A Gap Analysis on Implementation of Safety Management System in Airport: A Case Study

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***Abstract*—The aviation industry in Indonesia is considered flourishing as the national airline industries are expected to grow and develop well in the future, according to the Ministry of Industry. This condition has resulted in increasingly dense schedules of departure and arrival of aircraft at the airport. Improved aircraft flight schedule will be directly proportional to the increase in the risk of the accident flights and serious incidents. To prevent the associated risk, there are standards that must be met to be able to carry out the flight activities safely. The International Civil Aviation Organization has set the airport safety management system (SMS) as a mandatory standard for airline industries. This research aims to investigate the implementation of the SMS, i.e., safety management manual (Doc 9859). A gap analysis is performed to compare the standard with the observed phenomena. The case study was conducted in Adisumarmo International Airport which is located in Boyolali, Central Java Province. The results show that there are indeed gaps in the implementation of the standard. The fault tree analysis and barrier analysis are then employed to identify the cause of failure.**

Keywords—airport, barrier analysis, fault tree analysis, gap analysis, safety management system

I. INTRODUCTION

Indonesia's aviation sector has been growing at a brisk pace in terms of number of passengers, airlines, fleets, flights, and airports. For example, the number of airline passengers has increased from 9 million in 1990 to around 90 million in 2016. The same goes for the country's airline fleets which have escalated in numbers by more than ten-fold from 102 airplanes in 1990 to 1,030 in 2017 [1]. This aviation sector offers huge investment opportunities given the country's unique geographical conditions coupled with a rising middle-class and a strengthening domestic as well as international tourism industry.

Constraints, however, still remain including regulatory issues and poor airline management as well as the failure of the country's infrastructure and human resources to keep pace with the growing number of passengers and flights. According to National Transportation Safety Committee of Indonesia (NTSC, Indonesian: *Komite Nasional Keselamatan Transportasi*, KNKT), between 2010 and 2016 in Indonesia, from the total of 82 aviation accidents and 130 serious incidents, 67.12% of them are caused by human error; the rests are caused by technical aspect (15.75%), environmental situation (12.33%), and facilities' condition (4.79%) [2]. This statistics emphasizes the role of standards that must be met to ensure the safety of any flight-related activity.

The standards in the aviation industry are mostly established by International Civil Aviation Organization (ICAO). One of those standards is the airport safety management system (SMS). SMS which is defined as a management tool for the management of safety by an organization [3], is widely recognized as providing a systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures [4].

The ICAO has made the practice of SMS in the airline industry mandatory since 1 January 2009 [5]. The standard is then considered as the main framework for the airport SMS documents in several countries, such as the Civil Aviation Safety Authority (CASA) in Australia, the U.S. Federal Aviation Administration/Airport Council Research Program/ Transportation Research Board (FAA/ACRP/TRB), Transport Canada Civil Aviation (TCCA), and the United Kingdom Civil Aviation Authority (UK CAA) [6]. The SMS also has been adopted into Indonesian regulation as Ministry of Transportation regulation [7].

It is considered essential to internalize the requirements of SMS into the organizational culture and the daily routines of individual employees so that they will know how to integrate the system with their own duties. According to this concept, as a policy maker, top managers have to demonstrate their appreciation of an SMS and commitment to its execution. In addition, middle and line managers, who generally need to carry out the SMS policies, have to embed the key elements and features in the job design for their subordinates.

The objective of this research is to analyze the standard conformity, i.e., the SMS, with the actual condition. Twelve elements from four components of the safety management manual (Doc 9859) [8] are used in this research. A case study

This research is partially supported by the Faculty of Engineering of Diponegoro University, as "Gap analysis on the application of PKPS 139 (DOC 9859 ICAO) as safety management system standard of PT. Angkasa Pura I Kantor Cabang Bandara Adi Sumarmo Surakarta" (Grant Number: 171/SK/UN7.3.3/V/2017).

