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Accidents in Engineering and Socio-technical Systems: The Science and Recent Advances

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Abstract

Since the invention of the steam engine, many engineering innovations have propelled the human civilization forward and the society has changed dramatically. At the same time, accidents of various kinds (e.g. car, rail, aircraft, ships, industrial, etc.) have never stopped taking place. Hence, for any engineering and socio-technical system, safety has become one of the most important concerns in modern society. In order to understand the science of accidents, some notable accident theories and models were reviewed in this paper and their relative merits and demerits were discussed as well. The study finds that accident models and theories are diversified and different from each other. Therefore, the science behind accident cannot be unified into a single discipline. Also, changes in human civilization over the years have given birth to new modes of accidents (such as automobile, aircraft, spacecraft and etc.). This study, thus, searches the unified science of accidents and therefore, discusses the newly developed accident analysis technique called the Logic Programming Technique (LPT). It is expected that this new domain of safety engineering may contribute to achieving safety in the future automobile industry.

Keywords: Accident theory; Safety science; Logic programming technique

Introduction

The human society has evolved tremendously since the invention of the steam engine. In almost every decade new inventions and technologies have reshaped the way people interact and do business. Such tremendous change has brought comfort and efficiency in various aspects of human lives, yet one important factor still concerns all till today is the safety of socio-technical systems. It is indeed beyond question that new technology brought significant benefits to the society; at the same time, it brought new modes of accidents which were previously unknown. For example, car accidents were not present before the invention of the diesel engine; air crash never happened before the invention of aircraft; spacecraft never exploded before its invention; so many such accidents can be cited as examples.

In an effort to understand the science behind accidents this research paper investigated the existing accident theories and models. A literature review revealed that accident theories and models can be classified in various ways. Some classification examples can be found in Qureshi [1], Khanzode et al. [2] and Awal and Hasegawa [3,4]. However, in this study the following classification of accident theories and models are considered:

1. Statistical analysis and trends
2. Risk analysis
3. Domino theory
4. Epidemiologic theory
5. Control and System theoretic model

The fundamental points of this group of accident theories and models are discussed in the following sections. Later a comparative study is conducted over these accident theories and models. This comparison reveals the strengths and weaknesses which indicate the importance of further research on accident prediction and analysis.

Statistical Analysis and Trends

The scientific approach of studying accidents started in England at the beginning of 20th century when Vernon [5] published his extensive study on the causation of industrial accidents. Vernon considered fifty thousand industrial accidents collected from four different factories across the United Kingdom and produced a statistical analysis of hourly variation of distinct categories of industrial accidents. This research showed a systematic approach of identifying various accident causation factors. Vernon classified factors into two main headings: (i) factors of personal origin and (ii) factors of external origin.

Since then significant research on accident studies has been conducted where the statistical tools have been used to identify various correlating factors that contribute towards the causation of accidents. Statistical analysis reveals share or percentage of different factors, the relationship among various factors and overall trends of accident causation against different kinds of timelines. Awal [6], Awal et al. [7] and Hossain et al. [8] may give some insight into this topic. Figure 1 shows an example from Awal et al. [7] where the monthly variation of total maritime accidents in Bangladesh was shown along with ship collision accidents.

It was interesting to note that the total number of accidents remains below the average during the months of December and January; whereas the collision accidents increase above the average line. Therefore,

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during these two months, collision type accidents occur more than any other type of accidents. Hence, such a statistical analysis may assist decision makers to allocate resources on collision prevention rather than focusing on other types of accidents. Another example of statistical accident analysis can be found in Massie and Campbell [9] which is shown in Figure 2. In this example, the fatal involvement of men of different age groups in car crashes is shown. It was observed that with the increase in age of drivers the fatal consequences decrease significantly. Therefore, it can be comprehended that measures taken on younger people may significantly reduce fatality due to car crashes. These examples indicate that the goal of statistical analysis is to identify some trend(s) correlating with some probable factors. Various kinds of hypotheses can be drawn and tested if sufficient statistical data is available.

