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Model of Human Elements for Maintenance Engineering in Maritime Field

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Abstract: Various accidents surveys have the conclusion that human error is a primary cause of most major accidents on board. One of them can be contributed by maintenance errors in the critical elements on board. Regarding with this issue, the focus of this work is to prediction of human error probabilities during the process of maintenance to make improvement on maritime field. For decreasing of human error in maritime field, an expert method, from safety risk assessment, was adopted as a vehicle to predict the human error probabilities. In this research many good scenarios from maintenance event on board were studied in detail to make synergy effect with design of human factors assessment.

This process is done by forming a model of human reliability assessment with combined maintenance culture. This model consists of several steps, which the first step by analyzing the input as symptoms of functional failure, qualitative analysis of human errors, interpretations, quantifications, maintenance and safety culture effects, which aims to evaluate human error on board, especially in the areas of maintenance equipment

This modeling process is to establish a task error types of equipment, and interpret the types of failures on the equipment between single failures, multiple failures, Common Cause Failures (CCFs), Common Cause of Non Critical Failures (CCNFs) are then classification with error mode from human error.

The result from modeling on accident is indicated by the relations between the mode analyses with a critical error events are dominated by the critical condition of the engine overheats with the total of 36.6.%, the equipment have critical events caused by human error are generally influenced by mistake total percentage of 23 %, lapses, slips with the total of 19 %, and violations with the percentages of 16 %. Single failure could be

considered a starting point for maintenance culture. In the maintenance culture describes the maintenance of a balance between three critical demands to anticipate, react and monitoring and reflecting as well as between the demands of equipment.
Keywords: equipment failures, Common Cause Failures (CCFs), Common Cause of Non Critical Failures (CCNFs), human error, cognitive interpretation

1. INTRODUCTION

1.1 Background

Various accidents surveys have the conclusion that human error is a primary cause of most major accidents in maritime field. One of them were contributed by maintenance errors in the critical elements in maritime field. Regarding with this issue, the focus of this work is to prediction of human error probabilities during the process of maintenance to make improvement on maritime field. For decreasing of human error in maritime field, an expert method, from safety risk assessment, adopted as a vehicle to predict the human error probabilities.

Maintenance is particularly vulnerable to error because the work is often complex. Many activities involved in there such as frequently removal and replacement of a variety of components in the systems, incorrect action error, not restored to operational state, procedural error, involving cognition and action, these activities may also have the potential to induce unwanted and un-anticipated events and may render critical systems unavailable.

1.2 Review

The maintainer often does not directly see the consequences of their error but the effects of maintenance errors or unsafe acts are significant, affecting on not only economic performance but also more importantly on public safety. As illustrated by these high profile safety critical events, such as The Sultana, on 2000 years, The Erika ship accident and especially common cause. Several studies were conducted in the field. Explained in [1] that The accident causation model describes the causality behind an accident. It is from this model possible to describe performance-shaping factors and it is possible to describe performance both in a sense where it is adequate in the given situation and in a sense where it fails. In the last case the performance can be described using human error taxonomies. Some well-known examples of human error taxonomies are: The Human and Organizational Error Taxonomy (Reason 1997), Slips, lapses, mistakes, and violations (Reason 1990), Errors of omission, errors of commission, extraneous acts (Swain 1982, Swain & Guttman 1983) and Skill, rule, and knowledge based behavior (Rasmussen 1981). These taxonomies are actually in use in the maritime domain as tools in the retrospective analysis of accidents or in proactive human reliability assessments, (one example is Merrick et al. 2000). As illustrated by these examples, it is not just the design of the maintenance and inspection tasks themselves which influence the likelihood of maintenance errors occurring; wider organizational issues can also have an impact on maintenance performance.

