Journal of Environmental Health and Sustainable Development

Helping HSE Team in Learning from Accident by Using the Management Oversight and Risk Tree Analysis Method

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ARTICLE INFO

ORIGINAL ARTICLE

Article History:
Received: 15 April 2016
Accepted: 11 August 2016

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Keywords:
Accident,
Analysis,
Management,
Prevention.

ABSTRACT

***Introduction*:** The effects of accidents vary from minor injuries to fatalities and from insignificant damage to severe damage to the environment and property. In order to prevent accidents in the work place, the root causes of and events should be identified using a systematic method and the results should be published. The current study aims to investigate the given causes of an accident in order to implement preventive actions in accidents and similar organizations.

***Materials and Methods*:** In this case study, after choosing the main event; to analyze the accidents, at first a set of questions in Management Oversight and Risk Tree (MORT) were answered. By answering the questions, the final events, and the inappropriate management risks (color-coded red) followed by the leading causes of the accident were identified.

***Results*:** After analyzing the given accident, 22 inappropriate final events (color-coded red) and 4 assumed risks were identified. Of the total 12 identified basic causes, about 75 % were classified as the management policies and decision makings group, 17 % as the individual factors, and 18 % as the environmental factors group.

***Conclusion*:** The analysis using MORT method helped the organization with learning lessons from the accident especially at the management level. In order to prevent the similar and dissimilar accidents, the inappropriate informational network within the organization, inappropriate operational readiness, lack of proper implementation of work permit, the inappropriate and lack of updated technical information systems regarding equipments and working process, and the inappropriate barriers should be considered in a special way.

Citation: Mohammadfam I, Mohseni S, Sohrabi MS, et al. **Helping HSE Team in Learning from Accident by Using the Management Oversight and Risk Tree Analysis Method.** J Environ Health Sustain Dev. 2016; 1(2): 91-9.

Introduction

Accidents are the main causes of death and disability which are placed at the third rank after the cardiovascular diseases and cancer around the world. Currently, the remarkable advances in industrial affairs and the possibility of using modern transportation system to travel, the use of electricity power and machinery, contact with chemicals and etc. have caused human beings to encounter with countless incidents. Annually, millions of accidents around the world occur. Some of these accidents cause human death and others lead to the whole or partial disability. Generally, all accidents cause their victims suffer

from pain as well as economic and financial losses [1].

According to the International Labor Organization (ILO):

- Over 317 million on the job-accidents occur annually.
- More than 2.3 million workers die of work-related accidents and occupational diseases every year.
- About 4 percent of the world's Gross Domestic Product (GDP) is spent on accidents and work-related diseases [2].

In spite of the significant improvements achieved in safety science and introducing system safety which emphasizes on hazards' identification and control before converting to the accident, it is still impossible to reach the zero rates of accidents and certainly it will not be the case in the future. Investigating the occurred accidents and incidents increases the authorities' awareness to determine the related causes and finally design appropriate programs to prevent the future similar accidents and factors leading to human and material resources waste [3].

A systematic approach is required to investigate and analyze incidents to avoid them effectively. Therefore, accident-related studies have always been considered as an undeniable part of safety science. Moreover, the proper design and appropriate implementation of these studies will provide a platform for preventive measures regarding the possible accidents in the future. Therefore, it can be said that, accidents and near miss provide an opportunity to avoid similar incidents in the future by learning from experiences and taking the required lessons. The United States Department of Energy (DOE) divides accidents' investigation process into 3 stages: collection of evidences and facts, analysis and investigation of these facts and evidences, and finally development of conclusions and judgments of needs, as well as writing the report and publishing [4].

Accident related studies that include precise analysis and explanation of data followed by presenting suggestions, have been used broadly in the context of safety science and their results were announced to all leading countries. Experts believe that using the others' information and experiences about past events is one of the ways for preventing those accidents and is considered as an important factor in continuous improvement and development of safety performance [5].

A lot of accidents can be avoided by knowing the factors which caused them. To realize this, causes of the accident should be determined first. At the next step, the acquired knowledge and awareness should be employed. In this case, hazards can be detected before converting to accidents and accidents can be avoided consequently [6].

In this vein, in recent years new techniques regarding accidents' investigation and analysis have been introduced to improve the effectiveness of research and also to revise and expand techniques. Management Oversight and Risk Tree (MORT) is one of the mentioned techniques. This technique arose from a project undertaken and defined by Bill Johnson in 1970 to provide a risks management program for US nuclear industry. This technique implementation method was revised in 2002 and 2009 for the first and second time, respectively. In this study, the revised guideline of 2009 was used. The same as Fault Tree Analysis (FTA), this technique is an analytical tree in which the accident is determined by the term "loss". This technique is able to analyze the accident as well as the near miss. Due to chart depicting and visual characteristics, this technique helps the analysts to find the relationship between events and imagine the probable hazards. If MORT technique implementation method is correctly understood, it will be performed easily due to having a ready set of questions. MORT is a comprehensive method to detect the effective factors in the accident in a regular and systematic way. As this technique emphasizes on management factors contributing to an accident, it can also be used as a mean to evaluate the quality of safety program available in the organization [7].

