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RESEARCH ARTICLE

PARAMETRIC EVALUATION OF SAFETY CULTURE IN CONSTRUCTION INDUSTRIES

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ABSTRACT

Global studies and research reveals that, construction is the most hazardous process and is responsible for severe and fatal injuries. The construction process is a phenomenal, complex, temporary and complicated activity, it demands for aversatile, comprehensive and easy-to–adopt parametric approach to evaluate and improve its safety performance. The parameters are Lead and Lag indicators. The Lead indicators are pro-active and lag indicators are reactive. It has been the traditional and historical practice, to report the safety performance by the Lag indicators like number of injuries, man-days lost, extent of disability, compensation etc. The author during the course of periodic review of progress observed that accidents and its consequences are the only parameters reported on the safety performance of the construction project. This traditional practice doesn't seem to be the right approach as the absence of accident does not mean that the safety performance is good. At present, nationally or internationally, there are no uniform, harmonized or standardised and accepted bench – marking metrics / indicators available for reporting, comparing and improving safety performance in any industry. In this study the key parameters combining the Lead and Lag indicators are identified and quantified for construction industry, based on the safety performance of a group of 30 organisations which consists of construction, production and processing, services and research and development units. The purpose is to objectively assess the safety performance. This exercise facilitates in building the robust Occupational Safety and Health (OSH) Management System in the construction industry.

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1. INTRODUCTION

The safety performance of construction industry has been traditionallymeasured by metrics like no of reportable loss time injuries, man days lost, frequency rate, severity rate, disabilities, medical claims, compensation, etc as per the standards available in the country. These are called quantitative Lag indicators. These are negative and reactive. This information is used for comparing between the contractors, inter and intra industries, sectors etc. Globally, it is well known that the construction is a hazardous process and the sector is responsible for many disabling and fatal injuries as compared to any other sector. Due to the best prevailing occupational safety and health management system practices in the construction industries, the fatality rates per annum per lakh of workers have progressively showing a down ward trend from tens to ones but the severe disabling injuries could not be fully prevented. The random recurring accidents taking place in construction industries at one place or another indicate that the preventive safety measures are inadequate (Table 1). The Table 1 gives the compendium of typical values of the fatality rates per annum per lakh of workers involved in construction activity in different countries. The underlying cause for fatalities during construction in different parts of the world is the non-availability of pro-active safety performance metrics of construction industry for effective evaluation, monitoring and control by the management to prevent accidents. The safety performance is the indicator of the safety culture prevailing in the work place. The term Safety Culture was first evolved post- Chernobyl accident in nuclear industry in 1986. The Chernobyl disaster highlighted the importance of safety culture and the impact of managerial and human factors on the outcome of safety performance (Flin *et al*., 2000; IAEA, 1991). The term 'safety culture' was first used in INSAG's (1988) 'Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident' where safety culture was described as:"That assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance." It is observed thatthe simple, applicable definition / statement of safety culture, available in literature and relevant to construction industryis the ways and means in which safety is managed in the workplace, and often reflects "the attitudes, beliefs, perceptions and values that employees share in relation to safety" (Cox and Cox, 1991)

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or in other words, "the way we do safety around here" (CBI, 1991) The author also during the course of study and the review of safety management / cultural practices prevailing construction activity in many countries observed thatpersons working in any part of the world are more prone to the risk of recurring severe disabling / fatal work injuries at any point of time as compared to any other industry /occupation. The researchers / practitioners worldwide equivocally advocate that currently there are no standard, uniform and harmonized national or international safety performance indicators that are accepted by the construction industry nor any other industry. The need for positive safety metrics (Lead indicators also) to improve safety performance is strongly felt because the present practice of relying excessively on reporting lag indicators has limited utility because of post-accident recording of statistically less significant high consequence random events. The reporting through lag indicators also causes knee-jerk corrections / reactions by the project (the construction unit is called as Project) management promotes over-confidence and complacency when reportable injuries do not happen for some time due to a chance. The authenticity of the management information system reports is dependent on the transparency and openness of the reporting method. The Lagquantitative indicators are post-event based and do not appraise the shortcomings and measures for improvements needed in the construction processA multi-factoring metric method, which considers Lag & Leadindicators and which includes the safety management practices is a comprehensive and systematic way of measuring safety culture of a construction industry. The lead indicators which can be considered are no of safety meetings, site inspections by all levels, safety audits , tool box meetings, safety promotion schemes, safety suggestions for improvement of work environment, etc which are positive and pro-active. The worldwide researchers, academicians and practitioners advocate for the need of pro-active, objective and quantitative assessment of safety culture in construction industry. Aproactive approach and positive safety performance metrics are essential for the project management to promote hazard control measures and to prevent accidents in construction industry.