1.3 Objectivities

Regarding with any issued, Thus, we aimed at evaluating the significant human risk factors in accident of KM.Gemilang and accumulation data from 2005-2008. years The objective is help better to manage operational maintenance supported by human reliability assessment and maintenance culture based on the condition limited resources. The purpose of the model of the human elements is to introduce method of doing maintenance on equipment through cognitive interpretation so that maintenance culture can be developed on maritime field

2. THE MODEL OF THE HUMAN ELEMENTS FOR ENGINEERING MAINTENANCE

2.1 Total failures from the system or equipment in applied human error

Many of the accidents in the maritime environment was influenced by the systems or equipment's has through accumulation from total failures so that maintenance engineering still needs to be improved. Explained [2] that in technical risk assessments and safety analyses, typical failures of safety critical systems are modeled in the form of representations such as event trees and fault trees. The failure probabilities of various hardware components in the system is combined together using the logic represented by these models to give the probability of the failure. There are a number of systems that could contribute to the mitigation of an accident sequence, the probabilities of failure of each of the individual systems (which have been evaluated using fault tree analysis) are then combined using an event tree. Correlation with maintenance engineering [3] that the approach used to identify applicable and effective preventive maintenance task is one that provides a logical path to address each functional failure of system. The purpose is determined the direction of flow analysis and helps to determine the functional consequences of the failure of system, which may be different for each cause of failure. Further development of the analysis will determine if there is duty applicable and effective maintenance that will preventive or corrective it.

2.2 The modified model for human reliability assessment combined with maintenance culture.

Safety management system can only accomplish so much; however, due to the inherent design of equipment is a significant contributor. Indeed, accepted good practice in the field of safety is that wherever practical, health and safety risks are controlled in the first instance through the design. Dependence on training, procedures and controls another organization should be regarded as a fall back where the control design is not feasible [4].

Selection of safety performance indicators should be soundly based on the model underlying the safety and strength of precursors that lead to failures of attention [12]. For effective development requires a model, because the maintenance activities is needed to identify where to direct limited one single aspect can often be inefficient or even misleading Shown in the figure 1.

