New Approach: Looking for the Underlying Causes of BOU ALI SINA Petrochemical Massive Fire Using the Socio-Technical Context

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Not long ago, the effectiveness of traditional methods of risk assessment were seriously doubted when observing the unusual frequency of hazardous events in the Iran's fossil fuel industry. Such uncertainties, made us to try different contexts to look for the underlying causes of the catastrophic events, like what happened on July 6, 2016 at the BOU ALI SINA petrochemical plant (BASP) in Iran. The article is aimed at introducing a new approach to analyzing the contribution of various decision-making levels of a society in formation of dangerous circumstances. To better clarify the mechanism of causation, using the framework of sociotechnical systems by Rasmussen et al., three levels of decision making along the continuum of social power, are selected and their performance as the incorporeal safety barriers against formation of large scale accidents are assessed. These three layers, respecting their extents of responsibilities are called "Thinkers", "Tailors" and "Soldiers".

To represent the behavior of these levels when they are exposed to the influence of surrounding environment, the "Swiss cheese" metaphor, developed by Reason et al. was borrowed to represent the "holes" on the Swiss cheese slices.

Interestingly, at the end of study, a clear pattern of accident-causation was revealed as a viable evidence that shows the capability of the model to explain the way that tragic accidents occur. Since this method was specifically used to investigate the BASP fire, selected levels were of the Iran's energy industry. The developed frame work, with potential to be generalized to other domains of social accidents as well, is called the "Social Protective Layers against Tragic Events", SPLATE.

Keywords: Sociotechnical system, Risk Management, Human Error, Layers of Protection, SPLATE, Swiss Cheese Model.

1. Introduction

The increasing frequency of fire and explosion incidents in the Iran's oil, gas and petrochemical plants, particularly during the second quarter of 2016, conveyed a clear message to the entire community of the process-safety practitioners of Iran, declaring that: something is not right out there. Receiving several incident reports during a short period of time, each highlighting a different factor as the main contributor of the accident, initiated serious doubts about the usefulness of all those time-consuming hazard identification analyses performed everyday under different titles and methodologies.

The doubts became more certain, when the sequence of mishaps on July 6, 2016 led to an extensive fire at the BOU ALI SINA Petrochemical (BASP) plant in Mahshahr, a port city in the southern part of Iran.

The BASP tragedy was an opportunity for us to address different risk management contexts trying to find the primary origins of the large-scale incidents rarely noticed within the after-accident inspection reports. With such mindset, the structure of socio-technical system (Rasmussen and Svedung, 2000) was preferred as the main framework for the research and the uncertainties brought by the rapid pace of technological changes, particularly in the oil & gas industry of Iran, as the source of the "environmental stressors" (Rasmussen and Svedung, 2000).

Trying to build the hypothetical sociotechnical system, three levels with higher intense of power in the oil & gas industry of Iran, were selected consisting of:

i) Legislation/law making level (Thinkers);
ii) Managerial level (Tailors);
iii) Individuals (Soldiers);

Moreover, since the context of socio-technical system, due to its intrinsic focus on the social concerns, is not the best platform to analyze the mechanism of the accidents' causation, the Swiss cheese metaphor (Reason, 1990)developed by the James reason (1990) was borrowed to represent the behavior of the selected social decision-making levels, as the protective barriers against passage of the incidents' causal paths.

By embedding the concept of "Pathogen Metaphor"(Reason, 1990) into the sociotechnical system context, a new framework was developed, capable to illustrate the contribution of more affecting social levels in the formation of tragic events like the BASP fire.

1.1. Delimitations

Respecting the main objective of the article, following discussions should not be interpreted as an incident report nor an attempt to criticize the engineering knowledge possessed by the Iranian governmental companies involved in the field of oil and gas refining. This paper also does not intend to undermine the qualifications of those managers who are in charge at different levels of decision making within the Iran's oil, gas and petrochemical industry.

Also, the phrase of "Failure in making right decision" refers to those unconstructive and non-value adding decisions, made by the constituting bodies of the concerned level, which are not aligned with objectives of the safety management system.

2. The Day of The Accident

At about 6:00 P.M. on Wednesday 6 July, 2016, the fire alarm in the unit 900 of the BASP went off indicating that a blaze of fire was detected at some point within the unit boundaries.