Table 1. Typical construction fatality rates in different countries

Country/Region	Fatalities (per Annum per 100,000 Workers)	Year
Australia	1.85	2013
Canada	8.70	2008
Europe	23.00	2012
France	2.64	2012
Finland	5.90	2008
Germany	5.00	2008
Ireland	9.80	2013
Israel	12.12	2015
India	10.00	2008
Norway	3.30	2008
Sweden	5.80	2008
Switzerland	4.20	2008
United Kingdom	1.62	2015
United States of America	9.80	2014

(Source:https://en.wikipedia.org/wiki/Construction_site_safety)

2. Evolution of construction safety culture

The historical evolution of safety at work, emergence of the safety management system and the phenomenal development of safety culture in the construction industry from themedieval age to the current stage is elucidated in the following paragraphs.

A.General

The construction in one form or other is always associated with the human involvement and intervention. The progress of construction process is directly linked with the evolution and development of human civilization. The construction of massive palaces and buildings involving intensive slavery have been the earlier part of the world history. Globally, in the poor and exploited society, struggle for survival became a fundamental concern rather than looking for safe environment. The concept of safety nearly eloped among the poor labourers who were willing to risk their life for day to day needs. For the masters, the life of the labours (for all practical purposes slaves) was cheaper than expenses on improving work environment and safety. In the early history of construction many people (including women and children) lost their lives due to exploitation, adverse / hostile working environment, long working hours, primitive tools, manual handling, and inhumane treatment by constructors. There was no method of enforcing and assuring the safety, health and welfare at work in Medieval Period of human history.

B.History of Construction Safety (up to 18th Century)

The first building code was enacted by the sixth Babylonian King Hammurabi in 1700 BCE ((Before Common Era or Before Christ) Babylonian law) is known as Code of Hammurabi (King, 2005), which may be a draconian law for modern civilizedsociety. There are 282 codes, the codes which are related to building construction, public safety & health, liability, penalty and compensation. The generally accepted first building code which was in the Code of Hammurabi, which specified (Hammurabi's Code of Laws, 2008) Code 229. If a builder builds a house for someone, and does not construct it properly, and the house which he built falls in and kills its owner, then that builder shall be put to death. Code 232. If it ruins goods, he shall make compensation for all that has been ruined, and in as much as he did not construct properly this house which he built and it fell, he shall re-erect the house from his own means. Code 233. If a builder builds a house for someone, even though he has not yet completed it; if then the walls seem toppling, the builder must build the walls solid from his own means. Similarly, Law of Moses (1393-1273 BCE) also stipulates, specific construction aspects which is also an earlier form /part of the building code. The Bible book of Deuteronomy, Chapter 22, Verse 8, states that: "When you build a new house, make a parapet around your roof so that you may not bring the guilt of bloodshed on your house if someone falls from the roof".

C. Safety Legislation Post - Industrial Revolution (19th Century Onwards)

In the 19thcentury, the evolving changes in societies worldwide, industrial revolution, end of slavery, immigration, etc brought about enactments of number of building acts / laws like The London Building Act, 1844, Baltimore Building Code in 1859, etc. Globally, construction has sprung up in the late 19th century. There had been construction of many historic monuments, buildings, bridges, tunnels, railways, etc with large number of laborers. History of construction speaks about occurrence of injuries and fatalities in the construction process without recording and reporting as there was no formal safety and health measures at work. For centuries, humans have faced poverty and have been exploited by the masters (rulers).

In the poor and exploited society, struggle for survival became a fundamental concern rather than looking for safe environment. The construction Industry draws their resources from this very poor and exploited society who nether have any consciousness for the safe working environment nor any education or knowledge to ask for their right for safety. The apparent cause could be due to no regulation or state control of construction activities and prevailing inhumane working conditions. The modern civilization and societal development at the advent of many independent nations emerging, the construction has been gradually under the state control. Many colonial and provincial laws, indirectly regulating the construction activities were enacted. The first Factories Act in British India was passed in 1881. It was designed primarily to protect children and to provide for some health and safety measures to workers. It was followed by many re-enactments and amendments from time to time.