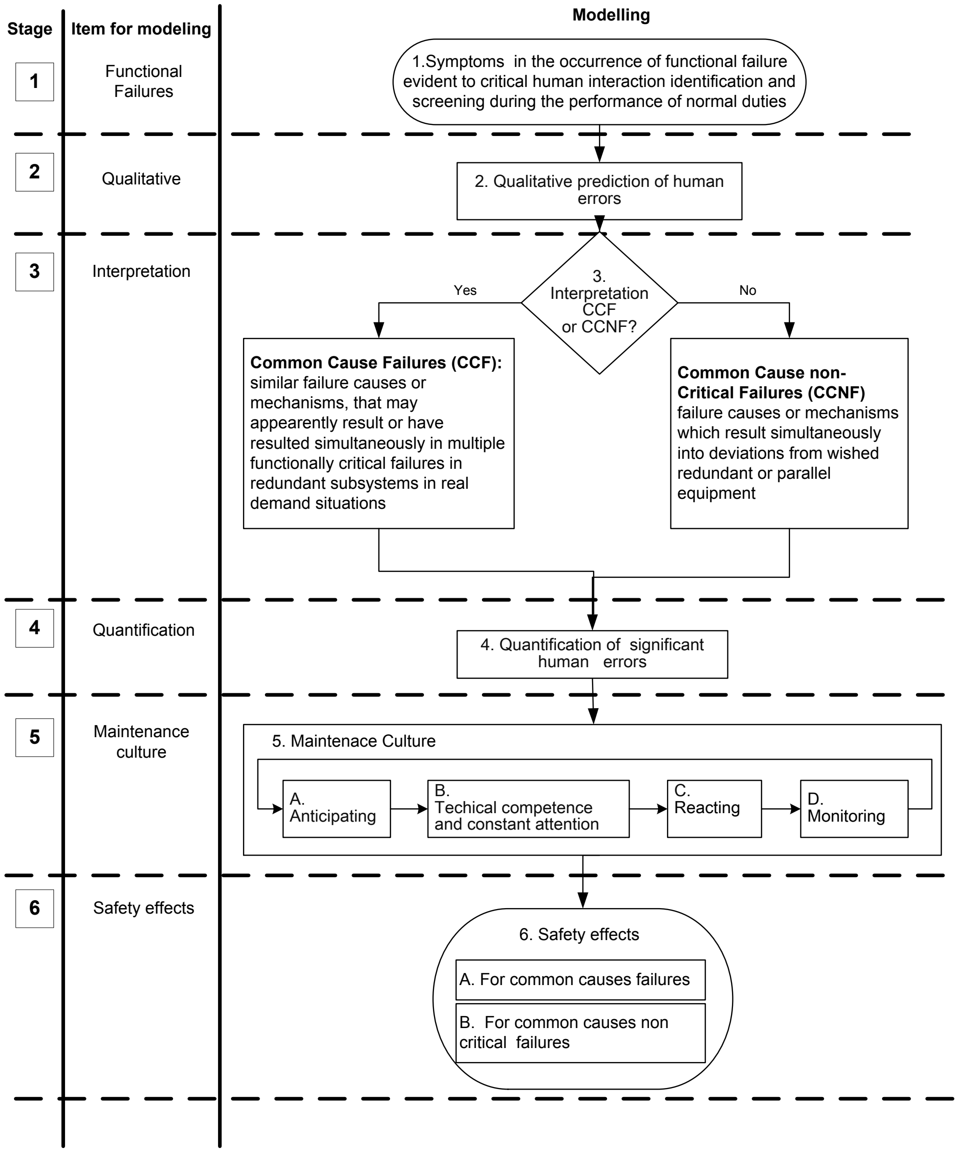

Figure1. Systematic human interaction reliability assessment combined with maintenance culture.

This model comprises six stages:

Table 1. Stage of modeling

Stage	Item for modeling	Description
1	Input as a symptoms of functional failure	This stage involves the symptoms analysis is provided an indication of the main areas at risk from human error so that resources expended on human reliability assessment can be appropriately prioritized.
2	Qualitative analysis of human errors	This stage involves the prediction error that can arise, using models of human error and factors performance analysis, and the nature of human interaction is involved (e.g. consequences of operation, personality, environment, interaction with equipment).
3	Interpretation	This stage involves interpretation about the cognitive function relevant to the identification of system states, or the diagnosis of plant situations [dec2008]. As a Common Cause Failure (CCFs) or Common Cause Non Failure (CCNFs).
4	Quantification	This stage involves a numerical quantification of the probability or frequency with errors (or change of error recovery) that identified in the previous stage (stage 3) in order to obtain the root causes of errors. After this stage , the probability of errors is combined with analysis of hardware to provide the overall measure of risk.
5	Maintenance culture	This stage involves the assessment of maintenance culture, the idea is that if the demands of instrumental (flexibility, methodologies, and learning) are adequately implemented in the organization, to suppose that the maintenance organization able to meet critical demands. Critical maintenance activities in order to anticipate demand based on equipment condition and state of crops and the impact of maintenance actions, and to plan maintenance tasks and resources required in advance.
6	Safety Effects	Common Cause Failures(CCFs) Task is necessary to ensure safe operation for leading multiple errors. Common Cause Non Failures (CCNFs) Task is required to ensure the availability necessary to avoid the safety effects of multiple failures so early warning of causes or mechanisms must be considered or leading to CCFs failures.

3. TASK TYPES ERROR OF EQUIPMENT

Failure is the termination of the ability of an item to perform the required functions and relations of human actions is involved of course can be interpreted as a human un-intended or intended action that produces an unintended result as we known human error [5]. The original cause coding used by the crew on board in the failure and repair work orders in is shown as an example in table 2.

