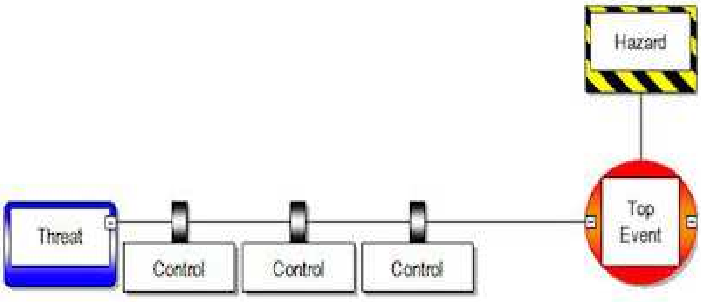

Figure 3: Prevention Control

Recovery controls are like preventative controls, on the right part of the top event, controls are included that show how the situation is to be overseen with a specific end goal to stop an accident from happening. These controls are considered to decrease the probability of the top event forming into a result and moderating the seriousness of the outcome.

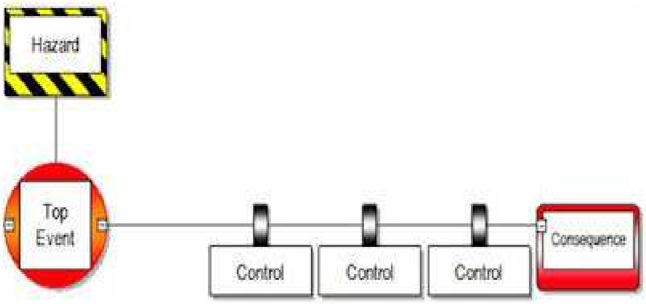

Figure 4: Recovery Control

Escalation factors A condition that prompts expanded hazard by overcoming or diminishing the viability of controls (a control rot component). The controls are rarely 100% powerful and history shows us that they do come up short. We have to comprehend the factors that reason this to happen. An escalation factor is a condition that prompts expanded hazard by lessening the adequacy of controls. An escalation factor cannot directly cause the top event or consequence rather it increases the likelihood that the scenario will progress because the associated control will be degraded or fail.

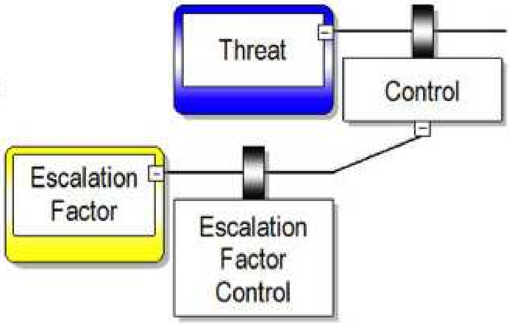

Figure 5: Escalation Factor and Escalation Factor Control

Escalation factor controls are the final step in terms of the bow-tie's main elements which can be defined as a control that manages the conditions which reduce the effectiveness of other controls.

The difference is that they work in an alternate piece of the graph, e.g. they control the escalation factors. It is the expansion of data that depicts how the escalation factors are overseen.

Building Bow-Tie Model for Airline Company

Building up the bow-tie diagrams and basic assignments ought to be done in an organized way with a specific end goal to get quality data and best speak to the genuine hazard control courses of action. In this study Bow-Tie method has been built by a Pegasus Airline company (Turkey- low cost airline) workers in summer 2017.

Facilitated workshops including individuals who are frequently standing up to with the risks have turned out to be the best method for recognizing genuine controls and catching past episodes and current practice. Openness is a fundamental fixing amid these sessions if any shortcomings in controls will be revealed. To support free dialog, the workshop should keep running in a legitimate and drawing in the form. [10].

The true benefits from the bow-tie process are largely independent of the means by which the bow-tie is constructed, e.g. by hand or electronically. A number of software tools are available to construct bow-ties and manage the information behind the diagram. It should not be forgotten however that many of the benefits of the approach are associated with the actual implementation of the process and involvement of the workforce, which is often easier to achieve using hand drawn bow-ties in a brainstorming, workshop setting. The software is ideal for speeding up the reproduction of bow-tie diagrams and organizing the information for further interrogation, retrieval and update [11].

For the model which is built for the Pegasus Airline company, Long Haul Flight chosen as a hazard topic which is starting point for creating Bow-Tie models. Basically, hazards are often part of normal business activities and not necessarily something that can or should be eliminated. For this example, we are not focusing on eliminating the hazard of long haul flight.

Top event is a point in time, which describes the release or loss of control over a Hazard. The undesired system states. One of the top event might occur in long haul flight is the case of No Alternate Airport.