The preliminary reports revealed that the fire was initiated due to the occurrence of a leakage from a pump suction line which recently was removed for maintenance purposes. As the rate of leakage escalated due to an increase in the rupture's diameter, large amount of hot liquid spilled over the ground. The fluid's high operating temperature together with exposure to the atmospheric pressure, speeded up the formation of a massive buoyant vapor cloud that soon began to crawl towards the adjacent equipment. Once the moving cloud reached the hot surface of the unit's fired heater, the entire space including the whole length of the distillation tower, with more than 121 m of height, was embraced by flames.

Owing to the high velocity of wind at vicinity of the tower's top, the burning droplets entrained out of tower's shell, travelled across the plant and set fire to one of the feed stock storage tanks with 52 m diameter, on the opposite side of the plant.

Finally, thanks to the bravery efforts of all firefighting crew came along from the entire region and after 60 horrifying hours, the fire ultimately got under the control.

One week later, the overall damage made by fire was estimated about 110 million Euros, regardless of the severe environmental damages caused by routing a great amount of firefighting foams and extinguishing compounds directly into the Persian Gulf.

Figure 1 Paraxylene Distillation Tower (C-8001) Surrounded by Flames

Figure 2 Fire spread to the naphtha storage tank (TK-2001 C)

3. The Sociotechnical Side of Tragic Events

Every single accident that takes place, beside the technical, financial and political aspects, possesses a social side of view which defines the actions of the key players in the surrounding society, prior and after the time of the accident. The former, which encompasses transactions between different levels of society and the impacts they exert on the degree and frequency of the tragic events, is a topic with higher demand for attention than what is already paid. The inadequacy of current safety management systems in comparison with the "increasing potential of large-scaled accidents" correlated with the growth of industries was the rationale behind the selection of the social paradigm, so-called as the socio-technical system throughout the

manuscript. This concept represents a hierarchical structure through which, the concerned system is analyzed by being decomposed into its organizational levels.

The present study, albeit highly inspired by the impressive results of aforesaid authors, has some deliberate deviations from the antecedent premises:

1) In contrast with the concept of "pro-active risk management methodology", the focus of which is on the "Normal Activities" that unwittingly lay the foundation of the disasters, the present study sought for those abnormal and unusual circumstances that emerge after failures of the influential decision-making levels in making the right decisions.

2) Unlike the objectives pursued by the Rasmussen et al. (2000) to generate a comprehensive approach to address all aspects of risk mitigation, this article can be interpreted as an attempt to incorporate the concept of layers of protection (Summers, 2003) in the framework of sociotechnical system to come up with a model to interpret the role of social levels in formation of tragedies, like what happened at BASP.

3) As one of the basic assumptions made for developing the model, it was assumed that the lower levels of decision making encounter the adverse effects of dynamic environments only when as result of failure on the upper surfaces, they become directly exposed to the environmental stressors.

4) Inconsistent with the "Pathogen metaphor" theory in which causal factors are not able to singly stem the formation of catastrophic events, in this paper each failure is assumed capable to complete the path of causation and therefore is not only necessary abut also sufficient for triggering the accidents.

5) Rather than focusing on the positive correlation between the likelihood of accidents and the number of "pathogens", in this paper it is assumed that disasters' probability will decrease as the resistance of decision making levels against the adverse effects of dynamic environment increases.

6) Unlike the "Pathogen Metaphor"(Reason, 1990), in which all failures were studied in the context of human error and were divided into "Active" and "Latent" groups, in this paper all failures (except for individual level) are considered as the "incorporeal" (Hollnagel, 2008) type of failures with an origin in the systemic deficiencies in higher levels.

Through the following sections, the major possible failures of each level are identified and the mechanism by which the accident's path of causation may succeed to pass through them, is described.

4. Selected Social Levels

To build the frame work of the sociotechnical system, as described in the intro, three levels of decision making with higher degree of influence in the hierarchy of the Iran's oil & gas industry, were selected so that their Achilles' heels in case of facing the difficulties imposed by their agile environment, can be diagnosed.

These three nominated levels are:

i) Legislation/Law Making Level
ii) Managers' Level (e.g., Top, middle, and operational managers)
iii) Individuals' Level (e.g., Operators, employees, and designers)

4.1. Legislation/Legal Level

The first level under review is the lawmakers and the governmental bodies that (compared to the other social levels) dominate more power. This level, is highly involved in producing the procedures and regulations that become the mandatory rules for the rest of members. We called them the "Thinkers".

Taking a closer look at the way these regulations are being produced, will disclose that even such authoritative level cannot remain intact from the effects of prospective changes in a dynamic society. The more authority that this level has, the more severe consequences that it will cause in case of failure to make the right decision.