Alvarado-Corona et al, conducted a research on earthquake hitting the central part of chili and

released the effective factors causing the loss and damage to help reducing the similar incidents' consequences. Perhaps some of these factors included the inadequate technical information related to earthquake warning, inadequate informing and communication within the organization, inadequate operational readiness in the times of disaster, defects in the evacuation and rescue process, and the inappropriate implementation of permit to work [8]. Using MORT technique, Appicharla conducted a research on the space shuttle challenger disaster in 2012 to determine the accident's causal factors such as inappropriate communications, inadequate analysis of the previous research, inadequate risk assessment system and its control, inappropriate operational readiness, inappropriate policy implementation, inappropriate technical information systems, and inappropriate barriers [9]. In 2011, Appicharla analyzed a passenger train collision with a car at an intersection. In order to analyze the accident by using MORT technique, the reports of the Rail Accident Investigation Branch and the Rail Safety and Standards Board were applied in this study. The analysis results identified factors such as the inappropriate data analysis, inappropriate risk assessment and control system, inappropriate hazard analysis process, inappropriate standards, and inappropriate revision of safety program [10]. In addition, one of the studies done in the natural disasters' domain using this technique is a research conducted in 2010 by Santos-Reyes et al, on the flooding disaster of Mexico's state of Tabasco. Following the accident, the root causes were announced to be the inappropriate operational readiness, inappropriate inspection process, inappropriate barriers, inappropriate supervision support, and inappropriate technical information systems [11]. Interestingly, Santos-Reyes et al, have gone further and used MORT technique to analyze an accident which had occurred due to social anomie. After analysis, the inappropriate information system, failing to take lessons from similar events in the past, inappropriate support and guidance from supervisors and senior managers, inappropriate operational readiness, inappropriate response in emergency situations, and inappropriate barriers were introduced as the root causes of the accident[12]. The purpose of these studies for investigating the accidents using this technique was to uncover the accidents' causes and to learn from them to reduce the rate of accidents' occurrence and their unwilling outcomes in the future accidents. The current study was also conducted to uncover the root causes of the accidents and to disseminate them to prevent the similar incidents.

Materials and Methods

To investigate the accident which happened in an excavated channel, this case study was conducted in a gas power plant in Golestan province. This accident led to a mapping technician's death nailing in the channel. Like the Fault Tree Analysis (FTA), this technique is an analytical tree. The accident was determined by the term "loss" in this technique. This technique is able to analyze the accident as well as the near miss. Moreover, MORT is a comprehensive method to detect the effective factors in the accident in a regular and systematic way. This technique emphasizes on management factors contributing to accident and can also be used as a means to evaluate the quality of safety programs applied in an organization [12].

MORT implementing method:

An important incident was chosen among a chain of incidents occurred during the accident and placed on top of the MORT diagram (Figure1).

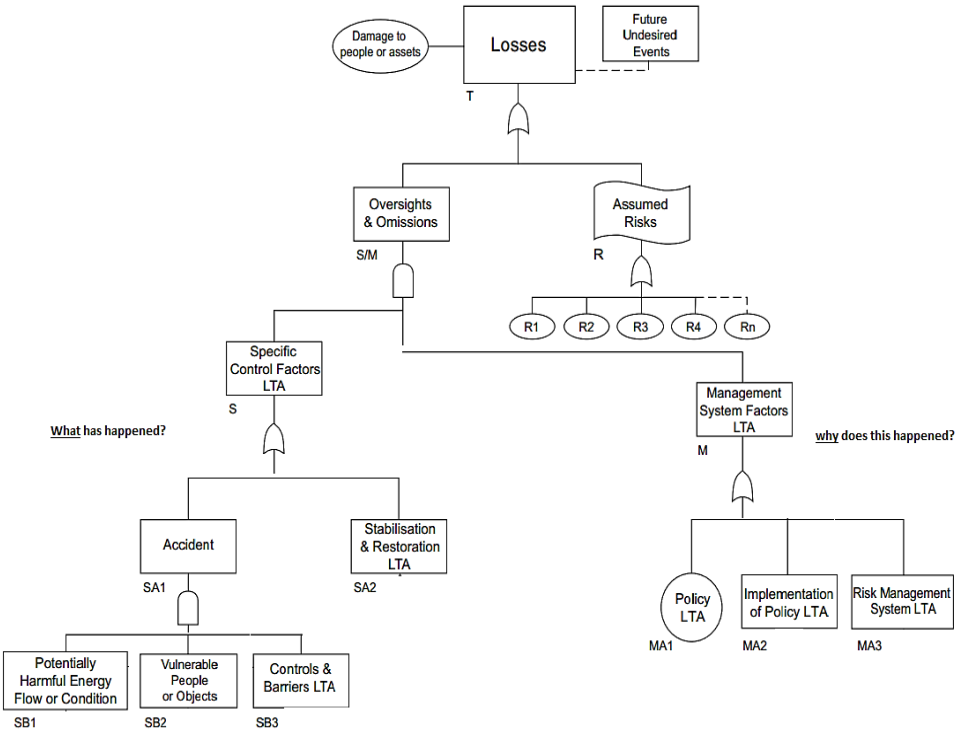

Figure 1: Top part of MORT chart

In this method the final events situation is determined with color-coded red (inappropriate or LTA; less than adequate), green (appropriate), black (an event which did not occur in this accident), and blue (incidents requiring more research to determine their situation). Then, a set of questions, more than 50 pages, were applied the same as the technique which a small part of it is presented below [13]. For better understanding, a branch of the extended MORT diagram (Figure 2) is presented below.

