APPLICATION OF HUMAN FACTORS ANALYSIS AND INTERVENTION IN STRUCTURING INDONESIAN NTSC'S RECOMMENDATIONS: A CASE STUDY OF WAMENA AIRPORT AIR ACCIDENTS

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STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person.

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ABSTRACT

Wamena airport experienced accidents in 2002, 2008, 2009, 2013, 2015, and 2016. All accidents were cargo flights and in approach and landing flight phases. As the Swiss Cheese concept accident happened when errors penetrated safety defenses' layers in straight line. Structuring (Indonesian NTSC) KNKT's investigations, under HFACS framework to understand the human factor failures type and HFIX strategy to close the failures by applying the recommendations, need to be done in air accident investigation. Prioritizing the implementation's recommendations using AHP, eleven aviation experts and practitioners were questioned in this study, when failure intervened by two or more interventions. There were layers without any failures in accident 2008, 2013, and 2016. Accident in 2016 has no recommendation due operators' safety actions were considered relevant to block failures. Accidents in 2002, 2009, 2013, and 2015 have failure which intervened by two or more recommendations and AHP was used to prioritize the intervention. There were failures remaining open in accident 2002, 2009, 2013, and 2016. Repetitive failure of repetitive accidents in 2002, 2009, 2013, 2015, and 2016 is an un-stabilized approach and has not been blocked with effective interventions. HFACS and HFIX are useful to framework accident investigation, preventing similar accident happened in the future.

Keywords: HFACS, Swiss Cheese, HFIX, AHP, Un-Stabilized Approach.

DEDICATION

I dedicate this works for the Aviation Safety of Indonesia

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CHAPTER 1 - INTRODUCTION

1.1. Background

Komite Nasional Keselamatan Transportasi (KNKT) or Indonesian National Transportation Safety Committee (NTSC) published an aircraft accident final report on September 26, 1997. The following accidents and incidents were happened in Indonesia investigated, reported, and stored in KNKT's database. There were 191 accidents and incidents investigated from 1997 until 2019 in total in the database. This study is focusing on what happened in Wamena airport of Papua, and total Papua events were 53 accidents and incidents during the period as shown in Figure 1.1.

Figure 1.1. Indonesia Air Accidents and Incidents 1997-2019 (KNKT)

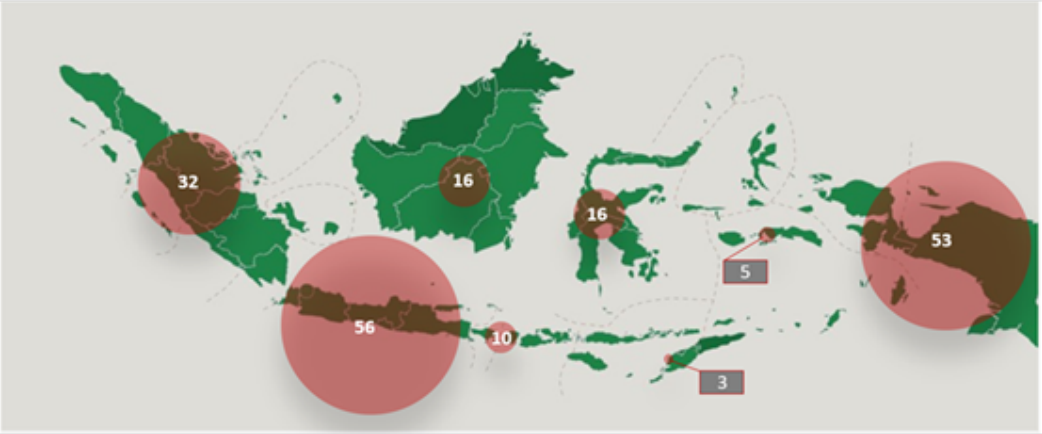

Figure 1.2. Area of Air Accidents and Incidents in Indonesia (1997-2019) (KNKT)

These accidents and incidents happened spreading all over Indonesia's area. Giving an overview of area distribution, this study divides into eight groups: Sumatera, Java, Kalimantan, Bali and West Nusa Tenggara, Sulawesi, East Nusa Tenggara, Maluku, and Papua. The total accidents and incidents in each group are 32, 56, 16, 10, 16, 3, 5, and 53 respectively as shown in Figure 1.2. Based on some characteristics of 53 accidents and incidents happened in Papua, 24 accidents and 29 incidents, eight turbo jet engine aircrafts and 45 propeller aircrafts, 50 fixed wing aircrafts and three rotary wing aircrafts or helicopters, one agriculture 21 cargo and 31 passenger flights. From flight phases group consists of four on takeoff, eleven on cruise and descend, nine approach, 27 landing, and two on ground phase as shown in Table 1.1.

Table 1.1. Papua Accidents and Incidents Characteristic Analysis 1999-2019 (KNKT)

Papua Accidents & Incidents Report 1999-2019					
53 Events					
Level of Damage					
29 Incidents			24 Accidents		
Type of Propulsion					
8 Turbojet			45 Propeller		
Percentage of Fixed Wing & Rotary (Helicopter) Analysis					
50 Fixed Wing			3 Rotary Wing		
Type of Operation					
1 Agriculture Flight		21 Cargo Flights		31 Passenger Flights	
Phases of Flight					
4 Take off	0 Climb	11 Cruise/Descend	9 Approach	27 Landing	2 On Ground

Incidents and accidents can be happened not only in an airport but on-route of a flight, based the published report by KNKT since 2002 until 2017 incidents and accidents happened in Papua's airports or airstrips, Wamena Airport experienced ten incidents and accidents as showed in Figure 1.3.

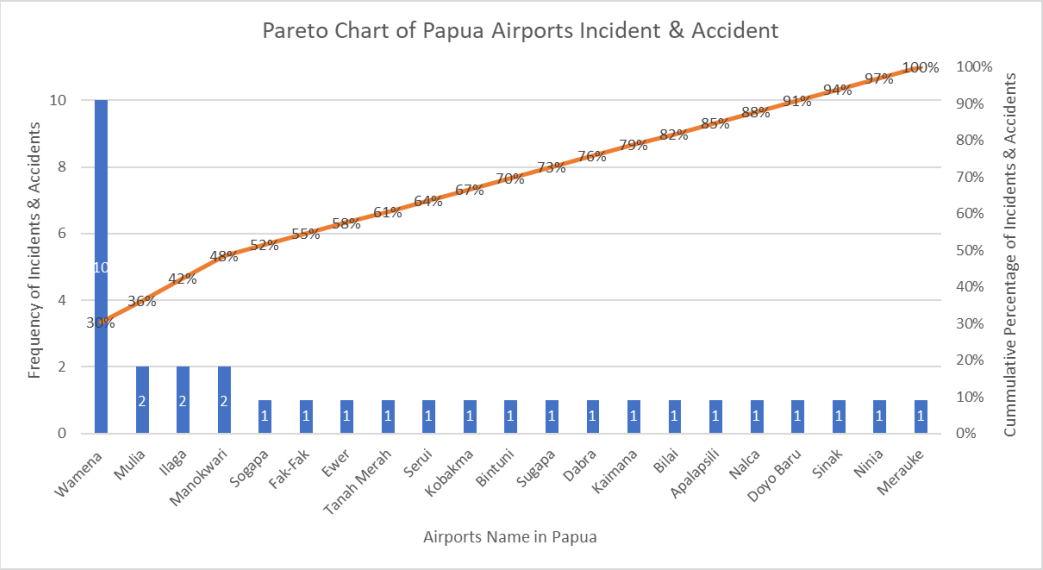

Figure 1.3. Pareto Chart of Papua Airports Incident and Accident (2002-2017) (KNKT)

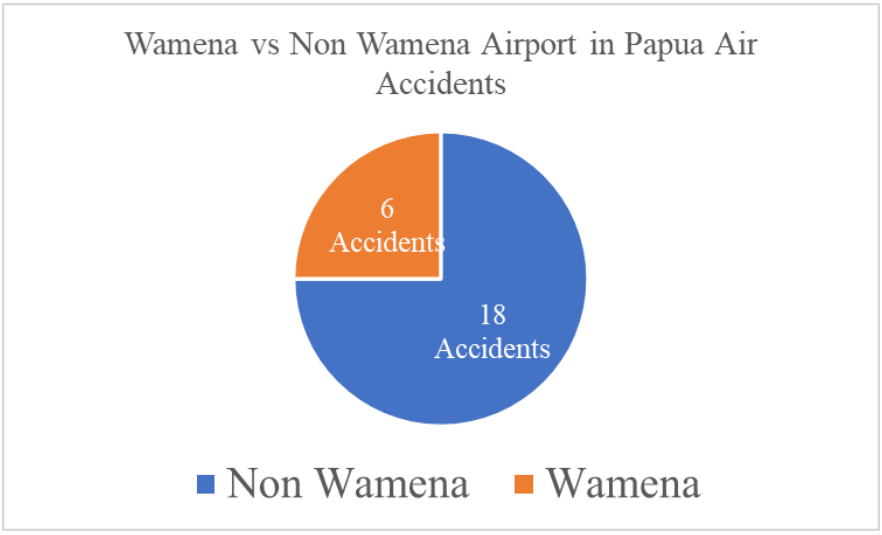

Figure 1.4. Wamena vs Non Wamena Airport in Papua Air Accidents (2002-2017) (KNKT)

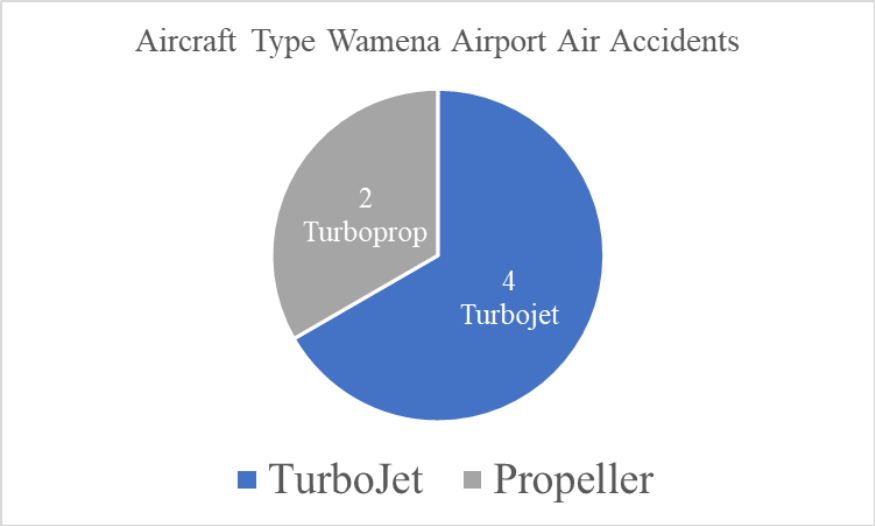

Figure 1.5. Aircraft Type Wamena Airport Air Accidents (2002-2017) (KNKT)

An aircraft accident is where an aircraft experienced mishap event and result in aircraft substantial damage and person suffers serious injury or death, incident means occurrence other than accident Civil Aviation Safety Regulation (CASR) 830. Total 24 Papua accident events of Table 1.1., Wamena airport experienced six accidents or 25%. Those six accidents all were cargo flights and in approach and landing flight phase, four of them turbo jet aircraft and two were propeller driven aircraft as shown in Figure 1.4., and Figure 1.5.

Structuring in methods used or by frame working the finding of accident's reasons should be properly done with effective intervention actions to reduce accidents rate or preventing future happening. This study proposes the Human Factor Analysis Classification System (HFACS) framework and Human Factor Intervention Matrix (HFIX) interventions as introduced by Weigmann and Shappell (2003) in aviation accidents and incidents. The framework was also used for various industries studied by Garret et.al. (2009), Diller et.al. (2013), Madigan et. al. (2016), and Theophilus et. al. (2017) detailed review shown in Chapter 2.5.1. In aviation HFACS framework study was used by Efthymiou et.al. (2019), Daramola (2014), Harris et. al. (2008), Harris et. al. (2013), Widyanti et. al. (2018), and Filho et.al. (2019) for aviation civil, military, helicopter accidents or incidents in detail review shown in Chapter 2.5.2. A combination of HFACS in the Unsafe Act layer and HFIX as the intervention's

strategy of aviation errors, incidents, and accidents was used in study of Shappell et.al. (2007), Chen et. al. (2013), Lin et. al. (2015), Chen et. al. (2016), Chen et.al. (2017), and Chen et. al. (2018) detailed review shown in Chapter 2.5.3. Identifying the error in aviation using HFACS for all layers combined with Analytical Hierarchy Process (AHP) was used by Kilic et.al. (2019) in the study as per review shown in Chapter 2.5.4. Wamena airport and runway along with available Instrument Flight Rule (IFR) approach detail description can be seen in Chapter 3.4.

1.2. Research Problems

Air Accident investigation needs a tool or framework to guide the process. Giving the failures identified during the investigation and effective recommendations to block the errors or failures will prevent similar accidents from happening in the future when action comprehensively done by stake holders. Case studies of Wamena airport experienced the highest rate of incidents and accidents as shown in Figure 1.3., ten events were compared one or two for other airports and airstrips all over Papua between 2002 until 2017. The six accidents in Wamena airport which were investigated and reported by KNKT on April 26, 2002, were cargo flights and in landing phase. Even though KNKT has analyzed and published the findings and made recommendations but other accidents in 2008, 2009, 2013, 2015, and 2016 another cargo flights in approach and landing phase were still happening.

1.3. Research Objectives

The objectives of this research are:

1. To structure KNKT's investigation using HFACS and human error intervention strategy of the recommendations for each defense layer in these accidents.
2. To prioritize implementation recommendations preventing layer's penetration when the failures on each layer intervened by more than one recommendation.

1.4. Significance of Study

Three significant reasons of the study are:

1. Structuring six accidents KNKT's findings in Wamena airport using HFACS framework.
2. Modelling a human error recommendations' intervention using Analytical Hierarchy Process (AHP).
3. Comprehensive experts from ATC, engineers, authority, and pilots of the airline.

1.5. Research Questions

The questions need of the study are:

Why all these accidents were in approach or landing phase?

Why does Wamena airport experiences air accident regularly?

How do the operators, ATC, and authority prioritize the recommendations and policy made to prevent accidents happening again?

1.6. Expected Outcome

By structuring the investigation process by HFACS framework and choosing correct priority of human error interventions (HFIX) strategy made, layers of defend will not be perforated and accidents prevented.

1.7. Limitation

The study of Wamena air accidents, which were only investigated and reported by KNKT.

CHAPTER 2 - LITERATURE REVIEW

2.1. Swiss Cheese Model

Human factor initially was introduced and developed by James Reason as organizational approach model on human errors (Reason, 1990). Shown in Figure 2.1., known as "Swiss Cheese" Model. The last defence layer is unsafe act where active failures located, in the past air accidents investigation primary targeted this layer and commonly called pilot's errors. It can be understood by looking this concept that mishaps happened when four layers of defences fail to block the failure making straight line penetrating all layer's result in incidents or accidents. The unsafe act layer is where the pilots are doing the flying activities and can contribute direct to accident. But as this is the last layer pilots also be able to prevent accident or incident happened by understanding, identifying and then action blocking it.

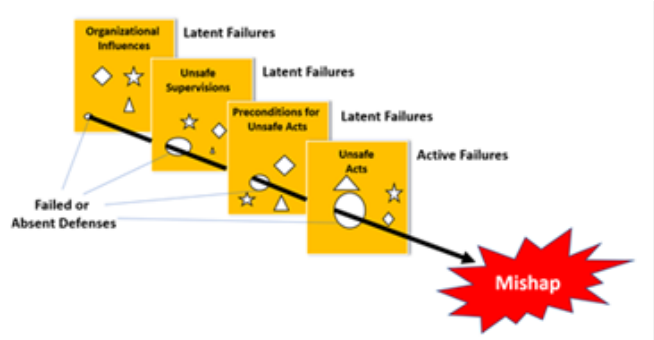

Figure 2.1. "Swiss Cheese" Model of Accident Caution (Reason, 1990)

2.2. Human Factor Classification Analysis System (HFACS)

Understanding the Swiss Cheese and its development into HFACS is like Fishbone Diagram as shown in Figure 2.2., which multicausal of different level layer will result in mishap if not corrected as earliest possible. Mishap is contributed from different category Organizational Influences, Unsafe Supervision, Pre-Condition of Unsafe Act, and Unsafe Act. which then each category is also contributed of its subcategories.

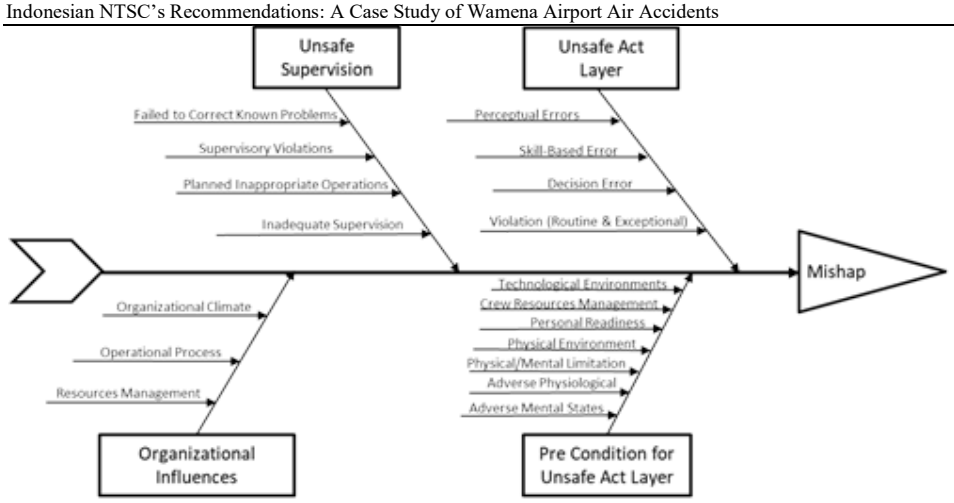

Figure 2.2. Fishbone Diagram of HFACS

HFACS Framework as shown Figure 2.3. (Weigmann and Shappell, 2003) developed and defining the "holes" or absent of defenses in the "Swiss Cheese" Model (Reason, 1990) and ideally used by investigators to analyze human factor accidents framework. In this study will analyze the six accidents that happened in Wamena airport using the HFACS framework.

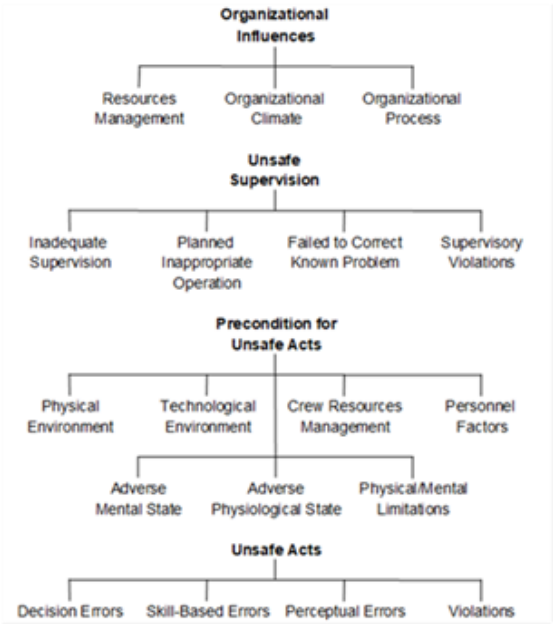

Figure 2.3. HFACS Framework (Weigmann & Shappell 2003)

Level 1 Unsafe Acts:

1. Decision error is "Thinking" errors came from consciousness, goal oriented behavioural mistake, misuse, and misinterpretation relevant information. Poor execution of procedures and choices e.g., inappropriate manoeuvres or procedure, systems & procedures inadequate knowledge, exceeded ability, wrong response to emergency.
2. Skill-based error is practice behaviour occurs with little or no conscious, a mistake due to a complacent approach instigation. In examples such as inadvertent switches activation, omitted checklist item breakdown visual scan, inadvertent flight control uses poor technique, airmanship, over controlled of flight, too reliance on automation, prioritize attention failure, overload task, negative habit, distraction, see & avoid failure.
3. Perceptual Error is when sensory input is degraded, resulting inaccurate or incorrect action being implemented. In examples such as night flying, poor weather, visually impoverished environment visual illusion, spatial disorientation, vertigo misjudge distance, airspeed, altitude, clearance.
4. Violations consists of:
   a) Routine Violation "Bending the Rules" can be a habit in nature and are often facilitated by management structure, that accepts these violations to complete a task effectively. In examples such as inadequate flight briefing, unauthorized approach violation training rule, follow ATC radar, SOP, Manual violation orders or regulations.
   b) Exceptional Violation "Breaking the Rules" is an isolated departure from authority neither, typical of the individual or condoned by management. In examples such as unauthorized manoeuvre, improper take off technique fails doing aircraft performance computation, exceed aircraft limit, accept unnecessary hazard not current or qualified, below regulated altitude.

Level 2. Preconditions of Unsafe Acts:

1. Technological Environments categorizes a wide variety of technological issues. In examples such as equipment/controls design, automation, checklist display/interface characteristics, task factors.

2. Physical Environment categorizes the physical operation setting & ambient environment. In examples such as weather, altitude, terrain & lighting, vibration, heat, toxins.
3. Adverse Mental States of acute psychological and/or mental condition, that negatively affect performance. In examples such as mental fatigue, pernicious attitudes, misplaced motivation, stress, overconfidence loss situational awareness, task saturation poor flight vigilance, drowsiness get-home-itis, distraction, channelized attention circadian dysrhythmia.
4. Adverse Physiological acute medical and/or physiological condition that inhibit safe operation. In examples such as illness, intoxication, motion sickness hypoxia, fatigue, effects of Over the Counter (OTC) medications.
5. Physical/Mental Limitation categorized as permanent physical/mental disability that negatively impacts on operational performance. In examples such as vision, strength, intelligence, mental aptitude, general knowledge, chronic mental illness, insufficient reaction time, information overload, inadequate experience for situation complexity.
6. Crew Resources Management (CRM) includes a variety of communication, coordination, and teamwork issues that impact performance. In examples such as lack of teamwork, lack of assertiveness, poor communication/coordination pilots/ATC, lack of leadership, lack of adequate briefing, misinterpretation of traffics calls.
7. Personal Readiness consideration of off-duty activities that are required to operate effectively. In examples such as sufficient rest, alcohol restriction, poor dietary practise, poor risk judgement, self-medicating, overexertion, inadequate training.

