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Safety Consciousness: An Antidote to Industrial Accidents

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I. INTRODUCTION

Occupational Safety and Health Academy (OSHA)- (2005) ascertained that there are at least 60,000 fatal accidents on construction sites annually around the world. Workplace accidents are not only very devastating but also can give major impact to daily production depending on the type of work at stake. The introduction of machines in the workplace facilitated a lot of tasks and made work less cumbersome in several instances. But one of the dark sides of mechanization is the occurrence of accidents which sometimes result in injuries or loss of lives at the worst situations. Accidents are caused by several factors either related to workers or working condition. Employers however have a responsibility to provide safe working condition and to preserve their workers.

Industrial safety on the other hand has direct influence on the production process. If employers accurately and fairly check the safety measures, it will definitely prevent accidents and ensure regular flow of work; because if they should pay adequate attention to industrial safety, it will not only be beneficial to the workers but also would fulfill the interest of the employers. In this paper we shall discuss the meaning and concept of accident and safety, causes of accidents, accident proneness; their cost and measurement. After that we elaborate the industrial safety and method for reducing accident or safety measures.

Concept and Meaning of Industrial Accidents

The word accident is derived from the Latin verb **accidere**, signifying “fall upon, befall, happen, chance.” Other definitions include the following:

1. a short, sudden and unexpected event or occurrence that results in an unwanted and undesirable outcome … and must directly or indirectly be the result of human activity rather than a natural event’. (Hollnagel, 2004: 5).
2. Accidents are the result of technical failures, human errors or organisational problems (Hovden, Albrechtsen and Herrera, 2010: 855).
3. An accident as an unplanned and uncontrolled event in which the action or reaction of an object, substance, and person results in personal injury or the productivity thereof (Heinrich, 1959).

Going by these definition, it can be gathered that accidents are often sudden and unexpected event taking place in complex manners, something happening by chance; something unforeseen, unexpected, unusual, extraordinary, or phenomenal, taking place not according to the usual course of things or events, out of the range of ordinary calculations; that which exists or occurs abnormally, or an uncommon occurrence. Accidents are not only costly to industrial economy but they also results in anguish, injuries, pain or even death of the worker involved (Blaum & Maylor, 2004). Scholars have previously reported the diverse forms of accident prevalent in an industrial environment to include but not limited to scaffold accidents (O.S.H.A 2005; HSE, 2006; Mccann & Paine; 2002, U.S dept of labour 2005); accidents due to slip, trips and falls Tappin et al (2004); crane accidents (Neitzel 2001; Skinner et al, 2006 cited in Kadirii et al 2014). Ladder accidents (O.S.H.A 2005; Mitra et al, 2007 cited in Kadiri et al 2014); and electrocution and electrical accidents (Taylor et al 2002; Crowley & Homce, 2001). Ultimately, accidents lower the morale and satisfaction of the worker, decreases the rate of production and even taints corporate reputation. Therefore, industries need to work hard to find out the causes of accident and also provide safety measures to minimize its occurrences.

Models of Causes of Industrial Accident

The history of accident models to date can be traced from the 1920s through three distinct phases. The phases are broadly categorized as follows:

- Simple linear models
- Complex linear models
- Complex non-linear models (Hollnagel, 2010).

Each type of model is underpinned by specific assumptions:

- **The simple linear models -** assume that accidents are the culmination of a series of events or circumstances which interact sequentially with each other in a linear fashion and thus accidents are preventable by eliminating one of the causes in the linear sequence.
- **Complex linear models** -are based on the presumption that accidents are a result of a combination of unsafe acts and latent hazard conditions within the system which follow a linear path. The factors furthest away from the accident are attributed to actions of the organisation or environment and factors at the sharp end being where humans ultimately interact closest to the accident; the resultant assumption being that accidents could be prevented by focusing on strengthening barriers and defenses. The new generation of thinking about accident modeling has moved towards recognizing that accident models need to be non-linear.
- **Complex non-linear model**- that accidents can be thought of as resulting from combinations of mutually interacting variables which occur in real world environments and it is only through understanding the combination and interaction of these multiple factors that accidents can truly be understood and prevented (Hollnagel, 2010).

The types of model, their evolution, together with representative examples are described in the ensuing sections.