Risk Analysis

One of the most applauded branches of statistical analysis of accidents is risk analysis, which gained popularity after the introduction of Fault Tree Analysis (FTA) [10,11] and Event Tree Analysis [12]. Since then a significant number of studies has been conducted on the development and application of risk analysis in solving practical problems. In traditional risk analysis, the principal task is to identify distinctive threats and simultaneously determine consequences of the respective threats if they are to occur in reality. There are two types of risk analysis: (i) quantitative risk analysis and (ii) qualitative risk analysis. Risk analysis is popular in solving real engineering problems and academic exercises because of its technical facility and wide range of applicability. An example of ship collision risk analysis using fault tree is shown in Figure 3. This example reveals that the probability of ship collision with another ship can be computed in a fault tree when all the probability values of the connected events are known [13]. Risk analysis may also provide a picture of total accident occurrence probability as shown in Figure 4. The figure shows the probability of tanker ship collision taking place in the Gulf of Finland for different types of traffic flow in one year [14]. The results obtained from such analysis can only provide some guidance on the chances of occurrence of an event, here, in this case, the accident event. Similar studies on wide range of scientific and engineering applications can be found (e.g. safety of nuclear power plants [15], underwater tunnel excavation [16], and many more). These studies are useful in the policy level where Risk Control Options (RCOs) can make an impact in reducing the risk values. However, risk analysis cannot provide the advantage of knowing how an accident may take place. For the occurrence of

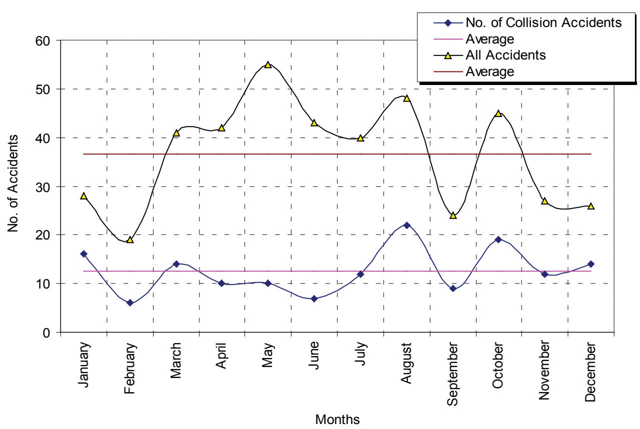

Figure 1: Monthly trend analysis of maritime accidents in Bangladesh.

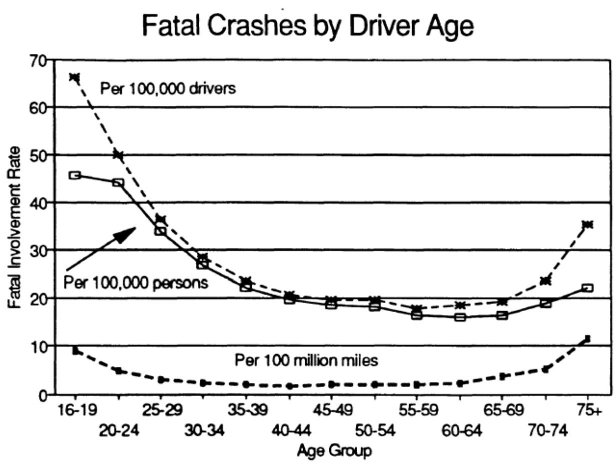

Figure 2: The observed relationship between age and fatality in car crashes in the United States using one year (1990) data.

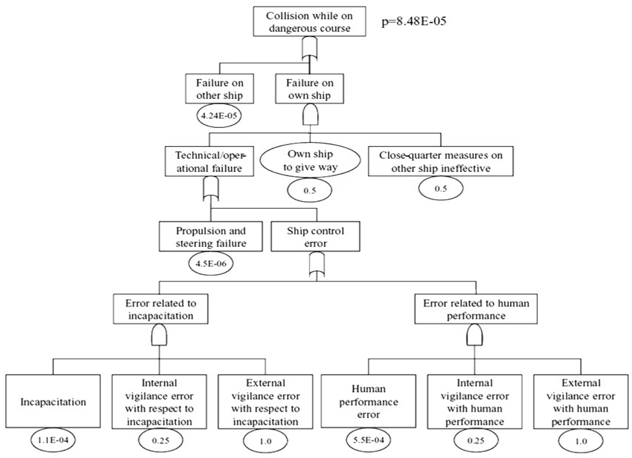

Figure 3: Fault tree applied to derive causation probability for ship collision in good visibility.

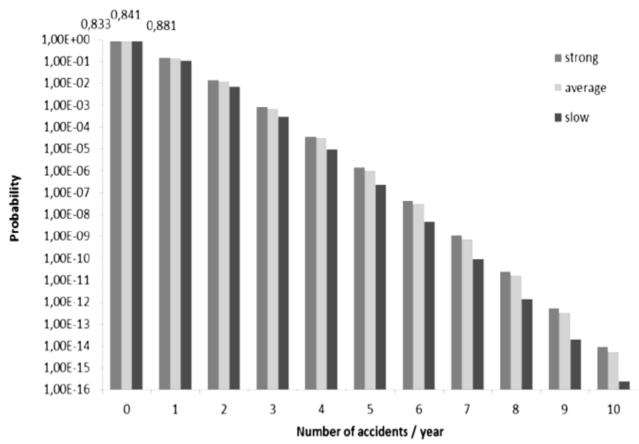

Figure 4: The probability distribution of the number of tanker collisions in the whole Gulf of Finland in 2015 for the three traffic scenarios "slow", "average" and "strong".