Level 3. Unsafe Supervision

1. Inadequate Supervision inappropriate oversight and supervision of personnel and resources. In examples such as training, professional guidance, leadership, current publication, tech data, procedure, accountability lack, perceive authority lack, track performance failure, operational doctrine failure, over-task or untrained supervisor, track qualification, loss of supervisory situational awareness.

2. Planned Inappropriate Operation task assignment of known inappropriate operational issues. In examples crew pairing, risk assessment, not adequate crew rest, over workload.
3. Failed to Correct Known Problems classified as such when problematic issues are known to management and fail to act accordingly. In examples such as fail to correct inappropriate behaviour, fail to identify risk behaviour & correct safety hazard, fail to initiate corrective action, fail to report unsafe tendencies.
4. Supervisory Violations the wilful disregard of procedures, regulation, and policy by management. In examples such as assigned unqualified crews, fraud docs, inadequate docs, violated procedures, fail enforcing rules and regulation, authorized unnecessary hazard.

Level 4. Organizational Influences

1. Organizational Climate is viewed as the overall organizational atmosphere regarding culture, policy, & strategic direction. In examples such as Structure (chain of command, communication, supervisor accessibility or visibility, authority delegation, formal accountability of actions); Policies (promotion, hiring, firing, retention, drugs, alcohol, accident investigation); Culture (norms, rules, customs, values, beliefs, attitudes).
2. Operational Process categorized as the procedures that are carried out by management to achieve the desired. In examples such as Operation (operational tempo, incentives, quotas, time pressure, schedule); Procedures (performance standards, clearly defined objectives, procedures/instructions about procedure); Oversight (safety program, risk management program, monitoring & checking of resources, climate, safe work environment ensuring process).
3. Resources Management, management of assets along with personnel and financial issues to achieve the organization output goal. In examples such as Monetary/Budget Resources (excessive cost cut, lack of funding); Equipment/Facility/Resources (poor aircraft design, buying unsuitable equipment, fail to correct known design flaws).

2.3. Human Factor Intervention Matrix (HFIX)

The HFIX, which introduced by Shappell and Weigmann (2009), is three dimensional framework which pits four Unsafe Act against five interventions approaches and five evaluations criteria.

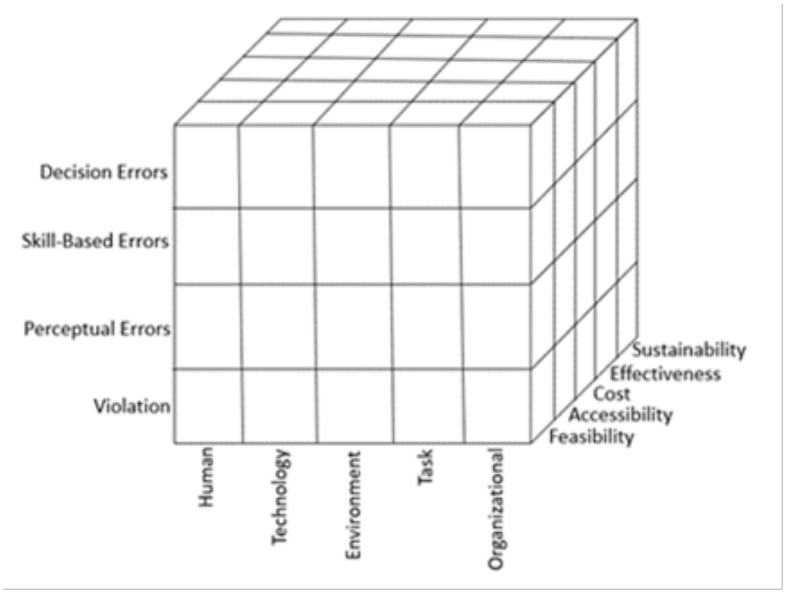

Figure 2.4. Human Factor Intervention Matrix on Unsafe Acts Layer (Weigmann & Shappell 2009).

Table 2.1. Summary of Human Factor Intervention Approach (Weigmann & Shappell 2009).

Approach	Subcategory	Advantage/Disadvantages
Organizational/administrative approach; focuses on amending management processes such as planning, organization, staffing, leadership, and control, to improve safety.	>Rules, regulation, & policies >Information management & communication >Research & special study >Human resources management	*Advantage:* The approach possesses comprehensive impact relatively quick to implement, & low budget requirement. *Dis-advantage:* The approach is easily repelled by. employees on a regular basis.
Human/crew approach; focuses on enhancing human resources management, such as through selection, staffing, training & promotion.	> Selection > Training > Motivation > Crew interaction	*Advantage:* The approach is relatively inexpensive to implement & has a relatively quick impact. *Dis-advantage:* Impact of the approach is limited by the nature of human capacities & subsequent reinforcement.
Technology/engineering approach; elucidates human error intervention strategies by using advance operational facilities, technology, job aids and user-friendly man machine interface.	> Design/repair > Inspection	*Advantage:* Human errors can be efficiently & accurately remedied by the approach. *Disadvantage:* The measures require extensive cost & long. time for implementation.
Task/mission approach; focuses on rearranging tasks to reduce the physical & mental workload operators	> Procedure > Manual	*Advantage:* The approach can be implemented with relatively low cost, & the impact can be realized quickly. *Dis-advantage:* Effectiveness can be limited by the nature. of the task, work environment, & compliance.
The operational/physical approach; focuses on improving the immediate environment of frontline. operations.	> Technological (layout & design) > Physical environment	*Advantage:* The approach is effective in eliminating tangible hazardous factors *Dis-advantage*: The measures can be very costly & sometimes Impractical

To evaluate the intervention strategies effectively, HFIX framework has 5 criteria:

- Feasibility: "Can it be done?" "To evaluate whether a strategy has potential to succeed currently".
- Acceptability: "Will operators accept it?" "To evaluate whether the organization agrees to support the strategy".
- Cost: "Can we afford it?" "To examine the financial and opportunity cost".
- Effectiveness: "Will it work?" "To evaluate whether the strategy achieved the company's objective".
- Sustainability: "Will it last?" "To evaluate whether a strategy satisfy the needs of stakeholders".

2.4. Analytical Hierarchy Process (AHP)

AHP is a tool for deciding in Multi Criteria Decision Making (MCDM) process. The tool is commonly used in aviation industry for planning, choosing alternative option, conflict resolving, and optimization. AHP developed by Saaty in 1971.

Table 2.2. AHP's Nine-Point Scale

Numerical Rating	Verbal Judgement
9	Extremely preferrable
8	Very strongly to extremely preferrable
7	Very strongly preferrable
6	Strongly to very strongly preferrable
5	Strongly preferrable
4	Moderately to strongly prefferable
3	Moderately prefferable
2	Equally to moderately preferrable
1	Equally preferrable

In AHP analysis pairwise comparisons and nine-point scale are applied to evaluate the relative importance among considering elements, along with a geometric mean approach to combine individual judgement and obtain the consensus judgement of the entire team. As suggested by Saaty (2008), consistency ration (CR) of the survey can be regarded as reliability of the responses. When CR is 0.1 or below, it is practicable logically, and when the ratio is 0.2 or below, it is acceptable. However, when the ratio exceeds 0.2, it can be regarded as deficient in consistency.

Four phases basic steps of AHP methodology are as followed (Saaty, 2008):

1. Structuring, create an appropriate AHP hierarchy model, which contains the goal, criteria, and the decision alternatives.

2. Data collection: organize a team of evaluators 'Decision maker (DM)' to assign pairwise comparison to the criteria in the AHP hierarchy model. Calculating Group AHP by aggregating in each pairwise, and consistency ratio (CR).

3. Normalized weights in different hierarchies: merge the pairwise judgment matrices of each hierarchy level with the geometric mean approach to find the corresponding consensus pairwise comparison judgement matrices.

4. Synthesis: synthesis the solutions for the decision problem.

Ratio matrix of all weights (W):

$$\mathbf{W} = \left[\frac{w_i}{w_j}\right] = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & \vdots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{pmatrix} \quad (1)$$

A pairwise comparison matrix (A):

$$\boldsymbol{A} = [a_{ij}] = \begin{pmatrix} 1 & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2j} & \cdots & a_{2n} \\ . & . & . & . & . & . \\ 1/a_{1j} & 1/a_{2j} & \cdots & a_{ij} & \cdots & a_{in} \\ . & . & . & . & . & . \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1/a_{in} & \cdots & 1 \end{pmatrix} \quad (2)$$

$$\boldsymbol{Aw = \lambda_{max.} w} \quad (3)$$

Where:

$\boldsymbol{\lambda_{max}}$: eigen value; $\boldsymbol{w}$: weight vector

$$\boldsymbol{CI = \frac{\lambda_{max} - n}{n-1}} \quad (4)$$

Where: $\boldsymbol{CI}$: consistency; $\boldsymbol{n}$: number of compare elements

Table 2.3. Average Random Consistency Index (RI)

N	1	2	3	4	5	6	7	8	9
Random Consistency Index (RI)	0	0	0.52	0.89	1.11	1.25	1.35	1.45	1.49

$$\boldsymbol{CR = CI/RI} \quad (5)$$

Where:

$\boldsymbol{CR}$: Consistency Ratio.

$\boldsymbol{RI}$: Average Random Consistency Index

$$\boldsymbol{G = (DM1)^{1/k} x (DM2)^{1/k} x (DM3)^{1/k} ... (DMk)^{1/k}} \quad (6)$$

Where:

G: Aggregation of judgement comparison matrix

k: Total of decision makers

DM1: Pairwise comparison matrix of Decision Maker 1 (DM1)

DM2: Pairwise comparison matrix of Decision Maker 2 (DM2)

DM3: Pairwise comparison matrix of Decision Maker 3 (DM3)

DMk: Pairwise comparison matrix of Decision Maker k (DMk)

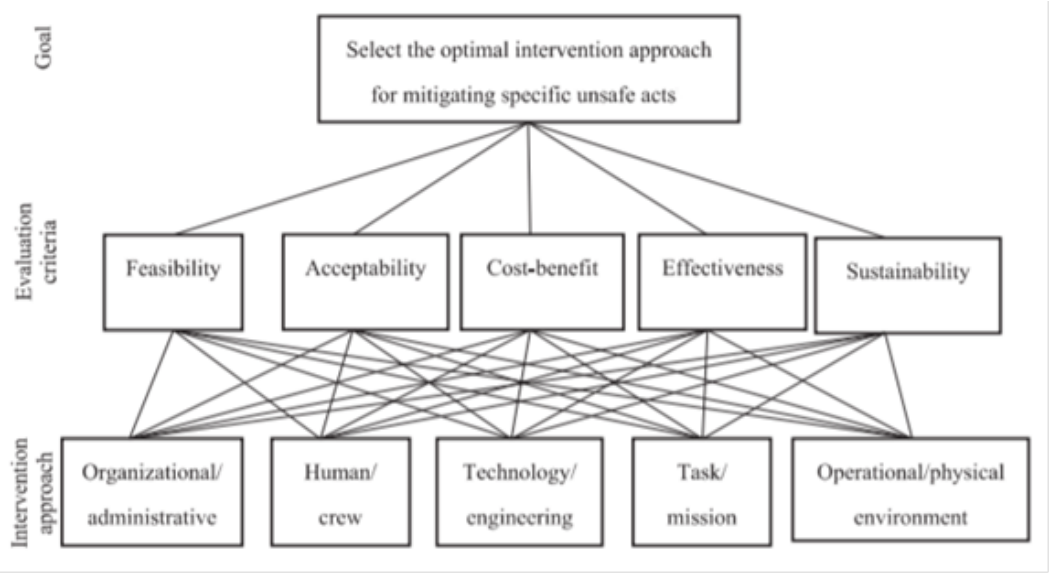

Figure 2.5. AHP Structure for Human Factor Intervention on Unsafe Acts Layer

2.5. Previous Studies

2.5.1. HFACS Framework in Various Industry

Human factors have been widely acknowledged and caused mainly of all incidents and accidents in high-risk complex systems in various industries. Human Factor Analysis Classification System (HFACS) is used to framework of incidents or accidents investigation. Construction industry having 1,000 accidents in year 1995 until 2009 and HFACS is developed to analyzing human caused of accidents, (Garret et.al., 2009) studied HFACS framework investigation in construction accidents combine with Human Errors Analyzing Training (HEAT) framework. In health care, (Diller et.al., 2013) studied HFACS framework of 105 serious events within two years, to resolving the deficiencies such as (not standard/not reliable, blaming "who" did the occurrence instead "why", not specific for actions plan, no standard nomenclature) in previous Root Caused Analysis (RCA) method used in the industry. (Madigan et. al., 2016) studied about UK's railway five types of incidents from 78 minor safety incidents between January 2012 till May 2014 report of seven UK's Train Operating Companies (TOC), using HFACS framework and the index of concordance to measure of interrater reliability's usefulness. (Theophilus et. al., 2017) propose a novel HFACS-OGI (Oil Gas Industry) by at level one adding Act of Sabotage under Violation, level two adding Contractor Environment under Environment Factor, at level 2 replacing Condition of Operator into Individual and Team, at level four adding Management of Change and Process Safety Culture and adding level five Regulatory and Statuary Influences with International Industry Standards and National Regulatory Framework as the sub level five. HFCAS-OGI is suitable to categorize eleven accidents of US Chemical Safety Board (US CSB).

2.5.2. HFACS Framework in Aviation

HFACS framework widely used by researchers in aviation, (Efthymiou et.al., 2019) studied about fifty Controlled Flight into Terrain (CFIT) between 2007 until 2017. Daramola 2014 analyzed accidents happened in Nigeria between 1985 until 2008 comparing accidents and fatality rates with global average levels using HFACS framework. Harris et. al., 2008 studied of 41 accidents in Republic of China (ROC)

between 1999 until 2006 frame-working with HFACS. In 2013 Harris et al also did research about 523 military accidents of Republic of China (ROC) Air Force to identify poor pilots training deficiencies with two major causals are errors of judgment and poor decision-making. Widyanti et. al., 2018 analyzing 53 Indonesian air accidents between 2001 until 2012 the incorporating with Hofstede's national cultures with HFACS's framework. In this study the Indonesian characteristics of high collectivistic, low uncertainty avoidance, high power distance, and masculinity dimension which influenced most to the air accidents. Filho et.al., 2019 studied about 211 helicopters accidents in Brazil between 2006 until 2015 used the HFACS framework.

2.5.3. HFACS and HFIX Frameworks in Aviation

Weigmann and Shappell (Shappell et.al, 2007) suggested, HFACS which is the framework of identifying human errors can be paired with HFIX as the intervention strategy framework when the causes of occurrence are determined.

Chen et. al., 2013 studied 31 investigated incidents report between 2009 until 2011, using HFACS framework of Unsafe Act Layer and HFIX intervention strategy implementations with Inter Rater Reliability. The major result recommendation on Organizational/Administrative and Human/Crew to implement on Decision Error and Violation respectively.

Lin et. al., 2015 analyzed 15 military accidents of Republic of China Air Force (ROCAF) approached under HFACS Unsafe Act layer framework and HFIX intervention with AHP to prioritize the hierarchy from eight commanders and 14 subordinates consists of ten pilots and four maintenance staffs. The top three results from commander order sequence weights are Task/Mission (0.215), Organization/Administrative (0.214, and Human/Crews (0.206). The subordinate order sequence weights are Task/Mission (0.203), Human/Crew (0.201), and Operational/Physical Environment (0.200).

Chen et. al., 2016 modelled HFACS framework on Unsafe Act layer, HFIX intervention strategy, Analytical Hierarchy Process (AHP), and Zero One Goal Programming (ZOGP) to mitigate skill-based errors in military flight operation, with

result skill-based errors in flight operation can be mitigated by Human/Crew intervention.

(Chen et.al, 2017) approached the study with HFACS, HFIX, AHP and Zero One Goal Programming (ZOGP) methods for one of near miss incident case study in one commercial flight. The comprehensive approach was not only participated by three experienced pilots who log on 8,000 flight hours each but maintenance manager, finance, and marketing as decision makers. ZOGP used for applying the intervention strategy within limited resources, budget, and manpower in the airline internally. The results: five interventions approach priorities to mitigate each unsafe act using AHP are 1. Technology or engineering vs. skill-based errors with 35.3%, 2. Human/crew vs. decision errors with 34.5%, 3. Operational or physical environment approach vs. perceptual errors with 32.6%, 4. Organizational or administrative approach vs. violations with 31.9%. ZOGP result to optimize of budget and manpower priorities as 1. Organizational or administrative with recommendation senior managers to motivate sub-ordinate in complying policy, Standard Operating Procedure (SOP) and regulations, 2. Human or crew with recommendation suspend the crews on duty for two weeks and send for Crew Resources Management (CRM) training, 3. Operational or physical environment with recommendation reducing interference from ambient environment.

(Chen et. al., 2018) studied 78 accidents applying HFACS framework on Unsafe Act layer and Human Factor Intervention Matrix (HFIX) to implement interventions strategy with hierarchical regression analysis. The main result Technology/Engineering intervention suitable to remedy Perceptual Error on Unsafe Act layer, and Human/Crew intervention on Decision Error in the same layer.

2.5.4. AHP-HFACS Framework All Layers

Kilic et.al, (Kilic et.al, 2019) did study in finding of the gross navigation errors cause during transatlantic flight and prioritizing using Fuzzy AHP within HFACS framework. Decision makers consisted of two very experienced Boeing 777 pilots who have more than 15,000 flight hours with more than 25 years of experience in flying the route and one senior first officer Boeing 777 pilot with 3,500 flight hours.

The result in the study, the highest errors came from supervision with first criteria 9.5% is "lack of training provided by companies, second 9.3% is "Use of inappropriate route for oceanic crossing by dispatchers", and third is 8.7% is "Failure to take measure against oceanic errors". The recommendations are that company should pay close attention on training for crews or flight dispatchers and company or crews should take preventive actions in oceanics errors.

2.6. Safety Management System (SMS)

Safety Management System (SMS) is a method to structure, identify, delineate, communicate, controlling, eliminating, and searching the risks. Weigmann and Shappell proposed SMS approached by HFACS integrated with HFIX, and ergonomic theory to correct errors for the organizations as shown in Figure 2.6.

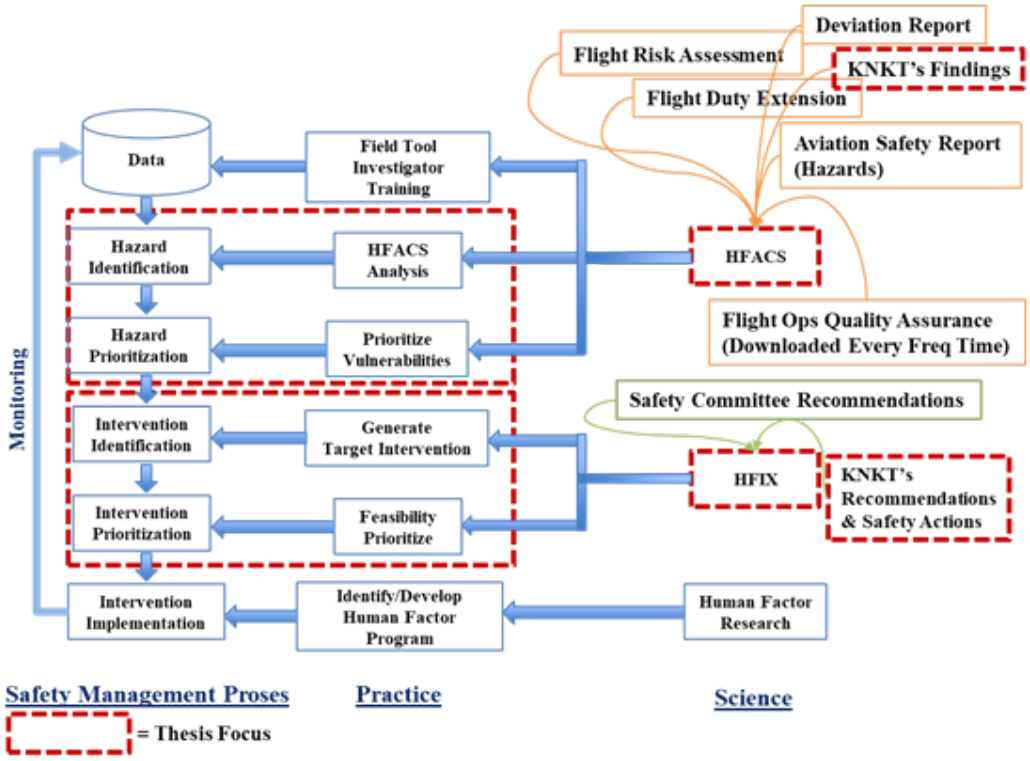

Figure 2.6. Safety Management System (SMS) Framework (Weigmann and Shappell 2009)

The thesis focuses on Swiss Cheese concept extended into HFACS framework and intervention strategy HFIX, mind mapping as shown in Figure 2.7. expanded by analyzing the latent and active failures from KNKT's finding then intervened by the recommendations from KNKT and Safety Action from the operator using AHP when the failure approached by two or more intervention to priority the interventions taken.