978-1-5386-5813-0/18/$31.00 ©2018 IEEE

was conducted in a state-owned enterprise in Indonesia which is responsible for the management of airports. The location is in Adisumarmo International Airport which is located in Boyolali, Central Java Province. A gap analysis then was performed by comparing the document with the observed phenomena.

II. Research Methods

In order to carry out the gap analysis to investigate what has been done by the company with the real situation, an initial gap analysis checklist [8] is employed. There are four components which comprise twelve elements. The first component is safety policy and objectives. It consists of five elements, i.e., management commitment and responsibility (it contains 7 questions); safety accountabilities (8 questions); appointment of key safety personnel (4 questions); coordination of emergency response planning (7 questions); and SMS documentation (7 questions). The second component is safety risk management. It consists of only two elements, i.e., hazard identification (7 questions); and safety risk assessment and mitigation (6 questions). The third component is safety assurance. It consists of three elements, i.e., safety performance monitoring and measurement (8 questions); the management of change (4 questions); and continuous improvement of the SMS (6 questions). The last component is safety promotion. It consists of two elements, i.e., training and education (4 questions); and safety communication (3 questions).

Those questions have to be answered with "Yes/No/Partial" answers. A deep interview and field observation are conducted to answer those questions in the SMS. These responses will provide an initial indication of the broad scope of gaps and hence overall workload to be expected. A "Yes" answer indicates that the organization meets or exceeds the expectation of the question concerned. Score for "Yes" answer to each question is 10. A "No" answer indicates a substantial gap in the existing system with respect to the question's expectation. Score 0 is given for each "No" answered question. A "Partial" answer indicates that further enhancement or development work is required to an existing process in order to meet the question's expectations. Score 1 to 9 is given for each "Partial" answered question. It depends on the actual condition at the object of the research. The questionnaire may be adjusted to suit the needs of the organization and the nature of the product or service provided. This initial information should be useful to senior management in anticipating the scale of the SMS implementation effort and hence the resources to be provided.

When the gap does exist, the fault tree analysis (FTA) is then employed to understand how systems could fail. It is also used to identify the best ways to reduce risk or to determine—or get a feeling for—event rates of a safety accident or a particular system level (functional) failure. It is a top-down, deductive failure analysis in which an undesired state of a system is analyzed using Boolean logic to combine a series of lower-level events. Although the FTA is mainly used in the fields of safety engineering and reliability engineering, it is highly utilized in the aerospace [9] nuclear power, chemical and process [10]–[12], pharmaceutical [13], petrochemical, and other high-hazard industries.

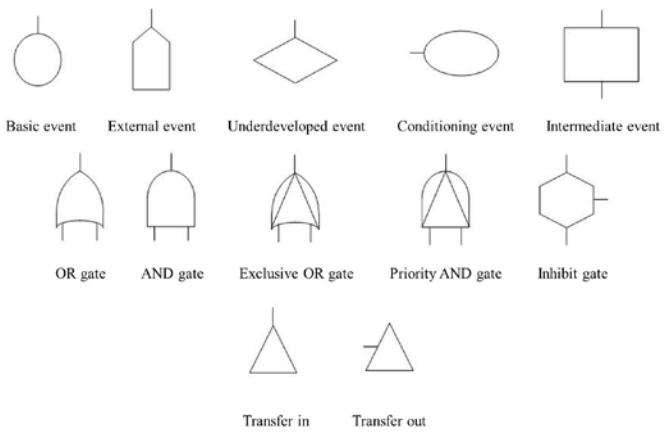

Fig. 1. Event, gate, and transfer symbols used in fault tree analysis.