1. Simple sequential linear accident models

Simple sequential accident models represent the notion that accidents are the culmination of a series of events which occur in a specific and recognisable order (Hollnagel, 2010) and now represent the "commonest and earliest model of accident research ... that describing a temporal sequence" where the "accident is the overall description of a series of events, decisions and situations culminating in injury or damage .. a chain of multiple events" (Surry, 1969). Theories within this model include the following:

Heinrich's Domino Theory

The first sequential accident model was the 'Domino effect' or 'Domino theory' (Heinrich, 1931). In 1930, Heinrich was working for an insurance company as an engineer in the USA. He analyzed 75,000 accident reports, and attempted to develop a chronological sequence of inter-connected causal of accidental injury (Heinrich 1959). The model is based in the assumption that: the occurrence of a preventable injury is the natural culmination of a series of events or circumstances, which invariably occur in a fixed or logical order … an accident is merely a link in the chain. (p. 14). This model proposed that certain accident factors could be thought of as being lined up sequentially like dominos.

Heinrich proposed that an:

… accident is one of five factors in a sequence that results in an injury … an injury is invariably caused by an accident and the accident in turn is always the result of the factor that immediately precedes it. In accident prevention the bull's eye of the target is in the middle of the sequence – an unsafe act of a person or a mechanical or physical hazard (p. 13).

Domino theory of accident causation was originally developed by H W Heinrich in the late 1920s. His work is the basis for several contemporary theories in accident causation. Based on the domino model, accidents could be prevented by removing one of the factors and so interrupting the knockdown effect. Heinrich proposed that unsafe acts and mechanical hazards constituted the central factor in the accident sequence and that removal of this central factor made the preceding factors ineffective. He focused on the human factor, which he termed "Man Failure", as the cause of most accidents. Giving credence to this proposal, actuarial analysis of 75,000 insurance claims attributed some 88% of preventable accidents to unsafe acts of persons and 10% to unsafe mechanical or physical conditions, with the last 2% being acknowledged as being unpreventable giving rise to Heinrich's chart of direct and proximate causes (Heinrich, 1931, p.19). Heinrich's model was criticized for too much focus on the immediate circumstances surrounding accidents, when it is now recognized that unsafe acts and conditions have systemic and organizational causes.

Bird and Loftus' Domino Theory or Loss Causation model

Like Heinrich's theory, the Bird and Loftus domino theory emphasizes that the contact incidents can be avoided in unsafe acts and conditions are prevented. However the theory, Bird and Loftus (1976) updated the domino sequence to reflect the management's relationship associated with the causes and effects of all incidents.

Bird and Loftus's theory uses five dominos that represent the following events involved in all incidents:

i. **Lack of Control**

Control refers to the four functions of a manager: planning, organizing, leading, and controlling. Lack of control can be in different forms, for example purchasing substandard equipment or tools, not providing adequate training, or failing to install adequate engineering controls.

ii. **Basic cause**

There are two factors personal factors and job factor of cause. Personal factors can be lack of knowledge or skill, improper motivation, and physical or mental problems. For job factors, it including inadequate work standards, inadequate design or maintenance, normal tool or equipment wear and tear, and abnormal toll usage such as lifting more weight than the rated capacity of an overhead crane.

iii. Immediate cause

This explains that unsafe acts and unsafe conditions are the immediate cause of accident.

iv. Incident

"an undesired event that could or does make contact with a source of energy above the threshold limit of body or structure" (Bird and Loftus, 1976). There are 11 types of contact incident event as follow: struck-by, struck-against, contact-by, contact-with, caught-in, caught-on, and caught between, foot-level-fall, fall-to-below, overexertion and exposure.

v. **People-property- loss**

These are the adverse results of the accidents.