SD3. Inspection LTA:

This branch considers the contribution of equipment, processes, utilities, operations, etc. inspection related to the problem in question. In the following each part is explained.a1. Planning Process LTA: This branch considers whether the scope of inspection plan considered all the areas relevant to the problem in question adequately.

Was the management aware of any aspects relevant to the problem in question not included in the plan?

b1. Specification of Plan LTA: This branch considers whether the problem in question is related to how the inspection plan was specified.

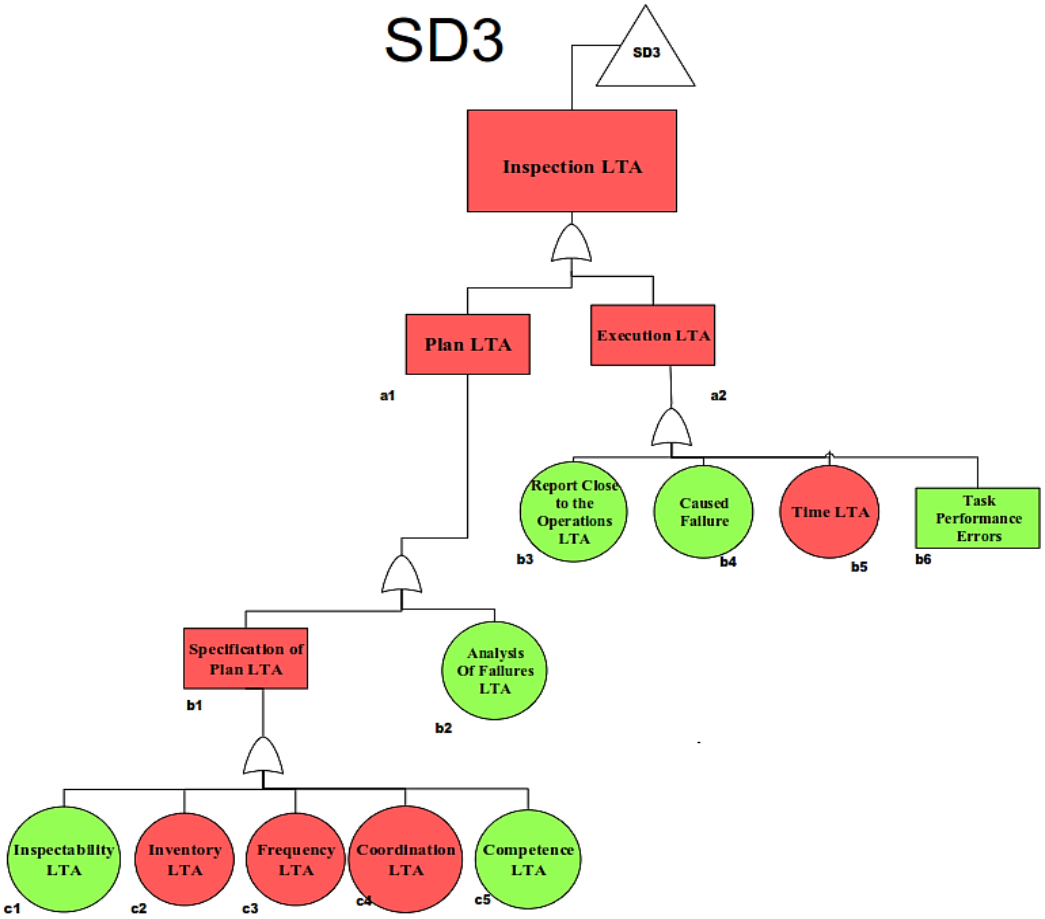

Figure 2: The parts of accident MORT chart

C_1. Inspect ability LTA: is the problem in question a result of inadequate inspect ability?
C_2.Completeness of the Plan LTA: Is there an adequate inventory of what is needed or inspected
C_3.Schedule LTA: did the plan schedule inspections frequently enough to prevent or detect undesired changes? Was the schedule readily available to the inspection personnel?
C_4.Co-ordination LTA: did the inspection plan address methods adequately for minimizing problems with disruption to equipment, processes, utilities, operations, etc. when they are under inspection? Was the schedule coordinated with operations to minimize conflicts?
C_5. Competence LTA: Was personnel competence adequately specified/ developed for the inspection tasks in question?

In order to answer these questions and judge from the events in this study, the required data was gathered through investigating the existing evidences (work permissions, safe work procedures, monitoring work posts' checklists, personal protective equipment's delivery receipts, accident reports, and the accident's existing photos) as well as the environmental evaluations based on walking talking through method (interview the staff who witnessed the incident, research and development unit experts, plan and control production experts, and HSE experts).