D. Current Safety Legislations (20th Century onwards)

The 20th century has seen a sea change in the human history after the two world wars, with emergence of independent nations, socio-economic development, industrialization, infra-structure development, galore of scientific inventions and discoveries in place. The scientific and technological endeavors with rapid trade, commerce and sectorial development has led to construction of modern engineering and technological marvels in almost all parts of the world. This experiencehas revealed a number of vulnerabilities, susceptibilities, risks and weaknesses in the safety, health and welfare aspects of workers who are involved in the nation building and development process. The prospective states / nations have felt the requirement of safety measures to protect the workers from the hazards arising out of growing industrial activities in their country. A radical necessity for ensuring humane working conditions worldwide was mooted. This led to the establishment/ creation of International Labor Organization (ILO) at Geneva in the year1919 after the World War I, to reflect the belief that universal and lasting peace can be accomplished only if it is based on social justice (http://www.ilo.org/global/about-the-ilo/history/lang--en/index.htm). There was keen appreciation of the importance of social justice in securing peace, against a background of exploitation of workers in the industrializing nations of that time. There was also increasing understanding of the world's economic interdependence and the need for cooperation to obtain similarity of working conditions in countries competing for markets. Reflecting these ideas, the Preamble states:

- Whereas universal and lasting peace can be established only if it is based upon social justice;
- And whereas conditions of labor exist involving such injustice hardship and privation to large numbers of people as to produce unrest so great that the peace and harmony of the world are imperiled; and an improvement of those conditions is urgently required;
- Whereas also the failure of any nation to adopt humane conditions of labor is an obstacle in the way of other nations which desire to improve the conditions in their own countries.

The Factories Act of 1948 was promulgated after Independent India. The Factories Act, 1948 (http://www.labour.nic.in/sites/default/files/TheFactoriesAct1948.pdf) came into force on the 1st day of April, 1949. Its object is to regulate the conditions of work in manufacturing establishments which come within the definition of the term 'factory' as used in the Act. The safety, health and Welfare provisions are covered in the act and rules thereunder. Successfully over the years many labor legislations have been enacted in India covering safety, welfare and social justice aspects. The Constitution of India, which was adopted and enacted ontwenty-sixth day of November, 1949, under Part IV Directive Principles of State Policy. Article 42 reads that - Provision for justand humane conditions of work andmaternity relief is nevertheless fundamental in the governance of the country and it shall be the duty of the State toapply these principles in making laws.Thus, itis the onus on the welfare state like India to make laws for the betterment of its citizens. The enactment of "The Occupational Safety and Health Act, 1970" at United States of America (USA) (https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=oshact&p_id=2743) and "The Health and Safety at Work etc. Act 1974 (also referred to as HSWA, the HSW Act, the 1974 Act or HASAWA)" at Great Britain (http://www.hse.gov.uk/legislation/hswa.html) has brought tremendous impetus worldwide on the occupational health and safety in all occupations including construction.

E. Occupational Health and Safety Overview during Construction

In the preceding paragraphs safety and health aspects in construction activities were scarcely covered. In view of the large scale construction activities being undertaken in early 1980s, the need is felt to focus more in this sector. In the international scenario construction is given due attention and consideration. The International Labour Organisation (ILO)'s Safety and Health in Construction Convention, 1988 (No. 167) (http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C167) has come into force from Jan 11, 1991. Many countries have ratified this convention. This Convention applies to all construction activities, namely building, civil engineering, and erection and dismantling work, including any process, operation or transport on a construction site, from the preparation of the site to the completion of the project. This is an excellent piece of convention which aims to ensure safe work place with the mutual co-operation between workers and employers with the active involvement of national governments. The employer'sprimary role is to ensure that workers are adequately and suitably a) informed of potential safety and health hazards to which they may be exposed at their workplace; (b) instructed and trained in the measures available for the prevention and control of, and protection against, those hazards. In the implementation process, the national government shall - (a) take all necessary measures, including the provision of appropriate penalties and corrective measures, to ensure the effective enforcement of the provisions of the Convention; (b) provide appropriate inspection services to supervise the application of the measures to be taken in pursuance of the Convention and provide these services with the resources necessary for the accomplishment of their task, or satisfy itself that appropriate inspection is carried out. The spirit of the convention in toto is to improve safety performance in construction industries around the world. The construction activities have been developing with time along with the civilized society but with no legal definition till late 20th century.