II. SEQUENTIAL ACCIDENT MODEL

Sequential models were attractive as they encouraged thinking around causal series. They focus on the view that accidents happen in a linear way where A leads to B which leads to C and examine the chain of events between multiple causal factors displayed in a sequence usually from left to right. Accident prevention methods developed from these sequential models focus on finding the root causes and eliminating them, or putting in place barriers to encapsulate the causes. Key models developed in this evolutionary period include energy damage models, time sequence models, epidemiological models and systemic models.

i. Time sequence models

Benner (1975) identified four issues which were not addressed in the basic domino type model: (1) the need to define a beginning and end to an accident; (2) the need to represent the events that happened on a sequential time line; (3) the need for a structured method for discovering the relevant factors involved; and (4) the need to use a charting method to define events and conditions.

ii. Epidemiological models

Epidemiological accident models can be traced back to the study of disease epidemics and the search for causal factors around their development. Gordon (1949) recognised that "injuries, as distinguished from disease, are equally susceptible to this approach", meaning that our understanding of accidents would benefit by recognising that accidents are caused by: a combination of forces from at least three sources, which are the host – and man is the host of principal interest – the agent itself, and the environment in which host and agent find themselves (p. 506) Recognising that doctors had begun to focus on trauma or epidemiological approaches, engineers on systems, and human factors practitioners on psychology Benner (1975); considered these as only partial treatments of entire events rather than his proposed entire sequence of events. Thus Benner contributed to the development of epidemiological accident modeling which moved away from identifying a few causal factors to understanding how multiple factors within a system combined. These models proposed that an accident combined agents and environmental factors which influence a host environment (like an epidemic) that have negative effects on the organism (a.k.a organisation). Accidents are usually the result of a combination of factors, each one of which may vary from situation to situation.

iii Systems Model

By the 1980s OHS researchers realised that previous accident models did not reflect any realism as to the true nature of the observed accident phenomenon. As noted by Benner: one element of realism was non-linearity … models had to accommodate non-linear events. Based on these observations, a realistic accident model must reflect both a sequential and concurrent nonlinear course of events, and reflect events interactions over time (1984, p. 177). This was supported by Rasmussen (1990) who, whilst quoting Reason's (1990) resident pathogens, acknowledged that the identification of events and causal factors in an accident are not isolated but "depend on the context of human needs and experience in which they occur and by definition ... therefore will be circular" (p. 451). Systemic accident models which examined the idea that systems failures, rather than just human failure, were a major contributor to accidents (Hollnagel, 2004) began to address some of these issues (but not non-linear concepts) and recognised that events do not happen in isolation of the systemic environment in which they occur.

Accident models also developed with further understanding of the role of humans, and in particular the contribution of human error, to safety research. A skill-rule-knowledge model of human error was developed in the earlier work of Rasmussen & Jensen (1974) and has remained a foundation concept for understanding of how human error can be described and analysed in accident investigation. Research by Rouse (1981) contributed to the understanding of human memory coding, storage and retrieval. Cognitive science came to the fore in accident research, and further work by Rasmussen (1981; 1986) and Reason (1979; 1984a; 1984b; 1984c) saw the widespread acceptance and recognition of the skill based, rule-based and knowledge-based distinctions of human error in operations. Rasmussen (1990) wrote extensively on the problem of causality in the analysis of accidents introducing concepts gleaned from philosophy on the linkage between direct cause-effect, time line and accident modelling.

Rasmussen explored the struggle to decompose real world events and objects, and explain them in a causal path found upstream from the actual accident where latent effects lie dormant from earlier events or acts. At this stage, Rasmussen recognised that socio-technical systems3 were both complex and unstable. Any attempt to discuss a flow of events does not take into account: closed loops of interaction among events and conditions at a higher level of individual and organizational adaption … with the causal tree found by an accident analysis is only a record of one past case, not a model of the involved relational structure" (1990, p. 454). In calling for a new approach to the analysis of causal connections found in accident reports Rasmussen heralded in a more complex approach to graphically displaying accidents and understanding and capturing the temporal, complex system and events surrounding accident causation.

Reason's early work in the field of psychological error mechanisms (Reason 1975; 1976; 1979) was important in this discussion on complexity of accident causation. By analyzing everyday slips and lapses he developed models of human error mechanisms (Rasmussen 1982). Reason (1990) went on to address the issue of two kinds of errors: active errors and latent errors. Active errors were those "where the effect is felt almost immediately" and latent errors "tended to lie dormant in the system largely undetected until they combined with other factors to breach system defences" (p. 173). Reason, unlike Heinrich (1931) and Bird and Germain (1985) before him, accepted that accidents were not solely due to individual operator error (active errors) but lay in the wider systemic organisational factors (latent conditions) in the upper levels of the organisation. Reason's model is commonly known as the Swiss Cheese Model