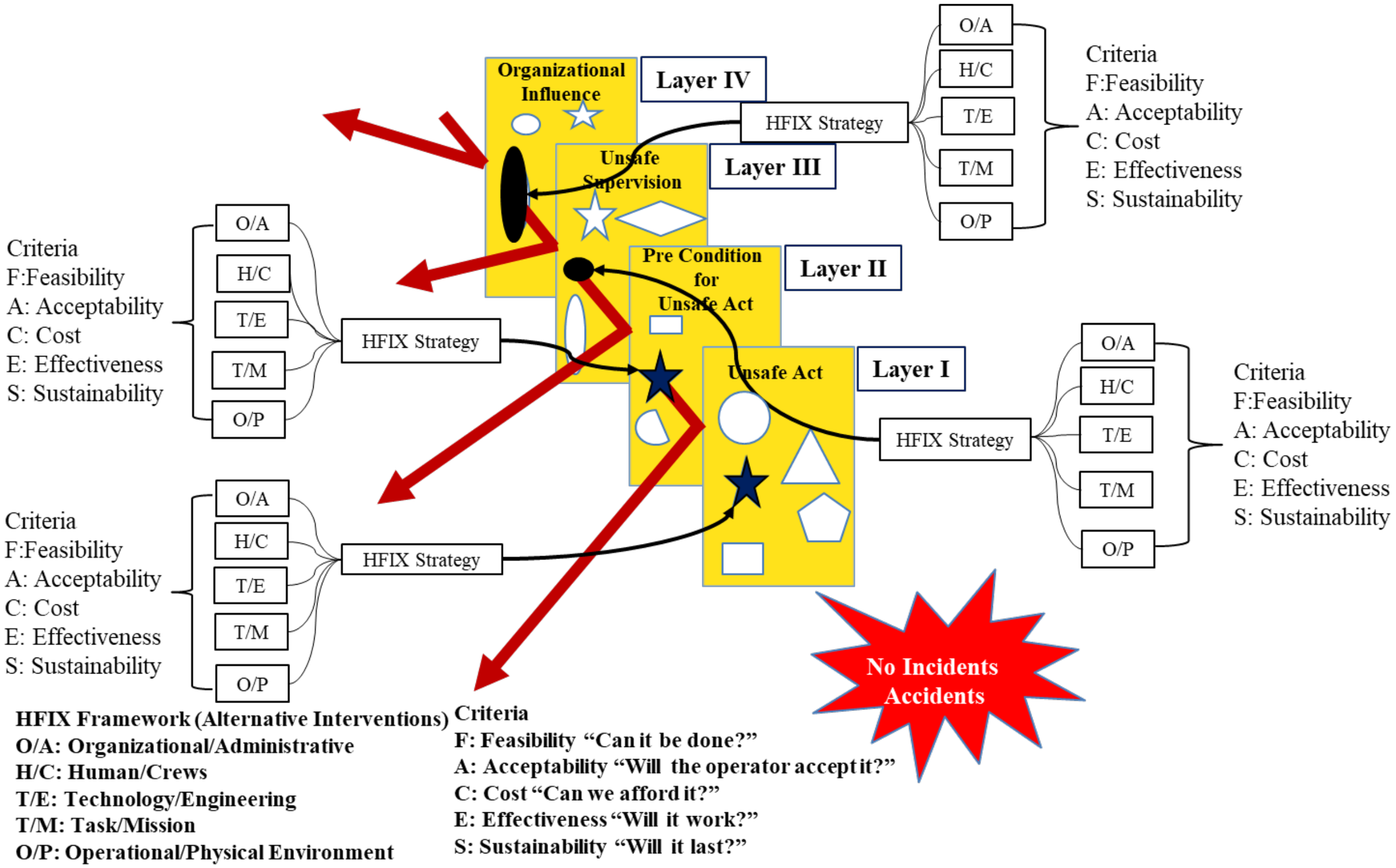

Figure 2.7. Mind Map HFACS Framework & HFIX-AHP Intervention Strategy Implementation

CHAPTER 3 – RESEARCH METHODOLOGY

3.1. Research Methodology

The research methodology is shown in Figure 3.1. Human factor classification analysis and intervention are used to approach the data of incidents and accidents investigated by Komisi Nasional Keselamatan Transportasi (KNKT) focusing accidents that happened in Wamena Airport. The priority interventions were taken and done by AHP from experts during briefing, discussion, and questionnaires filling. Consistency ratio check by Super Decision software. Aggregation matrix is done for the group AHP result weighing and analyzed.

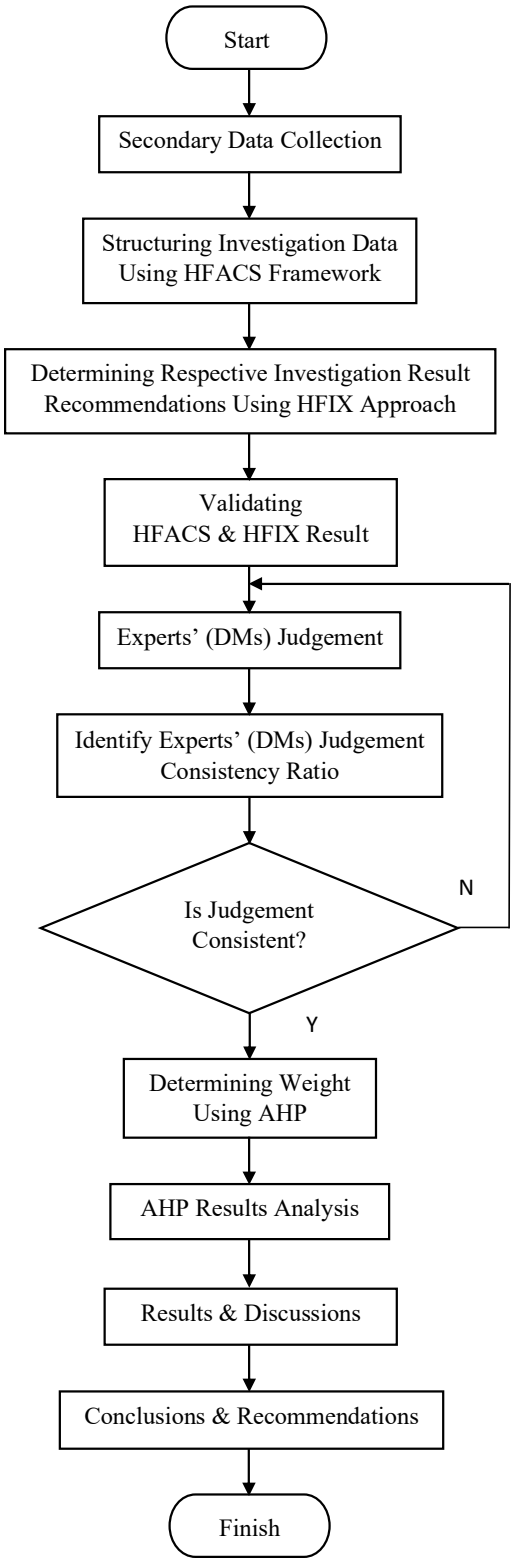

Figure 3.1. Research Methodology

3.2. Secondary Data Collection

This study used primary data and secondary data. The primary data were taken from the questionnaires filled from experts or The DMs of Pilots, Authority, and Air Traffic Controller (ATC). The secondary data were taken from official report of KNKT's investigation on the website from accidents happened in Wamena airport.

3.3. Structuring Investigation Data Using HFACS Framework and Determining Respective Investigation Result Recommendations Using HFIX Approach

Structuring the investigations or data report of KNKT's investigations or secondary data using HFACS framework and determining KNKT's recommendations to respective accident investigation result using HFIX approach. by the first author who has 28 years flying experience as pilot, advisor, and co-advisor with Doctorate level of education.

3.4. Validating HFACS & HFIX Result

Validating the previous step by conducting interview and discussion with experts from pilots, engineers, Air Traffic Controllers (ATC), and KNKT's investigators. Prior interview or discussion given to experts, who are experienced in Papua or Wamena operation, the map mapping of HFACS framework and HFIX strategy implementation will be briefed and introduced.

3.5. Experts' (DMs) Judgement and Identify Experts' (DMs) Judgement Consistency Ratio

The expert's judgment as Decision Maker (DM); DM1, DM2, DM3, DM4, and DMk of pilots, engineers, Air Traffic Controller (ATC) and inspectors collected through a survey in the form of the questionnaires. The judgements are to determine the priority of KNKT's recommendations when a failure is intervened by two or more recommendations. Designing simple and understandable questionnaires and collecting the filled ones for further step of research's calculation in group AHP global weight. The questionnaires consist of two types, first one is comparison between goal and the criteria as example shown in Figure 3.3. and secondly comparison between criteria

with intervention's alternatives as example given shown in Figure 3.4. AHP's hierarchy diagram of the goal, criteria and alternative as an example shown in Figure 3.2., were briefed as well prior filling the questionnaires. Discussion was also done with experts to have enrichen the alternative interventions of KNKT's recommendations of Wamena air accidents.

Identifying experts (DMs) judgement consistency ratio accepted by the study is 0.1 or below should be achieved. The Super Decision software calculation of questionnaires consistency should be satisfactory gained before group AHP can be calculated. Quantification of qualitative data from questionnaires is critical step or redo process should be done when data become inconsistent or invalid.

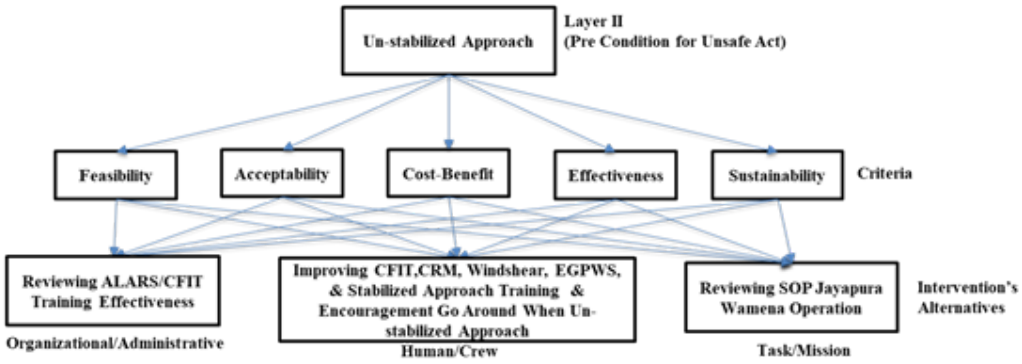

Figure 3.2. Analytical Hierarchy Process (AHP) of Wamena Air Accident for Layer II, Pre-Condition for Unsafe Act (KNKT 2015).

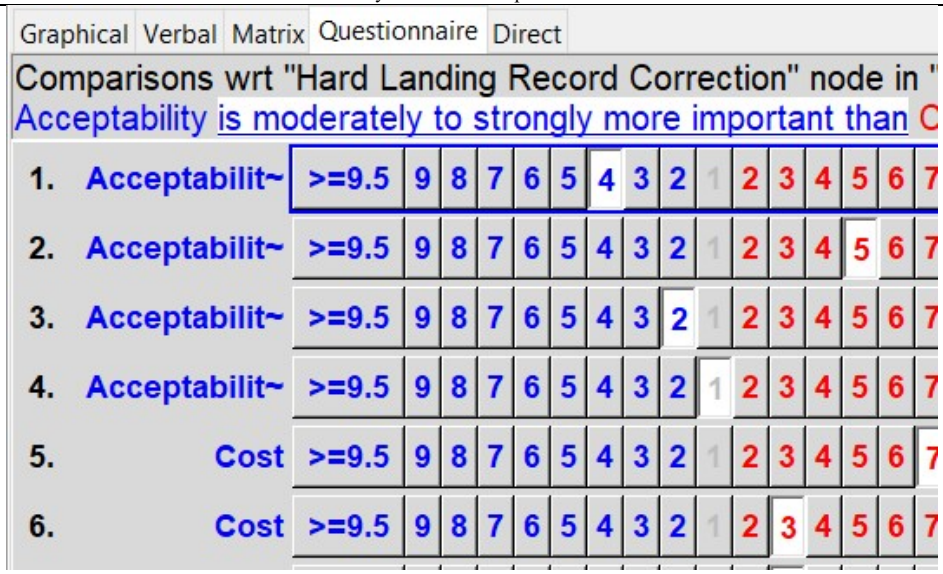

Figure 3.3. Example of Super Decision AHP Questionnaire between the Goal "Hard Landing Record Correction" Pairwise with HFIX Criteria of Accident 2016.

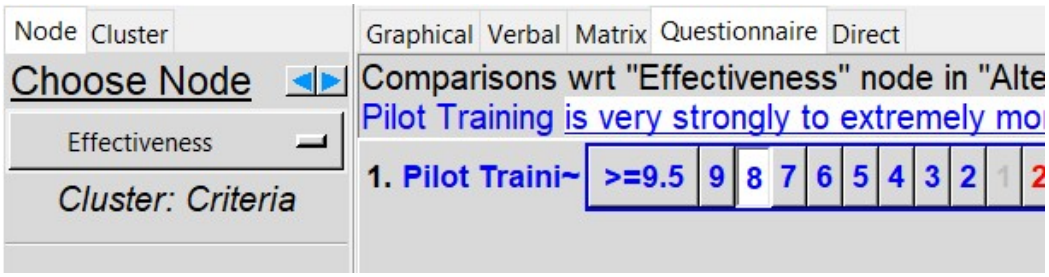

Figure 3.4. Example of Super Decision AHP Questionnaire between the Effectiveness' Criteria Pairwise with Interventions Alternative Pilot Training and Review Procedure.

3.6. Determining Weight Using AHP

Determining global weight of priority recommendations taken using Analytical Hierarchy Process (AHP) are done by Super Decision software version.3. To get the group AHP result, Formula 6 (Aggregation of judgement comparison matrix) is used then input into Super Decision software in matrix menu.

3.7. Location of Study

Due to Pandemic Covid 19 situation, briefing, discussion, and training of HFACS & HFIX frameworks and AHP questionaries done by online platform, phone, emails from home with the experts, and KNKT's office visit with strict Covid protocol.

All the accidents data are taken from Wamena airport air accidents, the airport is in Wamena City of Papua Province of Indonesia. Wamena airport condition can be explained the situation with approach charts shown in Figure 3.5., and Figure 3.6. The Jeppesen charts are taken from Aeronautical Information Publication (AIP) in each state and are standard internationally accepted.

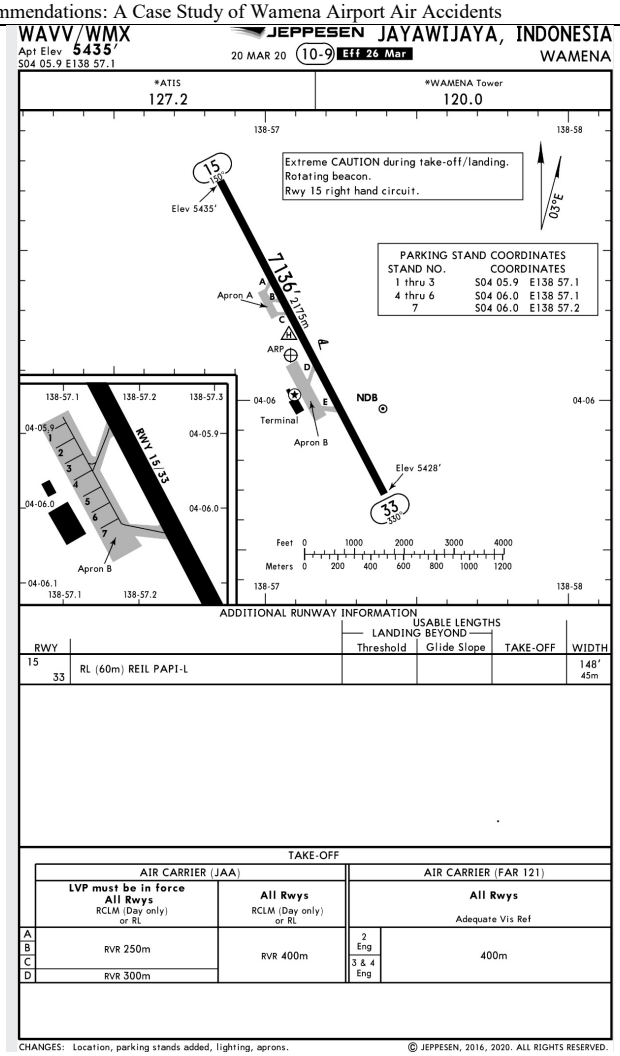

Figure 3.5. Wamena Airport Chart

Courtesy of Jeppesen

Condition of Wamena airport chart is depicted in Figure 3.5. described from top left to bottom right. ICAO four letter code of Wamena airport WAVV, three letter code WMX, with airport elevation is 5,435 feet, coordinate of the airport reference S04 05.09 E138 57.1, produced Mar 20, 2020, and effectively used Mar 26, 2020. Page 10 until 9, location Jayawijaya Indonesia. ATIS radio frequency 127.2 and Wamena tower radio frequency 120.0. Wamena airport has runway 15 with azimuth 150° and runway elevation is 5,435 feet and runway 33 with azimuth 330° with runway elevation 5,428 feet. It has runway length 7,136 feet or 2,175 meter and two aprons A and B with taxi way A, B, and C for apron A and taxi way C, and D for apron B. Wamena has note about "CAUTION during takeoff and landing", "rotating beacon",

"runway 15 with right hand circuit or right horse track pattern for visual approach", and notes for parking stands latitude longitude location on apron B stand one till seven. Additional runway information for runway 15 and 33, contains of Runway Lights (RL) sixty-meter, Runway End Identification Lights (REIL), and Precision Approach Path Indicator (PAPI) on the Left (L) side of runway, with runway width is 148 feet or 45 meters. Takeoff visibility minimum for air carrier under Joint Aviation Authority (JAA) can do the take off if Low Visibility Procedure (LVP) in force for day only with Runway Centre Line Marking (RCLM) available or Runway Lights (RL) is Runway Visual Range (RVR) 250 meters for Category (Cat) A (approach speed less than 90 knot), Cat B (approach speed 91-120 knot), Cat C (approach speed 121-140 knot), and for Cat D (approach speed 141-165 knot) is Runway Visual Range (RVR) 300 meters visibility. If LVP is not in force for all runways the visibility minimum is Runway Visual Range (RVR) 400 meters. Under Federal Aviation Regulation (FAR) take off minimum visibility for all runways required with adequate visual reference for twin engines, three engines, four engines' aircraft are 400 meters.

Require Navigation Performance (RNP) Instrument Flight Rule (IFR) approach chart for runway 15 depicted in Figure 3.6. The chart produced March 20, 2020, and effectively can be used after March 26, 2020. The chart is only available for aircraft Cat A (approach speed less than 90 knot), and Cat B (approach speed between 91-120 knot). The course for final is 152° started at point "POINX" at 8,500 feet with Minimum Decision Altitude (MDA) is 6,450 feet which is 1,015 feet above runway elevation 5,435 feet. At this MDA point VV401 if pilots can see the runway and in stabilized condition (correct speed between Vref-Vref + 20 knot, Rate of Descend (ROD) less than 1,000 feet per minute, power set, landing configuration, path angle, runway centerline, complete briefing, complete checklist and landing clearance received) flight can be continued for landing or else should do go around with procedure as follow "Turn Right direct to VV402 to PYRAM 12,000 feet to BALIM 13,000 feet for holding or instructed by Air Traffic Controller (ATC). Maximum speed for go around is 130 knot and minimum approach climb gradient is 3%". On the right top chart circle shape is Minimum Sector Altitude (MSA). Inbound track 155° to 110° is 13,000 feet as per note one, inbound track 110° to 320° is 17,000 feet, and 320° to 155° is 15,000 feet with reference sector from airport. The altimeter used is in hector Pascal (hPa) and the runway elevation is 184 hPa, the transition altitude is

Flight Level (FL) 180 or transition altitude 18,000 feet. The approach required the Global Navigation Satellites System (GNSS) of the aircraft. The highest point in Wamena airport area pointed in black arrow is 13,866 feet. BALIM's holding is left hand holding pattern with an inbound course of holding is 120° and outbound holding is 300°. The visibility minimum for Cat A and B is 5,000 meters and not applicable for Cat C and above aircraft.

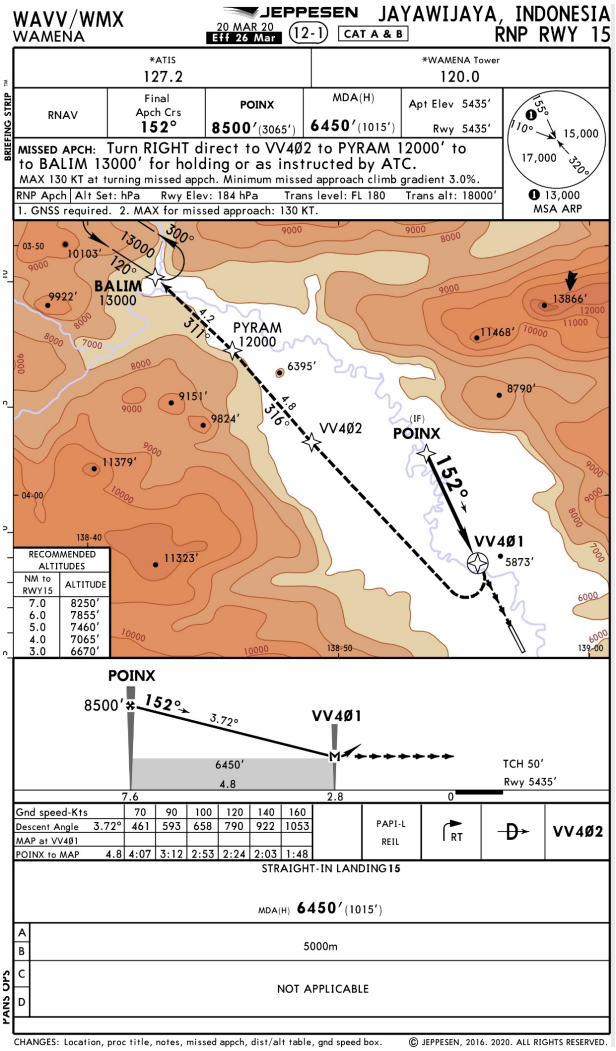

Figure 3.6. RNP Chart Runway 15

Courtesy of Jeppesen

CHAPTER 4 – RESULTS AND DISCUSSIONS

The latent failures or active failures are HFACS frame worked from KNKT's findings of the accident investigation for Wamena air accident each layer for each event year of the accidents. When this failure intervened with one KNKT's recommendation or safety actions done by operator, AHP will not be implemented unless when two or more recommendations applied in one failure AHP used to prioritize the intervention strategy.

4.1. HFACS Framework Investigation Data Structuring and HFIX Recommendations Approach

The HFACS framework data, structured in each layer of all accidents related. And the HFIX intervention strategy approach using each group category of all accidents related.