E. Regulation of Construction Safety inIndia

In India, the labour welfare and related matters are in the Seventh Schedule, List III - Concurrent List, of the

Constitution of India. The acts/ rules as appropriate, related and relevant to the subject can be laid by both central and state governments, but administration / jurisdiction falls under the state government. The Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996 (lawmin.nic.in/ld/P-ACT/1996/) was enacted to regulate the employment and conditions of service of building and other construction workers and to provide for their safety, health and welfare measures and for other matters connected therewith or incidental thereto. This is a first positive step to improve the working conditions of the construction workers in India. A versatile definition of the building and construction work was given in the Act which reads as"building or other construction work "means the construction, alteration, repairs, maintenance or demolition, of or, in relation to, buildings, streets, roads, railways, tramways, airfields, irrigation, drainage, embankment and navigation works, flood control works (including storm water drainage works), generation, transmission and distribution of power, water works (including channels for distribution of water), oil and gas installations, electric lines, wireless, radio, television, telephone, telegraph and overseas communications, dams, canals, reservoirs, watercourses, tunnels, bridges, viaducts, aqueducts, pipelines, towers, cooling towers, transmission towers and such other work as may be specified in this behalf by the appropriate Government, by notification but does not include any building or other construction work to which the provisions of the Factories Act, 1948(63 of 1948), or the Mines Act, 1952 (35 of 1952), apply;

In Chapter VII of the above act, Safety and Health Measures are laid down for Building and Other Construction Works. In Section 40, the Power of appropriate Government to makerulesfor the safety and health of building workers are prescribed —

(1) The appropriate Government may, by notification, make rules regarding the measures to be taken for the safety and health of building workers in the course of their employment and the equipment and appliances necessary to be provided to them for ensuring their safety, health and protection, during such employment.
(2) In particular, and without prejudice to the generality of the foregoing power, such rules mayprovide for all or any of the following matters, namely: based on the research study and experience, few such works which have high potential for injury and fatal accidents reported are highlighted.
(1) The safe means of access to, and the safety of, any working place, including the provision of suitable and sufficient scaffolding at various stages when work cannot be safely done from the ground or from any part of a building or from a ladder or such other means of support;
(2) The precautions to be taken in connection with the demolition of the whole or any substantialpart of a building or other structure under the supervision of a competent person and the avoidance of danger from collapse of any building or other structure while removing any part of the framed building or other structure by shoring or otherwise;
(3) The erection, installation, use and maintenance of hoists, lifting appliances and lifting gearincluding periodical testing and examination and heat treatment,where necessary, precautions to be taken while raising or lowering loads, restrictionson carriage of persons and appointment of competent persons on hoists or other lifting appliances;
(4) The adequate and suitable lighting of every workplace and approach thereto, of every place where raising or lowering operations with the use of hoists, lifting appliances or lifting gears are in progress and of all openings dangerous to building workers employed;
(5) The precautions to be taken to prevent inhalation of dust, fumes,gases or vapours during anygrinding, cleaning, spraying or manipulation of any material and steps to be taken to secure and maintain adequate ventilation of every working place or confined space;
(6) The measures to be taken during stacking or unstacking, stowing or un-stowingof materials or goods or handling in connection therewith;
(7) The safeguarding of machinery including the fencing of every flywheel and every moving part ofaprime mover and every part of transmission or other machinery, unless it is in such a positionor of such construction as to be safe to every worker working onany of the operations and as if it were securely fenced;
(8) The safe handling and use of plant, including tools and equipment operated by compressed air;
(9) The precautionsto be taken in case of fire;
(10) The limits of weight to be lifted or moved by workers;
(11) The steps to be taken to prevent danger to workers from live electric wires or apparatusincluding electrical machinery and tools and from overhead wires;
(12) The keeping of safety nets, safety sheets and safety belts where the special nature or the circumstances of work render them necessary for the safety of the workers;
(13) The standards to be complied with regard to scaffolding, ladders and stairs, lifting appliances, ,ropes, chains and accessories, earth moving equipmentand floating operational equipment;
(14) The precautions to be taken with regard to pile driving, concrete work, work with hot asphalt, tar or other similar things, insulation work, demolition operations, excavation, underground construction and handling materials;
(15) The safety policy, that is to say, a policy relating to steps to be taken to ensure the safety and health of the building workers, the administrative arrangements therefor and the matters connected therewith, to be framed by the employers and contractors for theoperations to be carried on in a building or other construction work;
(16) The provision and maintenance of medical facilities for building workers;
(17) Any other matter concerning the safety and health of workers working in any of the operations being carried on in a building or other construction work.