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an accident event, it relies completely on a subjective judgment of the expert who employs this analysis.

Domino Theory

Domino theory is one of the earliest theories of accident causation, which utilized metaphoric example of domino effect. Heinrich [17] utilized the concept of domino effect where a series of domino arranged in such a manner that the fall of the first domino creates a cause-effect sequence which eventually results in fall of the last domino. Therefore, Heinrich proposed that accident occurs in a chain of events, which can be traced back from injury to ancestry and social environment.

Heinrich elaborated that the individual fault can be related to other factors in sequence, just like a domino. There are five dominoes according to this theory as shown in Figure 5. Heinrich explains that undesirable personality traits can be passed along through inheritance or develop from person's social environment and both inheritance and environment contribute to faults of a person. This can be considered as the first domino. The second domino deals with worker personality traits. Heinrich explains that inborn or obtained character flaws contribute to accident causation. According to Heinrich, natural or environmental flaws in the worker's family or life cause these secondary personal defects, which are themselves contributors to unsafe acts or the existence of hazardous conditions. The third domino is the direct cause of incidents - the unsafe act. Heinrich [17] defines four reasons why people commit dangerous acts: (i) improper attitude, (ii) lack of knowledge or skill, (iii) physical unsuitability and (iv) improper mechanical or physical environment. Heinrich later subdivides these categories into 'direct' and 'underlying' causes and concludes that combination of multiple causes creates a systematic chain of events that leads to the accident. The goal of domino theory is to establish a linear cause-effect relationship among various social and individual factors using five metaphoric dominoes. Domino theory has been applied in various industrial applications such as process industry [18], safety of civil engineering construction sites [19] and many more.

The application of domino theory in various fields of science and engineering probably has led to the evolution of linear cause-effect analysis of accidents. Such analyses encompass various forms, for example, root cause analysis, fishbone diagram and others. These tools or methods have gained popularity and proved to be useful in the safety analysis of Biogas production [20] and safety of electric transformers [21].

Epidemiologic Theory

Gordon in 1949 first proposed the epidemiologic theory of accident causation [22]. Gordon considered accidents as an ecologic problem. In this study, it is stated that the causative factors in accidents have been seen to reside in agents, in the host, and in the environment, as shown in Figure 6. The mechanism of accident production is that process by which the three components interact to produce a result, the accident. Therefore, the cause of accident comes from the interaction between the host, agent, and environment. The hypothesis is if home accidents are primarily a public health problem then the problem is reasonable to be approached in the manner and through techniques that have proved useful for other mass disease problems.

Haddon [23] in 1968 proposed a 2D dimensional matrix for injury control which was mainly developed for the car crash. Such matrix helps to identify the host, agent and environmental factors in temporal order (prior to the event, during the event and post-event) and helps to identify preventive measures. Haddon later in 1970 introduced ten strategies for reducing losses which were based on the energy transfer concept [24]. The reason behind this energy transfer concept is because that major class of ecologic phenomena in nature involves the transfer of energy.

In 1990, Reason [25] proposed that there are latent human failures which result in accidents without any visible causes. The proposal included the following three concepts: (i) latent failure, (ii) local triggering event, (iii) system defenses. The study discussed the differences between active and latent human failure and a framework for the dynamics of accident causation. Later on, Reason [26] developed and proposed the Swiss cheese model and the organizational Accident Model shown in (Figures 7 and 8). Organizational accidents occur within modern complex technological societies having multiple causes. The accidents involve many people operating at different levels of their respective companies. Hazard cause losses and barriers are there to prevent. Like Swiss Cheese, there are holes in the barriers. When all the holes align then hazards pass through and cause losses. Each barrier represents each level of organizational defenses against losses.