What follows, contain some of the observed detrimental factors that led to major failures in the legislature level of Iran's energy industry.

4.1.1. Lack of Rules Anticipating Upcoming Changes

Within an un-steady environment where the systems are being more complicated every day and undertaking a simple task requires more specialty knowledge than ever, the need for a set of rules to draw the public attentions to the underlying risks that every innovation might bring and to the necessity of establishing an infrastructure to improve the resilience characteristics of organizations as well, is becoming more noticeable. The tragedy of BASP, can be attributed to the lack of such concerns

within the legislation body of Iran. Neglecting the ever increasing need for updating the running procedures, particularly in a very high sensitive domain like the energy industries, can let the high level risks easily pass the first layer and threat the levels with lower power intensity.

4.1.2. Lack of Rules Minimizing the adverse effects of competitive environment

In a very volatile environment, when the limiting resources enforce companies to spend their greatest effort to keep their market share, adhering to safety regulations can be deemed impossible at least in some critical moments. In such environment, companies begin to propose more aggressive schedules by over-loading the available resources to come up with more competitive prices which nearly always are accompanied by putting the safety aside.

Therefore, lack of mandatory rules addressing this circumstances to prohibit companies from neglecting the safety concerns can be counted as another void area which leads to the passage of risks caused by dynamic environment as well as posing a significant threat to the lower levels.

4.1.3. Lack of mandatory rules enforcing to learn from accidents

The industry of hydrocarbon processing has witnessed many misfortunes since its inception. Under the skin of each tragic story, there is so much to learn and the most valuable of all is to remember that no matter how safe we think we are, some chaotic moments will emerge that were not even deemed applicable before. This can obviously be seen in the history of formation of the most well-known safety directives and regulations in the field of process-safety risk management. A good reference is the first edition of SEVESO directive which was published in 1982 after tragic dispersion of the dioxin into the local atmosphere at a city near Milan (Anon., 2012).

Unfortunately even after BASP fire, neither of a rigorous determination to make serious improvements nor a strong willingness for reconsidering the safety system procedures, seeking the gaps and out dated information, were observed.

In figures 4.1(a), 4.1(b) and 4.1(c), the passage of causal path through different holes made on the surface of the first layer is presented.

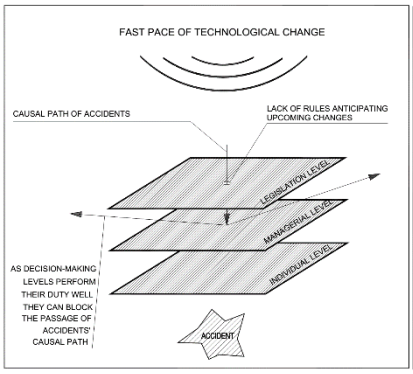

Figure 4.1(a) Passage of Accidents' Causal Path through the Legislation Level due to "Lack of Rules Anticipating Upcoming Changes"

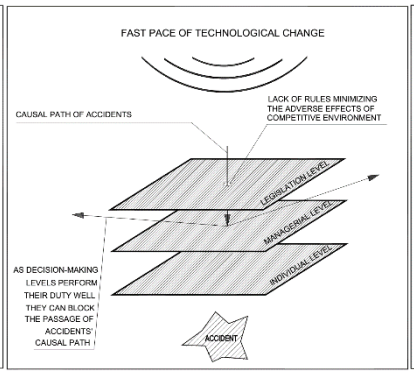

Figure 4.1(b) Passage of Accidents' Causal Path through the Legislation Level due to "Lack of Rules Minimizing the Adverse Effects of Competitive Environment"

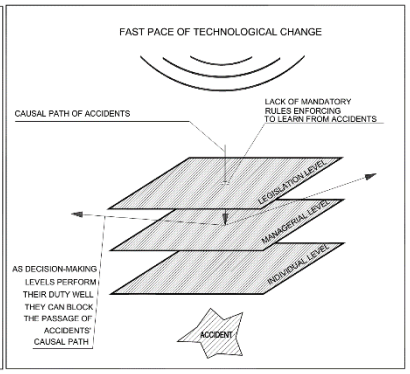

Figure 4.1(c) Passage of Accidents' Causal Path through the Legislation Level due to "Lack of Mandatory Rules Enforcing to Learn from Accidents"

4.2. Managerial Level

As the second most influential level of the sociotechnical system, the leadership of an organization stands that despite its limited control on the outside environment, has to overcome the emerging challenges and is responsible to lead the company under his command towards success.