Table 2. 4 M* Relation matrix between the failure and repair work

	A (Man)	**B (Machine)**	**C (Media)**	**D (Management)**
A (Man)	settings of parameter	design of equipment. equipment of standardizations	stress, fatigue,	wrong installation
B (Machine)	operation of machine irrelevant to the task	wrong installation of machine over reliance on the technology by operators	motions, fatigue, temperature	wrong order
C (Media)	loose connections	corrosion	noise vibration	Limit time and value
D (Management)	delayed actions	compatibility operating conditions equipment of standardization	crew responses	not coordination of maintenance management

Remarks; 4 M means Man, Machine, Media and Management

From table 2, in adaptation from source [6] that the failure and maintenance helps to identify candidates of human errors related to maintenance activities from the failure and maintenance history.

To reduce the effects of human error, then one of the functions of cognitive as known representation used to assist in the screening of candidates human error from equipment failure or system in order to establish maintenance culture of interconnected with other in figure 1. There are two steps used to identify the type of maintenance that to apply the taxonomy of error modes from cognitive human function and to distinguish the types of errors on the equipment or system.

3.1 Distinguishing the types of failures on the equipment

A system is often composed of many machines, which interact with one another. Sometimes a system have failed because one of the components which have failed to function. A component can fail due to many factors. Failures of components or system are due to impact and classified into single and multiple failures according to the effect from impact. Usually Any shock which leads to single failure or multiple failure and will be in to perform maintenance culture if the failure of human failure can be distinguished from the component of mechanism as well [8] Shown in table 3.

Table 3. Types of failure on the equipment

Types of failure	Description
Single failure	Failures of components are due to impact [8]
Multiple failure	The simultaneous failure of more than one component [8]
CCFs (Common Cause Failures)	Defined multiple failures that act on parallel or redundant circuit Some error is wrong or omitted is a trigger for human originated common cause failures, if they cannot meet their required function properly [7].
CCNFs (Common Cause Non Critical Failures)	Defined the equipment are not essential to the good function. In general, if the deviation gets worse, these precursors can develop into a common cause of failure [7].

3.2 Applying from the taxonomy of error modes

The classification system used for the analysis of error mode based on Hollnagel's error taxonomy CREAM [9,6]. Ten of the twenty-two modes of Cognitive Reliability and Error Analysis Method (CREAM) is identified in this analysis. Four additional fault modes, such as control failures, miss-calibration, and wrong input also generated a total of thirteen addressed mode error in this study. The taxonomy and definitions of the error mode from human error is used in this study have been modified given in figure 2.