4.1.1. Unsafe Act Layer HFACS Framework of Accidents Data

Accident's findings reported by KNKT, occurring in 2002, 2008, 2009, 2013, 2015 and 2016 approached by HFACS focusing in the Unsafe Act layer. The findings are:

1. The decision error was "Failure to estimate distance to turn final properly" (KNKT 2002).
2. Skill-based errors were: Fire brigade not ready to handle emergency fire (KNKT 2002), At touchdown aircraft bounced three times, lead to failure of nose gear (KNKT 2002), The Rescue Fire Fighting Service RFFS team arrived at the aircraft about 10 minutes after the aircraft stopped on taxiway "E"& The RFFS commenced applying foam suppressant to the aircraft 5minutes after they arrived at the aircraft (KNKT 2008), Senior in Command (SIC) concerned about Pilot in Command (PIC) handling flight recorded the anxiety (KNKT 2009), The aircraft touchdown with 2° misalignment with runway and steer (KNKT 2013), At touchdown the engines were asymmetric (KNKT 2013), Pilots unidentified effect of wind shear speed increased 148-154 knots, Thrust N1 reduce from 72% to 38% resulted aircraft touched 35 m from

runway with 3.68 G (KNKT 2015), Touched down 125 m from beginning runway 15 with 3.25 G (KNKT 2016).

3. Routine Violations were: Approach with overspeed & high angle (KNKT 2002), Failure to respond Ground Proximity Warning System (GPWS) (KNKT 2002), Enhanced Look-Ahead function appeared to have been inhibited (KNKT 2009), Nonconformance of operator published operating procedure (KNKT 2009), Stabilized approach below 500 feet as per Company Operating Manual (KNKT 2013), At 5520 feet aural warning "CAUTION WINDSHEAR" not responded by pilots (KNKT 2015), Aural warning "SINK RATE" not responded by pilots (KNKT 2015), At 7000 feet runway not insight PM advised go round (KNKT 2016).
4. Exceptional Violations were: Fire Brigade Equipment Unserviceable & unable to handle the aircraft fire (KNT2002), Flap not deploy during landing due to overspeed protection (Note: Interview with Captain Pilot speed brake extended fully until after landed) (KNKT 2002), Second attempt approach after overshoot join low level downwind 150-350 feet above ground level (KNKT 2009), Not respond "DON'T SINK" & "TOO LOW TERRAIN" for overshoot on right downwind on second attempt approach (KNKT 2009), Not respond "DON'T SINK", "TOO LOW TERRAIN" (KNKT 2009), "BANK ANGLE", & "TERRAIN TERRAIN" during base lag turns second attempt approach (KNKT 2009), EGPWS aural warning been disregarded by pilots "TOO LOW TERRAIN" eleven times & "SINK RATE" 2 times (KNKT 2013), At 5700 feet two Nautical Miles (NM), aural warning "SINK RATE" (KNKT 2016).

4.1.2. Pre-Condition of Unsafe Act Layer HFACS Framework of Accidents Data

The HFACS framework investigation of KNKT's findings for air accidents in Wamena airport on this layer are:

1. Environmental Factors

    a. Technological Environments: Wamena Airport equipped with Non-Direction Beacon (NDB) only Visual Flight Rule (VFR) Airport

(KNKT 2002), Blank radio transmission at gap area from Air Traffic Controller (ATC) to aircraft (KNKT 2002), The Beta lights did not illuminate during the landing roll, precluding the use of reverse thrust. & the brakes overheated due to stopping the aircraft using maximum braking, without the assistance of reverse thrust (KNKT 2008). Crews not familiar with EGPWS equipment (KNKT 2009), Visual Approach Slope Indicator at Wamena airport was inoperative (KNKT 2015 & 2016).

b. Physical Environment: Wamena Airport elevation was 5083 feet (KNKT 2009), Visibility 4 KM, required VFR approach 4,8 KM (KNKT 2013), Gusty wind not (windshear possibility) reported by ATC to pilots (KNKT 2015), Visibility 2 KM, required VFR approach 4,8 KM (KNKT 2016).

2. Condition of Operator

a. Adverse Mental States: Other traffic with the same Estimate Time of Arrival (ETA) (KNKT 2002), Not respond "DON'T SINK" & "TOO LOW TERRAIN" for overshoot on right downwind on second attempt approach (KNKT 2009), Not respond "DON'T SINK", "TOO LOW TERRAIN" , "BANK ANGLE",& "TERRAIN TERRAIN" during base lag turns second attempt approach (KNKT 2009), Crews unable to develop good situational awareness (KNKT 2013), Passing Jiwika 10000 feet thrust idle, high altitude and over speed, 8000 feet flaps selected to 40°, 25 second after due to flap load limiter moved to 39.9° (KNKT 2015), Pilot in Command PIC insisted to continue approach Pilot Monitoring (PM) reminded the unstable condition (KNKT 2016).

3. Personal Factors

a. Crew Resources Management: Other traffic with same ETA, the sequence of landing not been declared by ATC (KNKT 2002), The controller activated the crash alarm before the aircraft entered taxiway "E". (KNKT 2008), Lack of crew coordination as the KNKT's

recommendation to effectively implemented (KNKT 2009), Minimum communication between pilots (KNKT 2013).

b. Personal Readiness: Absent of Emergency Respond Plan (KNKT 2008), Encouragement to pilots to go round when facing windshear (KNKT 2015).

4.1.3. Unsafe Supervision Layer HFACS Framework of Accidents Data

From KNKT's findings under this layer HFACS framework are:

1. Inadequate Supervision: Fire Brigade not ready to fight fire due lack of training (KNKT2002), Absent of Emergency Respond Plan (KNKT 2008), Crews did not receive Enhanced Ground Proximity Warning System (EGPWS) training stated in Company Training manual (CTM) (KNKT 2009), Operator should document specific training (KNKT 2009), Operator should document and implement Crew Resources Management (CRM) program (KNKT 2009), Company didn't give correct implementation of Company Operating Manual (COM) on stabilized approach (KNKT 2013), Company didn't give sufficient training for Crew Resources Management (CRM) implementation (KNKT 2013), Emphasize the implementation for Approach and Landing Accidents Reduction (ALAR) & Controlled Flight Into Terrain (CFIT) (KNKT 2015).
2. Planned Inappropriate Operation: Knowing the visibility below 4.8 KM for VFR pilots continued flying (KNKT 2016).
3. Failed to Correct Known Problems: Absent of Emergency Respond Plan (KNKT 2008), Trend hard landing not corrected, require installation flight data analysis (KNKT 2015), FDR recorded within 107 hours, 170 lags, 5 times hard landing 2G (KNKT 2015).
4. Supervisory Violations: Operator pilot not approved to give training for the foreign pilots (KNKT 2002), Absent of Emergency Respond Plan (KNKT 2008), This aircraft approved combi operation (cargo-passengers), at accident

was cargo flight but used passengers' weight & balance (Note not directly affect the accidents) (KNKT 2009).

4.1.4. Organization Influence Layer HFACS Framework of Accidents Data

The Wamena accidents investigation's finding under this layer category of HFACS framework are:

1. Organizational Climate: Government check pilot, lack of authority's supervision and exam validation for foreign pilots (KNKT 2002), No GO AROUND procedure for Wamena Airport for runway 15 (KNKT 2009), Lack regulator's supervision on the specific training implementation (KNKT 2009), Lack regulator's supervision the Crew Resources Management (CRM) implementation (KNKT 2009).

2. Operational Process: Absent of Emergency Respond Plan (KNKT 2008), Operator simulator training program did not cover action & responses to EGPWS aural alert & warning (KNKT 2009), Company Training Manual (CTM) stated about Ground Proximity Warning System (GPWS) but not Enhance GPWS (EGPWS) (KNKT 2009), No procedure detailing to inhibit terrain features in EGPWS (KNKT 2009), Known VFR traffics to/from Wamena 150 flights/day (KNKT 2013), Rubber deposit 600 m start from runway threshold (KNKT 2015), lack of safety program & risk assessment implementation (KNKT 2015 & 2016)

4.1.5. Human Factor Intervention (HFIX)

HFIX data are taken from Indonesian NTSC's narrative safety recommendations of the accidents in in Wamena on April 21, 2002; March 6, 2008; April 9, 2009; May 31, 2013; August 28, 2015; and Sept 13, 2016. The recommendations are structured into human factor interventions (HFIX) are classified as per following (Shappell et. al., 2007):

1. Organization or administrative approach: Directorate General of Civil Aviation (DGCA) requires reviewing the status of the RFFS equipment at

Wamena (a Class 2 Airport) to ensure compliance with ICAO Annex 14 Standards (KNKT 2008), Senior management of the operator distributed notice to pilots for operation department, safety notice from safety department (KNKT 2015). Indonesian authority needs to supervise the safety recommendation on safety program and risk assessment implementation (KNKT 2013).

2. Human or crew approach: Fire brigades personals need to be trained standardly (KNKT 2002), Directorate General of Civil Aviation (DGCA) needs to establish and exercise an Emergency Response Plan for Wamena in accordance with ICAO Annex 14 Standards (KNKT 2008), Retraining to be done for the pilots such as: Enhanced Ground Proximity Warning System (EGPWS), Crew Resources Management (CRM), Approach and Landing Accidents Reduction (ALAR), Controlled Flight into Terrain (CFIT), and encourage pilots to do "GO AROUND" when flight not met the criteria of stabilized approach either visual or instrument condition (KNKT 2009).

3. Technology or engineering: Airport authority need to check fire equipment regularly (KNKT 2002), A published holding and GO AROUND procedure for runway 15 at Wamena airport, and more airport equipment beside Non-Directional Beacon (NDB) need to be installed (KNKT 2002). Airport Fire Department need to be activated standardly (KNKT 2002). Operator/airline recommended to phase out aircraft type Transall C-160 (KNKT 2008), Visual Approach Slope Indicator (VASI) need to operate normally (KNKT 2015). Radio communication relay need to be set up due to limited range of aircraft communication in Wamena. Later even the minimum stated still as Visual Flight Rule (VFR) there is and instalment of a Required Navigation Performance/Global Positioning System (RNP/GPS) Instrument Flight Rule (IFR) approach chart for Category A & B aircraft but most of the aircrafts type which experienced accidents can't comply with this latest technology due not in the category. Establishment the flight data analysis program (KNKT 2015).

4. Task or mission approach: the risk assessment which should be done before departure weather in Wamena airport need to meet with VFR criteria, visibility 5 km and cloud ceiling 1000 feet above ground level (KNKT 2016).

5. The operational or physical environment approach: 150 flights daily, and Wamena airport surrounding by mountains with airport elevation 5430 feet limit the operation performance (KNKT 2013)

4.2. Wamena Air Accident 2002

The mind mapping of accident 2002 can be shown in Figure 4.1.

1. The recommendation's intervention "to stop non type certificate aircraft with special permit in 2004" will block all layers related foreign pilots and foreign aircraft for Wamena operation.
2. The recommendation's intervention "to regularly train the fire brigade personals" will block "fire brigade personals were not ready" failure.
3. The recommendation's intervention "to regularly check fire brigade equipment" will block "fire brigade equipment was unserviceable failure".
4. The failure of "ATC didn't clearly give traffic sequence for landing" in Layer III and "Five traffics ingoing and outgoing almost same time" in layer II have no recommendation's intervention which are still potentially penetrated by other errors in the future and can cause incidents or accidents.

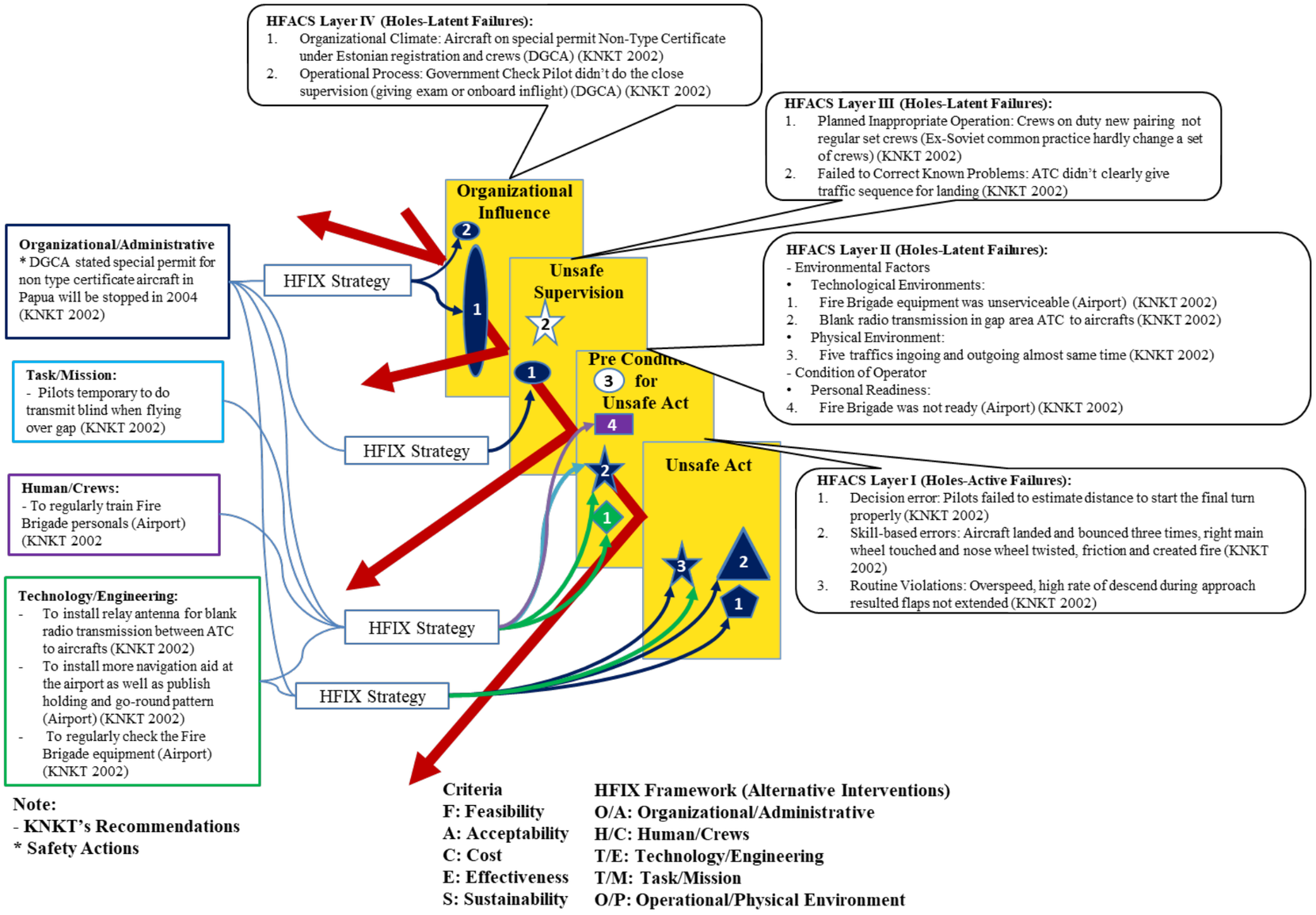

Figure 4.1. Swiss Cheese Model, HFACS Framework &
HFIX-AHP Intervention Strategy Implementation (KNKT 2002)

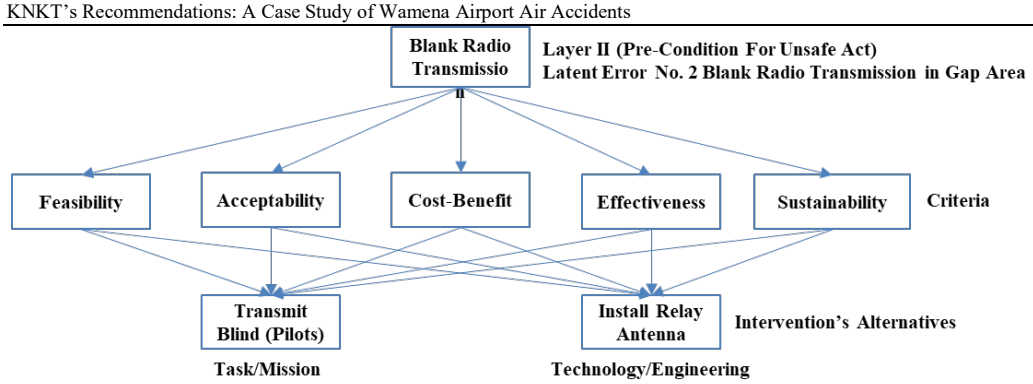

Figure 4.2. AHP Accident 2002 Blank Radio Transmission.

Table 4.1. Accident 2002 Group AHP Result-Avoiding Radio Blank Transmission

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"To avoid blank radio transmission"	0.14309	0.12595	0.05161	0.50654	0.17281	
Installing Radio Relay	0.27069	0.43225	0.10466	0.89016	0.67005	**0.66527**
TIBA Procedure	0.72931	0.56775	0.89534	0.10984	0.32995	**0.33473**

5. Avoiding radio blank transmission AHP as shown in Figure 4.2. and Table 4.1. the weighing result from eight DMs (3 ATC's, 4 pilots, and 1 inspector pilots) the group AHP result to be effectively implemented, "Installing Radio Relay" is more prioritized to be done, with 66.52% and pilots "Transmitting Blind Communication" between aircrafts in the air as known by Traffics Information Broadcasts Alert (TIBA Procedure) with 33.47% priority. TIBA is still needed since radio relay maintenance is hard to do (located top of the mountain, solar cell only with regular battery problem, security issues for maintenance staffs to access to the site and Wamena ATC is only Aerodrome Control Tower (ADC) with limited range and altitude authority to control the traffics with no RADAR availability.

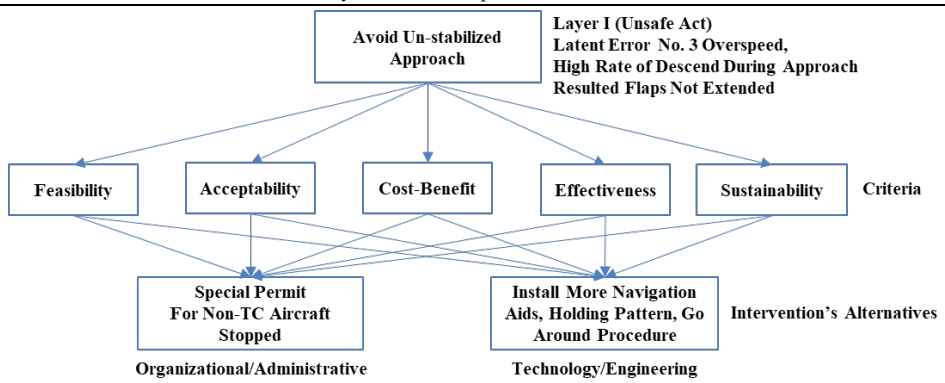

Figure 4.3. AHP Accident 2002 Avoid Un-stabilized Approach.

Table 4.2. Accident 2002 Group AHP Result-Avoiding Un-Stabilized Approach

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"To avoid un-stabilized approach"	0.15352	0.16761	0.05196	0.45607	0.17084	
Stop Permit Non-TC Aircraft	0.63576	0.12581	0.79989	0.64192	0.43251	**0.5269**
Add Nav Aid, Go Around & Holding Procedure	0.36424	0.87419	0.20011	0.35808	0.56749	**0.4731**

6. Avoiding un-stabilized approach AHP shown in Figure 4.3. and Table 4.2. weighing result of DM's member consists of four pilots, and one inspector pilot. The group AHP result to be effectively implemented for "Stopping Special Permit for Non-TC Validation Aircraft" is more prioritized to be done with 52.69% compared with "Adding Navigation Aids, Go Around Procedure & Holding Pattern" with 47.31% priority. Doing this is to stop the operation of foreign registered aircraft and foreign crews with many latent and active failures faced. "Adding navigation aids, go around procedure, and holding pattern" is still expected to be solved, and it is useful for other operators and aircrafts also for local crews since weather rapidly change is common in Wamena and if a flight even under Visual Flight Rule (VFR) for the approach can experience Instrument Flight Condition (IFC) during go around and go around procedure, holding pattern and more navigation aids can be the escape route if un-stabilized approach happened.

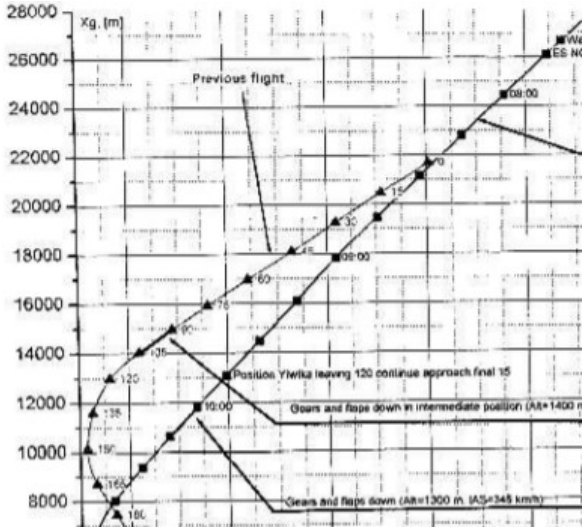

Figure 4.4. Flight Path of AN 72, April 21, 2002, While Landing at Wamena (KNKT 2002)

Shown in Figure 4.4. lateral graphic un-stabilized condition of accident aircraft with rectangle icon. The triangle icon's sequences were trajectories of previous traffic Indonesian registered aircraft which landed safely, flew Visual Flight Rule (VFR) approach over North gap (Pass Valley to Yiwika) then directly flew final for runway 15, correct altitude correct speed and correct configuration, compared with accident traffic the rectangle icon, too high, too close with final course and even passed final course, too fast and result landing configuration wasn't attained or un-stabilized approach end up with accident.