III. COMPLEX NON LINEAR ACCIDENT MODELS

There has been considerable overlap in the development of the various conceptual approaches to accident causation. In parallel with the development of thinking around epidemiological models and systemic models the thinking around the complexity of accident causation led to non complex linear models. Key researchers in this approach have been Perrow, Leveson and Holnagel. Perrow began to argue that technological advances had made systems not only tightly coupled but inheritably complex, so much so that he termed accidents in these systems as being "normal". Perrow's normal accident theory postulated that tightly coupled systems had little tolerance for even the slightest disturbance which would result in unfavourable outcomes. Thus tightly coupled systems were so inherently unsafe that operator error was unavoidable due the way the system parts were tightly coupled. (Perrow, 1984) Components in the system were linked through multiple channels, which would affect each other unexpectedly, and with the complexity of the system meaning that it was almost impossible to understand it (Perrow, 1984; Tenner, 1996).

Two new major accident models were introduced in the early 2000s with the intention of addressing problems with linear accident models (Hovden, et al., 2009):

· The Systems-Theoretic Accident Model and Process (STAMP) (see Leveson,
2004).

· The Functional Resonance Accident Model (FRAM) (see Hollnagel, 2004)

i. Systems-Theoretic Accident Model and Process (STAMP)

Leveson's model considered systems as "interrelated components that are kept in a state of dynamic equilibrium by feedback loops of information and control" (2004, p. 250). It emphasised that safety management systems were required to continuously control tasks and impose constraints to ensure system safety. This model of accident investigation focused on why the controls that were in place failed to detect or prevent changes that ultimately lead to an accident. Leveson developed a classification of flaws method to assist in identifying the factors which contributed to the event, and which pointed to their place within a looped and linked system. Leveson's model expands on the barriers and defences approach to accident prevention and is tailored to proactive and leading safety performance indicators (Hovden, et al., 2009). However this model has had little up take in the safety community and is not widely recognised as having a major impact on accident modeling or safety management generally. Roelen, Lin and Hale (2010, p.6) suggest that this may be because Leveson's model does "not connect to the current practice of safety data collection and analysis" making it less favourable than event chain models such as Reason's

ii Functional Resonance Accident Model (FRAM)

Erik Holnagel is one of the more forward thinking researchers in the area of accident modelling and the understanding of causal factors. While Hollnagel's early published work (Cacciabue & Hollnagel 1995; Hollnagel 1993; 1998) centred on human/cognitive reliability and human/machine interface his later work Barriers and Accident Prevention (2004) challenged current thinking about accident modelling. He introduced the concept of a three dimensional way of thinking about accidents in what is now known to be highly complex and tightly coupled socio-technical systems in which people work. He describes systemic models as tightly coupled and the goals of organisations as moving from putting in place barriers and defences to focusing on systems able to monitor and control any variances, and perhaps by allowing the systems to be (human) error tolerant. Hollnagel's Functional Resonance Accident Model (FRAM) , is the first attempt to place accident modelling in a three-dimensional picture, moving away from the linear sequential models, recognising that "forces (being humans, technology, latent conditions, barriers) do not simply combine linearly thereby leading to an incident or accident" (Hollnagel, 2004, p. 171).

FRAM is based on complex systemic accident theory but considers that system variances and tolerances result in an accident when the system is unable to tolerate such variances in its normal operating mode. Safety system variance is recognised as normal within most systems, and represents the necessary variable performance needed for complex systems to operate, including limitations of design, imperfections of technology, work conditions and combinations of inputs which generally allowed the system to work. Humans and the social systems in which they work also represent variability in the system with particular emphasis on the human having to adjust and manage demands on time and efficiency (p. 168). Hollnagel's (2005) theory of efficiency-thoroughness trade-off (ETTO) expanded on these demands on the humans, where efficiency was often given more priority to thoroughness and vice versa. Hollnagel recognised that complex systems comprise a large number of subsystems and components with performance variability usually being absorbed within the system with little negative effect on the whole. Four main sources of variability were identified as:

· Humans
· Technology
· Latent conditions
.Barriers (p. 171).

