Chapter 2
Why Do Accidents Happen? A Critical Review on the Evolution of the Construction Accident Causation Models

2.1 Introduction

High accident rate in construction is a universal problem which needs to be tackled by all parties concerned (Poon et al. 2008). Although in the last decade there was a downward trend in construction accidents in many places such as Hong Kong due to implementation of numerous safety schemes, improvement in construction accident records is still necessary (Figs. 2.1, 2.2). A previous research study in Hong Kong has shown that an accident imposes huge costs on the society (UK HM Revenue and Customs Department 2011) and over $10 million of compensation was paid for non-fatal accidents each year during 2004–2008 (Table 2.1). The direct financial costs of accidents are only the tip of the iceberg when compared with the indirect ones. The injured employees and their families suffer from loss of earnings and grief. Accidents on site also lower staff morale, induce negative corporate image and lead to extension of time in the project because of work re-arrangements (Li 2006). This chapter aims at studying and analyzing the evolution in accident causation models.

2.2 Changes in Construction Industry 1960: Present

2.2.1 From Low-Rise Building to the Tower of Babylon

In early 20th century, structural members were designed to carry primarily the gravity loads. Advances in structural design and building materials reduce building weight; taller building construction which can house more people has gained its popularity. Among the fifty tallest buildings in the world, only one was constructed in 1960s and the majority were constructed in 1980s and after (Toole 2002). Nevertheless, building slenderness increases also implies that lateral loads consideration becomes more important (Debrah and Ofori 2001a, b).

R. Y. M. Li and S. W. Poon, *Construction Safety*, Risk Engineering,
DOI: 10.1007/978-3-642-35046-7_2, © Springer-Verlag Berlin Heidelberg 2013

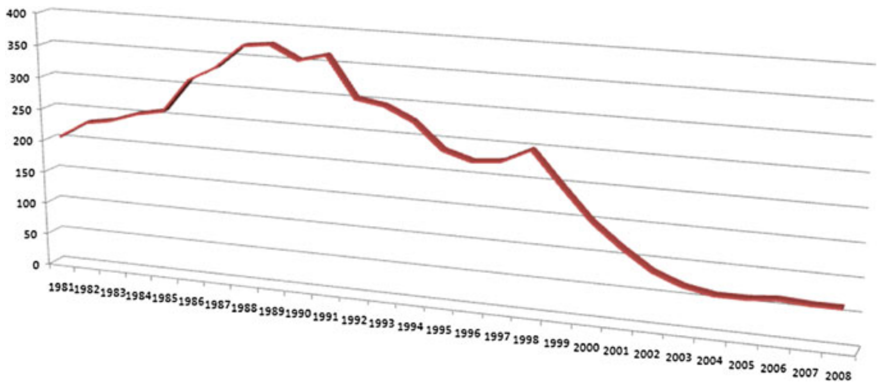

Fig. 2.1 Construction accident rates and safety scheme

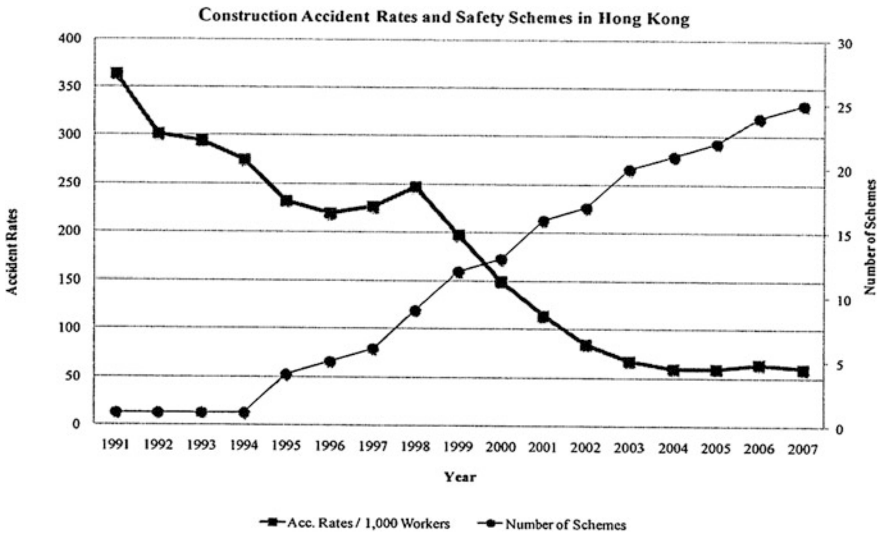

Fig. 2.2 Construction accidents per 1,000 employees in Hong Kong (Holmes 1999; Poon et al. 2008; Jannadi 1995; Sharma and Jha 2012)