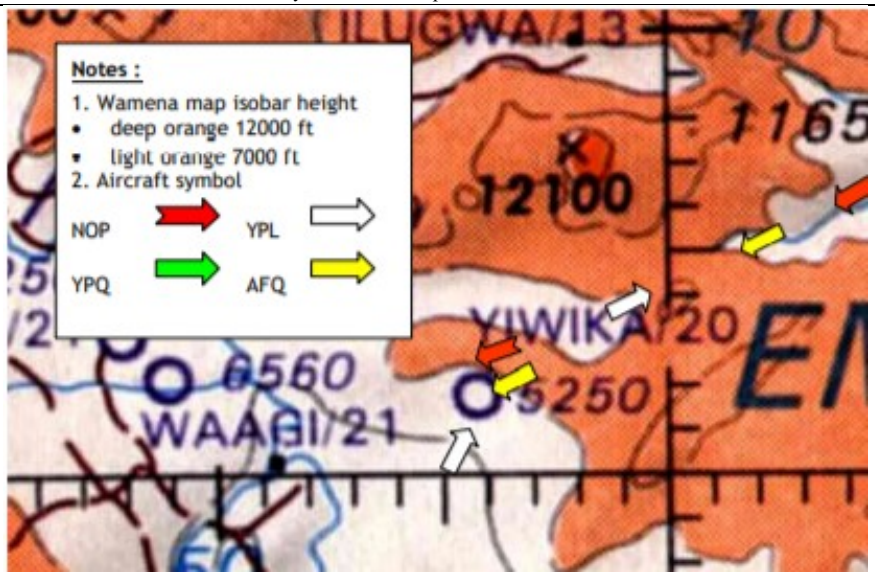

Figure 4.5. Situation at Wamena at 00:07 ZT till 00:09 ZT (KNKT 2002)

Depicted on Figure 4.5. Wamena airport terrain located in Baliem Valley is surrounded with mountains in deep orange colour with 12,100 feet in the left side and 11.810 feet on the right side of Pass Valley gap or north gap. Traffic flow situation on accident 2002 the red arrow was the accident traffic overtaking from above of another traffic the yellow arrow which was slower and lower over Yiwika. The green arrow was another traffic that was position and landed earlier from accident traffic. The white arrow was departure traffic from Wamena which also using same Pass Valley gap.

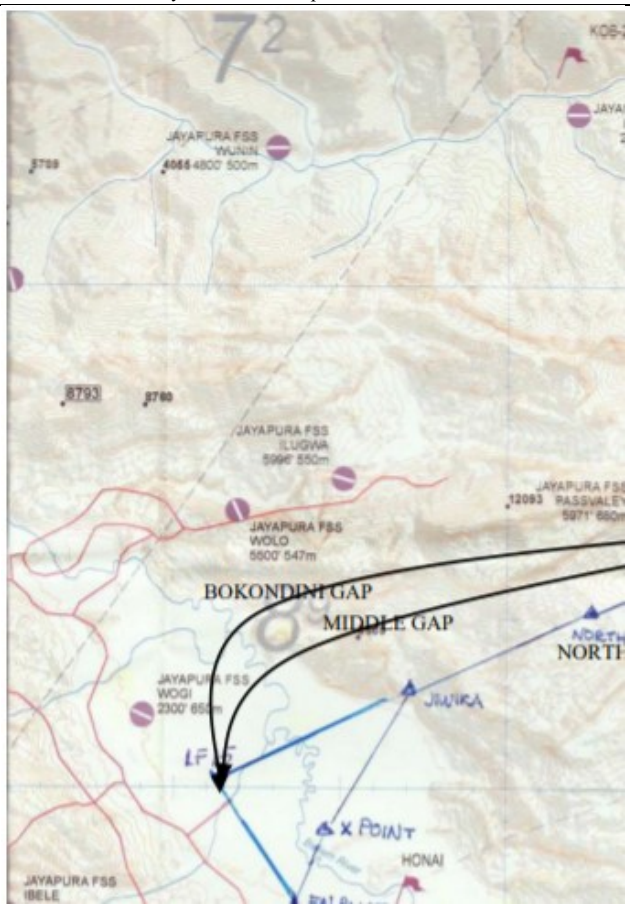

Figure 4.6. The Illustration of "Gaps" Routes of Incoming and Outgoing (KNKT 2013)

Depicted on Figure 4.6. there are three gaps for incoming traffics from Jayapura which can be used visual descend and approach North, Middle and Bogondini as shown Figure 3.4. As per flight rule traffics can descend below the highest terrain, if traffic able to maintain visual separation with terrain. The accident traffic took the North gap, cut to final runway 15 and was too high and too fast.

4.3. Wamena Air Accident 2008

The mind mapping of accident 2008 can be seen in Figure 4.8.

1. The investigation findings did not state any failures (holes) in layer III even though HFACS framework stated that accident will only happened if all four layers are penetrated.

2. The recommendation's intervention "to phase out (not using) Transall C-160 aircraft per July 10, 2009" will block all layers. The layer related technical issue of this aircraft including why "beta light didn't illuminate (Thrust Reverser failure)" during landing roll, "maximum brake", "brake overheat" then created "fire" will also be blocked by phasing out this type aircraft, even the root cause of why this aircraft experienced "beta light not illuminated, why the maximum brake created fire" were not investigated.
3. The recommendation's intervention "to review the status of the Rescue Fire Fighting Service (RFFS) equipment at Wamena airport & establish an ERP for Wamena airport" will block "No Emergency Respond Plan (ERP) of Wamena airport failures".
4. The recommendation "to exercise an ERP for Wamena airport" will block "Rescue Fire Fighting Service (RFFS) arrived at on-fire aircraft ten minutes after aircraft stopped taxiway "E" & RFFS commenced applying foam suppressant five minutes after arrived at on-fire aircraft" failures.

Figure 4.7. Transall C-160, at Taxiway "E" Wamena Airport
(KNKT 2008)

Shown in Figure 4.7. Because of ten minutes late arrival and five minutes delaying the process of fire extinguishing from RFFS the fire became uncontrolled and total lost aircraft damage.

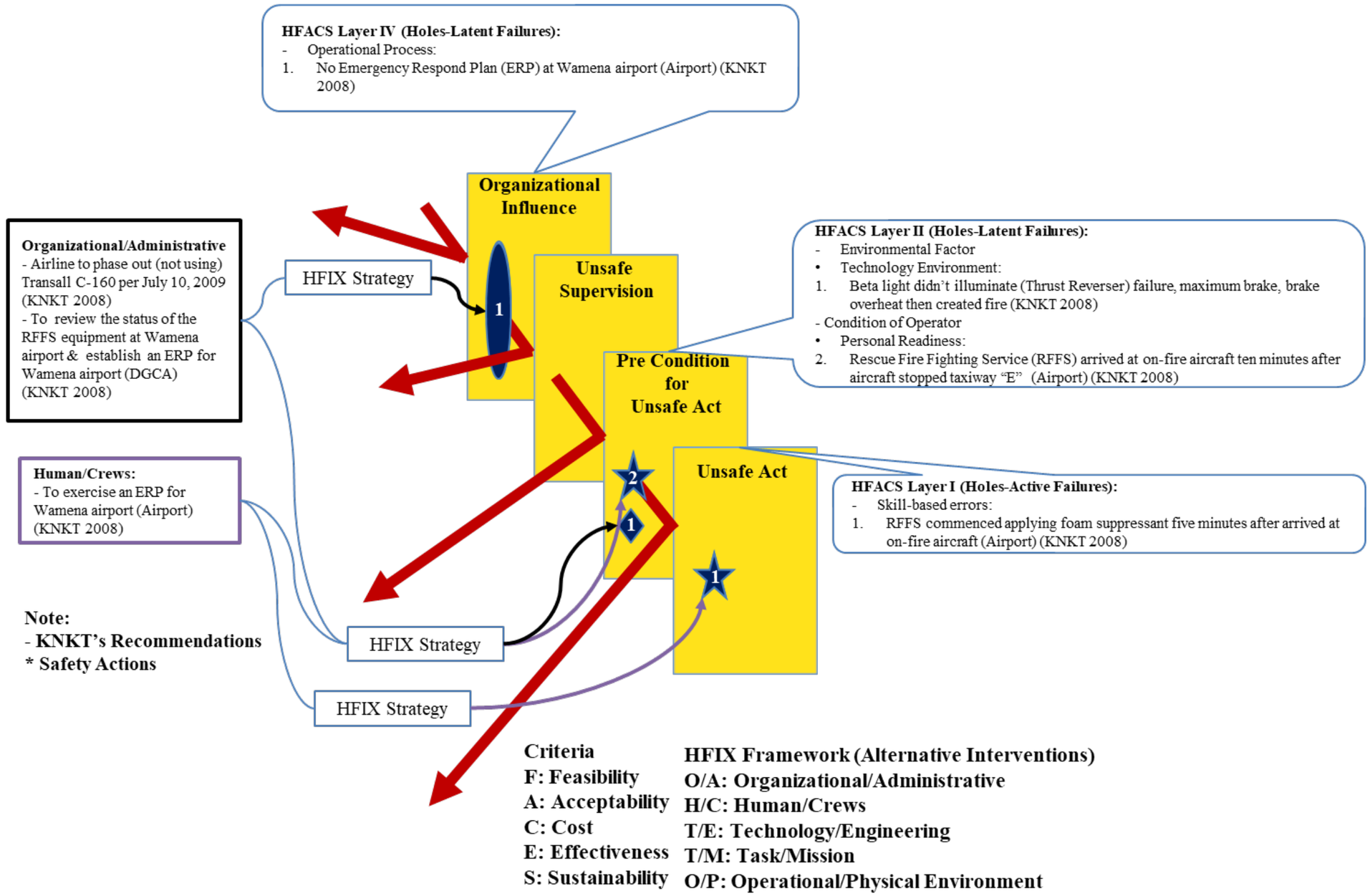

Figure 4.8. Swiss Cheese Model, HFACS Framework &
HFIX-AHP Intervention Strategy Implementation (KNKT 2008).

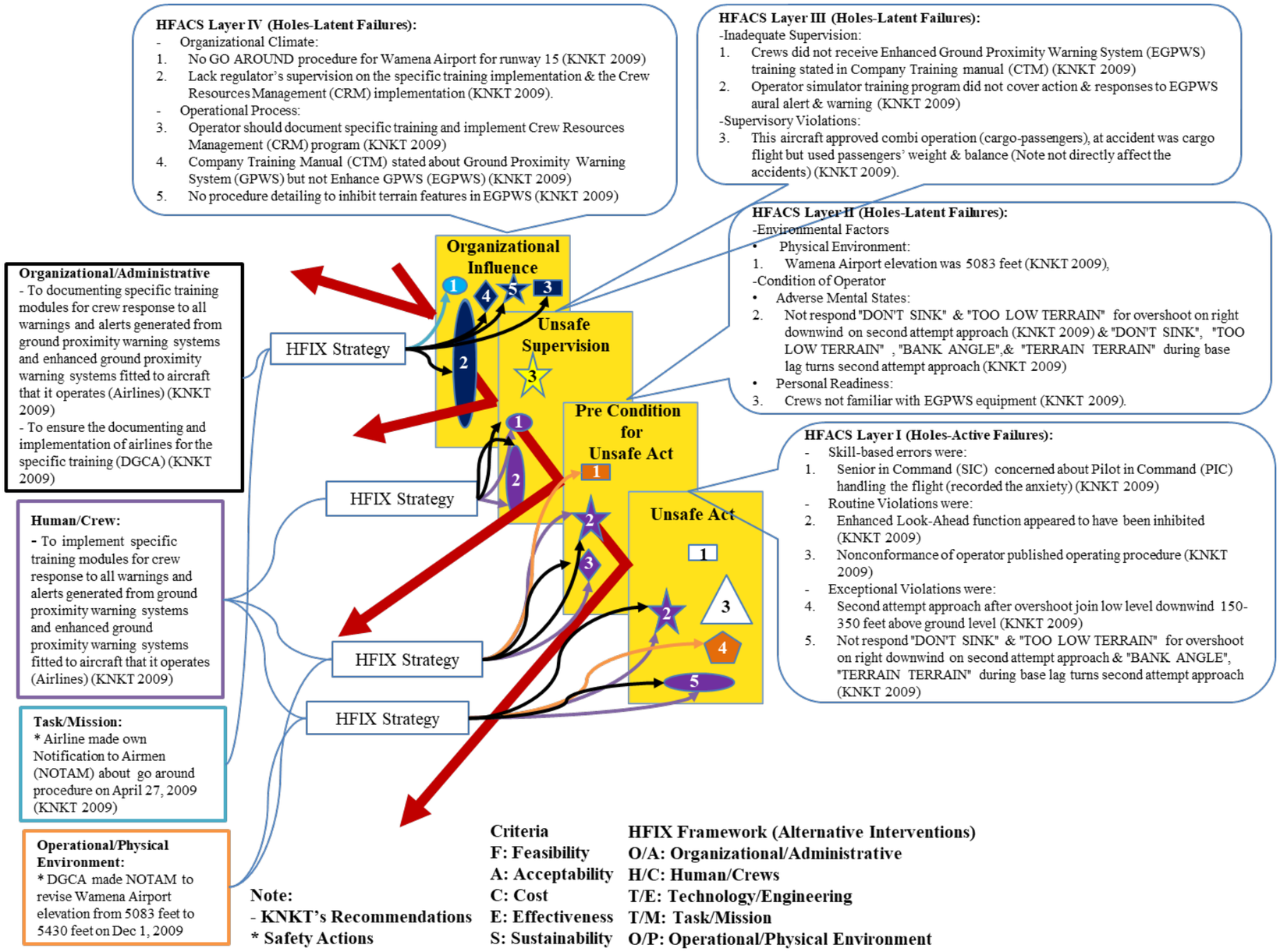

Figure 4.9. Swiss Cheese Model, HFACS Framework &
HFIX-AHP Intervention Strategy Implementation (KNKT 2009).

4.4. Wamena Air Accident 2009

The mind mapping of accident 2009 can be seen in Figure 4.9.

Layer IV (Organizational Influence)

1. "No GO AROUND procedure for Wamena Airport for runway 15" failure will be blocked by "Airline or operator's Notification to Airmen (NOTAM) own made go around procedure", but the differences of go around procedure own made by operators will not be effectively blocked the errors and even can create conflict of traffics in Wamena airspace due no standardization procedure. Standard Instrument Flight Rule (IFR) approach chart for Cat C aircraft including the go around procedure if followed strictly as IFR will limit the landing weight for Wamena operation not only by runway length but also approach climb landing weight limit (when only one engine operative in approach configuration and should make go around has to overcome certain gradient of climb) and landing climb landing weight limit (when both engines operating in landing configuration has to go around also need to overcome certain gradient of climb), and the least landing limit between these three is the limit. Doing strictly IFR that payload brought by operator will be little, but operator can choose the regulation and go around procedure between VFR or IFR, and standard IFR approach chart and go around becoming escape plan choice selection of operator. The suitable installation IFR approach in Wamena is Required Navigation Performance (RNP) approach using Global Positioning System (GPS) from satellites even most of the aircrafts not installed with GPS and not capable of doing RNP approach, but standardization is important to block any error. Error due to own made approach chart by operator can be shown in figure 32 and 33, on December 1, 2009, KNKT made the recommendation and DGCA created a NOTAM about Wamena airport elevation revision from 5,083 feet into 5,430 feet in figure 32 and 33 this operator chart effectively used start July 03, 2013, still use 5,084 feet elevation.

2. All other latent failures like "Lack of authority supervision of operator's specific training documentation and implementation", "Operator should document in the Company Training Manual (CTM) and implement specific training (EGPWS) and Crew Resources Management (CRM)", and "Procedure about inhibiting looked ahead terrain feature" in this layer will be blocked by organizational/administrative interventions recommended by KNKT like "Authority ensuring to supervise the documenting and implementation operator's specific training", and "Operator should documenting specific training modules for crews responding generated warnings and alerts by GPWS or EGPWS".

Layer III (Unsafe Supervision)

1. "The aircraft (Combi Aircraft) was using passenger's weight and balance in cargo flight" failure was clarified by KNKT, this error was not directly affecting the accident and flight's weight was below the limited landing weight.

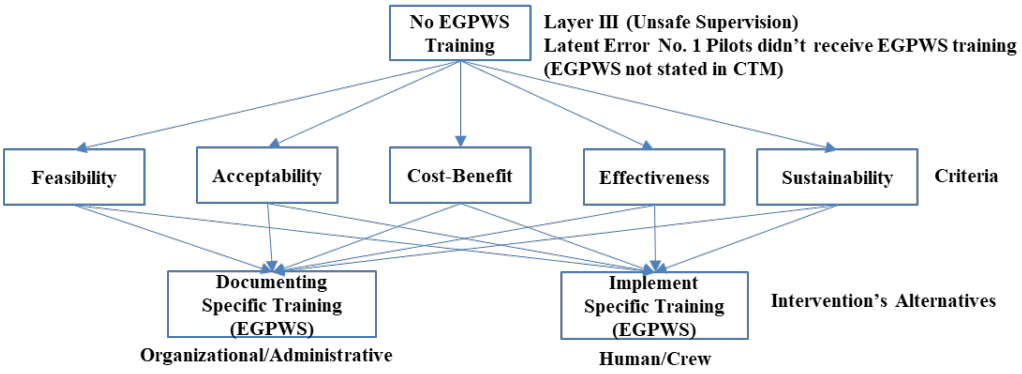

Figure 4.10. AHP Accident 2009 No EGPWS Training.

Table 4.3. Accident 2009 Group AHP Result-EGPWS Crews Training

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"EGPWS crews training"	0.11729	0.13509	0.0464	0.51741	0.18381	
Documenting EGPWS Specific Training	0.15349	0.2831	0.35268	0.11344	0.10942	**0.15142**
Implementing EGPWS Specific Training	0.84651	0.7169	0.64732	0.88656	0.89058	**0.84858**

2. Shown in Figure 4.10. the AHP of accident 2009 for no EGPWS training and Table 4.3. the weighing results. "Crews did not receive EGPWS training" failure will be blocked by two recommendation's intervention which are "implementing Specific Training (EGPWS)" which based on group of AHP from 6 DM's 84.85% priority and "documenting EGPWS specific training (training curriculum)" with 15.14% priority to be effectively blocked the failure.

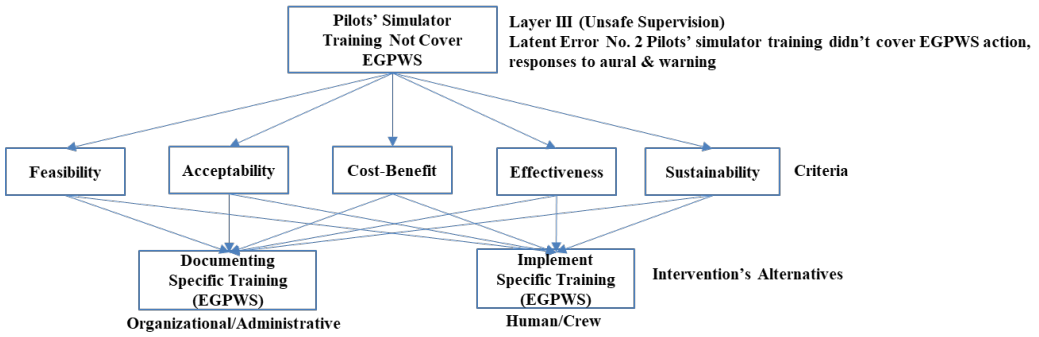

Figure 4.11. AHP Accident 2009 Covering EGPWS on Simulator Training.

Table 4.4. Accident 2009 Group AHP Result-Covering Pilot Simulator Training on EGPWS

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"Covering pilot simulator training on EGPWS"	0.10534	0.15056	0.04981	0.52403	0.17026	
Documenting EGPWS Specific Training	0.21723	0.22252	0.34568	0.11615	0.10462	**0.15228**
Implementing EGPWS Specific Training	0.78277	0.77748	0.65432	0.88385	0.89538	**0.84772**

3. As shown in Figure 4.11. The AHP of accident 2009 hierarchy, covering EGPWS on simulator training and in Table 4.4. the weighing results. "Operator simulator training program did not cover action & responses to EGPWS aural alert & warning" failure will be blocked effectively by "interventions of implementing pilots training on EGPWS" with 84.77% priority and "documenting specific training curriculum" with 15.22% priority.

Layer II (Precondition for Unsafe Act)

1. "Wamena Airport elevation was 5083 feet" error in this layer was blocked by "Directorate General of Civil Aviation DGCA Notification to Airmen (NOTAM) made to revise Wamena Airport elevation from 5083 feet to 5430 feet on Dec 1, 2009".

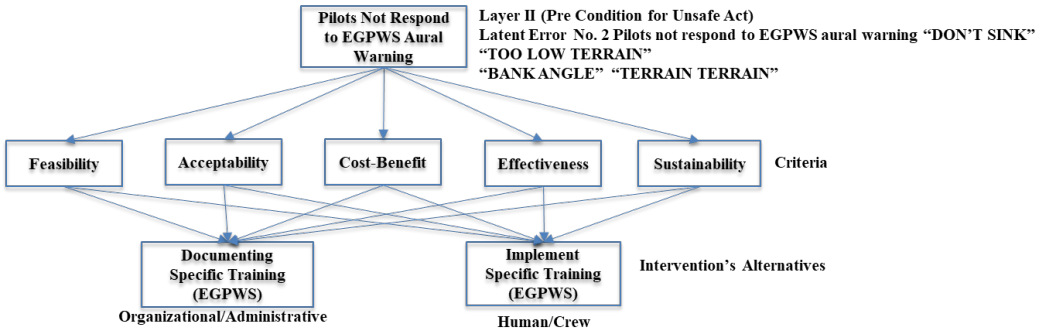

Figure 4.12. AHP Accident 2009 Pilot Not Respond EGPWS Warning.

Table 4.5. Accident 2009 Group AHP Result-Pilots didn't respond on EGPWS aural & alert warnings.

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"Pilots didn't respond on EGPWS' aural & alert warnings"	0.07377	0.16424	0.05058	0.55246	0.15894	
Documenting EGPWS Specific Training	0.21723	0.11615	0.53641	0.10684	0.10462	**0.20073**
Implementing EGPWS Specific Training	0.78277	0.88385	0.46359	0.89316	0.89538	**0.79927**

2. As shown in Figure 4.12. AHP accident 2009 hierarchy on Layer II of pilot didn't respond EGPWS warning and Table 4.5. the weighing results. "Pilots didn't respond on EGPWS aural alert & warnings" failure will be blocked effectively by interventions of "implementing pilots training on EGPWS" with 79.92% priority and "documenting EGPWS specific training curriculum" with 20.07% priority.