This stressful condition becomes worse when due to lack of supportive legislation, the managerial level has to confront a difficult dilemma: Showing the profitability of the business to the shareholders or making investment on the increase of the system's preparedness against possible but rare accidents.

As a matter of fact, leadership level of each organization is accountable for two important jobs: 1) to fully understand the importance of respecting the rules (made by the legislation authorities) and 2) to properly incorporate those rules into the organization, taking into account the running values and existing culture. So, we called them "Tailors", since they are responsible to properly formulate the rules to best fit the organization under their control.

Followings are the more likely reasons for failure of this level that shrinks its power as a resistance against outside stressors.

4.2.1. Failure to Create a Resilience Safety Culture

The notion of resilience engineering, as described in the recent literature of safety culture (Hollnagel et al., 2011)(Azadeh et al., 2014)(Shirali et al., 2016), can be described as an approach of making improvements in all levels of an organization to produce robust and flexible processes to proactively use resources in facing challenges like economic pressures.

Although the increase of system's flexibility facing mishaps and choosing the long term profit may seem aiming to a same target, the major difference is that: not choosing the economic profit (when it has a mutual-exclusivity with the safety concerns) is the first step of the long road towards creating a resilient culture.

By establishing the fundamentals of resilience engineering, managers will be able to make the system under their control such flexible that not only is prepared for facing disasters but also acquires an insight to anticipating the different forms of risk in order to adjust itself based on complexities under pressure (Haimes, 2009).

Recalling the list of three possible failures on the lawmaking level, soon it becomes appear that the major contributing factor which escalates the ignorance towards the prospect of rare incidents, is the lack of supporting legislation to enforce the managers to get prepared for the upcoming black swans (Taleb, 2001).

Interestingly, like what was argued in previous section (e.g. Failure to trade-off between short and long term benefits), once the upper level fails, the exposure of the lower levels to the projections of the environmental stressors escalates its failure. Taking the effects of such interference by an external factor into account, represents one of the divergence points from the Swiss cheese (Reason, 1990) model.

4.2.2. Failure to Trade-off between Short and Long Term Profits

The leadership of an organization, or a petrochemical plant in our case, has to maintain the balance between the rate of production and the plant's safe operation. These conflicting demands requires the managers to perform an open-eyed trade-off between the profitability of the unit and the safety of workers (Erkan et al., 2015). Lack of supportive rules prohibiting the executive managers of an organization from sacrificing the sake of safety on the reward of more profits, make companies become so prone to fail in choosing the right decision particularly during upset economic conditions or within a competitive market.

Regarding the BASP fire, deciding not to shut the Paraxylene unit down (perhaps for economic reasons and difficulties in restoring the system back to service), especially when it became known that the isolation of the pump's suction line was not properly done, was an unforgivable mistake that can be categorized in this group.

4.2.3. Problems have been fixed

Another prevalent mistake among the managerial level is a bias called "Problems have been fixed", which was first introduced by Levesson and Dulac (2005) in their simplified model of drift to failure, exemplified by the processes in place at NASA during the space shuttle Columbia loss in 2003.

Such bias which is very similar to the optimism, makes managers believe that since no major accident has been occurred for a while, it won't either take place at least in near future. Most managers under effect of such bias believe that not experiencing tragic events for a while, can be interpreted as it won't happen in near future.

Managers with such mindset, encouraged by false confidence, will neglect many of their managerial responsibilities particularly their sensitivity against upcoming disasters. Likewise other failures in this level, the traces of upper level deficiencies can be found, that for this case is the failure of lawmaking level to make rules emphasizing the importance of learning from the accidents.

As the leadership fails to pick the right choice, as depicted on the figures 4.2(a), 4.2(b) and 4.2(c), the path of causation will be able to pass this layer through the fractures appeared on its surface that gets them one step closer to the moment of accident.