Holnagel proposed that when variables within the system became too great for the system to absorb them; possibly through a combination of these subsystem variables of humans, echnology, latent conditions and barriers; the result will be undetectable and unwanted outcomes. That is a 'functional resonance' results, leading to the system being unable to cope in its normal functioning mode. Hollnagel's FRAM model presents a view of how different functions within an organisation were linked or coupled to other functions with the objective of understanding the variability of each of the functions, and how that variability could be both understood and managed. The functions are categorised as inputs, outputs, preconditions, resources, time and control. Variability in one function can also affect the variability of other functions (p. 173).

In 2010 Hollnagel launched a web site in support of the growing cohort of researchers and OHS professionals interested in using the model as a tool for understanding and managing accidents and incidents. While the Functional Resonance Accident Model provided a theoretical basis for thinking about accident causation Hollnagel clearly differentiated between models that aided thinking about accident causation and methods of analysing accidents as part of investigations. The Functional Resonance Analysis Method evolved from the conceptual thinking embodied in the model which was highlighted by retaining the FRAM acronym. A detailed description of theb method is given in Sundstrom & Hollnagel (2011). .

iii Complexity and accident modeling

While the FRAM model begins to address complexity of organisation and the relationship with accident causation Dekker (2011) takes the discussion of complexity further to challenge the notion of accident modelling and the predictive ability of accident models. In describing complexity of society and technology

Dekker considers that:

The growth of complexity in society has got ahead of our understanding of how complex systems work and fail. Our technologies have got ahead of our theories. Our theories are still fundamentally reductionist, componential and linear.

Our technologies, however are increasingly complex emergent and non-linear. Or they get released into environments that make them complex, emergent and non-linear (2011, p.169). Accidents occur in these complex systems by a “drift into failure” which occurs through a slow but steady adaptive process where micro-level behaviours produce new patterns which become embedded and then in turn are subject to further change. Dekker’s position is that as there are no well-developed theories for understanding how such complexity develops and the general response is to apply simple, linear ideas in the expectation that they will assist in understanding causation (p.6). He considers the search for the “broken and part or person” that underpins linear models where risk is considered in terms of energy-to-be-contained, barriers and layers of defence, or cause and effect are misleading because they assume rational decision-making (p.2)

Aside from these models, there are other factors that have been considered as mostly responsible for accidents, some of which though have been covered in the earlier discussion. These factors are broadly divided into: Work related factors and person related factors.

1. Work related factors:
- Nature of work
- Inadequate safety devices
- Faulty layout
- Inadequate ventilation
- Noise
- Work schedule
- Long hour of work
- Speed of work
- Faulty design of design

2. Person related factors
- Age, sex, experience
- Health
- Absenteeism
- Alcohol addiction
- Fatigue
- Frustration
- Neuroticism
- Carelessness
- Mental ability

Accident Proneness

No matter what the causes of accidents are, some worker records more accidents than their counterparts. Any worker who is accident-prone in one specific situation may not be so in other. If two workers are operators on similar machine under identical situation, one may commit more accidents than the other. The first worker will be called an ‘accident-prone operator’. Harrell (1964), “Accident-proneness is the continuing tendency of a person to have accidents as a result of his stable and persisting characteristics”. Accident proneness is a condition in which a “human being is mentally inclined, strongly disposed, attitudinally addicted or personally destined to become continually involved in an on-going and never-ending series of accidents or injuries”. In the opinion of Blum and Naylor (1968), “accidents do not distribute themselves by chance, but happen frequently to some men and infrequently to others as a logical result of combination of circumstances”.

Cost of Accidents

There are some direct and indirect costs incurred in accident. Which not only affect the victim family as well as worker itself but also affect the production as well as employers some of these costs are direct and other indirect. They listed below:

1. **Direct costs**- Lebean & Duguay (2013) says it consists of the cost components associated with treatment and “repair” of the injury, plus other components directly related to the accident, such as:
- Victims’ compensation costs

- Medical bills for victims
- Waste of materials
- Loss of quality in output,
- Property damage
- Emergency services
- Funeral cost (see Access Economics, 2006) etc.

1. **Indirect cost**: Indirect costs are costs that are not directly related to the treatment and repair of the injury but rather to the lost opportunities of the injured employee, his family, the employer, the co-workers, and the community (Leigh et al., 2000).