Control and System Theoretic Model

In 1970, Suchman [27] proposed the social deviance hypothesis for

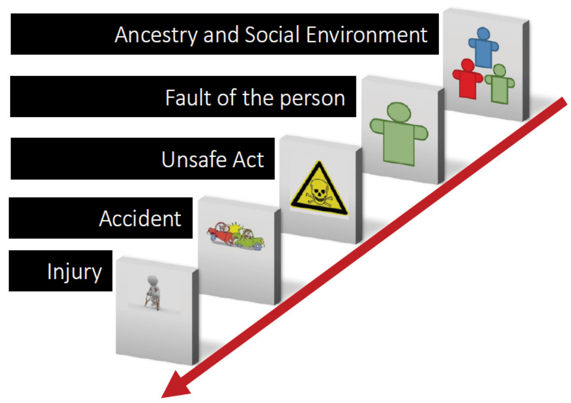

Figure 5: The fundamental concept of domino theory.

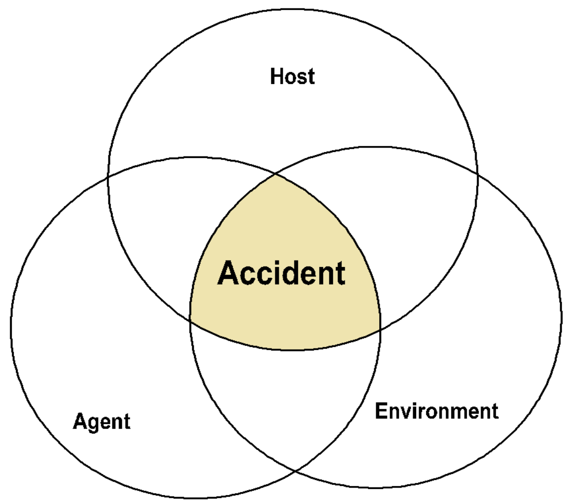

Figure 6: Host, agent and environment triad in accident causation.

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accident causation. Suchman considered accident as a social control problem and rejection of social constraint is considered as the cause of an accident. Kjellen and Larsson [28] proposed Deviation Concept for occupational accident control. The proposal stated that deviation from the norm causes accidents in a production process. Rasmussen [29] and Rasmussen and Svedung [30] discussed risk management in dynamic society and proposed AcciMap for accident investigation. Rasmussen's work fundamentally considers accidents as a control problem, which utilizes control engineering metaphors in a social context. Rasmussen presented an interesting control structure which is based on control architecture applied at the different level of social structure. This is shown in Figure 9. Branford's research [31] can be considered as an example that applied AcciMap and studied loss of control at various levels of the Uberlingen mid-air collision.

Perrow [32] proposed the term 'Normal Accident' which became very popular in various high-tech industries. According to Perrow, a normal accident is a characteristic of a system. Given the characteristics of the system, multiple and unexpected interactions of failures are inevitable. The interactive complexity and tight coupling the system characteristic inevitably produces an accident; therefore, it is called 'Normal Accident' or 'System Accident'. The premises of this idea are: (i) people make mistakes, (ii) big accidents begin from small beginnings and (iii) many failures originate due to organization/technology. Hollnagel and Goteman [33] proposed Functional Resonance Accident Model (FRAM). The idea suggested that accidents occurred due to functional resonance within a system. The basic concept of FRAM is shown in Figure 10. Leveson [34] introduced System-Theoretic Accident Model and Process (STAMP) which is essentially a model of control system applied in the social structure. She suggested that accidents occur when there is a lack of constraints. In general, control and system theoretic models attempt to discover weaknesses within the concerned system and prescribe various control parameters to prevent accidents.

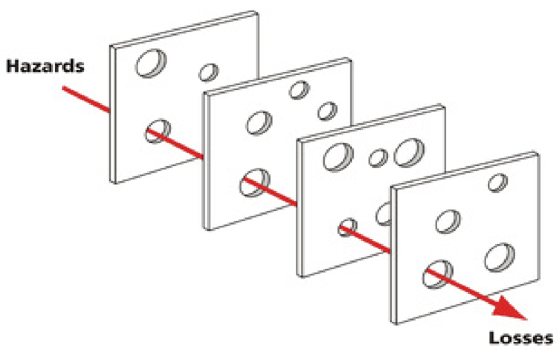

Figure 7: Swiss cheese model of accident causation.

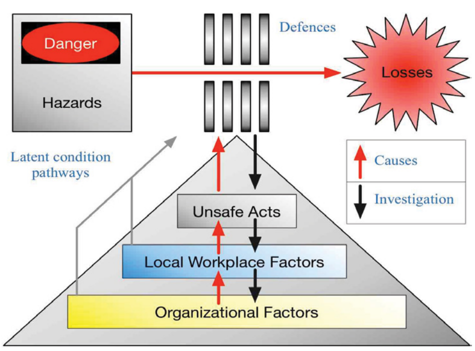

Figure 8: Reason's organizational accident model.