In India, the state governments are empowered to inspect and enforce the provisions of this Act. The author's experience and the feedback obtained from various quarters suggest that due to large scale construction activities taken up in the country the inspection and enforcement machinery and mechanism is inadequate and should be strengthened.

3. METHODOLOGY

A.Literature review

To conduct the above research study effectively adequate, suitable and reliable data is collected from primary (first-hand information through field visits, observations, discussions with persons, e-mails, etc) and secondary (published reports / unpublished reference material / seminars / conferences proceedings / reference books /text books / journals / websites , etc) sources. More emphasis is given to primary sources as the research work is oriented towards human engineering aspects with a practical approach as the construction of a mega –project involving more than 85% of work force in the range illiterate – semiliterate – unskilled to semi-skilled. Eliciting / Collecting information from them is a challenging task. The information is collected through views, opinions, suggestions and comments from various sections of the population (target groups) like researchers, practitioners at regulatory bodies, industries (sites & headquarters), academicians, veterans, etc at national national and international levels, on the proposed research topic. The structured and un-structured methods like, an opinionnaire / questionnaire / interview, personal interactions, telephonic discussions, investigations, reviews and assessment are deployed to collect data from various geographical locations in India. The surveyis mainly focussed on safe working practices, management commitment, communication, interactions, interdependencies and inter-relationships between the complex human, organisational and technological (HOT) practices, etc in the safety culture in the construction industry. The survey is grossly encompassed on the core elements and factors evolved around the construction safety. About 1000 persons responded to the survey.

The survey revealed that there is no unique, dedicated and well defined statement on safety culture applicable for any industry. It is a specific term, which depends on applicability, suitability and adoptability of the industry. The Safety culture has been defined in a variety of ways, few such which are available in literature are:

- "The way we do things around here"
- A set of attitudes, beliefs, or norms
- A safety ethic

In general, for the purpose of simplicity , study and understanding the safety performance of the construction industry in the research work the term "safety culture" is stated as 'the attitude , behaviour and commitment of all levels of personnel deployed in the work place towards the safe work environment at all times'.

B. Development of Construction Safety Culture Management Model

The safety culture management system for the purpose of this study meansthe systematic, cumulative and integrated approach towards the performance of Occupational Safety and Health Management System in the construction industry. The Occupational Health and Safety Management Systems – Requirements (OHSAS 18001:2007) (http://www.aims.org.pk/wp-content/uploads/2014/08/OHSAS-18001-2007-Standards.pdf) is an Occupational Health and Safety Assessment Series (OHSAS) Standard which specifies requirements for an occupational health and safety (OH&S) management system, to enablean organization to control its OH&S risks and improve its OH&S performance.

The safety culture management system is built on the typical bedrock safety principlesin construction (Guide to Best Practice for Safer Construction, 2007), modified and adopted for suitability and applicability for construction industries in India;

Principle 1: Establish leadershipcommitment for safety at all levels
Principle 2: Prevent accidents by safe design of work environment.
Principle 3: Promote hazard communication and prompt management
Principle 4: Reinforce safe behaviour and preventive safety measures
Principle 5: Strive to improve safety culture

The safety culture during construction involves the following steps, such as Development of a safety culture road map, Establishing management leadership and Commitment, Developing organisational structural frame work, Promoting occupational health and safety (OHS) in design, Planning and construction stages, Consulting and promoting a participativecommunication system for Safety Information and Management at all levels, Periodic measurement of safety performance and Improving the safety culture., The safety culture management system enablesa construction organization which includes acompany, corporation, firm, enterprise, authority or institution, or part or combination thereof, whether incorporated or not, public or private, that has its own functions and administration, to develop and implement a policy and objectives which take into account legal requirements and information about OH&S risks. It is intended toapply to all types and sizes of organizations and to accommodate diverse geographical, cultural and social conditions.The success of the system depends oncommitment from all levels and functions of the organization, and especially from top managementincluding visitors, temporary workers and contractor personnel. A system of this kind enables an organization to developan OH&S policy, establish objectives and processes to achieve the policy commitments, take action as needed to improve its performancemetrics and demonstrate the conformity of the system to the requirements of this OHSAS Standard. The Construction Safety Culture Management System Model is based on the methodology known as Plan-Do-Check-Act (PDCA Cycle) represented in Fig 1, which is analogous and in line with OHSAS Standardrequirements.