2.2.2 From Traditional Procurement to Integrated Procurement

Before 1980s, building firms enjoyed post-war expansion due to rebuilding, capital investment catch-up and increasing levels of immigration, which provided economic buoyancy. Clients were led by their design team—they were not encouraged to be involved in a significant degree during decision making in design and construction, design and construction were separated (Zhu et al. 2010). Between 1980 and 1999, traditional procurement method was losing ground (Kim and Rhee 2009),

Table 2.1 Construction accident compensation in Hong Kong (Goodhart and Hofmann 2008)

Years	Total number of non-fatal accidents	Total PSLA ('000)	Total loss of earning ('000)	Total loss of earning capacity ('000)	Total special damages ('000)	Total future treatment ('000)	Total deductions from ECC and victims' faults ('000)	Total sum of compensation ('000)
2008	29	6,779	26,964	267	610	584	4,005	32,443
2007	16	3,400	13,980	950	530	279	890	15,937
2006	19	7,260	20,234	875	1,378	2,669	7,640	39,643
2005	23	6,085	24,645	2,404	506	382	7,771	25,725
2004	14	2,940	11,283	431	211	116	5,174	10,998

design and build gained popularity. The time, cost and quality became part of the construction service ethos. Since 1999 practitioners in Australia and UK, Latham stressed more on construction productivity and efficiency and multi-skilling of the trades to reduce disputes between unions and trades (Zhu et al. 2010). Clients seek solutions rather than pure construction services (Lingard and Rowlinson 1994). Concepts from manufacturing such as best practice, quality assurance benchmarking and re-engineering have influenced the construction industry, pre-qualification criteria for consultants, contractors and sub-contractors adopted. Integrated forms of procurement based on the principles of concurrent engineering (CE) which promotes cooperation and collaboration between project participants from the outset of a project have been advocated. Moreover, with the client's and project advisor's involvement during design development, the project team can jointly develop the project goals and objectives (Zhu et al. 2010).

2.2.3 From Conventional Construction Method to Complicated Ever Changing Digital and Prefabricated Construction

Construction industry has long been regarded as a labor intensive industry. Construction of bridges, buildings, dams etc. has been done by a great number of workers. International Alliance of Interoperability (IAI) founded in the USA in 1995 turned on the engine of digital construction, system-independent exchange of information between all stakeholders was developed (Lin and Mills 2001).

In the ten years' time since mid-1990s, information technology has changed the world of construction industry. CAD drawing has replaced handmade drawing, Video conferencing has replaced frequent freight face-to-face meeting, digital take-off has replaced traditional black and white take-off, and dynamic building information modeling has replaced static building design. Within this decade, man-made construction and design methods have been replaced by "n" kinds of software for quantity surveyors, architects, engineers, form workers and architects. If we view each of these from the system point of view, there are many new born subsystems each day in different parts of the globe. The World Wide Web even helps us to share the new building knowledge in a blink of an eye. All these technologies help us build faster but complicate the whole construction process at the same time—what the best method today does not mean it is the best for tomorrow. We are all trying to catch up with the latest technology.

Moreover, all the building services installations are carried out on site before 1980, with the help of modern technology, off-site fabrication of some building services components has become possible (Hwang et al. 2010). Design of tall, asymmetric and specially shaped buildings has gained popularity (Rowlinson 1997). Building technical complexity has also increased (Chun et al. 2012), profound understanding of the force flow in these types of structures is not easy as the building plan is not constant along the height of the building (Rowlinson 1997).

2.3 Evolution Theory

According to Darwin, "… each new variety, and ultimately each new species, is produced and maintained by having some advantage over those with which it comes into competition; and the consequent extinction of less favored forms almost inevitably follows" (Crotty 2009). The evolution theory of Darwin and Wallance is based on the mechanism of natural selection where such process stresses that organisms better adapted survive and breed (World Bank 2010), human evolution is one of the very good examples (Cecchetti 2009). Lamarckian Evolution states that a change in environment may lead to changed patterns of behavior which can necessitate new use of structures (Central Intelligence Agency 2010). Academic researchers developed construction accident causation models as early as 1960. Since then, many different accident causation models appear in journals and books. Complexities in building construction due to increase in building height, construction procurement and technology have led to a number of construction accident causation models developed over time. Our building and construction environment has become more complicated, so are our accident causation models (Fig. 2.3).