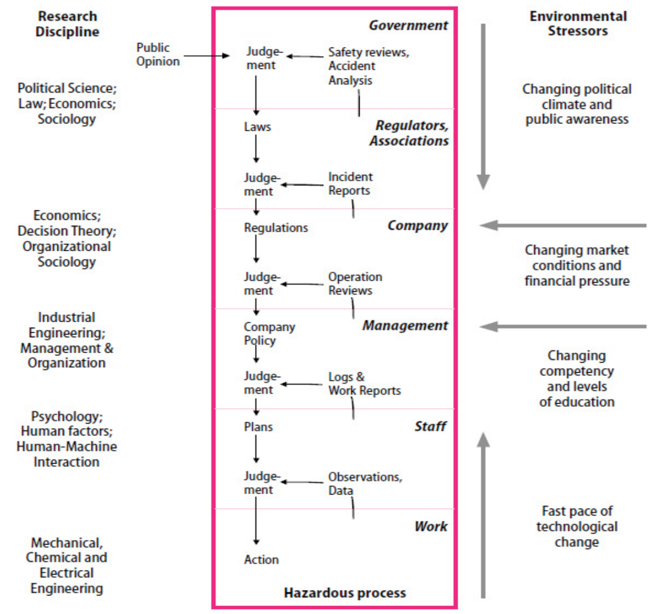

Figure 9: Rasmussen's concept of control of hazardous activity in nested social structure.

Findings of this Study

In this paper, five groups of accident theories and models were studied. The paper systematically presented the characteristics of each group and discussed their attributes with necessary figures. In order to summarize the findings of this study, a comparative sum-up is produced in this section. Three different questions were asked of each group of accident theories and models and they are analyzed in tabular forms as shown in (Tables 1-3).

The first question asked to the group of accident theories and models in 'what causes the accident? This is discussed in Table 1. In answer, it was found that each group is significantly different from the other. The statistical analysis and trends group is unable to provide any simple answer. It has been found that according to this group, an accident can be caused by various factors and the purpose of this group is to identify the correlation between the accident and the accident causing factors. Similarly, risk analysis group is unable to provide any simple answer; rather this group of theories and models can only compute risk value and assist decision makers in controlling risk and thereby allocating necessary resources. The domino theory provides a simple answer. Accidents occur due to faulty act and this faulty act is one of five dominos which fit into the concept of linear cause-effect relationship. Interestingly, the cause of accident according to epidemiologic theory is the interaction of host, agent, and environment. The accident comes out of this interaction. Lastly, the cause of accident according to control and system theory group is the lack of control and lack of understanding of the system dynamics. This group is comparatively new and requires further developments.

The second question asked to the accident theories and models is 'How the analysis is done?'. This is discussed in Table 2. In answer, it is found that statistical analysis and trends group requires a bulk amount of data for various statistical modeling. Therefore, in cases where the data is rare, such kind of theories and models are less useful. Similarly, the risk analysis group requires sufficient amount of data in order to utilize various methods of risk modeling. Once the risk model is constructed, Risk Control Options (RCOs) are applied and compared with a base value to undertake preventive measures. The domino theory group requires subjective judgment and analysis to define the dominoes. This theory/model is not handicapped by lack of numerical data. The epidemiologic theory group necessitates subjective judgment to identify the host, agent, and environment. The interaction among these three is also a matter of subjective analysis. Finally, the control and system theoretic group needs similar to the previous two groups, i.e. subjective judgment. The analysis identifies system components and role of control over the system.

The third question asked to the accident theories and models is 'How to prevent an accident?' The statistical analysis and trends group and risk analysis group require subjective judgment and decisions to apply preventive measures. The decisions of preventive measures are taken based on the correlation and risk values obtained from the analyses. The domino theory group suggests removing any of the dominoes so that the cause-effect chain is no longer continued. In many real-life examples this theory, however, is proven impractical. The epidemiologic theory group suggests stopping the necessary interaction among the host, agent and the environment in order to prevent accidents. In many organizational accidents, this group of theory appears to be successful to explain the accident phenomena. Finally, the control and system-theoretic group of accident theory and models impose constraints to prevent accidents. According to this group keeping necessary control is essential in preventing accidents. Table 3 briefly discusses these issues.

Logic Programming Technique (LPT)

The accident theories and models studied in this paper are fully dependent on the subjective judgment of human experts and in many cases are unable to deduce how an accident may take place. The current need in the discipline of safety science is to develop new techniques that can predict 'how' an accident may take place with reasonable accuracy. Such deficiency is identified in previous studies by Awal [35], Awal and Hasegawa [36-41]; these studies developed a new concept called Logic Programming Technique (LPT).