In accidents related studies, causes are investigated at three levels including: 1- direct causes (unintended release of hazardous materials and energy), 2- indirect causes (unsafe acts or conditions), 3- basic causes (policies and decisions, personal factors, and environmental factors) [14]. Some researchers were conducted on accidents only to detect and correct the direct and indirect causes (surface causes). But, in fact these detected indirect causes are an indication of the existence of some root causes which are often called basic causes[15]. In the current study, after extracting the

causes of an accident, the surface and basic (root) causes, and the frequency of these three groups of basic causes (policies, the management decisions about safety and personal and environmental factors) were determined. To get more familiar, some of these three groups of the basic causes are presented in the following:

Policies and safety management decisions: 1- safety policy: were not written or signed by the senior manager of the organization. 2- Safety executive methods have not been provided for performing the following items: safety sessions, job safety analysis, housekeeping, accident investigations, preventive maintenance and repair, and finally inspections and safety audit. 3- Safety in providing supplies and services was not considered. 4- Employee's safety was not considered with regard to the following cases: their selection methods, communicating with others, training, and etc.

Personal factors: 1- Physical: Inadequate strength and endurance 2- Experience: Inadequate knowledge and skills, a previous instance of accident, implementing unsafe work methods 3- Attitude: Toward others, people, firm, work, oneself, addiction to alcohol, using drugs, emotional upset. 4- Behavioral: risk taking, undermining risk, etc.

Environmental factors: 1- Unsafe designing of facilities: poor locating as well as restricted and busy access ways. 2- Unsafe operational methods in the normal and emergency state. 3- The weather 4- Geographical region and etc.[16].

Results

After analyzing the accident, MORT diagram was depicted (Appendix 1). Based on diagram 22 and considering table 1, the inappropriate final incident (color-coded red) was determined. In addition, 4 risks incorrectly accepted by the organization are presented in table 2.

Table 1: Final incidents with red color code

No	Incident code	Incident description
1	SB_1-b_3	Controls of the energy were less than adequate (LTA).
2	SB_2-c_2	Evasion was impracticable.
3	SC_1-SD_1-c_1- d_1	Individuals didn't making decisions adequately apply the knowledge from codes and manuals.
4	SC_1-SD_1-c_3-d_7	Structure of the internal communication network wasn't adequate.
5	SC_1-SD_2-b_5	All actions identified through operational readiness checks weren't adequately followed up.
6	SC_1-SD_2-a_2	Technical support provided to assuring the readiness of the work/process wasn't adequate.
7	SC_1-SD_2- a_4	Actual physical arrangement or configuration of the work/process wasn't identical with that required by latest specifications and procedures.
8	SD_3-c_2	There isn't an adequate inventory of what is to be inspected.
9	SD_3-c_3	plan schedule inspections didn't frequently enough to prevent or detect undesired changes.
10	SD_3-c_4	Schedule wasn't coordinated with operations to minimize conflicts.
11	SD_3-b_5	Time specified in the plan's schedule wasn't sufficient to adequately perform each task.
12	SD_5-a_2	Continuity of Supervision LTA.
13	SD_5-a_3-b_1-c_1	Absence of such a checklist contributed to the problem in question.
14	SD_6- a_3	A lack of open and frank communication between upper and lower levels contributed to problems in the control of the work/process in question.
15	SD_6- a_4	Codes, standards, and regulations (internal or external) did not cover the control of the work/process in question, management did not develop adequate standards and issue appropriate directives.
16	SD_6- a_7	Management wasn't adequately responsive regarding the problems proposed by lower levels.
17	SD_5-b_3-c_{14}	Fit between Task Procedures and actual Situation LTA.
18	SC_2- a_2- b_1	Barriers are not possible between energy source and target.
19	SC_2-a_3-b_1	Barriers are not possible on persons.
20	SC_2-a_4-b_1	Barriers are not possible to separate time and distance.
21	SD_5-b_3-e_{16}& SA_2-a_2-c_5-e_{16}	Emergency performance criteria training LTA.
22	MA_3- MB_5	Review of Risk Management System LTA.

Table 2: Assumed risk

Assumed risk states	Risk description	Risk reference in MORT analysis
Inappropriate	When energy is released (landslide) it's impossible for people in situ to escape.	$R_4 = SB_2$- c_2
Inappropriate	Creating a barrier between the energy source and given person is not possible due to inadequate space in the given place (channel).	$R_9 = sc_2$-a_2- b_1
Inappropriate	It is also not possible to create a barrier on the given person to be protected from the effects of energy.	$R_9 = sc_2$- a_3-b_1
Inappropriate	Time and place separation is also impossible for the person who performs the given action.	$R_9 = sc_2$-a_4-b_1

Discussion

Amongst the incidents occurred, the surface causes of the accident were presented on different levels of the above diagram. Further, the sub-branch, i.e., S, related to the inappropriate specific control factors (what has happened?) and 11 surface causes along with their associated code are presented below.

SC_1. Control of work and process LTA. SC_2. Barriers LTA. SD_1. Technical Information Systems LTA. SD_2. Operational Readiness LTA. SD_3. Inspection LTA. SD_5. Supervision and Staff Performance LTA.$SD_5.a_3$. Detection / Correction of Hazards LTA.$SD_5.a_4$. Performance Errors. SD6. Support of Supervision LTA. $SA_2.a_2$. Emergency Action LTA. $SA_2.a_3$. Rescue and Salvage LTA. (Lack of quick action to save the injured person due to the place's special conditions, i.e., inside channel, and lack of the necessary equipments).