- Lowered morale among workers
- Loss of corporate reputation
- Cost of training new workers
- Salary cost
- Administrative costs
- Paying for the time the accident victim is not on duty
- Production losses (see Gosselin, 2004).

Industrial Safety

Accidents have many causes and it will happen at any time. If employer provide safe work environment to workers, they automatically minimize the occurrence of accident.

Safety Measures

There is some safety measure which if seriously considered will be helpful to not only workers but also employer of the particular concern:

• **Appropriate training programmes**—for the avoidance or reduction of accidents in workplaces, employers must ensure that proper and adequate trainings are given to all workers, and especially the new hires; because they are not familiar to the workplace.

• **Safety habits**—if management tries to develop a sense of security at the time of training itself than it will automatically become habit at the actual performance. Workers are not inclined to accident because they adopted safety as their habit.

• **Handling safety devices**—the handling of safety devices is very important. Before handling equipment there should be a proper orientation about the proper use of these devices.

• **Safety campaigns**—Promote awareness about safety among the workers. It can be done by posters; slogans etc. or organize an effective accident prevention week; which create awareness about how to minimize accident in workplace, what safety measures should be if taken for doing flawless work.

Housekeeping—poor housekeeping like wet or dry, slippery and greasy floors, bad arrangement of machines, material leads accident. For maintaining a safe work place housekeeping details must be attended to.

• **Adequate selection**—selection of workers at workplace should be done by proper tests. Assign task to individual according to their compatibility. If work or task is compatible to worker than chance of accident should be minimized and of course workers will be satisfied and feel less fatigue.

• **Actuarial methods**—the actuarial method emphasis finding the cause of accidents based on actual data and developing reduction of conducted accident programmes from that angle. Mcfarland and Moseley's (1954) clearly indicate that accident repeaters committed many more violations than did accident-free-drivers. The number of vibrations of accident repeaters is much greater than proportional expectations. They are liable to believe that a man drives as he lives. Speed in private driving and violations which reflect attitude towards authority seem to be characteristic of repeaters. In brief the actuarial method involves studying accidents statistics to determine based upon statistical data those things which seem to be related to accident frequency (Blum & Naylor, 1968).

• **Regular inspection**—regular inspection should be done on workplaces to have opportunity of calling those who are not safety conscious to order. The inspector checks all the availability of proper working environment for workers and if any dissimilarity exists they counsel the worker and also inform the management.

• **Safety education programmes**—accidents can be reduced by safety education programmes which can be conducted by management and or other authorities. Regular foremen's meetings can be effective in reducing accidents. The United States Department of Labour (1947) has issued a "Guide to Industrial Accident Prevention through a Joint Labour-Management Safety Committee which suggests some points for a safety committee:

(i) Make immediate and detailed investigation of accident reports.
(ii) Develop accident data to indicate accident sources and injury rates.
(iii) Develop or revise safe practice and rules to comply with plant needs.

(iv) Inspect the plant to detect hazardous physical conditions or unsafe work methods.
(v) Recommended changes or additions to protective equipment and device to eliminate hazards.
(vi) Promote safety and first aid training for committee members and workers.
(vii) Participate in advertising safety and in selling the safety programme to workers.
(viii) Conduct regular scheduled meetings.

IV. CONCLUSION

The word accident is derived from the Latin verb **accidere**, signifying “fall upon, befall, happen, chance. Accidents are often sudden and unexpected event taking place in complex manners, and it happens by chance; it is unforeseen, unexpected, unusual, extraordinary, or phenomenal, taking place not according to the usual course of things or events, out of the range of ordinary calculations; and it exists or occurs abnormally, or in an uncommon circumstance. Accidents are caused by numerous factors: those from the individuals and those caused by the work environment. The costs of accidents are both direct- cost components associated with treatment and “repair” of the injury, plus other components directly related to the accident, such as: victims’ compensation costs, medical bills for victims, waste of materials, loss of quality in output, property damage, emergency services and funeral cost. Indirect - costs that are those not directly related to the treatment and repair of the injury but rather to the lost opportunities of the injured employee, his family, the employer, the co-workers, and the community)- lowered morale among workers, loss of corporate reputation, cost of training new workers, salary cost, administrative costs, paying for the time the accident victim is not on duty, and production losses . Safety consciousness is an efficacious approach to the reduction of accidents in the workplaces.

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