The basic symbols used in FTA are grouped as events, gates, and transfer symbols. Event symbols are used for primary events and intermediate events. Primary events are not further developed on the fault tree. Intermediate events are found at the output of a gate. The primary event symbols are typically used as follows: (i) basic event, i.e., failure or error in a system component or element; (ii) external event, i.e., normally expected to occur (not of itself a fault); (iii) undeveloped event, i.e., an event about which insufficient information is available, or which is of no consequence; (iv) conditioning event, i.e., conditions that restrict or affect logic gates; and (v) intermediate event gate can be used immediately above a primary event to provide more room to type the event description. Next is gate symbols, which describe the relationship between input and output events. The symbols are derived from Boolean logic symbols: (i) OR gate, i.e., the output occurs if any input occurs; (ii) AND gate, i.e., the output occurs only if all inputs occur (inputs are independent); (iii) exclusive OR gate, i.e., the output occurs if exactly one input occurs; (iv) Priority AND gate, i.e., the output occurs if the inputs occur in a specific sequence specified by a conditioning event; and (v) Inhibit gate, i.e., the output occurs if the input occurs under an enabling condition specified by a conditioning event. Last is the transfer symbols. They are used to connect the inputs and outputs of related fault trees, such as the fault tree of a subsystem to its system. They are transfer in and transfer out symbols. The symbols used in FTA are depicted in Fig. 1.

Further, barrier analysis is used to understand both why a problem happened and how it can be prevented. The premise of a barrier analysis is that a problem is prevented by having barriers in place to control hazards. There are three basic elements in barrier analysis: the target, the hazard, and the barrier. The target is usually a person performing a job. The goal for personnel safety is zero injuries. The target is the person to be protected. The hazard is a way in which the target can be harmed. Hazards are identified for different activities. Examples of hazards include elevated work, electricity or rotating parts. A hazard is also called a threat to the target. In this research, it is used 8P approach to conduct the barrier analysis, namely, people, process, policies, procedures, price, promotion, place/plant, and product. In this research, a deep interview with the top level management and field observation are performed to conduct the FTA and barrier analysis.

III. Case Study: Result and Discussion

A case study was conducted in Adisumarmo International Airport which is located in Boyolali, Central Java Province. A coordination with a state-owned enterprise which is responsible for the management of airports also has been done to carry out this research. The airport is considered to become the airport with the highest domestic passenger growth, namely 53% [14].

A. Initial Gap Analysis

The initial gap analysis checklist by [8] is employed to conduct the first step in an SMS gap analysis. This checklist contains 71 questions from four components which comprise of twelve elements (see Section II) that have to be answered with "Yes/No/Partial" answers. Initial gap analysis checklist for the fourth component is shown in Table 1. (The complete gap analysis checklist is available from the authors on request.) The recapitulation of the initial gap analysis is depicted in Table 2. There are nine elements which have "No" and "Partial" answers, i.e., element 1.1-6, 1.1-7, 2.1-1, 2.1-2, 2.1-4, and 4.2-1 for "Partial" answers; and element 1.2-3, 3.3-1, and 3.3-2 for "No" answers.

Several reasons for non-fulfillment of those elements are as follows. The first is that the company's overall safety policy is not communicated well yet. Next is safety policy review procedures that require a long period of time to be reviewed. The third is that the final flight authority is given from Juanda International Airport which is located in Surabaya. Next is that the hazard reporting formats are available for air safety aspect only. The fifth is that the hazard reporting system has not been implemented entirely. The sixth is that there is no feedback which is related to voluntary reporting. The seventh is that the SMS assessment procedure is not performed in internal company, but it is performed by the Director General of Civil Aviation. Next is that there has been no initiation stage to conduct SMS assessment internally. The last is that socialization of the safety information is still in the process of implementation.