Surface causes in occurrence of an accident are causes that appear immediately after the incident which occur mostly due to unsafe actions and conditions. However, identifying the hidden causes (root causes) which are far from the accidents, in terms of time and place, and usually occur at the organization level as well as presenting corrective measures for them are very effective in preventing accidents [17].

In MORT technique, the root causes of accidents appear in the sub-branch S at the final levels of the diagram, while inappropriate management factors (why it has happened), appear in the sub-branch M , in this regard, 12 causes' codes are presented below.

$SD_3.c_2$, $SC_1.SD_2.b_5$, $SC_1.SD_2.a_4$, $SD_3.c_3$, $SD_5.a_3.b_1.c_1$,$SD_5.a_2$, $SD_6.a_3$,$SD_6.a_4$,$SD_6.a_7$, $SD_5.b_3.e_{16}$, $SA_2.a_2.c_5.e_{16}$, and.$MA_3.MB_5$

Probably, due to different types of the studied incidents, some of the causes of accidents such as inadequate analysis of the previous research, inappropriate risk evaluation system and its control, inappropriate policy implementation in Appicharla's study [9], inappropriate data analysis, inappropriate risk assessment and control system, inappropriate risk analysis process in Appicharla's study [10], and failing to learn lessons from similar events in the past in Santos-Reyes et al study [12] are different from causes of the studied accident in the current research. Some of the discovered causes in this study namely inappropriate information network within the organization were repeated in the researches conducted by Alvarado-Corona et al [8], Appicharla [9], and Santos-Reyes et al [12]. The inappropriate operational readiness and the lack of correct implementation of permit to work can be seen among the extracted causes of the accidents investigated in the 3 studies conducted by Alvarado-Corona et al, Appicharla, and Santos-Reyes et al [11]. The causes such as inappropriate technical information systems and inappropriate barriers were repeated in the research done by Appicharla as well as Santos-Reyes et al [11, 12], and the inappropriate support of supervision was repeated in the study conducted by Santos-Reyes et al [11, 12].

In the light of the above, the root causes are divided into 3 groups, from 12 root causes obtained in this accident analysis, 9 causes were related to defects of the management's safety

policies and decisions, 2 causes were associated with personal factors, and 1 was related to the environmental factors domain.

Conclusion

As the initial investigation of HSE unit showed, the cause of accident was determined to be unsafe excavation against the existing codes and standards such as lack of using protective box and performing action without permit to work. However, the analysis using MORT technique helped the organization with learning lessons from the accident by uncovering the root causes especially at the management level. These causes had not been uncovered through the previous methods used by the workshop HSE team.

In most industries, usually, surface causes (direct and indirect) are determined after the accident's occurrence and investigation. But analyzing the accident using MORT method has revealed more root causes. This technique is very useful in root analysis of incidents especially for finding causes at management organization level.

From the 12 basic identified causes, 75% of them (with codes, SD_5-a_2, $SC_1.SD_5.a_3.b_1.c_1$, $SD_3.c_3$, $SD_3.c_2$, $SC_1.SD_2.b_5$ MA_3. MB_5, $SA_2.a_2.c_5.e_{16}$, $SD_5.b_3.e_{16}$, $SD_6.a_3$) were placed in the management's policies and decisions group, 17 % of causes (namely; $SD_6.a_7$,$SC_1.SD_2$. a_4) were put in personal factors' group, and 8 % of them ($SD_6.a_4$) were placed in the environmental factors' group. This indicates the importance of management policies and decisions in the occurrence of accident.

Organizations with the working operations such as the one in which this accident occurred can prevent the same incidents by studying the surface and root causes and learning from them. For instance, if the inspection and monitoring program had been implemented regarding the surface causes coded as SC, 1during the excavation operation; the same accidents could have been avoided. If preventive measures had been implemented for $SD_3.c_2$ and $SD_3.c_3$ root causes, in other words if the comprehensive, complete and scheduled inspection, and monitoring program with determined times of repetition had been formulated for discovering unwanted changes in this program, the other operations' starting and unsafe implementing followed by possible accidents could have been prevented. By studying similar basic causes in the accidents' analysis mentioned previously [7-11]. It can be said that lack of appropriate updated technical information systems regarding equipments, working processes and inappropriate barriers should be considered in a special way. Thus, taking corrective and preventive actions for this category of the root causes are effective in preventing similar and dissimilar accidents. It is also recommended to analyze a variety of accidents in different organizations using diverse and new techniques and report the results. This helps the organization managers and HSE experts to increase their knowledge by studying these extracted causes, especially the root and basic ones which play a significant role in occurring accidents, and accordingly create programs, codes, standards, and executive methods or revise them. In order to obtain better results and uncover this technique's weaknesses and strengths, it is required to measure the efficiency of this technique in the analysis of more accidents, either occupational or non-occupational ones. In addition, it is needed to compare the results obtained from this technique with the results obtained from other techniques of accident analyses.

Appendix

More information available at: http: jehsd.ssu.ac.ir.

Acknowledgements

Authors gratefully acknowledge Hamadan University of Medical Sciences and MAPNA groups for support of this research.

Funding

This study was funded by the authors.

Conflict of interest

We have no competing interests.