LPT is a method of logical deductions which utilize heuristics to search through given knowledge and attempts to discover 'how' accident may take place. The fundamental principle of LPT is logical deductions using deductive arguments. Propositional logics are utilized to develop logic worlds and find out how accidents take place within the world. Propositional logics are simple sentences which have one or more premise(s) and one conclusion. An example is shown in Figure 11. This simple format allows modeling systems of various disciplines. This is a significant advantage while studying accidents in the multidisciplinary platform.

Awal and Hasegawa [38,40,41] discussed the advancement of LPT into the agent-based perception-action technique. In this technique, all agents search through respective perceptions and actions. Thereby, logical deductions reveal all the possible sequence of events that may take place. Some of these events may lead to accidents which are of particular interest to achieve safety. Hence, Logic Programming Technique (LPT) can automatically deduce 'how' accidents can take place. Such deductions are generally difficult to produce by human judgment or subjective analysis alone because of the complexity and size of the problem space. Traditional accident analysis also becomes very difficult when there is a change in the system; whereas logic programming can handle system changes easily. For example, an addition of an event or an agent is simply done by adding arguments in the logic program; while in traditional accident analysis (e.g. fault tree analysis) such change complicates the total structure (tree in this case) and requires reconstruction of the structure again. Also in traditional accident analysis, the (e.g. fault tree) the combination of events is known. However, in Logic Programming Technique (LPT) the combinations of events are deduced automatically. This gives Logic Programming

No.	Type of accident theory	What causes the accident?
1.	Statistical analysis and trends	Accidents are caused by different correlating factors.
2.	Risk analysis	Accidents are caused by different correlating factors.
3.	Domino Theory	Linear cause-effect relation of 5 dominos results in an accident.
4.	Epidemiologic Theory	The causes of accidents are hidden in the system like a pathogen. Interaction among the host, agent and environment cause accident.
5.	Control and System Theory	Lack of control over a social or engineering system results in an accident.

Table 1: Comparison of accident theories and models: What causes the accident?

No.	Type of accident theory	How is the analysis done?
1.	Statistical analysis and trends	A collection of data results in a database and this database is used in various statistical modeling.
2.	Risk analysis	Various method of risk modeling is utilized. Once the risk model is constructed, risk control options are applied and compared with a set base value.
3.	Domino Theory	Subjective judgment and analysis are utilized to define the dominoes.
4.	Epidemiologic Theory	Subjective judgment and analysis are utilized to identify the host, agent, and environment.
5.	Control and System Theory	Subjective judgment and analysis are utilized to identify system components and their interaction. Control over the system in examined.

Table 2: Comparison of accident theories and models: How the analysis is done?

No.	Type of accident theory	How to prevent an accident?
1.	Statistical analysis and trends	Identify correlating factors and take measures related to the factors
2.	Risk analysis	Construct risk model and apply risk control options (RCOs)
3.	Domino Theory	Identify each domino with respect to social and human factors; remove the domino that causes an accident.
4.	Epidemiologic Theory	Identify the interaction among host, agent, and environment; take measures on the interaction.
5.	Control and System Theory	Study system components interaction and apply necessary control.

Table 3: Comparison of accident theories and models: How to prevent an accident?

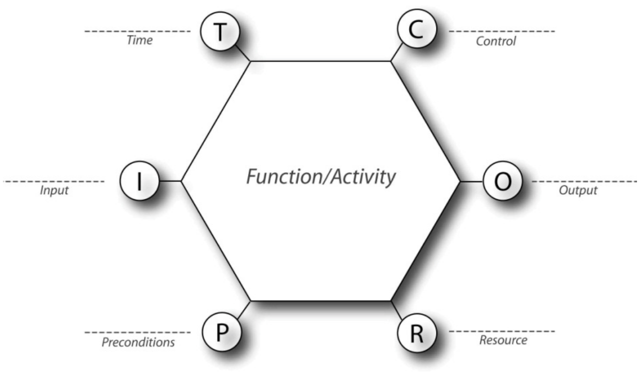

Figure 10: Basic of Functional Resonance Accident Model (FRAM).

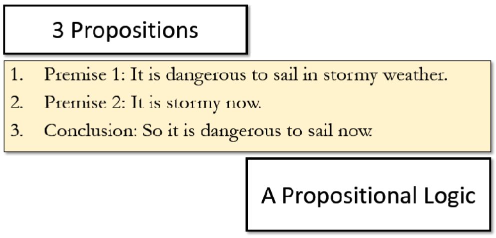

Figure 11: An example of a propositional logic.