TABLE I. Initial Gap Analysis of Component Safety Promotion

No	Question to be answered	Answer	Status of Implementation
Element 4.1 – Training and education			
4.1-1	Is there a programme to provide SMS training/familiarization to personnel involved in the implementation or operation of the SMS?	Yes	
4.1-2	Has the accountable executive undergone approprite SMS familiarization, briefing, or training?	Yes	
4.1-3	Are personnel involved in conducting risk mitigation provided with appropriate risk management training or familiarization?	Yes	
4.1-4	Is there evidence of organization-wide SMS education or awareness efforts?	Yes	
Element 4.2 — Safety communication			
4.2-1	Does [Organization] participate in sharing safety information with relevant external industry product and service providers or organizations, including the relevant aviation regulatory organizations?	Partial	The socialization has been performed, but not all entities are being involved.
4.2-2	Is there evidence of a safety (SMS) publication, circular or channel for communicating safety (SMS) matters to employees?	Yes	
4.2-3	Are [Organization] SMS manual and related guidance material accessible or disseminated to all relevant personnel?	Yes	

TABLE II. Initial Gap Analysis Recapitulation

Elements	Scores		
	Expectations	*Actual Conditions*	*Gap*
Safety policy and objectives	330	310	20
Safety risk management	130	122	8
Safety assurance	180	160	20
Safety promotion	70	66	4

B. Fault Tree Analysis

The main purpose of the FTA is to help identify potential causes of system failures. Since the gap does exist in several conditions/aspects/questions that have been identified in the previous subsection, then the FTA is used to understand how the systems could fail to meet the standard. Note that gaps appeared in all components in the SMS; hence four FTA are established.

Fig. 2 shows the FTA for failure in safety policy and objectives. There are eight intermediate events and six basic events. The intermediate events are failures which are risen as consequences from other failures. In Fig. 2, the first intermediate event is the failure in management commitment and responsibility. This failure comes as a result from two subsequent failures, i.e., safety policy review procedures that require a long period of time to be reviewed and the company's overall safety policy is not communicated well yet. The last is also considered as an intermediate event since it results from another failure, namely, socialization is only performed to the operational personnel. This failure is arisen from two basic events that are connected with OR gate, i.e., operational personnel tends to have more in safety and lack of personnel who understands more about safety. On the other side, the intermediate event safety policy review procedures that require a long period of time to be reviewed is only resulted from one basic event, namely no review procedure is available.

Fig. 3 shows the FTA for failure in safety risk management. There are four intermediate events and five basic events. In Fig. 3, the first intermediate event is the failure in hazard identification. This failure comes as a result of two subsequent failures, i.e., hazard reporting system has not been implemented entirely and there is no feedback which is related to voluntary reporting. The first acts as an intermediate event since it is resulted from another failure, i.e., hazard reporting formats are available for air safety aspect only. However, that first intermediate event also comes from one basic event, namely, no socialization about hazard reporting system. While the second intermediate event, i.e., there is no feedback which is

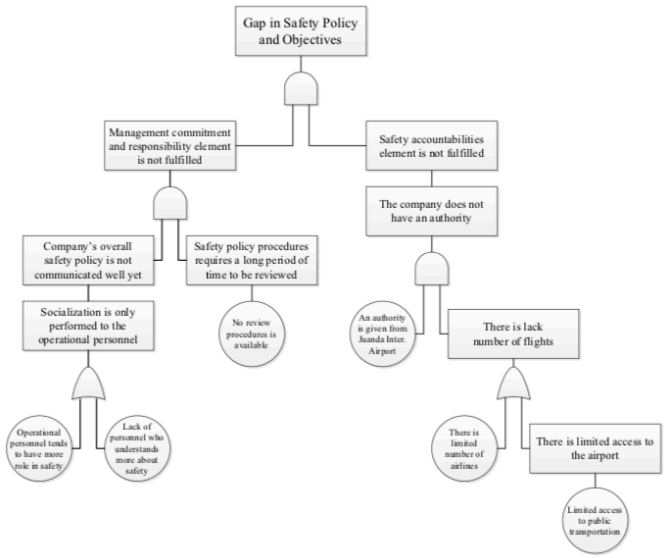

Fig. 2. Fault tree analysis for gap in safety policy and objectives.