2.4 Accident Causation Models

2.4.1 Energy Model (1961)

Haddon suggested that accident happens when there is an excess energy transfer (Lin and Mills 2001). Accident causing agents such as electrical, mechanical and

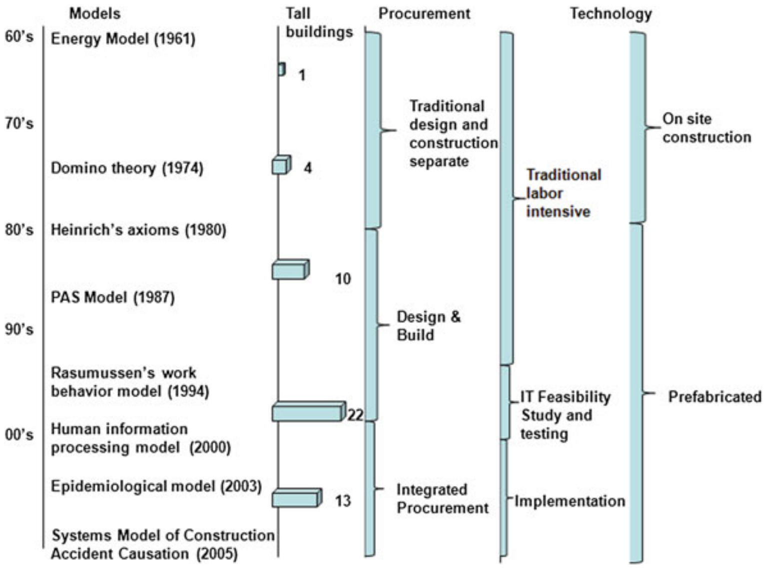

Fig. 2.3 Accident causation models, distribution of year of construction for the 50 tallest buildings in the world, procurement method and technology Timeline (Toole 2002; Zhu et al. 2010; Rowlinson 1997; Kim and Rhee 2009)

thermal, energy can lead to accidents. This model suggests that the occurrence of an accident basically follows the laws in physics: it happens after there is an excess amount of uncontrolled energy and consequences depend on the amount of energy (Briere et al. 2010).

Yet this model has received some complaints from Lingard and Rowlinson (2005) who pinpoint that the abstract nature of this model fails to lay down a good foundation in identifying hazards in routine work. It also fails to suggest the appropriate safety measures under different circumstances (Briere et al. 2010).

2.4.2 Bird' Domino Model (1974)

In 1974 suggested that an accident can be viewed as the last domino in the 'domino sequence' where an accident is the result of a sequence of events. The first domino falls on the second one and the second one's fall leads to the fall of the third domino, so on and so forth. Bird suggested that workers will be safe so long as the first domino, i.e., site management does not fall (Briere et al. 2010). However, other researchers point out that there are many factors which lead to accidents. It is inappropriate to regard accidents as the last event in a sequence (Li 2006). It can be the case like the last straw being placed on the camel (Fig. 2.4).

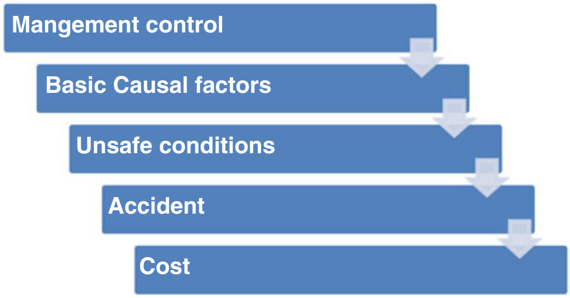

Fig. 2.4 The domino sequence (Edwards and Nicholas 2002)

Pheng and Shiua (2000)'s contention was that these unsafe conditions were symptoms of management oversight and mismanagement in planning, organizing, commanding, coordinating and control. Nevertheless, such model has failed to make a clear relationship between various relations among personal and organizational factors. Readers of domino sequence may misunderstand that personal factors and mental stress play the same role in accidents. Hence, such theory often leads to a false interpretation on the underlying accident causation factors. This is particularly true for those high rank officers who usually do not have to work on site and lack safety knowledge in depth (Briere et al. 2010).