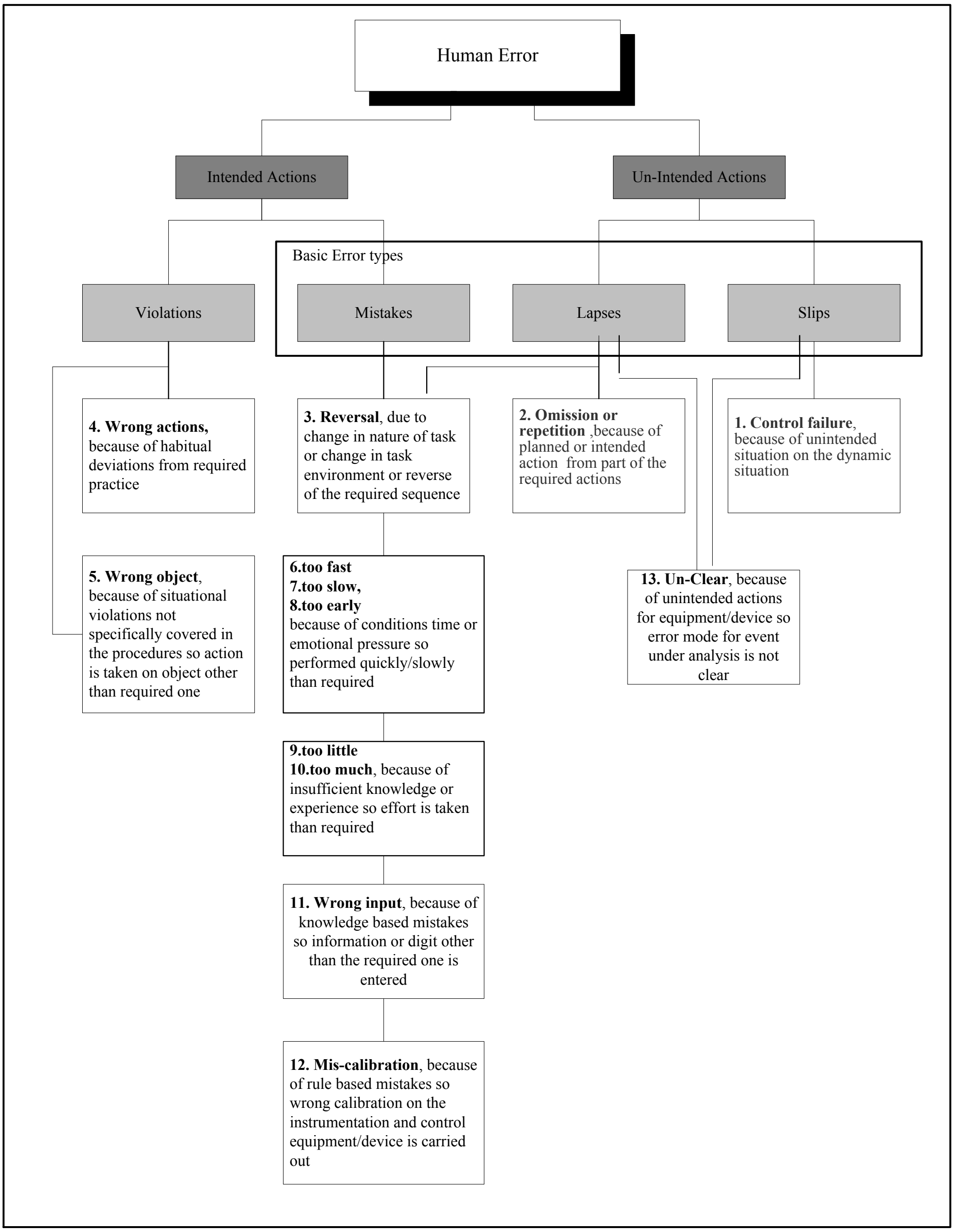

Figure2. The taxonomy of error modes from cognitive function

4. ANALYSIS AND CLASSIFICATION OF HUMAN ERRORS

Task and error type analysis was performed on the incidents reports for the unplanned on board KM. Gemilang trip events during 2006-2008. With the data, calculated reliability system with using are quantitative methods for any components there are in the system. In order to enable a better understanding of the analysis results and the report, important failure and error related terms used in this study are the first defined in figure 1.

In Table 4, an example of an analysis of human error in relation to maintenance [10] is presented. Identify tasks to be wrong as a "trigger failure" and the instant of time is a demanding task for analysis. The wrong task was searched by scrolling through the history of the earlier work of the failed equipment or system. Erroneous identification task required experience and technical knowledge of equipment maintenance and in some cases expert assessments are clearly needed to take the task possibilities, and simply by using from the table 3, to know the correlation between the types of failures on the equipment or system, shown in table 4.

Table4. Correlations between the types of failures on the equipment

Critical events	Root cause	Type of failure				Maintenance
		Single	Multiple	CCF	CCNF	
Engine will not crank with starter motor, or cranks slow	Remote control not in Neutral Position	O			O	Position the remote control exactly neutral
	Blown the ignition fuse or open circuit breaker		O	O	O	Replace the fuse-reset circuit breaker
	Loose and/or dirty wiring connection	O	O	O		Check the battery cables and starter circuit wiring. Clean and tighten all connections. Repair or replace the damaged wiring.
Engine Overheats	Loose or worn drive belt	O			O	Adjust or replace the belts as necessary.
	Collapsed, kinked, or leaking hoses.	O			O	Replace the hoses
	Transmission/engine oil cooler	O			O	Remove the water hoses and flush in opposite direction of the normal flow
	Faulty thermostat	O			O	Replace the thermostat
	Sea-water intake valve partially/ fully closed	O			O	Replace the impeller
	Faulty temperature, sending unit or gauge.	O	O		O	Test and replace as necessary
	Coolant level low in the fresh-water section of the cooling system.	O			O	Check the cooling system for leaks. Refill the system. See warning before removing the fill cap