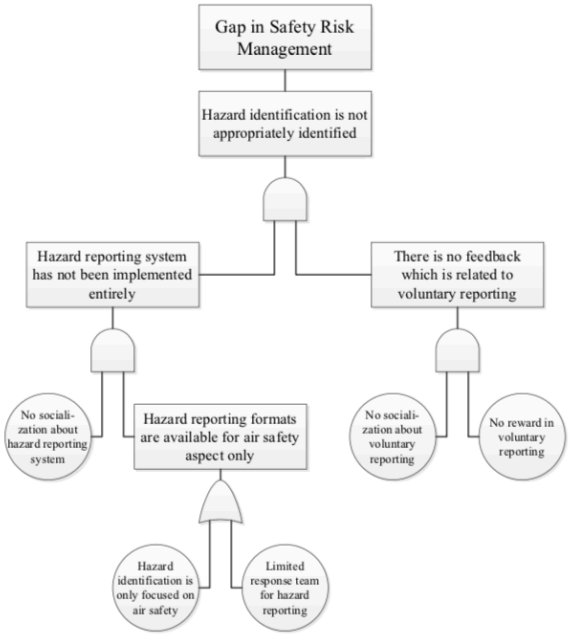

Fig. 3. Fault tree analysis for gap in safety risk management.

related to voluntary reporting are resulted from two basic events which are connected with AND gate. They are no socialization about voluntary reporting and no reward in voluntary reporting.

Fig. 4 shows the FTA for failure in safety assurance. There are four intermediate events and three basic events. In Fig. 4, the first intermediate event is the incompatibility of advanced development of elements in SMS. This failure comes as a result from two subsequent failures which are connected with AND gate, i.e., there is no procedure in SMS assessment and there is no planning for SMS assessment in the internal company. The first is resulted of a basic event, namely, the company has no authority in assessing the SMS; while the second is resulted from a basic event (there is no financial budget in assessing the SMS) and an intermediate event, i.e., there is no initiation stage for the implementation.

Fig. 5 shows the last FTA, which is FTA for failure in safety promotion. There are two intermediate events and two basic events. The first intermediate event, namely, safety communication element is not appropriate, acts as another intermediate event since it is resulted from another intermediate event, i.e., safety information has not been socialized entirely. The last intermediate event is resulted from two basic events that are connected with AND gate, i.e., there is a lack of enthusiasm from the company and the information is out of date.

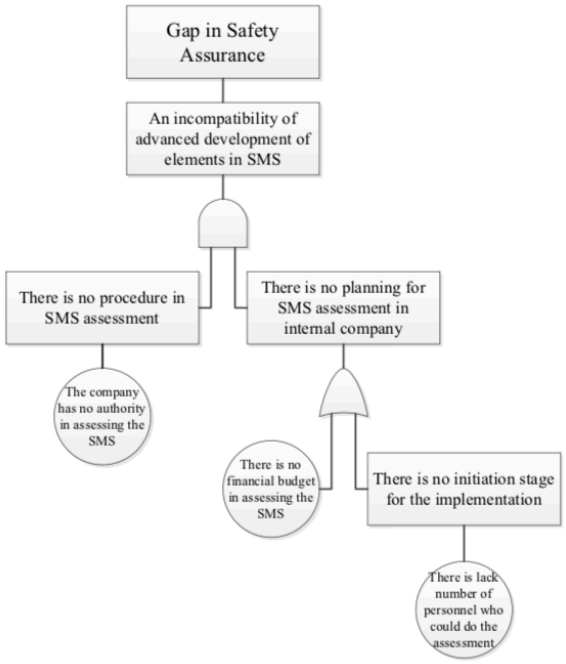

Fig. 4. Fault tree analysis for gap in safety assurance.