2.4.3 Heinrich's Axioms (1980)

Heinrich (1980) proposed that more than one-fifth of the accidents are caused by a series of unsafe acts which finally lead to accidents occurs. He further elaborates that the degree of injury is a matter of probability. Nevertheless, Cooke and Lingard (2011) suggest that Heinrich's model focuses too much on the immediate circumstances surrounding the incidents, it fails to include unsafe conditions which also have systemic and organizational causes. Furthernmore, it is misguided to attribute incidents to interaction of multiple causes.

2.4.4 Potential Accident Subject Model (1987)

Leather (1987) proposes that both endogenic and exogenic factors might affect the potential accident subject's acts and thoughts which might lead to accidents in Potential Accident Subject (PAS) model. The PAS stresses the dynamic relationship between various stakeholders on accidents, e.g., workers, managers within the construction companies or even those people who work outside the construction companies. Under PAS model, any person even the victim himself can be the "Potential Accident Subject". Furthermore, people's behaviors and attitudes

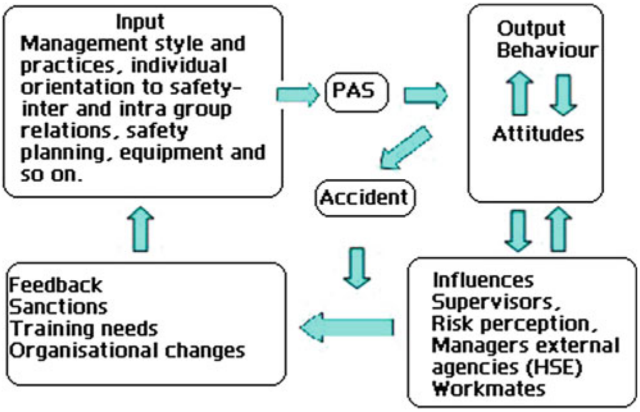

Fig. 2.5 PAS model (Peckitt 2004)

are affected by reward, management systems, punishment, training, and instructions given by seniors and so on. Some rewards for finishing tasks quickly may induce workers to take short cuts and ignore the possible sources of risks (Li 2006) (Fig. 2.5).

2.4.5 Rasumussen's Work Behavior Model (1994)

Rasmussen suggested that construction laborers' work is shaped by economic, functional, safety related objectives and constraints. The model identifies three zones: safe zone, (where the workers' behaviors comply with safety rules) hazard zone and loss of control zone. Most of the construction managers on site work along the cost gradient and the worker searches for the least effort gradient. All these end up with a systematic migration toward the boundary of acceptable performance only. In view of this, safety plans on site are often designed to act against the pressures outlined in the model. Nevertheless, the pressures that push workers toward the safe zone require a continuous effort. Rasmussen therefore proposes that accident prevention should focus on error tolerant work systems development which makes the boundary of loss of control reversible and visible (Eun and Resnick 2009) (Fig. 2.6).

2.4.6 Human Information Processing Model (2000)

Kjellen (2010) sheds light on human and environment interaction from an operator's point of view. Under this model, people are viewed as an information processor who makes their own judgment in response to environment risks,

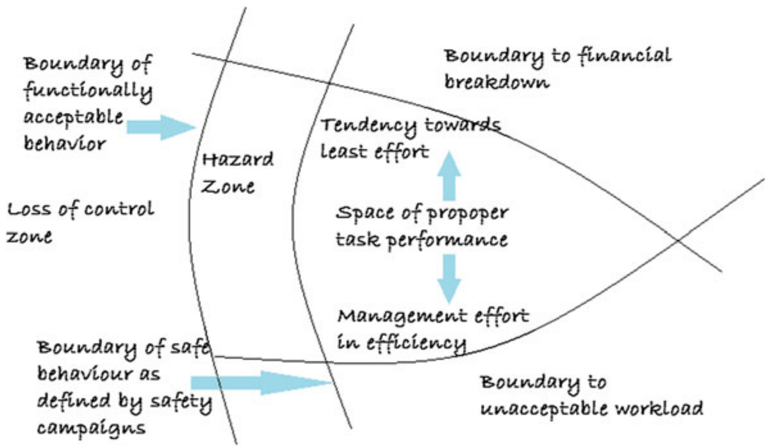

Fig. 2.6 Rasmussen's work behavior model (Mitropoulos et al. 2005)

hazards or deviations. Accidents happen when people are unable to handle information under complicated circumstances. Accident analysis is a very good practice to identify and evaluate the safety risks on site and provide suitable safety measures in turn.