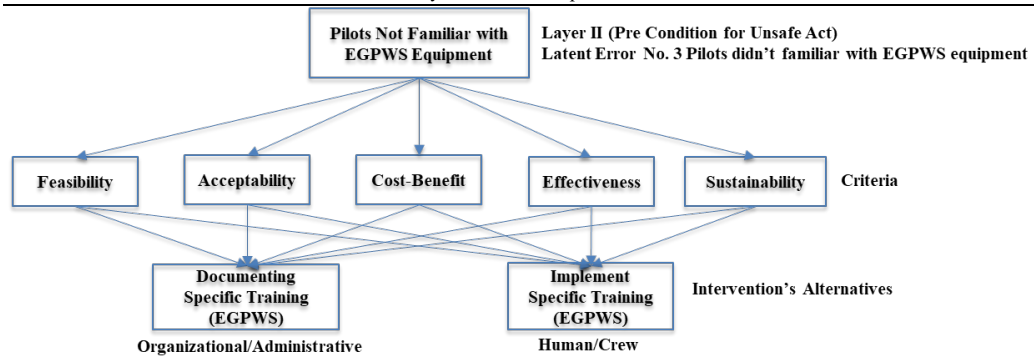

Figure 4.13. AHP of Accident 2009 Pilots Not Familiar with EGPWS.

Table 4.6. Accident 2009 Group AHP Result-Pilots were not familiar with EGPWS equipment.

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"Pilots were not familiar with EGPWS equipment"	0.14405	0.12996	0.0448	0.53397	0.14722	
Documenting EGPWS Specific Training	0.56887	0.22252	0.75136	0.11344	0.10462	**0.27871**
Implementing EGPWS Specific Training	0.43113	0.77748	0.24864	0.88656	0.89538	**0.72129**

3. As shown in Figure 4.13. AHP of Accident 2009 hierarchy pilots were not familiar with EGPWS equipment and Table 4.6. the weighing results. "Pilots were not familiar with EGPWS equipment" failure will be blocked effectively by interventions of "implementing pilots training on EGPWS" with 72.12% priority and "documenting EGPWS specific training curriculum" with 27.87% priority.

Layer I (Unsafe Act)

1. "Senior in Command (SIC) concerned about Pilot in Command (PIC) handling the flight (recorded the anxiety)" active failure in this layer not specifically blocked by recommendation and future operation still possibilities to be penetrated by CRM error and skill-based error.

2. "Nonconformance of operator published operating procedure" active failure also not being blocked by any recommendation specifically, the human/crew recommendation in this accident stated specific only for

EGPWS training not how to avoid routine violation by following operator's SOP.

3. "Second attempt approach after overshoot join low level downwind 150-350 feet above ground level" active failure was done by the pilots because Wamena elevation error stated 5.083 feet, even though pilots have low level downwind procedure in visual condition limited not below 500 feet Above Ground Level (AGL). This elevation error has been blocked by "DGCA NOTAM made to revise Wamena Airport elevation from 5083 feet to 5430 feet on Dec 1, 2009" as the recommendation's intervention.

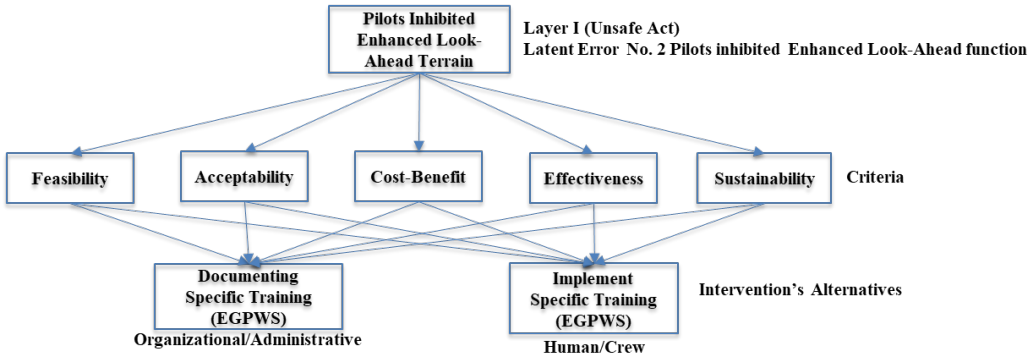

Figure 4.14. AHP of Accident 2009 Pilots Inhibited Enhance Look Ahead Terrain.

Table 4.7. Accident 2009 Group AHP Result-Pilots Inhibited Enhance Lookahead Terrain.

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"Pilots inhibited enhance look ahead terrain"	0.11593	0.15798	0.04661	0.56576	0.11372	
Documenting EGPWS Specific Training	0.22832	0.29341	0.88065	0.11344	0.1	**0.23491**
Implementing EGPWS Specific Training	0.77168	0.70659	0.11935	0.88656	0.9	**0.76509**

4. As shown in Figure 4.14. AHP of accident 2009 hierarchy, pilots inhibited Enhance Look Ahead Terrain and Table 4.7. the weighing results. "Pilots inhibited enhanced lookahead terrain" exceptional violation will be blocked effectively by interventions of "implementing pilots training on EGPWS" with 76.50% priority and "documenting EGPWS specific training curriculum" with 23.49% priority.

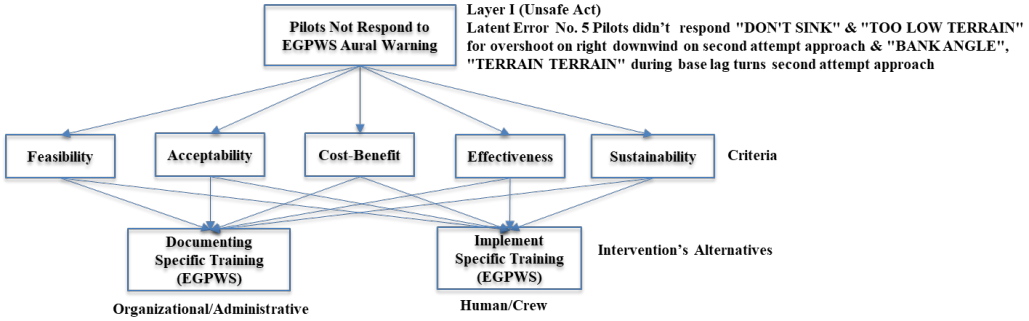

Figure 4.15. AHP of Accident 2009 Pilots Not Respond EGPWS Warning.

5. As shown in Figure 4.15. AHP of accident 2009 hierarchy on Layer I, pilots did not respond EGPWS warning and Table 4.5. the weighing results. "Pilots didn't respond on EGPWS aural alert & warnings" failure will be blocked effectively by interventions of "implementing pilots training on EGPWS" with 79.92% priority and "documenting EGPWS specific training curriculum" with 20.07% priority. Unlike in layer II in subcategory HFACS of adverse mental states both pilots were tunneling vision and focusing only on how to land the aircraft, in this layer I same error due to HFACS subcategory of exceptional violation or breaking the rule any repetitive aural warning from GPWS or EGPWS pilots should do action recovering the condition e.g., going around.

4.5. Wamena Air Accident 2013

The mind mapping of accident 2013 can be seen in Figure 4.17.

Layer IV (Organizational Influence)

Structuring the investigation using HFACS framework, this layer's latent failures were not found, and under HFACS framework accident will not be happened when the early layer not being penetrated. Under Organizational/Administrative alternative intervention there was a "DGCA takes responsibility in airline's implementation of KNKT's recommendations" recommendation which should be used to block any latent failures in organizational influence layer.

Layer III (Unsafe Supervision)

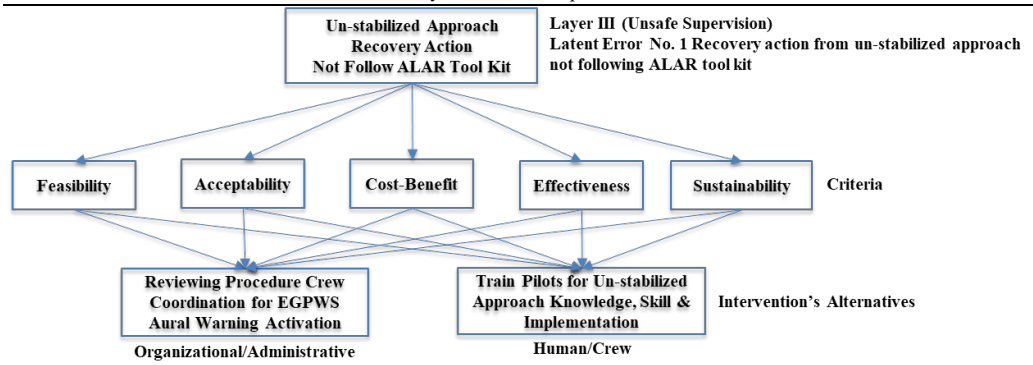

Figure 4.16. AHP of Accident 2013 To Avoid Un-Stabilized Approach

Table 4.8. Accident 2013 Group AHP Result-To Avoid Un-Stabilized Approach.

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"To avoid un-stabilized approach"	0.08955	0.17564	0.04738	0.53732	0.15012	
Pilot's knowledge, skill, to correct un-stabilized approach	0.87294	0.86948	0.32136	0.88754	0.89058	**0.80652**
Review procedure EGPWS on aural warning activation	0.12706	0.13052	0.67864	0.11246	0.10942	**0.19348**

1. The latent failure of "Recovery action from un-stabilized approach not following ALAR tool kit" which under inadequate supervision sub category of HFACS framework is intervened by "To ensure that pilots have adequate knowledge and skill to understand and correct implementation of stabilized approach" recommendation with 80.06% priority and "To review the procedure in crew coordination in respect to the EGPWS aural warning when activated" recommendation with 19.34% priority as shown in Table 4.8. is the weighing result and Figure 4.16. related hierarchy diagram.

2. "150 traffics daily inbound and outbound Wamena Airport" latent failure on layer III under sub category of planned inappropriate operation has no intervention recommendation to block the failure and with that amount of traffics daily Wamena ATC under super high workload with all the limitations such as: ATC has no radar and authority limited certain altitude and range which also result of barrier in radio communication relay not perfectly functional coverage 360°, Wamena airport has no Standard Instrument Arrival (STAR) and no Standard Instrument Departure (SID) and no Instrument Approach for Category C (Approach Speed between 121-140 knots) or bigger

aircraft, Wamena has no parallel taxiway to immediate exiting of landing traffics from the runway optimizing the flow, mixed between IFR and VFR traffics, and mixed between big jets and small slow airplanes.

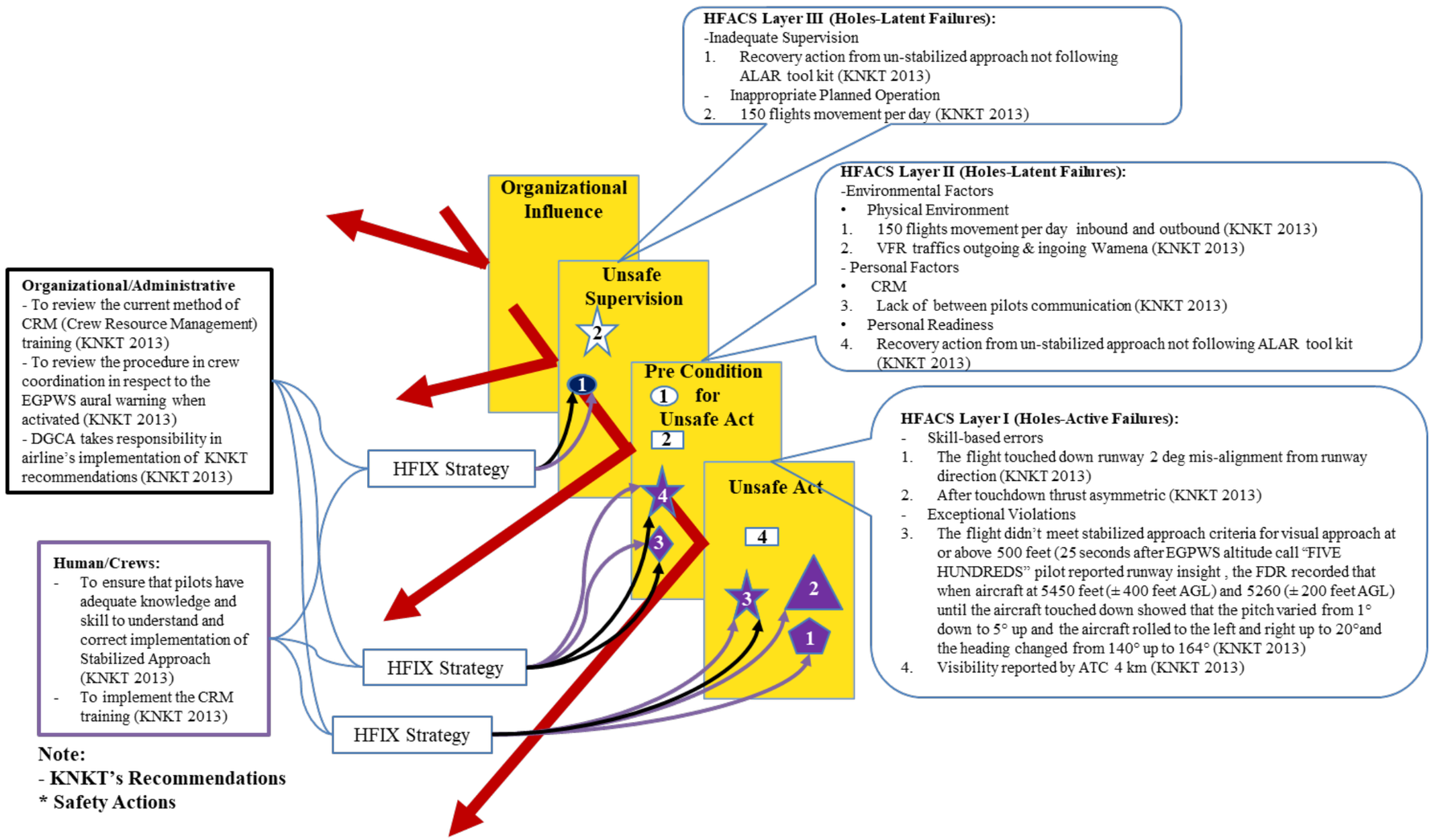

Figure 4.17. Swiss Cheese Model, HFACS Framework & HFIX-AHP Intervention Strategy Implementation (KNKT 2013).

Layer II (Precondition for Unsafe Act)

1. Failure number one "150 traffics daily" and failure number two "VFR traffics ingoing and outgoing" latent failures in this layer and under subcategory environmental factor-physical environment were still unblocked by any recommendations as per previous layer III (Unsafe Supervision) reasons, the holes will still be a chance to be penetrated and result in accidents or incidents in the future.

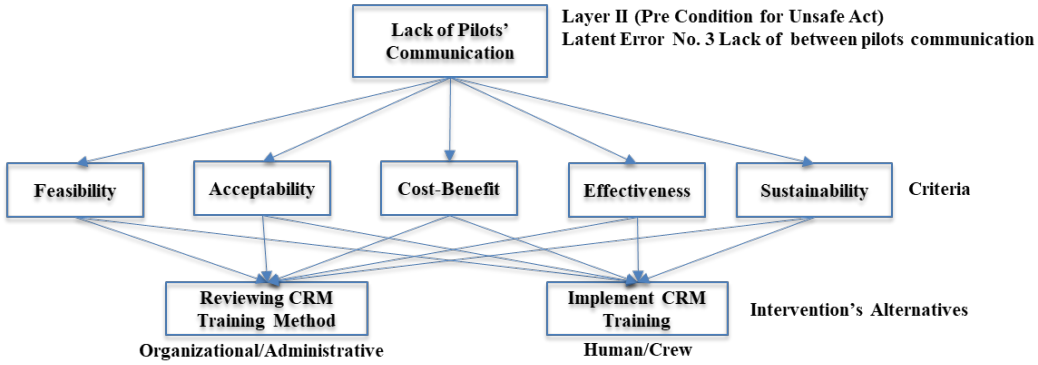

Figure 4.18. AHP of Accident 2013 Lack of Pilots' Communication.

Table 4.9. Accident 2013 Group AHP Result-To Block Lack of Pilots Communication.

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"To block lack of pilots communication"	0.10107	0.15468	0.04798	0.53621	0.16005	
Implement CRM training	0.33748	0.31503	0.14707	0.35268	0.89058	**0.35904**
Review current CRM training method	0.66252	0.68497	0.85293	0.64732	0.10942	**0.64096**

2. "The lack of pilots communication" latent failure in this layer and HFACS subcategory of personal factor-Crew Resources Management (CRM) was block by "To implement the CRM training" under the human or crew intervention alternative rank of 35.90% and "Review current CRM training method" with 64.09% priority as shown in Table 4.9. the weighing results and in Figure 4.18. the related hierarchy diagram. Reviewing operator's CRM training method become effectively prioritize according to the AHP

because implementation and training of CRM for pilots it has been mandatory training annually, but effective method will be stated in the curriculum or method itself.

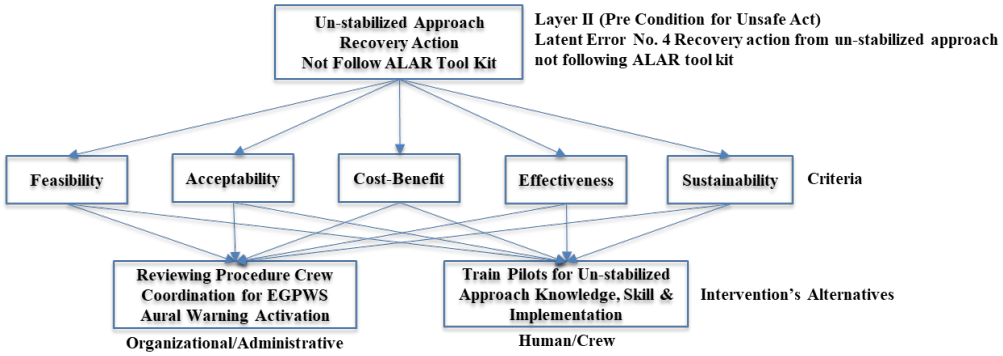

Figure 4.19. AHP of Accident 2013 Un-stabilized Approach Recovery

3. "Recovery action from un-stabilized approach not following ALAR tool kit" in this layer under subcategory of personal factor-personal readiness, which caused by inadequate supervision or training in previous layer (Unsafe Supervision or Layer III) result the crews were not ready to face the situation due lack of knowledge and skill on this issue. The alternative intervention ranks as Table 4.8. the weighing results and Figure 4.19. as the related hierarchy diagram. "To ensure that pilots have adequate knowledge and skill to understand and correct implementation of stabilized approach" has 80.06% priority and "To review the procedure in crew coordination in respect to the EGPWS aural warning when activated" with 19.34%.

Layer I (Unsafe Act)

1. "The flight touched down runway 2 deg misalignment from runway direction" and "After touchdown thrust asymmetric" are under skill-based error in HFACs subcategory, these two active failures result from the un-stabilized approach and are blocked by the Human or Crew alternative intervention with "To ensure that pilots have adequate knowledge and skill

to understand and correct implementation of Stabilized Approach" recommendation.

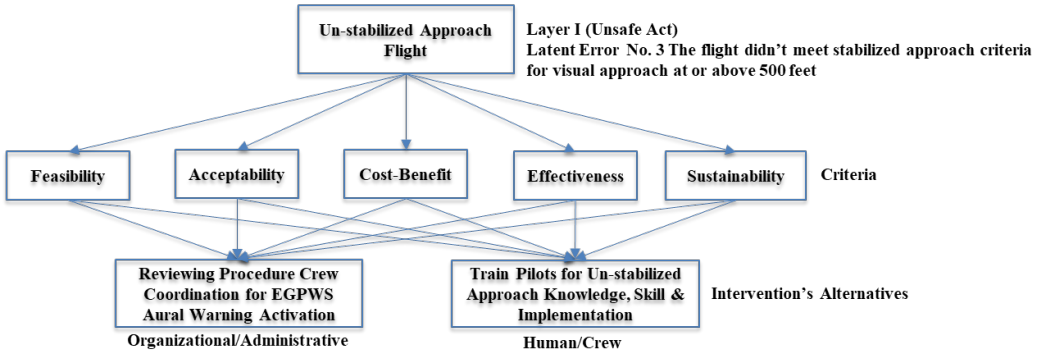

Figure 4.20. AHP of Accident 2013 To Avoid Un-Stabilized Approach.

2. "The flight didn't meet stabilized approach criteria for visual approach at or above 500 feet (25 seconds after EGPWS altitude call "FIVE HUNDREDS" pilot reported runway insight , the FDR recorded that when aircraft at 5450 feet (± 400 feet AGL) and 5260 (± 200 feet AGL) until the aircraft touched down showed that the pitch varied from 1° down to 5° up and the aircraft rolled to the left and right up to 20°and the heading changed from 140° up to 164°" is characterized as un-stabilized approach and in this layer under sub category of exceptional violation in HFACS framework. The alternative intervention rank of the recommendations as Table 4.8. with the weighing results and Figure 4.20. related hierarchy diagram. "To ensure that pilots have adequate knowledge and skill to understand and correct implementation of stabilized approach" has 80.06% priority and "To review the procedure in crew coordination in respect to the EGPWS aural warning when activated" with 19.34%.

Figure 4.21. BAe ATP on Short Final

(KNKT 2013)

Shown in Figure 4.21. last break out flight from cloud and condition in un-stabilized approach described in point 2 of Layer I (Unsafe Act).