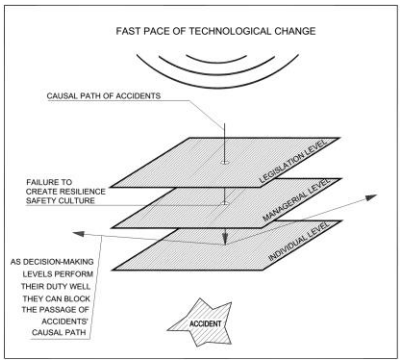

Figure 4.2(a) Passage of Accidents' Causal Path through the Managerial Level due to "Failure to Create Resilience Safety Culture"

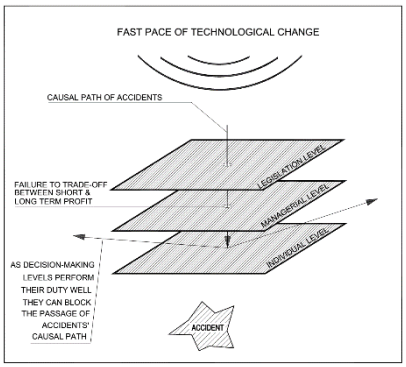

Figure 4.2(b) Passage of Accidents' Causal Path through the Managerial Level due to "Failure to Trade-Off between Short & Long Term Profit"

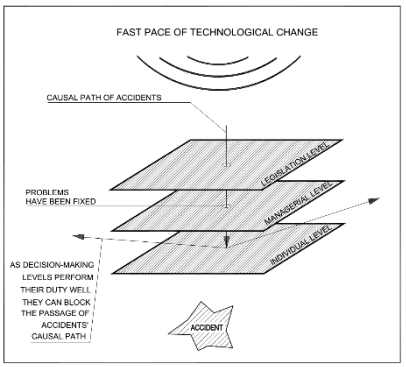

Figure 4.2(c) Passage of Accidents' Causal Path through the Managerial Level due to the bias called "Problems have been fixed"

4.3. Individuals' Level

The last level of decision making reviewed through the study was the individual's behavioral system comprised of three layers at which the individual's task decisions are made (Rasmussen, 1983).

1) Skill-based level
2) Rule-based level
3) Knowledge-based level

In order to analyze the performance of individual's level, specifically when exposed to the pressure caused by the fast pace of technological changes, it is crucial to address three most probable types of human errors (Schmidt, 2014) that can be committed by individuals while they are trying to perform their job:

- Lapses
- Mistakes
- Violations

Similar to what was observed on the other decision making levels, the same cause-consequence relationship was recognized between each specific failure on upper level (managerial level) and the corresponding errors on the level in below.

4.3.1. Lapses

"Lapses" happen despite an operator's best intentions. The operator knows what he should do; he wants to do it and knows how to perform the action, but he fails to do so (Rasmussen, 1983).

Since this error occurs on the skill-based level and hence is not the consequence of skill deficiencies or personal competencies, Lapses are usually expected in stressful work places where due to severe conditions, caused by uneven job assignment or very tight schedules, the individual may make an error without cautious attention or control (Pasman, 2015).

This circumstances mostly happen when as result of unrealistic plans imposed by over constrained projects or in consequence of incautious decisions made by the managerial level maybe on the rewards of more profit, employees are enforced to accept multi-tasking and hence making unwanted errors.

4.3.2. Mistakes

"Mistakes" also take place despite an individual's best intentions and efforts. The individual wants to do the right thing, but he doesn't know what is right; and even if he does, he does not know how to do it (Schmidt, 2014).

Above definition makes it clear the primary cause of committing mistake is the lack of sufficient knowledge about the job that the individual is about to perform. Such deficiency is either due to an incorrect employment or lack of necessary trainings for the acquired employees.

In either of cases, the finger of blame is pointed to the managerial level whose lack of faith in necessity of constant improvement either because they believe that everything is alright or nothing unpredicted will arise in future. This clearly can be tracked back to the managerial bias called "Problem Have Been Fixed" (Leveson and Dulac, 2005).

4.3.3. Violations

"Violations", as the third mode of failure on the individual's level, nearly always is committed deliberately by the employees who either do not believe in the existing regulations or try to cause some damage to the organization or people around.

Since the individual who commit violation is presumed able to distinguish between right and wrong and still refuses to follow the specified procedures by his/her will, it can nearly always be interpreted as a sign for a deeper inconsistency between the employee's personal values and the attributions promoted by the company, as a part of its culture.

This divergence, uncovers a considerable default by the leadership of the company to properly establish the foundations of safety culture, or in more advanced resilient format, within which not only employees perceive the advantages of the running procedures and rationale behind them, but also they become the true believers in the meritorious of the safe environment and the correlated benefits it brings to the whole system.

As described for the last level of decision making under study, it became known that commitment of all three individual's level errors, Lapse, Mistake and violation, is highly affected by failures on the higher, managerial level. As presented in figures 4.3(a), 4.3(b) and 4.3(c), the mechanism of passage of the accidents' causal path through the whole three levels of decision making is illustrated.