The steps involved in the PDCA Cycle are briefly described below:

1. Plan: To establish the objectives and processes necessary to achieve the desired safety performance in accordance with the organization's OH&S policy.
2. Do: Implement the processes, procedures and programs of OHS.
3. Check: This is the vital step of assessment of performance of the organisation. This involves monitoring and measuring of processes against OH&S policy, objectives, legal and other requirements, and report the results to the management.

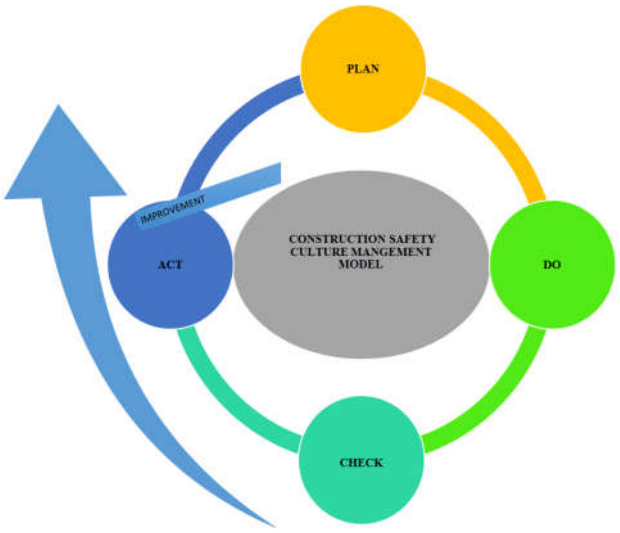

Fig.1. Construction Safety Culture Management Model (in the figure Improvement should come in the arrow)

In the checking step of process performance measurement and monitoring, the organization shall establish, implement and maintain procedure(s) to monitor and measure OH&S performance on a regularbasis.

This procedure(s) shall provide for:

a) both qualitative and quantitative measures, appropriate to the needs of the organization;
b) monitoring of the extent to which the organization's OH&S objectives are met;
c) monitoring the effectiveness of controls (for health as well as for safety);
d) proactive measures of performance that monitor conformancewith the OH&S programme(s), controls and operational criteria;
e) reactive measures of performancethat monitor ill health, incidents(including accidents, near-misses, etc.), and other historical evidence of deficient OH&S performance;
f) recording of data and resultsof monitoring and measurement sufficient to facilitate subsequent corrective action and preventive action analysis

4. **Act**: To taketimely actions to continually improve OH&S performance.

The present study is aimed at arriving at both qualitative and quantitative measures of OHS as Safety Culture metrics.

4. Studyand development of safety cultureindicators

A.General

This research study is focused on pragmatic guidance for persons / organisations who understand the fundamental principles of health and safety management in construction activitiesand have a strong desire, commitment, wish and will to improve the safety culture in their organisations by measuring the positive, pro-active and preventive efforts through indicators. The measurement of any parameter is significant for effective management. It is well known that "To control, manage and improve, the measurement (metrics) are vital". The management of safety relies on the systematic anticipation, monitoring and development of organisational performance (Reiman and Pietkainen, 2012).

B.Development of Safety Culture Indicators

The incidents / injuries / accidents should not be the absolute measure of safety performance. Historically and traditionally and even today in many instancesare considered as safety performance indicators and it is believed that accidents or incidents ratesare responsible for the bad safety culture. These are reactive, retrospective and lagindicators. They only indicate what went wrong in the past? The visualisation of any improvement in safety management system is the measurement of the existing / present performance with the past. In order to continually improve the safety performance, metrics play a critical role. The metrics can be Pro-active (P)or Lead Indicators and Reactive (R) or Lag Indicators. The Lead and Lag indicators are integrated in a pyramidal approach as represented in Fig.2

The parameters / elements for both lead and lag indicators are identified.