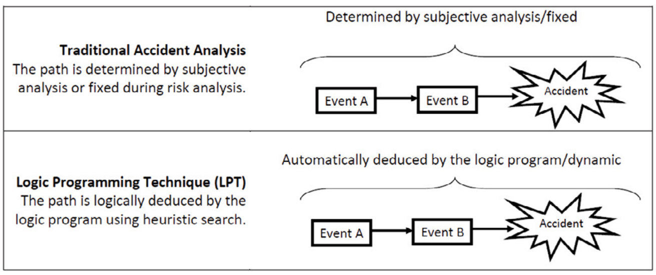

Figure 12: Difference between traditional accident analysis and Logic Programming Technique (LPT).

Technique (LPT) a significant advantage over other accident analysis techniques. Figure 12 shows this concept graphically.

Conclusion

This paper discussed and revealed the underlying science of accident causation in complex engineering and socio-technical systems. A number of accident theories and models have, therefore, been presented and categorized in this study. The study reveals that that over the years, particularly the past century, researchers from various fields, including engineers, medical doctors, psychologists, and other professionals have studied accidents and attempted to theorize the science of accidents. It has been found that the accident theories have transformed from a single root cause to linear cause-effect models, from epidemiologic concepts to organizational accident models and evolution of control and system theoretic concepts. This transformation and evolution of a broad range of accident theories/models suggest that understanding the science of accidents requires a wide perspective and vast knowledge domain. The study revealed that the problem space of safety science is diverse and incorporation of knowledge from multiple disciplines is necessary.

The application of LPT in complex industries such as automobile industry can be highly beneficial and it appears that the potential of application is immense. For example, LPT can be applied in automobile production facility where it can deduce possible event sequences that may lead to production failures. Also, LPT can be applied in the most modern driverless automobiles to deduce the errors in software that may lead to possible catastrophes. Having said the advantages and future potentials of LPT, there are some shortcoming of this method which needs to be studied further in order to utilize it in solving accident problems in complex socio-technical systems.

Reference

1. Qureshi ZH (2007) A review of accident modeling approaches for complex critical socio-technical systems. In Proceeding of the Twelfth Australian Workshop on Safety Critical Systems and Software and Safety-related Programmable Systems 86: 47-59.
2. Khanzode VV, Maiti J, Ray PK (2012) Occupational injury and accident research: A comprehensive review. Safety Sci 50: 1355-1367.
3. Awal ZI, Hasegawa K (2015) Analysis of Marine Accidents Due to Engine Failure - Application of Logic Programming Technique (LPT), Technical Information at the J Japan Ins Marine Eng. (JIME) 50: 39-46.
4. Awal ZI, Hasegawa K (2017) A study on accident theories and application to maritime accidents. Procedia engineering 194: 298-306.
5. Vernon HM (1918) An investigation of the factors concerned in the causation of industrial accidents, Health and Munition Workers Committee, Ministry of Munitions, Memorandum No. 21, His Majesty's Stationery Office, London.
6. Awal ZI (2007) A study on inland water transport accidents in Bangladesh: Experience of a decade (1995-2005), Technical Note at The Inter J Small Craft Technol. (IJSCT) 149: 35-42.
7. Awal ZI, Islam MR, Hoque MM (2010) The collision of marine vehicles in Bangladesh: a study on accident characteristics. Disaster Prev Manag 19: 582-595.
8. Hossain MT, Awal ZI, Das S (2014) A Study on the accidents of inland water transport in Bangladesh: The transportation system and contact type accidents, J Transport Sys Eng. 1: 23-32.
9. Massie DL, Campbell KL (1993) Analysis of accident rates by age, gender, and time of day based on the 1990 nationwide personal transportation survey. Final report (No. UMTRI-93-7), USA.
10. Watson HA (1961) Launch Control Safety Study, Bell Labs, Murray Hill, NJ.
11. Ericson CA (1999) Fault tree analysis A history, Proceedings of the 17th International System Safety Conference, Florida, USA 1-9.
12. Ericson CA (2015) Hazard analysis techniques for system safety. John Wiley and Sons.
13. Li S, Meng Q, Qu X (2012) An overview of maritime waterway quantitative risk assessment models. Risk Anal 32: 496-512.
14. Hänninen M, Kujala P, Ylitalo J, Kuronen J (2012) Estimating the Number of Tanker Collisions in the Gulf of Finland in 2015. Inter J Marine Navigation Safety Sea Transport. 6: 367-373.
15. Aldemir T (2013) A survey of dynamic methodologies for probabilistic safety assessment of nuclear power plants. Ann Nucl Energy. 52: 113-124.
16. Hong ES, Lee IM, Shin HS, Nam SW, Kong JS (2009) Quantitative risk evaluation based on event tree analysis technique: application to the design of shield TBM. Tunnel Underground Space Technol. 24: 269-277.
17. Heinrich HW (1931) Industrial Accident Prevention: A Scientific Approach, McGraw-Hill.
18. Alileche N, Olivier D, Estel L, Cozzani V (2017) Analysis of domino effect in the process industry using the event tree method. Safety Sci. 97: 10-19.
19. Sabet PGP, Aadal H, Jamshidi MHM, Rad KG (2013) Application of domino theory to justify and prevent accident occurance in construction sites. IOSR J Mech Civil Eng. 6: 72-76.