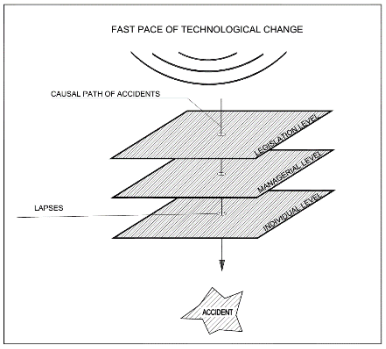

Figure 4.3(a) Passage of Accidents' Causal Path through the Individual Level due to "Lapses"

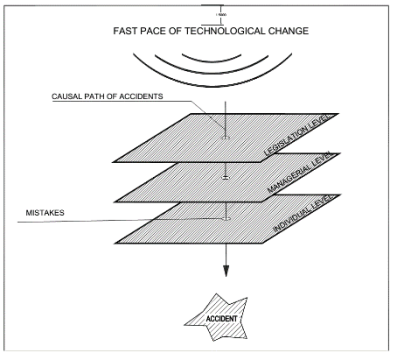

Figure 4.3(b) Passage of Accidents' Causal Path through the Individual Level due to "Mistakes"

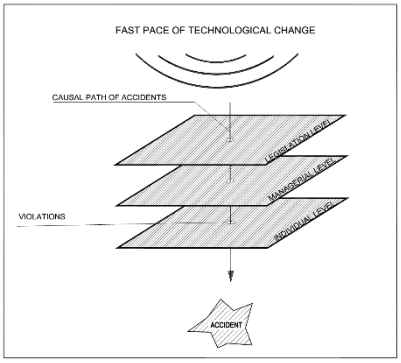

Figure 4.3(c) Passage of Accidents' Causal Path through the Individual Level due to "Violations"

Results

To summarize what was discussed as yet, followings can be highlighted as the major achievements of the article:

- The study proposes a new framework to analyze the behavior of different decision making levels in the context of sociotechnical systems in formation of tragic events, while they face the negative impacts of fast pace of technological change in the surrounding society.
- The proposed framework was constructed by embedding the concept of "Pathogen Metaphor" into the context of sociotechnical systems. By incorporating the significant role of the environmental stressors, and highlighting its share in formation of tragedies, a new parameter, which was overlooked before, is added to the original Swiss cheese model(Reason, 1990).
- The effect of the environmental stressors, can be interpreted as an accelerating factor in failure of the succeeding levels and thus formation of accidents. Such phenomenon contradicts the concept of independency between the protective layers, as is considered via the LOPA studies (Summers, 2003).
- Successfully explaining the mechanism of causation and indicating the associated underlying causes for an actual case, the BASP fire using the proposed approach, can be implied as its usefulness in assessment of the underlying causes, particularly those lying in deeper levels.
- As featured in figure 5(a), the etiology of the BASP fire using the structure of the new framework is illustrated.

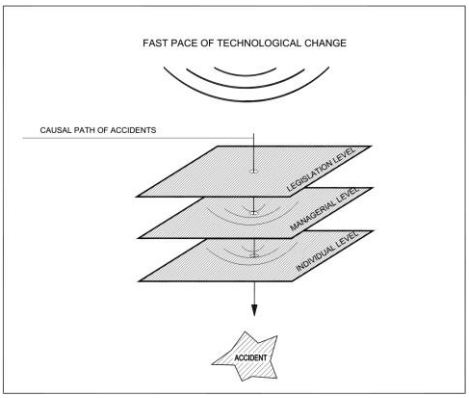

Figure 5.1(c) the etiology of the BASP fire using the "Social Protective Layers against Tragic Events", SPLATE framework.

5. Conclusion

The study proposes a new model which regarding its characteristics is called "Social Protective Layers against Tragic Events" SPLATE. The SPLATE is capable to explain the mechanism of causation for the tragic accidents in the context of social systems. As presented by the results, when it comes to the social behaviors, the likelihood of tragic accident formation will escalate as the accident's causal path reaches to the lower protective layers. This means that most of attention must be paid on the upper levels such as the lawmaking and governmental bodies that due to higher power can block more adverse effects of the changing environment.

The proposed model, although was used to interpret the behavior of levels in a specific system in a qualitative manner and was devoted to a particular accident, it possesses higher potential to be developed either qualitatively or quantitatively to be used in various fields of industry with ingrained various sort of hazards, especially those more related to the domain of social systems.

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