Transmission slipping erratic operation	Low oil level	O	O		O	Add specified oil. Check the transmission for leaks
	Transmission overfilled causing oil aeration.	O	O		O	Drain required amount of oil
	Transmission shift lever not fully engaged	O	O		O	Adjust the shift linkage and remote control. Check the shift cables for freedom of movement and binding
	Contaminated fluid or foreign object	O	O		O	Determine and correct the contamination source and change the fluid
Fireworks safety	let one of the hydrant fire in a state does not operate	O	O		O	Ready condition through flushing, inspection, lubrication and cleaning

Remarks "O" means "yes" correlation between types of failures on equipment.

Variations of maintenance from Table 4, and applied [5,10] indicate a few things that can be used to establish shaping maintenance culture, among others

Anticipating. All actions appropriate for retaining an item/part/equipment, or restoring it to, a given condition. Incorrect, incomplete or unclear planning of maintenance or operability verification actions such as maintenance, servicing, installation, alignment, corrective, inspection or functional testing phases of work. Deficiencies in definition of decision of work scope, work order, operation order or procedure

Maintenance technical support and operation.. Flexibility is the ability two coordinates for controlling operations of equipment or systems. Methodological is the ability to explain the actions taken and methods used. Learning is the ability to analyze about incidents, accidents and operational experience. Mindfulness in everyday activities because lack of training, specialist or cross-functional knowledge to the tasks or planning.

Responding about sudden and unexpected incidents. Because of the lack of knowledge or poor information on the violation, so specific training on human behavior in emergencies are given deviation violations can be minimized.

Monitoring. Monitoring is to control from condition of equipment and reflecting on the effects of maintenance actions because errors or deficiencies in the design or modification of documentation, equipment, systems, installations or computer programs.

5. APPLICATION

In this section, incidents were presented to illustrate human failure in maintenance accidents an incidents based approach. Investigated by the National Transportation Safety Committee, Indonesia

Within the KM.Gemilang on board case study detailed classification models for human errors in relation to maintenance was enhanced to individualize better the quality errors related to maintenance. The use error classification in table 2, describes how the direct effects of human error in relation to maintenance appear on the equipment level.

Table 6. The relations between the mode analyses with a critical error events and error mode

Critical events	Root cause ***	Error mode*													Sum	Ratio %
		1	2	3	4	5	6	7	8	9	10	11	12	13		
A Engine will not crank with starter motor, or cranks slow	A1	0	1	0	1	0	1	1	1	1	1	1	0	0	8	13.4
	A2	1	1	1	1	1	0	0	0	0	0	0	0	0	5	8.3
	A3	0	1	1	1	1	1	0	1	0	1	0	0	0	7	11.7
B Engine over heats	B1	0	1	0	1	0	0	0	0	0	0	0	0	0	2	3.3
	B2	0	1	0	1	0	0	0	0	0	0	0	0	0	2	3.3
	B3	1	1	0	1	0	0	0	0	0	1	0	0	0	4	6.7
	B4	0	1	0	0	0	1	0	0	0	0	0	1	0	3	5
	B5	1	1	0	0	0	1	0	1	0	1	0	0	0	5	8.3
	B6	0	1	0	0	0	0	0	0	0	0	0	1	0	2	3.3
	B7	0	1	0	1	0	1	0	1	0	0	0	0	0	4	6.7
C Transmissi on slipping erratic operation	C1	1	1	0	1	0	0	0	1	0	0	0	0	0	4	6.7
	C2	1	1	0	0	0	0	1	0	1	0	0	0	0	4	6.7
	C3	1	1	0	1	0	1	0	0	1	1	0	0	0	6	10
	C4	0	0	1	1	0	0	0	0	0	0	0	0	0	2	3.3
D Fireworks safety	D1	0	0	0	1	0	0	0	1	0	0	0	0	0	2	3.3
Remarks	Total	6	13	3	11	2	6	2	6	3	5	1	2	0	60	100