20. Moreno VC, Papasidero S, Scarponi GE, Guglielmi D and Cozzani V (2016) Analysis of accidents in biogas production and upgrading. Renew Energy 96: 1127-1134.
21. Murugan R and Ramasamy R (2015) Failure analysis of power transformer for effective maintenance planning in electric utilities. Eng Fail Anal. 55:182-192.
22. Gordon JE (1949) The epidemiology of accidents, Am J Public Health. 39: 504-515.
23. Haddon W (1968) The changing approach to the epidemiology, prevention, and amelioration of trauma: the transition to approaches etiologically rather than descriptively based. Am J Public Health Nation's Health. 58: 1431-1438.
24. Haddon W (1970) On the escape of tigers: an ecologic note. (Strategy options in reducing losses in energy-damaged people and property). Technol Review. (MIT) 72: 44-53.
25. Reason J (1990) The contribution of latent human failures to the breakdown of complex systems. Philosop Transactions Royal Soci London B. 327: 475-484.
26. Reason J (1997) Managing the Risks of Organizational Accidents. Aldershot: Ashgate.
27. Suchman EA (1970) Accidents and social deviance. J Health Social Behave. 11: 4-15.
28. Kjellen U, Larsson TJ (1981) Investigating accidents and reducing risks - a dynamic approach. J Occup Accident. 3: 129-140.
29. Rasmussen J (1997) Risk management in a dynamic society: a modeling problem. Safety Sci. 27: 183-213.
30. Rasmussen J, Svedung JRI (2000) Proactive risk management in a dynamic society. Karlstad: Swedish Rescue Services Agency.
31. Branford K (2011) Seeing the big picture of mishaps. Aviation Psychol Appli Human Factor. 1: 31-37.
32. Perrow C (1984) Normal Accidents - Living with High Risk Technologies, Basic Books: New York.
33. Hollnagel E and Goteman O (2004) The functional resonance accident model. Proceedings of Cognitive System Engineering in Process Plant 155-161.
34. Leveson N (2004) A new accident model for engineering safer systems, Safety Sci. 42: 237-270.
35. Awal ZI (2016) Development of logic programming technique for marine accident analysis, Doctoral dissertation, Graduate School of Engineering, Osaka University, Japan.
36. Awal ZI, Hasegawa K (2013) A Study on Accident Theories and Their Application in Costa Concordia Accident, Proceedings of the 16th Academic Exchange Seminar between Osaka University and Shanghai Jiao Tong University, 22-24 October 2013, Osaka, Japan, 33.
37. Awal ZI, Hasegawa K (2014) Analysis of Marine Accidents by Logic Programming Technique, Proceedings of the 10th International Symposium on Marine Engineering (ISME), 15-19 September 2014, Harbin, China, In USB Drive, Paper No. ISME127.
38. Awal ZI, Hasegawa K (2014) Application of Logic Programming Technique on Maritime Accident Analysis, Proceedings of the International Conference on Ship and Offshore Technology (ICSOT 2014), 4-5 November 2014, Makassar, Indonesia 59-66.
39. Awal ZI, Hasegawa K (2015) Accident analysis by logic programming technique, Safety and Reliability of Complex Engineered Systems: ESREL 2015, Zurich, Switzerland, September 7-10, 2015, 13-21.
40. Awal ZI, Hasegawa K (2016) A New Approach to Accident Analysis: Multiple Agent Perception-Action, Transactions of the Society of Naval Architects and Marine Engineer (SNAME), USA 124: 126-138.
41. Awal ZI, Hasegawa K (2013) Bridge Resource Simulator-A New Tool for Ship Accident Analysis. Proceedings of the Japan society of Naval Architects and Ocean Engineers (JASNAOE) 16: 51-54.