The next step for building model after defining hazard and top event is adding threats which may trigger or cause the top event to occur. Forgiven Bow-Tie model several Threats have been defined and added some prevention barriers also escalation factors:

- Wrong planning (Noncompliance with no alternate airport minima) is chosen to be first threat. To prevent this threat to occur 3 barriers has been built.
  - First of the barriers is Final check by dispatcher related to Operation Control Centre is a human sensory barrier which have good prevention level.
  - LIDO is a cloud based online route manual backup which helps pilots to have a digital copy of flight routes and helps to secure access to customized information – from anywhere, on many devices.
  - Flight crew NOTAM check is the last barrier to giving threat which is the action might happen before flight and while planning a flight.
- Sudden weather change after take-off is a natural threat for most of the flight. To prevent this threat to occur 1 barrier has been built.
  - No alternate airport minimal is a preventative barrier for sudden weather change which is procedure for airline companies and managed by OCC manager.
- High traffic leading to holding is an air traffic issue which might be a problem in crowded air traffic areas. Air traffic unit line up the incoming air-crafts to avoid air collisions and make the best usage of runways and taxi ways. To prevent this threat to occur 1 barrier has been built.
  - Euro control Air traffic flow management is responsible for regulations and applications of air traffic in their member state flight zone.
- Longer Route given by ATC, in some of the flights ATC might change given flight route to order traffic safety and manage high traffic. To prevent this threat to occur 1 barrier has been built.
  - OCC managers can add contingency fuel to prevent this kind of situations. This depends on company policy and procedures. But we have one escalation factor for this barrier which is what if aircraft use more than contingency fuel. To be able to understand the risk of this escalation factor we can look for historical data and crash reports with the risk management department.
- The airport is closed after take-off. This is a unique case which might happen due to the terror attack, bad weather conditions, some accident or incidents in runway or airport. To prevent this threat to occur 1 barrier has been built.
  - When the airport is closed for landing ATC is sending warning for the planes which in en route.

After we define possible threats which is given below next step to build Bow-Tie model is defining consequences. In our case, we have 2 possible consequences.

- Accident is the worst and a possible scenario for giving situation. The aircraft might have an accident due to lack of enough fuel. This might cost most of the life of all the passengers in , the plane is not able to use or repair require so much money and time. To prevent this accident happen, we can have two recovery control barriers
  - Holding fuel to be used in case of an emergency. This depends on company policy and procedures l which can be decided by the first officer captain. There is one escalation factor for this barrier which give us the question of what if there is no airport in the 45 minutes vicinity, but can be reduced risk by an

escalation barrier of acceptable due to very low probability.

  - OCC manager can give information about possible alternate airport information near en route and destination. This is mitigation factor in the accident.

- Bad reputation is another consequence of no alternate airport risk. This is less dangerous effect when comparing with possibility with the accident.

  - Compliance with regulations can reduce the effects of bad reputation or try to prevent bad reputation.

CONCLUSIONS

The benefits of using bow-tie diagrams for risk management have been realized by organizations worldwide across a variety of business sectors. Also known as barrier diagrams, they provide a readily understandable visualization of the relationships between the causes of business upsets, the escalation of such events to a range of possible outcomes, the controls preventing the event from occurring and the preparedness measures in place to limit the consequences. The bow-tie method has been proved itself as useful by airline companies and currently using as a risk management method. The bow-tie model which have been built in this article is currently in use with Pegasus Airline company.

REFERENCES

1. Blom, H. A. P., Bakker, G. J., Blanker, P. J. G., Daams, J., Everdij, M. H. C., Klompstra, M. B., 1998. Accident risk assessment for advanced ATM, In: Proceedings of the Second USA/Europe Air Traffic Management R&D Seminar, Orlando
2. Janic, M., 2000. An assessment of risk and safety in civil aviation. Journal of Air Transport Management 6, 43–50
3. Sage, A. P., White, E. B., 1980. Methodologies for risk and hazard assessment: a survey and status report. IEEE Transaction on System, Man, and Cybernetics SMC-10, 425-441
4. Spouge, J., 2004. A Demonstration Causal Model for Controlled Flight into Terrain. Det Norske Veritas, London
5. NUREG/CR-5485,1NELIEXT-97-O 1327 Guidelines on modelling Common-cause failures in probabilistic risk assignment 1988
6. A review of research on risk and safety modelling in civil aviation. Fedja Netjasov, Milan Janic, Journal of Air Transport Management 14 (2008) 213– 220
7. Luxhoj, J., Coit, D., 2006. Modeling low probability/high consequence events: an aviation safety risk model. In: Proceedings of the 2006 Reliability and Maintainability Symposium (RAMS), Newport Beach
8. British Civil Aviation Authority www.caa.co.uk
9. The bowtie method: A review A. de Ruijter, F. Guldenmund
10. Badreddine, A., Amor, N. B., 2010. A new approach to construct optimal bow tie diagrams for risk analysis. Trends Appl. Intell. Syst., 595–604
11. BowTieXP, "The Next Generation Bow-tie Methodology Tool," 2009. www.bowtiexp.com.
12. Reason, J. (1990) Human Error. Cambridge: University Press, Cambridge

APPENDIX: LIST OF TABLES