Yet, this model suffers from two very major drawbacks. Firstly, the model only sheds light on 'cold' variables with regard to human cognitive processes which does not conform well with real life situations. In reality, emotional variables such as threat do affect people's capability in problem solving and accident prevention. Secondly, internal information processes are absent. Interpretation by actual behavior observations and interviews becomes necessary but this requires expertise. Because of the two aforementioned problems, application of this model is limited to in-depth investigation with experts participation (Li 2006).

2.4.7 Epidemiological Model (2003)

Conventional safety theorists put the lens on finding out accidents and injuries. There is, however, a trend in encompassing environmental factors which may be possible to cause an accident. Based on this idea, the Epidemiological Model views accidents as a disease entity which arise as a product of interaction between the agent, environment and the host (Goetsch 2003). Nevertheless, whether the agent in accidents can be meaningfully separated from its environment is in doubt (Hacker and Suchman 1963).

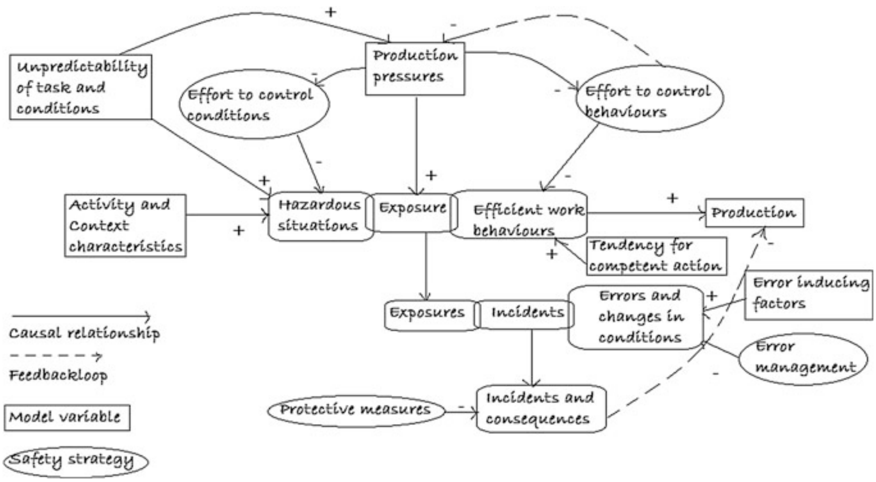

Fig. 2.7 System model of accident causation (Eun and Resnick 2009)

Table 2.2 Changes in accident causation models

	Initial accident causation models	Latest accident causation models
Direction	One	Multiple
Categories	Few	Multiple
Factors	Few	Multiple

2.4.8 Systems Model of Construction Accident Causation (2005)

Building on Rasmussen's model and various construction accident causation models in the past, this model identifies various variables which influence the probability of accidents during a construction activity. While the arrows in the figure indicate cause-effect relationships, the signs show the directions of the relationship between different factors. A positive sign indicates that when there are changes in factor X, Y changes in the same direction. A negative sign signifies the effect of changes in an opposite way. This model proposes that unpredictable tasks and environments increase the likelihood of accidents as it increases the likelihood of errors hazardous situations and production pressures (Eun and Resnick 2009) (Fig. 2.7).

2.5 Conclusion

To conclude, all the seven writers suggest that accidents are not random occurrences. Accidents happen because of failure in one or more factors. Nevertheless, when we take a closer look at the development of accident causation models over the years from 1961, we can see an interesting phenomenon: the models are getting more and more complicated (see Table 2.2). Accident causation models before mid-80s were a lot simpler than the later models, i.e., complicated models "survive" in natural selection. It is predicted that future accident causation models will be more complicated when high technological tools are used on site, and construction procurement and height of buildings have changed, i.e., Lamarckian Evolution also takes place in causation models.

Acknowledgments This chapter is a revised version of the paper "The evolution of construction accident causation models", presented in CIB Congress 2010, 10–14 May, 2010, Manchester. The authors would like to thank CIB for granting the right to republish.

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http://www.springer.com/978-3-642-35045-0

Construction Safety
Li, R.Y.M.; Poon, S.W.
2013, XII, 159 p. 54 illus., 30 illus. in color., Hardcover
ISBN: 978-3-642-35045-0