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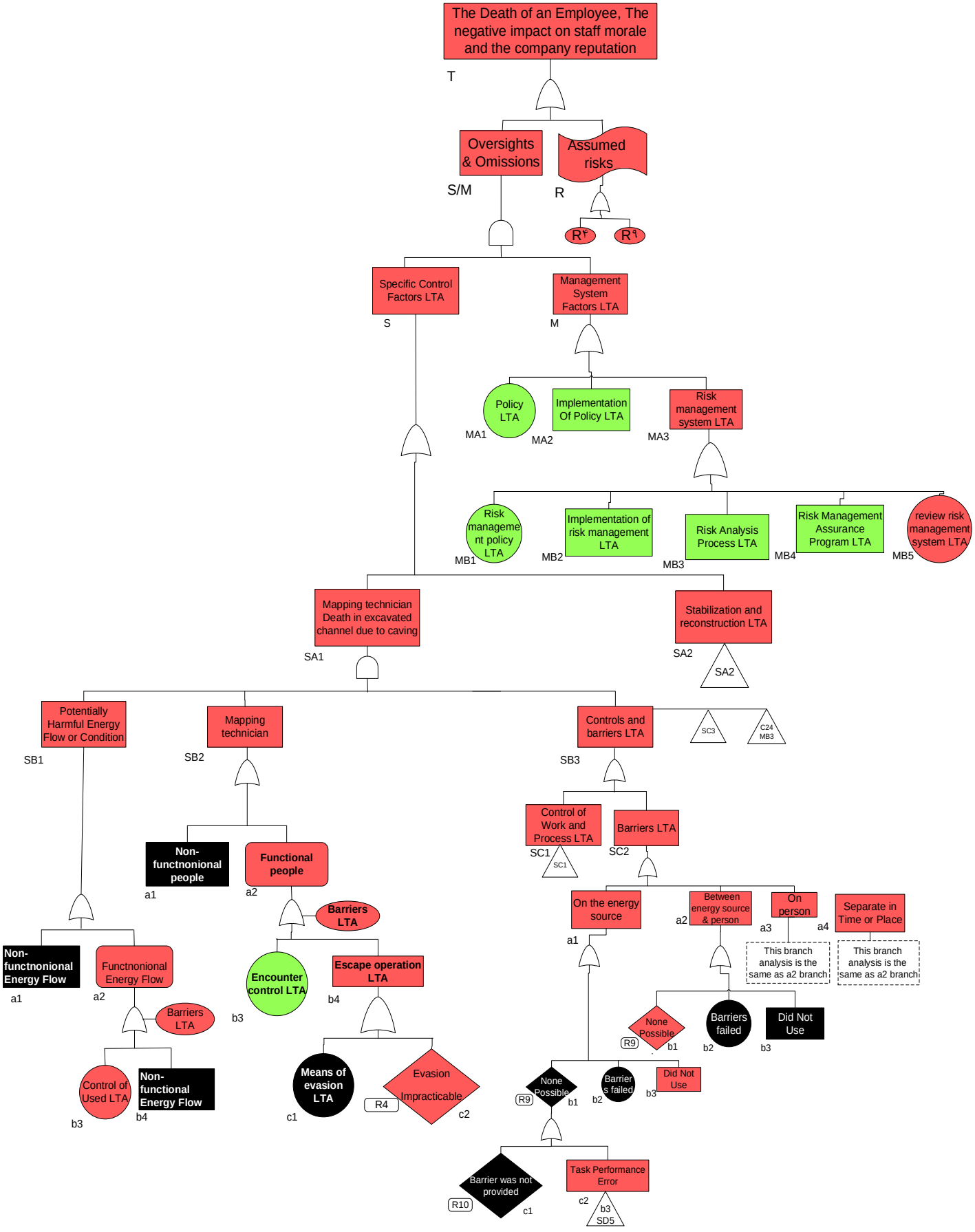
Appendix (1) the Management Oversight and Risk Tree (MORT)