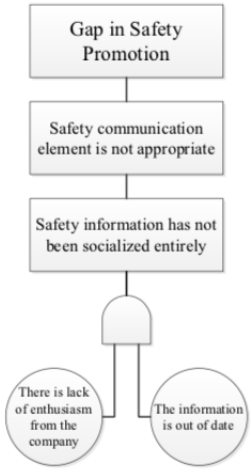

Fig. 5. Fault tree analysis for gap in safety promotion.

TABLE III. BARRIER ANALYSIS WORKSHEET OF GAP IN COMPONENT SAFETY POLICY AND OBJECTIVES

Target	Hazard	Barrier	Barrier Assessment	Recommendation
Company's overall Safety policy is not communicated well yet	Operational personnel tends to have more role in safety	Policy: Provision of job description related to safety policy to the personnel	The current job description has not involved safety policy, especially on administrative and marketing divisions	Provide job description associated with the safety policy to all existing personnel
		Procedure: Provision of training for new employees related to safety policy	Existing employees are less informed about safety policy	Evaluate employees regularly on safety policies
	Lack of personnel who understands more about safety	People: Training to management to understand safety policy	It is needed to add the number of trained employees	Add employees for training and socialization of safety policy
Safety policy procedures requires a long period of time to be reviewed	No review procedures is available	People: The procedure is established by board of directors	It takes too long	Add an expert personnel in evaluating company's safety policy
The company does not have a final authority	An authority is given from Juanda International Airport	Policy: Any information related to flight activity has to be coordinated by the authority	An information error might occur in busy time	Provide an authority for each airport
	There is limited number of airlines	Promotion: Landing fee exemption for one year	Promotion is too detrimental to the company	Add potential business around the airport to further attract more airlines
	Limited access to public transportation	Product: Cooperate with local governments by providing public transportation to the airport	The number of public transportation to the airport is still limited	Cooperate with the local government by adding public transportation to access the airport and increasing business and tourism potential

C. Barrier Analysis

The barrier analysis is then employed to recognize the reason why a failure happened. After all, it is also used to identify how the failure can be prevented; thus, some actions of recommendation could be suggested to prevent the failure. The barrier analysis is conducted by using a top event as target and a basic event as a hazard. In this research, the barrier analysis uses 8P approach (see Section II).

The main elements of the barrier analysis worksheet are the targets, hazards, barriers that have been executed, assessment of the barrier, and recommendations for improvement. The target is an intermediate event generated from the FTA that has been done previously, meanwhile the hazard is the basic event of the FTA and the barrier itself is an action that should be done by the company to prevent the hazard.

Since there are four components in the SMS—as a consequence there are four FTA, there are also four barrier analysis worksheets. Table 3 shows the barrier analysis worksheet for gap in safety policy and objectives. (The complete barrier analysis worksheets are available from the authors on request.)

IV. CONCLUSION

This research tried to analyze the gap between the airport SMS with the actual condition. A case study has been conducted in Adisumarmo International Airport. It is located in Boyolali, Central Java Province, Indonesia. A coordination with a state-owned enterprise in Indonesia which is responsible for the management of airports also has been done to carry out this research.

The initial gap analysis checklist (see Table 1 for the example on the first component and Table 2 for the recapitulation) has been carried out to investigate what has been done by the company with the real situation. Seventy-one questions in safety management manual (Doc 9859) [8] that come from four components (safety policy and objectives, safety risk management, safety assurance, safety promotion) and twelve elements are used in this research. There are 9 clauses that are not fulfilled; 6 of them are partially executed while the rests are not yet executed ("No" answers). On the other word, the company has performed 92.68% of the required components in airport SMS. In details, 93.94% is done in safety policy and objectives component, 93.85% is in the component of risk management, 88.89% is in the component of safety assurance, and 94.92% in the component of safety promotion.

Further, since there exist gaps in several conditions that have been identified in the initial gap analysis checklist, the FTA is then employed to identify how the systems could fail to meet the standard. Four FTA are established since the gap appeared in all components in the SMS (see Section III for the details of the FTA). The recommendations to avoid the failures are then suggested by using the barrier analysis.

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