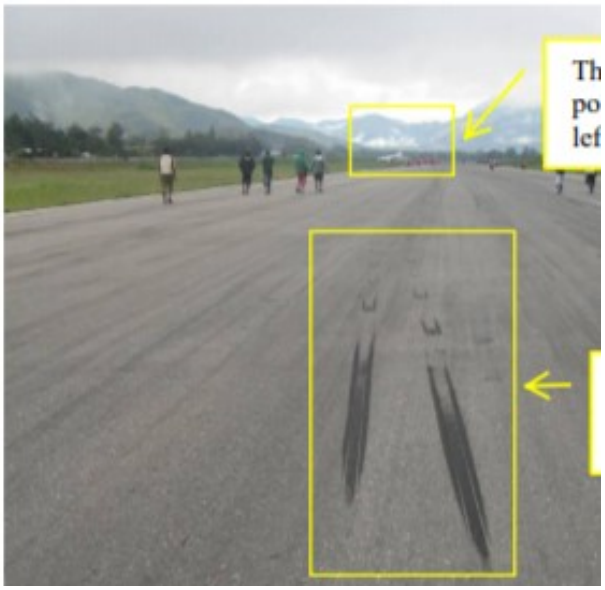

Figure 4.22. Mark 1st Runway Touch

(KNKT 2013)

And as result of continuing a flight in un-stabilized approach condition the accident's plane touched down left of centerline from runway 15 shown in Figure 4.22.

Figure 4.23. Mark Left Wheel

(KNKT 2013)

Figure 4.24. BAe ATP Mark Both Main Wheels Off the Runway

(KNKT 2013)

The trajectories from off centreline touchdown, then went off from runway as shown in Figure 4.23., and Figure 4.24. Detached accident aircraft's landing gear shown in Figure 4.25. and last stop position end up on grass left side of runway in Figure.4.26.

Figure 4.25. BAe ATP Landing Gear Detached
(KNKT 2013)

Figure 4.26. BAe ATP End Position
(KNKT 2013)

3. "Visibility reported by ATC 4 km" active failure in this layer is under subcategory of exceptional violation, pilots should not continue the approach in Wamena airport because visibility criteria did not meet the VFR approach which at least five km. The other thing about visibility reported found in this study, pilots can see the runway with average 3°

slope during landing and approach to runway "Slant Visibility" and ATC reported the visibility taken from the meteorologist is horizontal visibility. The slant visibility should be used and informed to pilots who doing the approach of a runway used with varies angle between horizontal to a certain degree above 3°. Weather characteristic of Wamena will be covered by low cloud even above 1000 feet AGL ceiling and horizontal visibility more than ten kilometers, even though condition met with VFR criteria approach but very hard for pilots to see the runway with 3° slant. This active failure is not blocked by any alternative intervention recommendations and possibilities to be penetrated in incidents or accidents will still be high in the future.

4.6. Wamena Air Accident 2015

The mind mapping of accident 2015 can be seen in Figure 4.28.

Layer IV (Organizational Influence)

1. "Rubber deposit 600 m start from runway threshold" latent failure in this layer sub categorize under operational process in HFACS framework is blocked by "To develop an airport maintenance program, review and improve the runway inspection system, and install VASI on the runway 15" organizational and administration intervention recommendations.

Layer III (Unsafe Supervision)

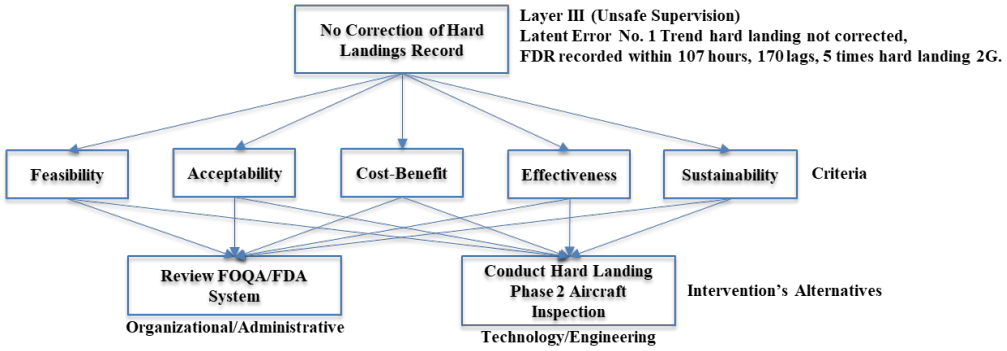

Figure 4.27. AHP of Accident 2015 No Correction of Hard Landings Record.

Table 4.10. Accident 2015 Group AHP Result-To Block No Correction on Hard Landing Trend.

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"To block no correction on hard landing trend"	0.09281	0.14789	0.04677	0.54317	0.16936	
To conduct hard landing phase I inspection	0.45438	0.82713	0.7906	0.19007	0.10782	**0.55774**
To establish FOQA/FDA system	0.54562	0.17287	0.2094	0.80993	0.89218	**0.44226**

1. "Trend hard landing not corrected, FDR recorded within 107 hours, 170 lags, 5 times hard landing 2G" in this layer sub categorized in fail to correct known problems under the HFACS framework, intervened by two recommendations or safety action "Conducting hard landing phase I inspection" with 55.77% priority and "Establishing Flight Operation Quality Assurance (FOQA)/Flight Data Analysis (FDA)' to be installed in the aircraft with 44.22% priority according to the AHP as shown in Table 4.10. the weighing result and Figure 4.27. related hierarchy diagram. The study found out that even though FOQA or FDR will record the hard landing in G's with or without any report from pilots, but recording will not be sufficient without further inspection to get effective visual examination not only in landing gear system but fuselage's strength as well.

Layer II (Precondition for Unsafe Act)

1. "Visual Approach Slope Indicator at Wamena airport was inoperative" latent failure under subcategory environmental factor of technological environment is blocked by "To develop an airport maintenance program, review and improve the runway inspection system, install Visual Angle Slope Indicator (VASI) light on the runway 15" technology/engineering intervention.
2. "Gusty wind not (windshear possibility) reported by ATC to pilots" latent failure under subcategory environmental factor-physical environment is blocked by "To improve ATCs wind-shear knowledge" human/crew intervention from KNKT's recommendation.

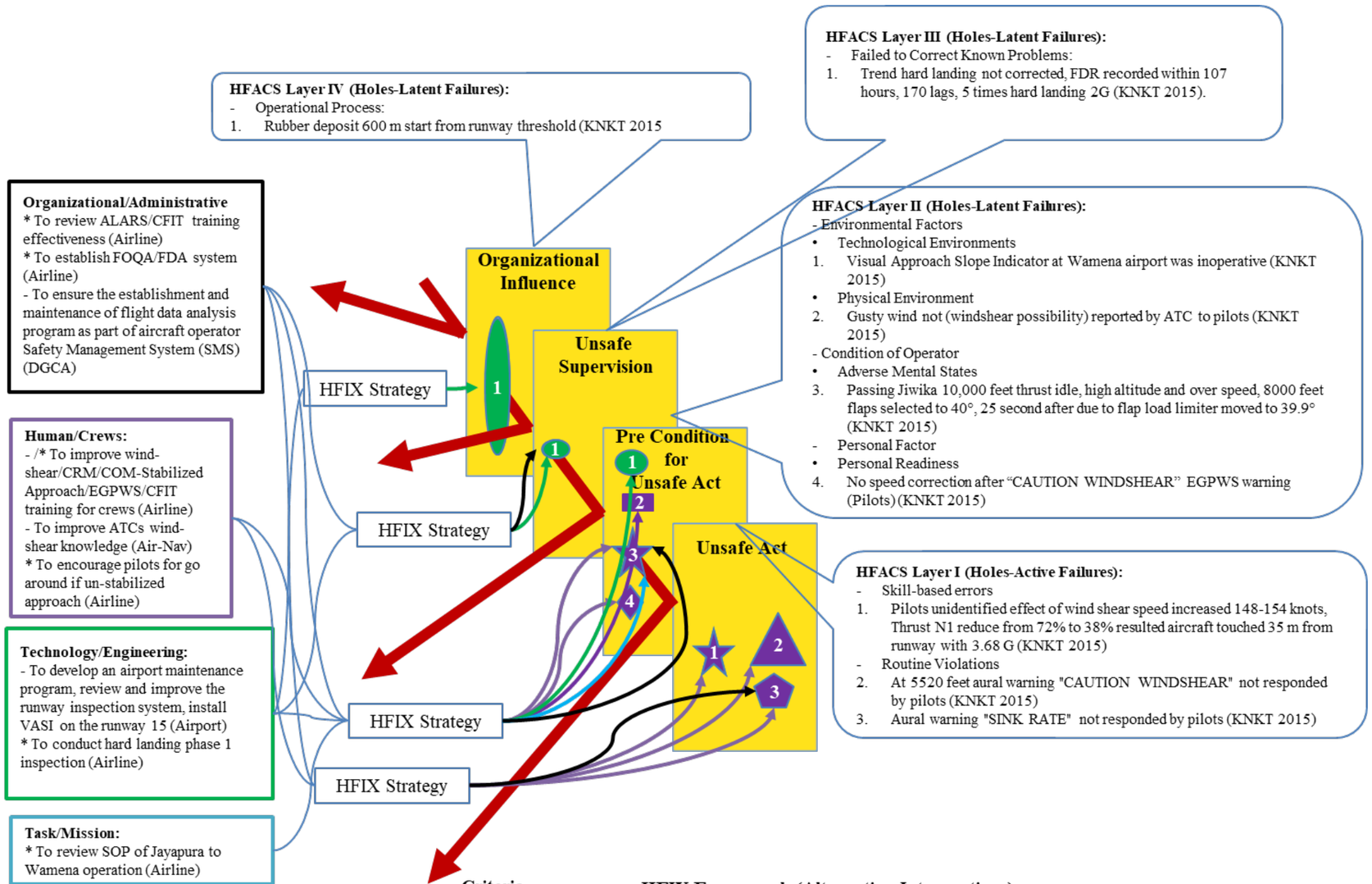

Figure 4.28. Swiss Cheese Model, HFACS Framework &
HFIX-AHP Intervention Strategy Implementation (KNKT 2015).

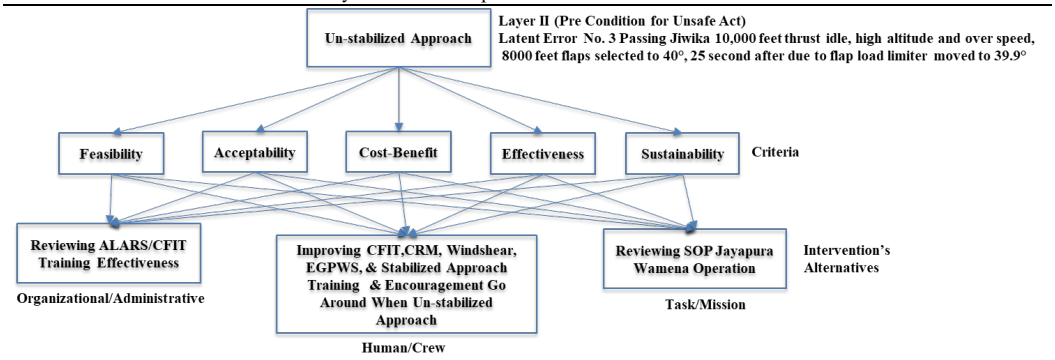

Figure 4.29. AHP of Accident 2015 Avoid Un-Stabilized Approach.

Table 4.11. Accident 2015 Group AHP Result-To Avoid Un-Stabilized Approach

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"To avoid un-stabilized approach"	0.1337	0.09642	0.04495	0.56005	0.16487	
To improve ALAR/CFIT/Stabilized-Approach training	0.77692	0.75359	0.70672	0.77579	0.78944	**0.69775**
To review ALAR/CFIT training effectiveness	0.13901	0.08788	0.12409	0.10673	0.08669	**0.14737**
To review SOP Jayapura to Wamena Operation	0.08407	0.15853	0.16918	0.11748	0.12388	**0.15488**

3. "Passing Jiwika 10,000 feet thrust idle, high altitude and over speed, 8000 feet flaps selected to 40°, 25 second after due to flap load limiter moved to 39.9°" latent failure sub categorized under condition of operator-adverse mental state, pilot's tunnel vision or focus only to land the aircraft even though in un-stabilized approach condition. And the latent failure is blocked by three recommendations and safety actions prioritize in the AHP as "To improve ALAR/CFIT/Stabilized Approach training for pilots" with 69.77%, "Reviewing Standard Operating Procedure (SOP) Jayapura to Wamena operation" with 15.48%, and "Reviewing ALAR/CFIT training effectiveness with 14.735 as shown in Table 4.11. the weighing results and Figure 4.29. the related hierarchy diagram.
4. "No speed correction after "CAUTION WINDSHEAR" EGPWS warning" latent failure under subcategory condition of operator-personal readiness is blocked by "To improve windshear/Crew Resources Management (CRM)/Company Operating Manual (COM)-Stabilized Approach/Enhance Ground Proximity Warning System (EGPWS)/Controlled Flight into

Terrain (CFIT) training for crews" recommendation and operator's safety action in intervention of human/crew category.

Layer I (Unsafe Act)

1. "Pilots unidentified effect of wind shear speed increased 148 to 154 knots, Thrust N1 reduce from 72% to 38% resulted aircraft touched 35 m from runway with 3.68 G" skill-based error active failure is blocked by "To improve wind-shear/Crew Resources Management (CRM)/Company Operating Manual (COM)-Stabilized Approach/Enhance Ground Proximity Warning System (EGPWS)/Controlled Flight into Terrain (CFIT) training for crews" and "To encourage pilots for go around if un-stabilized approach" recommendations and operator's safety actions in intervention of human/crew category.
2. "At 5520 feet aural warning "CAUTION WINDSHEAR" not responded by pilots" routine violation active failure is blocked by "To improve windshear/Crew Resources Management (CRM)/Company Operating Manual (COM)-Stabilized Approach/Enhance Ground Proximity Warning System (EGPWS)/Controlled Flight into Terrain (CFIT) training for crew's recommendation and operator's safety action in intervention of human/crew category as well.

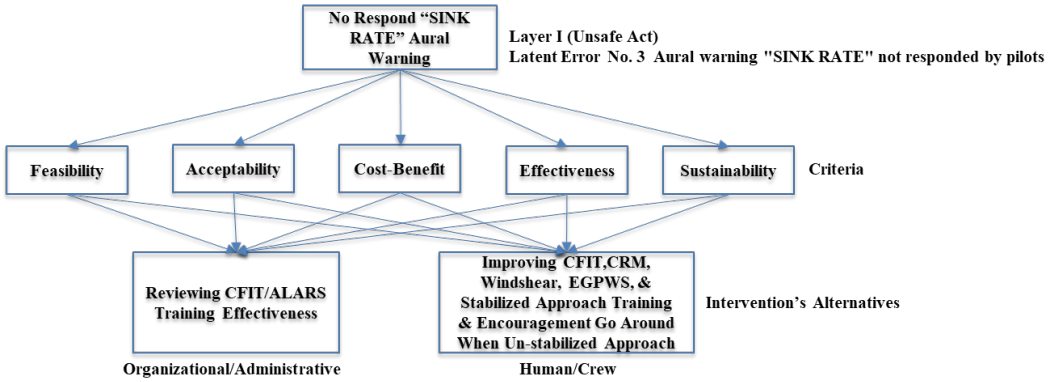

Figure 4.30. AHP of Accident 2015 No Respond Sink Rate Aural Warning.

Table 4.12. Accident 2015 Group AHP Result-To Block No Pilots' Respond on Sink Rate Warning.

Goal	Feasibility	Acceptability	Cost	Effectiveness	Sustainability	**Global Weight (Rank)**
"To block no pilots', respond on sink rate warning"	0.11491	0.09386	0.04113	0.58083	0.16928	
To review ALAR/CFIT training effectiveness	0.26409	0.64732	0.84246	0.10684	0.1	**0.50081**
To improve ALAR/CFIT/Stabilized-Approach training	0.73591	0.35268	0.15754	0.89316	0.9	**0.49919**

3. "Aural warning "SINK RATE" not responded by pilots" routine violation is intervened by "Reviewing ALAR/CFIT training effectiveness" safety action with 50.08% priority and "Improving ALAR/CFIT/Stabilized Approach training" safety action with 49.91% priority shown in Table 4.12. the weighing result and Figure 4.30. related hierarchy diagram. ALAR/CFIT training is mandatory annually and when the training does not effectively block the incidents or accidents, reviewing method according to the AHP will be prioritized to block any errors.

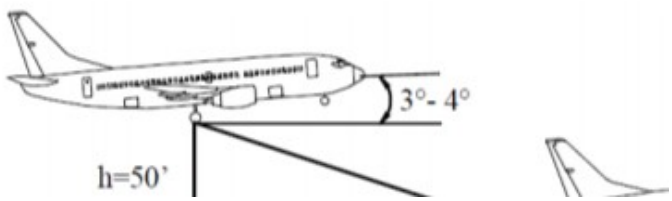

Figure 4.31. Boeing 737 Landing Flare Profile (Boeing 737 FCTM) (KNKT 2015)

Shown in Figure 4.31. correct technique for aircraft landing, explained from Boeing Flight Crew Training Manual (FCTM) above threshold at 50 feet then touch landing on the runway unlike the Layer 1 point 1, the accident aircraft touched down 35 meters before the runway end as shown the marking in Figure 4.32.

Figure 4.32. Touchdown Mark on The Surface before The Runway (KNKT 2015)

Figure 4.33. Metal Scratch Mark on Runway (KNKT 2015)

As resulted touched down hardly 3.68 G and cumulative previous hard landings as failure in previous layer shown in Figure 4.33. landing gear disintegration after touched and giving metal scratch on runway. And Figure 4.34. stop end poistion of accident traffic with colapse landing gears.

Figure 4.34. B 737-300 Aircraft Final Stop Position (KNKT 2015)

4.7. Wamena Air Accident 2016

The mind mapping of accident 2016 can be seen in Figure 4.35.

Layer IV and III (Organizational Influence and Inadequate Supervision)

These layers under HFACS framework have no latent failures or holes, structuring the investigation process using HFACS will not be possible this accident happened with these layers not penetrated.

Layer II (Precondition for Unsafe Act)

1. "Fifteen minutes before departure weather destination at Wamena visibility 3 km & cloud bases increasing from 200 to 1000 feet above ground level" latent failure under subcategory of environmental factor-physical environment in this accident will be blocked by airline or operator's safety notice with notice to pilots "to assess the risks operating to Wamena by visibility met 5 km, and cloud bases ceiling met 1000 feet AGL" intervention. In this study also found that competency of flight dispatcher, a license person who dispatched a flight and giving mission data briefing to pilots before flight started, needed to be improved and understanding weather forecast to meet the minima is critical information for pilots.

"At 7000 feet pilots didn't see visual check point & Pilot Monitoring (PM) advised go around but flight still be continued" latent failure under subcategory of personal factor-CRM will be also blocked by operator safety action in notice to pilots "to encourage pilots for go around if un-stabilized approach" intervention.

Layer I (Unsafe Act)

1. "Both flights touched down 125 m from runway 15 with 3.25 G" skill-based error and "at 5700 feet, distance 2 nm, EGPWS aural warning "SINK RATE"" routine violation active failure will be blocked by operator safety action in notice to pilots "to encourage pilots for go around if un-stabilized approach" intervention.

2. "Wamena's visibility when accident happened was 3 km" exceptional violation active failure will be blocked by operator safety action in notice to pilots "to encourage pilots for go around if un-stabilized approach" intervention.

3. "At 7000 feet ATC gave landing clearance to pilots when pilots still can't see the runway" exceptional violation active failure not specifically blocked by any recommendation's intervention and still possible penetrated by errors which will cause incidents or accidents in the future.

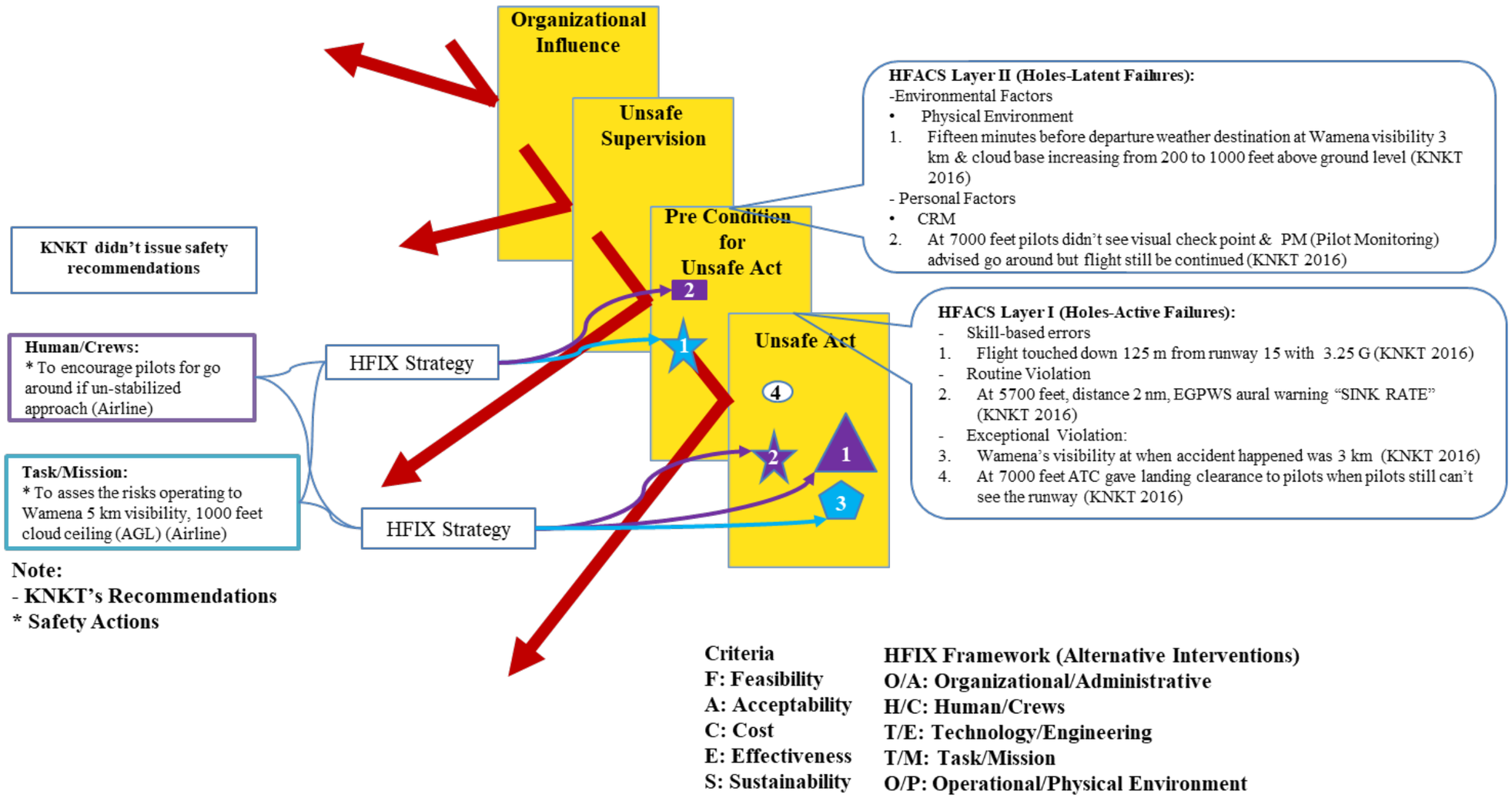

Figure 4.35. Swiss Cheese Model, HFACS Framework &
HFIX-AHP Intervention Strategy Implementation (KNKT 2016).