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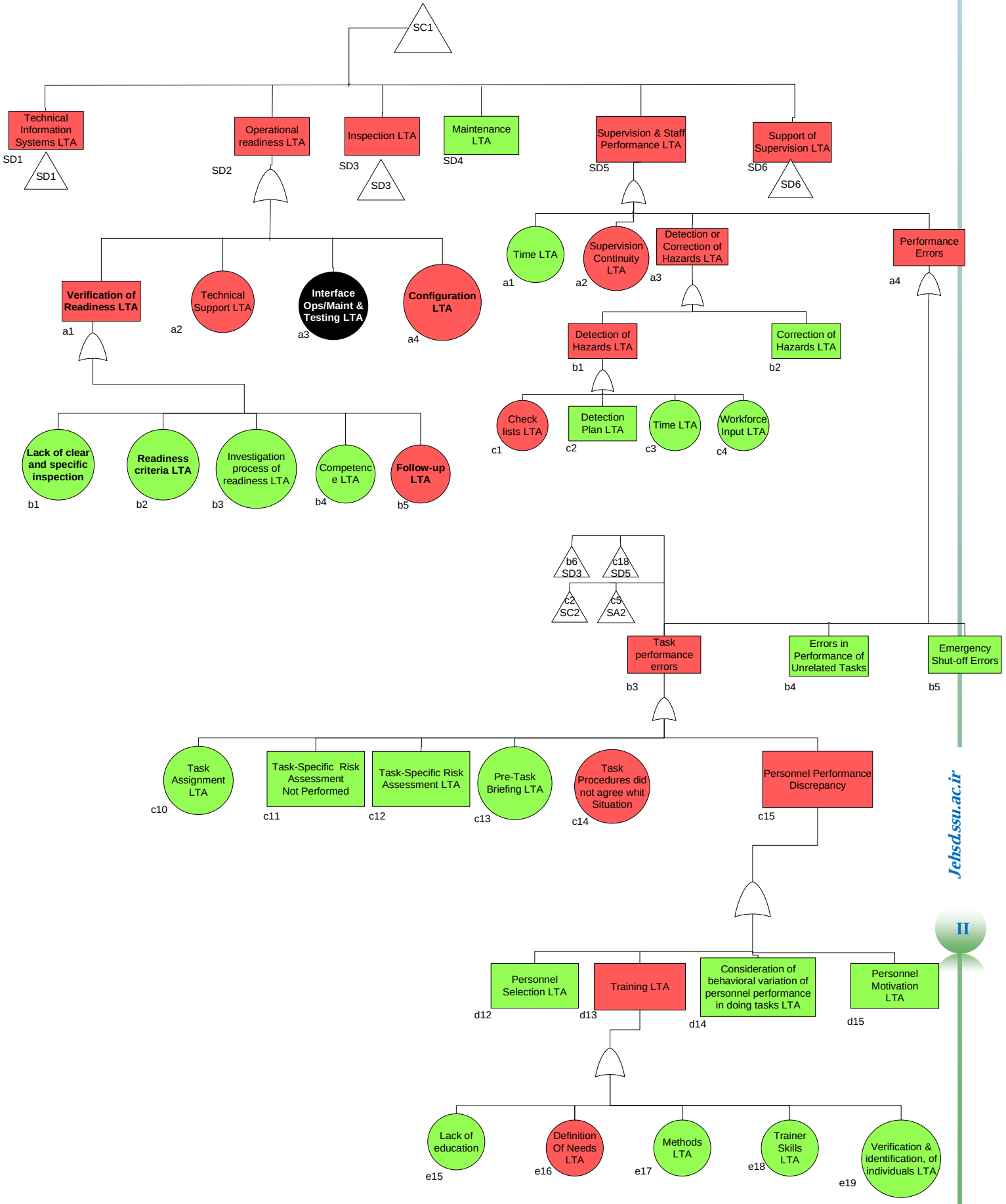

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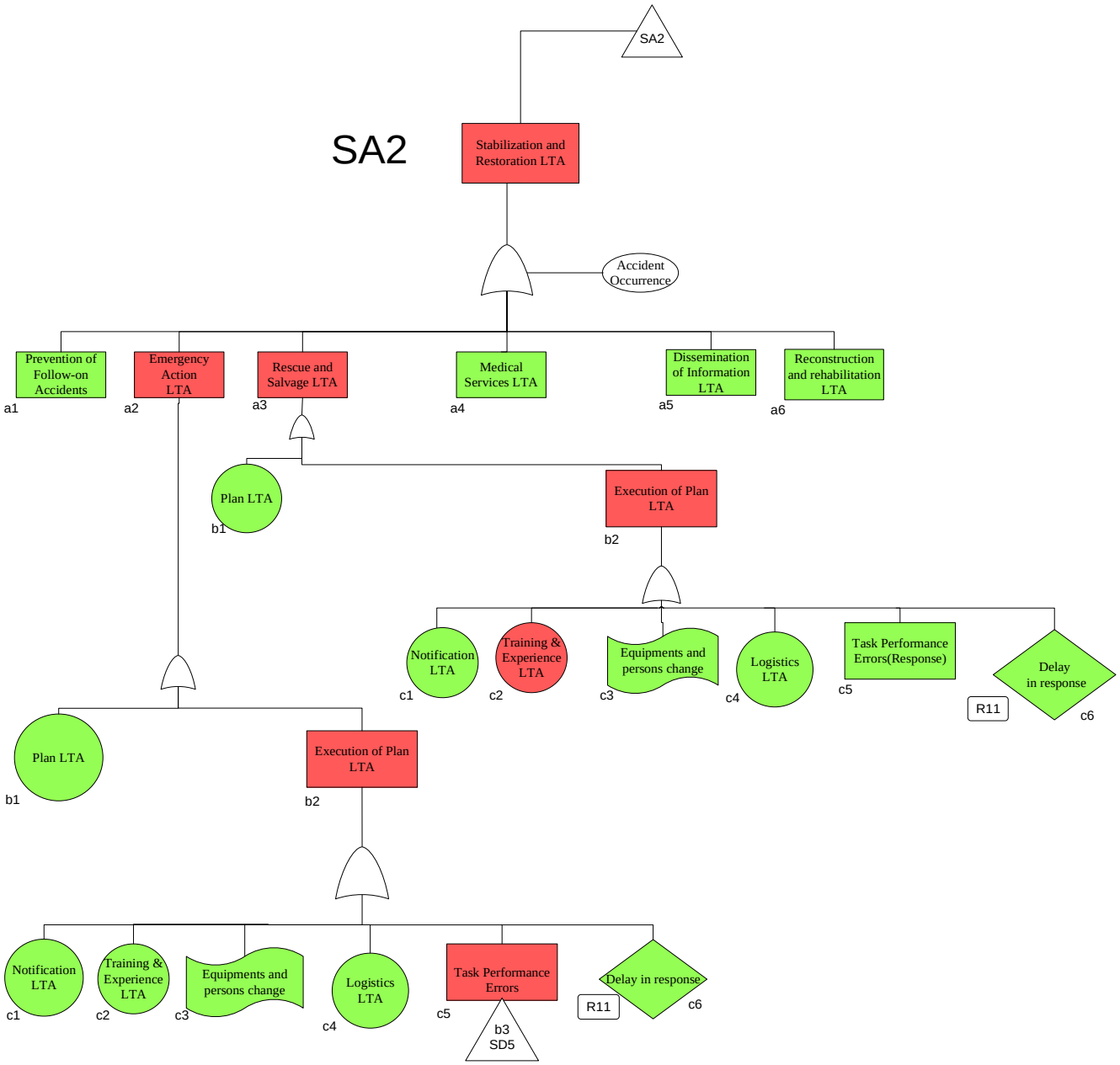