A1=Remote control not in neutral position
A2= Blowing the ignition fuse or open circuit breaker
A3=Loose and /or dirty wiring connection
B1=Loose or worn drive belt;
B2=collapsed kinked or leaking hoses
B3=Transmission/engine oil cooler
B4=Faulty thermostat

Error mode*
1 =control failure 2= wrong action 3=wrong object 4=omission; 5=reversal
6=too early 7=too much 8=too little 9=too fast;
10=too slow 11=wrong input 12=miss-calibration 13=unclear.

B5=Sea water intake valve partially/fully closed;
B6= Faulty temperature sending unit or gauge
B7= Coolant level low in the fresh water section of the cooling system
C1=Low oil level
C2=Transmission overfilled causing oil aeration
C3=Transmission shift level not fully engaged
C4=contaminated fluid or foreign object
D1= let one the hydrant fire in a state does not operate

The results from Table 6, indicated by the relations between the mode analyses with a critical error events are dominated by the critical condition of the engine overheats with the total of 36.6.%. While the error value analysis mode is dominated by the root cause of the condition of the remote control not in a neutral position, with the total of 13.4%, and the condition of loose or dirty wiring connection with the total of 11.7%.

The reason why the wrong action mode takes up a large portion of the total error modes every root cause is that the wrong action the condition from engine during operation on board and response to a transient contributes to burst on board

The results from figure 2 and table 6, indicated by the correlation between human error mode from cognitive function with critical failure, are mistakes dominated with the total 23 %, lapses, slips with the total 19 %, and violations with the percentages are 16%.

6. CONSIDERATION

(1) The system is influenced by mistake. According to the review of most of the analysis of a single error in accumulation data from 2005-2008 years given result that engine over heat as a critical events more involved in human error led to failure than any other critical events.

(2) Review the results of the root causes of human events common cause failure analysis shows also that the planning phase of maintenance work and operability verification measures is a very demanding task because of complex environmental planning different goals, safety requirements and instructions, and technical needs of multifunctional plants, maintenance and operation knowledge.

(3) Involvement dominate in single failure have to depend on error area engine will not crank. The dominance comes from the high number of maintenance objects. However, these results emphasize the responsibilities and requirements of both flexibility and specialization of the maintenance, design and planning of the operation, and the need for instrument mechanics skills and knowledge of instrumentation and automation and functional effects.

(4) The number of significant contributing cause "lack of knowledge" shows the need for specialist understanding and experience of a particular component on utility and crew, supervision and perform specific maintenance activities.

7. CONCLUSION

(1) Systems or equipment have critical events caused by human error are generally influenced by mistake. Shown from figure 2, according to the review of most of the analysis of a single error in given result that engine over heat as a critical events more involved in human error from intended actions and unintended actions to failure than any other critical events.

(2). Involvement dominates in single failure.

Single failure could be considered a starting point for maintenance culture, thus reducing the impact of latent failure that often used as the issue for cause of the accident under investigations that planning maintenance can be done in an integrated problem between knowledge of maintenance, design and skill instruments from technician.

(3) Variations of maintenance

Variations of maintenance from critical events is very demanding task because of complex environmental planning different goals, safety requirements and instructions, and technical needs of multifunctional plans, maintenance and operation knowledge.

(4) Quality of maintenance planning and verification of operation

Overview of the second set was analyzed single and multiple errors at both locations showed that most errors in relation to the maintenance comes from the use of machines. That are not less in accordance with the standards prescribed, although initially only a factor of common non-critical failure but the period of maintenance and less attention so that their use leads to multiple failure.

(5) Critical demands

From maintenance and instrumental demands needed to respond to critical demands drafted by the core analysis of maintenance tasks. This model describes the maintenance of a balance between three critical demands to anticipate, react and monitoring and reflecting as well as between the demands of equipment.

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