NOMOR : 12 / OPS-NPB / IX / 2
EFFECTIVE DATE : 13 SEPTEMBER 201
ATTENTION : ALL PILOT BOEING
SUBJECT : INCIDENT PK-YSY
CC : - OPERATION DIREC
- OPERATION MANA
- SAFETY DIRECTOR
- SAFETY MANAGER
- FLOPS

Mengacu kepada kejadian Serious Incident PK-YSY di Banda tanggal 13 sep 2016, saat mendarat yang mengakibatkan kerusak terhadap perusahaan. Dengan ini diingatkan kembali kepada reka Air agar tidak melakukan kesalahan yang sama.

Di instruksikan kepada seluruh Pilot B737-CL :

1.Pilot yang akan terbang ke Wamena harus Update Visibility 5 km dan Minimum Ceilling 1000 ft AGL)
2. Apabila terjadi Unstabilized Approach jangan ragu **Reff FCTM 5.4 (Stabilized Approach)**

Demikian Notice to Pilot ini dibuat agar dapat dilaksanakan seb perhatian dan kerjasamanya.

Figure 4.36. Notice to Pilots from Airlines Management (KNKT 2016)

Shown in Figure 4.36. is operator's safety action was given in format of notice to pilots to assess weather condition in Wamena airport to meet Visual Flight Rule (VFR) criteria five kilometers visibility and 1,000 feet cloud ceiling. The other point in the pilots' notice is encouragement to go around when stabilized approach parameters couldn't be met.

Figure 4.37. Operator Visual Guidance Terminal Area Chart (KNKT 2016)

Operators internally have their own visual guidance as shown in Figure 4.37., and 4.38. with go around procedure. This visual guidance has effective date of using July 1, 2013, and has an error on the elevation of airport still 5,084 feet even Directorate General Civil Aviation (DGCA) has published Notification to Airmen (NOTAM) on Dec 1, 2009, that Wamena elevation revised into 5,430 feet. Another issue publishing own chart is the unfamiliarity of other operator and ATC with the points made and can jeopardy the traffics safety from air collision.

Figure 4.38. Operator Visual Guidance Approach Runway 15 (KNKT 2016)

CHAPTER 5 – CONCLUSIONS AND RECOMMENDATIONS

Human Factor Analysis and Classification System (HFACS) framework, Human Factor Intervention (HFIX) and combine with Analytical Hierarchy Process are great tool to analyze, identify, and prioritize the KNKT findings and KNKT recommendations or operator's safety actions to block any failures and store them in aviation Safety Management System (SMS) database and learning from them to improve aviation safety.

5.1 Conclusions

Structuring investigations process of accidents or incidents comprehensively using HFACS framework will give clearer picture of latent and active failures in each layer of Swiss Cheese Model to understand why accidents and incidents happened. Understanding the framework if four layers have been penetrated that result in incident or accident, is important. Then stating failures as the cause of incident or accident in each layer in the report is critical for stake holder to understand, identify and action's policy blocking them.

Alternative interventions using HFIX framework of safety recommendations or and safety actions ideally should be given in accidents or incidents investigation process and final report on each failure of layer to block it.

When latent and active failure in a layer is approached by two or more interventions of safety recommendations or and actions, priority using criteria of feasibility, acceptability, cost-benefit, effectiveness, and sustainability to prioritize action taken blocking the failure in specified timeframe should be done. And using Analytical Hierarchy Process (AHP) is a suitable method to approach.

Conclusion of the study viewed each layer and year of Wamena accidents are:

Accidents in 2002

Layer IV

- The recommendation "to stop non type certificate aircraft with special permit in 2004" will block "Aircraft on special permit Non-Type Certificate under Estonian registration and crews" and "Government Check Pilot didn't do the close supervision (giving exam or onboard inflight)" failures.

Layer III

- The recommendation "to stop non type certificate aircraft with special permit in 2004" will block "crews on duty, new pairing was not regular set crews (Ex-Soviet common practice hardly change a set of crews)" failure.

Layer II

- The recommendation "to regularly train the fire brigade personals" will block "fire brigade personals were not ready" failure.
- The recommendation "to regularly check fire brigade equipment" will block "fire brigade equipment was unserviceable" failure.
- The recommendations "pilots temporary to do transmit blind when flying over gap" with 66.53% priority and "to install relay antenna for blank radio transmission between ATC to aircrafts" with 33.47% priority will block "blank radio transmission in gap area ATC to aircrafts" failure.

Layer I

- The recommendation "to stop non type certificate aircraft with special permit in 2004" will block "pilots failed to estimate distance to start the final turn properly" error.
- The recommendation "to stop non type certificate aircraft with special permit in 2004" will block "aircraft landed and bounced three times, right main wheel touched, and nose wheel twisted, friction and created fire" error.

- The recommendations "to stop non type certificate aircraft with special permit in 2004" with 52.69% priority and "to install more navigation aid at the airport as well as publish holding and go-round pattern" with 47.31% priority will block "overspeed, high rate of descend during approach resulted flaps not extended" violation.

Accidents in 2008

Layer IV

- The recommendation "to review the status of the RFFS equipment at Wamena airport & establish an ERP for Wamena airport" will block "No Emergency Respond Plan (ERP) at Wamena airport" failure.

Layer III

- No failure was stated in the investigation.

Layer II

- The recommendation "airline to phase out (not using) Transall C-160 per July 10, 2009" will block "beta light didn't illuminate thrust reverser failure, maximum brake, brake overheat then created fire" failure.
- The recommendation "to exercise an ERP for Wamena airport" will block "Rescue Fire Fighting Service (RFFS) arrived at on-fire aircraft ten minutes after aircraft stopped taxiway E" failure.

Layer I

- The recommendation "to exercise an ERP for Wamena airport" will block "RFFS commenced applying foam suppressant five minutes after arrived at on-fire aircraft" error.

Accident in 2009

Layer IV

- The safety action "*airline made own Notification to Airmen (NOTAM) about go around procedure on April 27, 2009" will block "No GO AROUND procedure for Wamena Airport for runway 15" failure.
- The recommendation "to ensure the documenting and implementation of airlines for the specific training" will block "lack regulator's supervision on the specific training implementation & the Crew Resources Management (CRM) implementation" failure.
- The recommendation "to documenting specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" will block "operator should document specific training and implement Crew Resources Management (CRM) program" failure.
- The recommendation "to documenting specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" will block "Company Training Manual (CTM) stated about Ground Proximity Warning System (GPWS) but not Enhance GPWS (EGPWS)" failure.
- The recommendation "to documenting specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" will block "No procedure detailing to inhibit terrain features in EGPWS" failure.

Layer III

- The recommendations "to implement specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 84.85% and "to documenting specific training modules for crew response to all

warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 15.15% will block "crews did not receive Enhanced Ground Proximity Warning System (EGPWS) training stated in Company Training Manual (CTM)" failure.

- The recommendations "to implement specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 84.77% and "to documenting specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 15.23% will block "operator simulator training program did not cover action & responses to EGPWS aural alert & warning" failure.
- "This aircraft approved combi operation (cargo-passengers), at accident was cargo flight but used passengers' weight & balance" failure not directly affecting the accidents.

Layer II

- The safety action "DGCA made NOTAM to revise Wamena Airport elevation from 5083 feet to 5430 feet on Dec 1, 2009" will block "Wamena Airport elevation was 5083 feet" failure.
- The recommendations "to implement specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 79.92% and "to documenting specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 20.08% will block "Not respond "DON'T SINK" & "TOO LOW TERRAIN" for overshoot on right downwind

on second attempt approach (KNKT 2009) & "DON'T SINK", "TOO LOW TERRAIN" , "BANK ANGLE",& "TERRAIN TERRAIN" during base lag turns second attempt approach" failure.

- The recommendations "to implement specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 72.12% and "to documenting specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 27.88% will block "crews not familiar with EGPWS equipment" failure.

Layer I

- The recommendations "to implement specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 76.50% and "to documenting specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 23.50% will block "Enhanced Look-Ahead function appeared to have been inhibited" violation.
- The safety action "DGCA made NOTAM to revise Wamena Airport elevation from 5083 feet to 5430 feet on Dec 1, 2009" will block "second attempt approach after overshoot join low level downwind 150-350 feet above ground level" violation.
- The recommendations "to implement specific training modules for crew response to all warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 79.92% and "to documenting specific training modules for crew response to all

warnings and alerts generated from ground proximity warning systems and enhanced ground proximity warning systems fitted to aircraft that it operates" with priority 20.08% will block "Not respond "DON'T SINK" & "TOO LOW TERRAIN" for overshoot on right downwind on second attempt approach & "BANK ANGLE", "TERRAIN TERRAIN" during base lag turns second attempt approach" violation.

Accident in 2013

Layer IV

- No failure was stated in the investigation.

Layer III

- The recommendations "to ensure that pilots have adequate knowledge and skill to understand and correct implementation of Stabilized Approach" with 80.65% priority and "to review the procedure in crew coordination in respect to the EGPWS aural warning when activated" with priority 19.35% will block "recovery action from un-stabilized approach not following ALAR tool" failure.

Layer II

- The recommendations "to review the current method of CRM (Crew Resource Management) training" with priority 64.10% and "to implement the CRM training" with 35.90% priority will block "lack of between pilots communication" failure.
- The recommendations "to ensure that pilots have adequate knowledge and skill to understand and correct implementation of Stabilized Approach" with priority 80.06% and "to review the procedure in crew coordination in respect to the EGPWS aural warning when activated" with priority 19.04% will block "recovery action from un-stabilized approach not following ALAR tool kit" failure.

Layer I

- The recommendation "to ensure that pilots have adequate knowledge and skill to understand and correct implementation of Stabilized Approach" will block "the flight touched down runway 2 deg misalignment from runway direction" error.
- The recommendation "to ensure that pilots have adequate knowledge and skill to understand and correct implementation of Stabilized Approach" will block "After touchdown thrust asymmetric" error.
- The recommendations "to ensure that pilots have adequate knowledge and skill to understand and correct implementation of Stabilized Approach" with priority 80.06% and "to review the procedure in crew coordination in respect to the EGPWS aural warning when activated" with priority 19.04% will block "The flight didn't meet stabilized approach criteria for visual approach at or above 500 feet (25 seconds after EGPWS altitude call "FIVE HUNDREDS" pilot reported runway insight , the FDR recorded that when aircraft at 5450 feet (± 400 feet AGL) and 5260 (± 200 feet AGL) until the aircraft touched down showed that the pitch varied from 1° down to 5° up and the aircraft rolled to the left and right up to 20°and the heading changed from 140° up to 164°" violation.

Accident in 2015

Layer IV

- The recommendation "to develop an airport maintenance program, review and improve the runway inspection system, install VASI on runway 15" will block "rubber deposit 600 m start from runway threshold" failure.

Layer III

- The safety actions "to conduct hard landing phase 1 inspection" with priority 55.78% and "to establish FOQA or FDA system" with priority

44.22% will block "trend hard landing not corrected, FDR recorded within 107 hours, 170 lags, 5 times hard landing 2G" failure.

Layer II

- The recommendation "to develop an airport maintenance program, review and improve the runway inspection system, install VASI on runway 15" will block "Visual Approach Slope Indicator at Wamena airport was inoperative" failure.
- The recommendation "to improve ATCs wind-shear knowledge" will block "gusty wind not (windshear possibility) reported by ATC to pilots" failure.
- The recommendations "to encourage pilots for go around if un-stabilized approach" with priority 69.78%, "to review SOP of Jayapura to Wamena operation" with priority 15.49%, and "to review ALARS/CFIT training effectiveness" with priority 14.73% will block "Passing Jiwika 10,000 feet thrust idle, high altitude and over speed, 8000 feet flaps selected to 40°, 25 second after due to flap load limiter moved to 39.9°" failure.

- The recommendation "to improve windshear/CRM/COM-Stabilized Approach/EGPWS/CFIT training for crews" will block "no speed correction after "CAUTION WINDSHEAR" EGPWS warning" failure.

Layer I

- The recommendation "to improve windshear/CRM/COM-Stabilized Approach/EGPWS/CFIT training for crews" will block "Pilots unidentified effect of wind shear speed increased 148-154 knots, Thrust N1 reduce from 72% to 38% resulted aircraft touched 35 m from runway with 3.68 G" error.
- The recommendation "to improve windshear/CRM/COM-Stabilized Approach/EGPWS/CFIT training for crews" will block "at 5520 feet

aural warning CAUTION WINDSHEAR not responded by pilot" violation.

- The recommendations "to review ALARS/CFIT training effectiveness" with priority 50.08% and "To improve windshear/CRM/COM-Stabilized Approach/EGPWS/CFIT training for crews" with priority 49.92% will block "aural warning "SINK RATE" not responded by pilot" violation.

Accident in 2016

In this accident 2016 KNKT did not make any recommendations due operators' safety actions were considered relevant to block failures.

Layer IV

- No failure was stated in the investigation.

Layer III

- No failure was stated in the investigation.

Layer II

- The operator safety action "to assess the risks operating to Wamena 5 km visibility, 1000 feet cloud ceiling (AGL)" will block "Fifteen minutes before departure weather destination at Wamena visibility 3 km & cloud bases increasing from 200 to 1000 feet above ground level" failure.
- The operator safety action "to encourage pilots to go around if un-stabilized approach" will block "at 7000 feet pilots didn't see visual check point and PM (Pilot Monitoring) advised go around but flight still be continued" failure.

Layer I

- The operator safety action "to encourage pilots to go around if un-stabilized approach" will block "flight touched down 125 m from runway 15 with 3.25 G" error.

- The operator safety action "to encourage pilots to go around if un-stabilized approach" will block "at 5700 feet, distance 2 nm, EGPWS aural warning SINK RATE" violation.
- The operator safety action "to assess the risks operating to Wamena 5 km visibility, 1000 feet cloud ceiling (AGL)" will block "Wamena's visibility at when accident happened was 3 km" violation.

Letting the latent and active failures remain open holes will jeopardize safety due to penetration of errors which will become incidents or accidents in the future. In this Wamena accidents study from 2002-2016 reports failures which still open are:

a. KNKT 2002 "ATC didn't clearly give traffic sequence for landing" in Layer III and "Five traffics ingoing and outgoing almost same time" in Layer II.
b. KNKT 2009 "Senior in Command (SIC) concerned about Pilot in Command (PIC) handling the flight (recorded the anxiety)" in Layer I and "Nonconformance of operator published operating procedure" in Layer I.
c. KNKT 2013 "150 flights movement per day" in Layer III, "150 flights movement per day inbound and outbound" in Layer II, "VFR traffics outgoing & ingoing Wamena" in Layer II, and "Visibility reported by ATC 4 km" in Layer I.
d. KNKT 2016 "At 7000 feet ATC gave landing clearance to pilots when pilots still can't see the runway" in Layer I.

Repetitive latent and active failures which are one of the causes in incidents or accidents indicate that root cause hasn't been blocked effectively and comprehensively for each layer by interventions of safety recommendations or actions. In this Wamena accidents study from 2002 until 2016 five of six accidents having "Un-Stabilized Approach" failure and with interventions such as

a. Human/Crew: "To encourage pilots for go around if un-stabilized approach" (KNKT 2016, 2015), "To improve windshear/CRM/COM-Stabilized Approach/EGPWS/CFIT training for crews" (KNKT 2015), "To ensure that pilots have adequate knowledge and skill to understand and correct implementation of Stabilized Approach" (KNKT 2013).

b. Organizational/Administrative: "To review ALAR/CFIT training effectiveness" (KNKT 2015), "To review the procedure in crew coordination in respect to the EGPWS aural warning when activated" (KNKT 2013).
c. Task/Mission: "Airline made own Notification to Airmen (NOTAM) about go around procedure on April 27, 2009" (KNKT 2009)
d. Technology/Engineering: "To install more navigation aid at the airport as well as publish holding and go-round pattern" (KNKT 2002).

5.2 Recommendations

The study can be further extended of relation in Human Factor in Aviation related with Operator Financial Condition, Cultural Approach, and Regulatory Approach to operate in Wamena, Papua. Some recommendations on further study which can be done or in safety as per below:

Financial Condition can be perspective of difficulties in financial inside the operator will create the condition for pilots to accomplish a mission even all conditions didn't meet with the requirements so company will get fresh cash flow for employees' salary. Another view is how crews or staffs to stay discipline not exceeding limit with landing and takeoff weight for extra cargo for own interest in getting extra money illegally. Other things like minimum staffs' wages versus staff's competency in perspective aviation safety can be further studied as well.

Regulatory, can be perspective of study in how authority approval to operate into Wamena airport even though if strictly IFR followed in case of Boeing 737 planes will be difficult to profit with limited payload carried. The mitigations of optimizing fully Visual Flight Rule (VFR) will result more payload to be carried but safety should not be compromised and risks mitigating started from early layer until last layer from any hazards.

The failures of these KNKT's investigations didn't mention about mental fatigue of crews staying in Papua for quite long period during the mission away from the family (most Boeing 737 pilots are based in Jakarta), which also created "get home it is syndrome" pilots take opportunity to fly every day and rush to complete the daily

missions. (Even some pilots took eight lags daily flight from Jayapura to Wamena with 16 landings). The condition didn't break any aviation rule of flight time, duty time, and weekly out-base days off. Further study related to this condition with aviation safety for Wamena operation can be further done as well.

KNKT's finding did not mention as well between pilots' minimum experience to operate in Papua with specified type of aircrafts effecting on accidents or incidents, the study of this relation with Wamena or Papua operation in aviation human factors and aviation safety can be further interestingly done.

The open failure about heavy traffic operating in Wamena 150 flights a day should be blocked by implementing slots arrangement to operate to Wamena, creating Standard Arrival Procedure (STAR), Standard Instrument Departure (SID), creating Instrument Flight Rule (IFR) approach for Category C aircraft including the go around procedure even most of the aircrafts not equipped and capable doing Global Positioning System (GPS) approach but facility accommodating should be available to be used by equipped aircrafts. STAR as example can use all arrival traffics from Jayapura to fly using Middle or Bokondini gap over Pyramid and holding if needed to sequence for landing from other landing and takeoff traffics. The SID as example can be departure left turn gaining altitude until passing the terrain and fly North gap to Jayapura or use visual departure when other traffics, and weather permitted. Having different flow of incoming and outgoing procedure will segregate the traffics density and mandated the flights following the procedure will make ATC's workload lighter. The go around procedure for Cat C aircraft can be as Cat A and B, limit the climb gradient and speed to minimize radius of turn during go around turn for keeping sufficient distance from right side terrain. Wamena Air Traffic Controller (ATC) should be equipped with radar to increasing the capability to control traffics with wider range and higher altitude for incoming and outgoing traffics, beside installing parallel taxiway which will optimize the traffic flow.

The repetitive failure, error, or violation is "un-stabilized approach" should be blocked comprehensively by implementation Safety Management System (SMS) in HFACS and HFIX framework and intervention, the earliest possible layer is blocked from failure will prevent accidents happened again in the future. Hazards or risks are

captured in mitigation as earliest possible in format of report then intervened in normal operation not in incident and accident investigation stage which already too late.

GLOSSARY

AIP Aeronautical Information Publication

AHP Analytical Hierarchy Process

ALAR Approach and Landing Accidents Reduction

ATC Air Traffic Controller

ATIS Automatic Terminal Information Service

Cat Category

CAPT Captain

COM Company Operating Manual

CRM Crew Resources Management

CFIT Controlled Flight into Terrain

CASR Civil Aviation Safety Regulation

CI Consistency

CR Consistency Ratio

DGCA Directorate General Civil Aviation

DM Decision Maker

EGPWS Enhance Ground Proximity Warning System

ERP Emergency Respond Procedure

ENG Engineer

FAA Federal Aviation Administration

FAR Federal Aviation Regulation

FCTM Flight Crew Training Manual

FL Flight Level

GNSS Global Navigation Satellites System

HFACS Human Factor Analysis Classification System

HFIX Human Factor Intervention Matrix

hPa Hecto Pascal

ICAO International Civil Aviation Organization

IFR Instrument Flight Rule

JAA Joint Aviation Authorities

KNOT Nautical Mile Per Hour

KNKT Komite Nasional Keselamatan Transportasi

L Left Side

LVP Low Visibility Procedure

MCDM Multi Criteria Decision Making

MDA Minimum Decision Altitude

MSA Minimum Sector Altitude

NM Nautical Mile

NOTAM Notification to Airmen

NTSC National Transportation Safety Committee

OTC Over the Counter

PAPI Precision Approach Path Indicator

PIC Pilot in Command

PF Pilot Flying

PM Pilot Monitoring

RCA Root Cause Analysis

RCLM Runway Centre Line Marking

REIL Runway End Identification Lights

RI Average Random Consistency Index

RL Runway Lights

RNP Required Navigation Performance

ROC Republic of China

ROCAF Republic of China Air Force

ROD Rate of Descend

RVR Runway Visual Range

SOP Standard Operating Procedure

SMS Safety Management System

STAR Standard Arrival

SID Standard Instrument Departure

SIC Second in Command

US CSB United States Chemical Safety Board

UK TOC United Kingdom Train Operating Company

VFR Visual Flight Rule

Vref Reference Speed

WAVV ICAO Four Letter Code for Wamena Airport

WMX Three Letter Code for Wamena Airport

ZOGP Zero One Goal Programming

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