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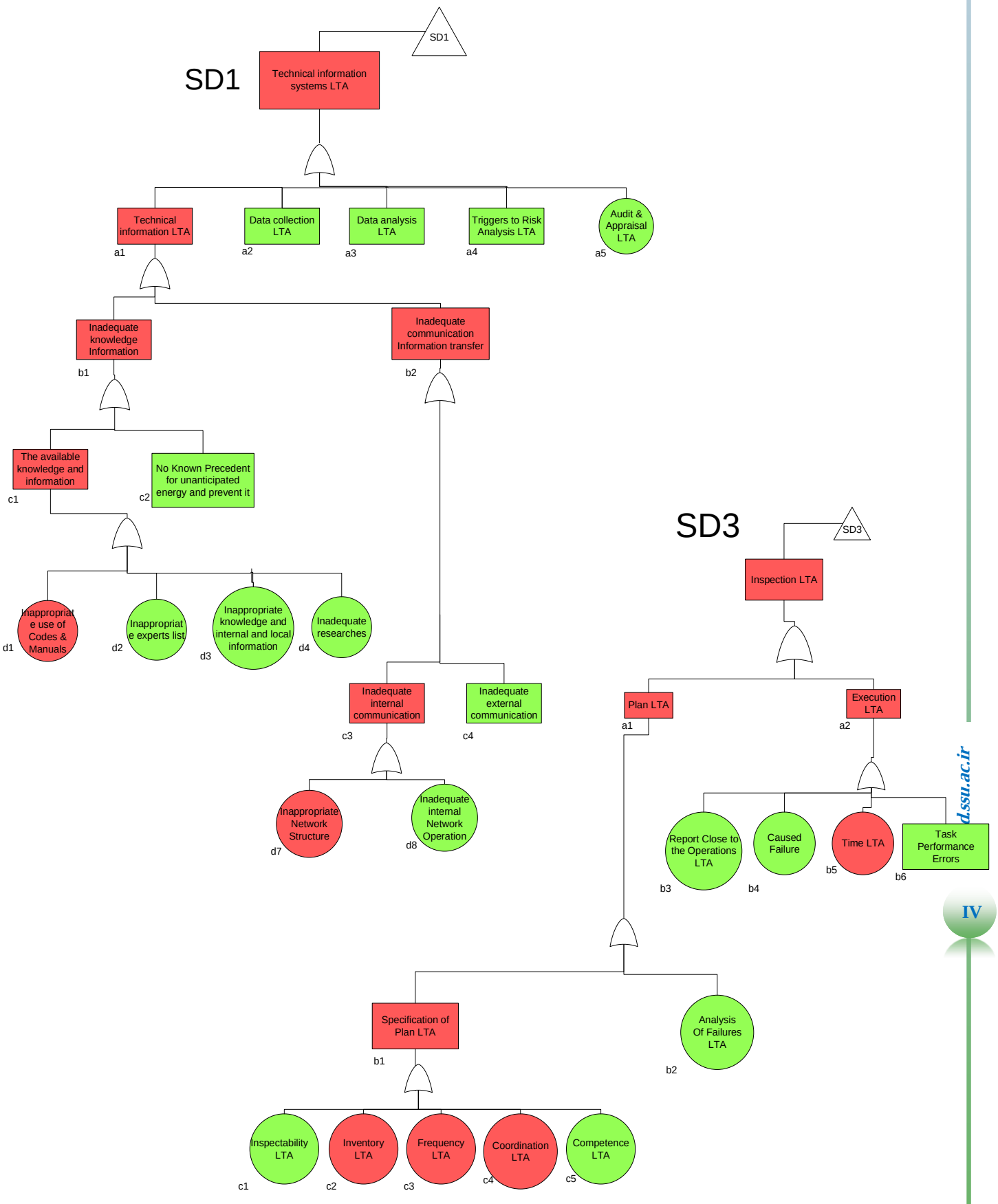

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