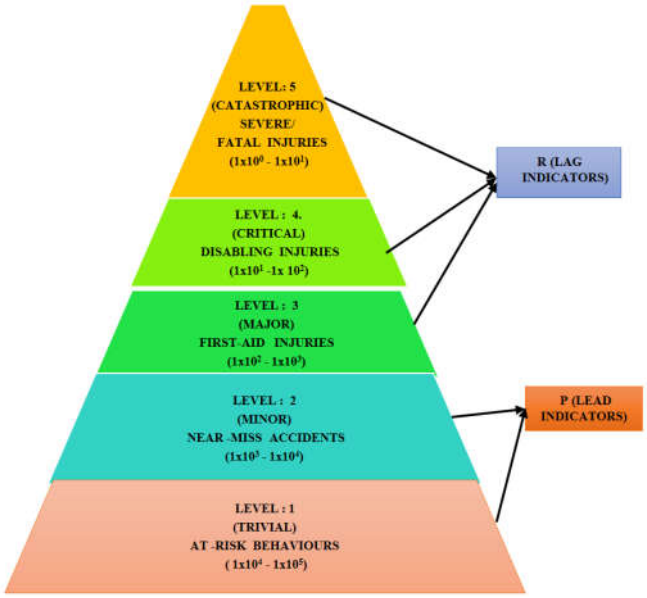

Fig. 2. Construction Safety Culture Pyramid

The Pyramidal approach (Process Safety Leading and Lagging Metrics, 2011) to safety culture metrics has 5 Levels. The Level: l &2 from base (bottom) indicates P (Lead indicators) and from Level 3 to 5 indicate R (Lag indicators). The numbers on brackets in the Fig.2 indicate the number of times (opportunities to check and correct the unsafe situations promptly) before a severe / fatal injury takes place. The probability of fatal injury (Level 5) to the at risk –behaviour (Level 1) (1 in 10, 000). It is to be noted that Ps are numerically large, if safety performance is based on Ps also then therewill be many venues to improve. The values assigned to each level are based on the information available from the literature and corroborated with the performancedata of about 43 organisations like construction projects, operating utilities, chemicalprocessing plants, engineering industry and research and development units for a period of about 16 years (2001-16). The available information and performance data on near misses and all injuries arecompared, studied, reviewed, analysed and interpolated /extrapolated to rationalize / harmonize the orders in 10s for presentation purpose. The Base of the pyramid indicates (Level 1- Trivial) many incidents / deviations in working practices, site conditions, management lapses, at-risk behaviours etc, wherein the defence layers can

tolerate / accept and prevent an incident/ injury. There numbers are in the order of $1x10^4$to$1x10^5$. This is the strong base to proactively control work environment and improve the construction safety culture management system. The next layer from bottom (Level 2 - Minor) indicates few random / isolated incidents which may not result in injuries (close calls), latent system failures , failure of equipment, symptoms of engineering / management failures, Near Misses, etc over a period of time. One level is breached but these are precursors which require attention of management and corrective actions should be initiated.There numbers are in the order of $1x\ 10^3$to $1x10^4$. They areone order higher than previous level.

As per the authors experience the transition time from Level 1 to 2 ranges from six to 12 months for manufacturing industry and for construction industry three to six months. The above two levels are termed as positive or pro-active or Lead Indicators. This indicators reveal the positive safety performance and an encouraging safety culture in construction industry. These are also called under current indicators which can rapidly manifest into severe injuries / fatal accident without any signs and symptoms. The sensible construction / project management team should take cognizance of it and initiate prompt safety measures. The third layer (Level 3 – Major) indicates failures of preventive measures and breach of protective layers which result in frequent occurrence of failures, more loss time injuries, repetitive acts and unsafe practices, continuing deficiencies, etc. These are challenges to the construction safety and the management should take such happenings seriously and initiate corrections and corrective actions immediately. There numbers are in the order of $1x\ 10^2$to $1x10^3$. They areone order higher than previous level. The probability of disabling injuries are high, so the management should put concerted efforts and enhance safety measures to prevent. As per the authors experience the transition time (latent failure to active failure) from Level 2 to 3 ranges from three to six months for manufacturing industry and for construction industry one to three months. The second apex level (Level 4- Critical) indicates failure of all protective and defence layers reflects in severe injuries / fatalities at regular intervals, in –breeding negligence, active system failures built –up over confidence at multiple levels, out-of-control contract management system, etc. This is an alarming stage, for construction activity /industry. This is the testimony of degraded / deteriorated safety culture. There numbers are in the order of $1x\ 10^1$ to $1x10^2$. They areone order higher than previous level. This indicates frequent reporting of disabling injuries and failure of safety measures. This requires strict enforcement actions.

As per the authors experience the transition (latent failure to active failure and progression of active failures) time from Level 3 to 4 ranges from three to six months for manufacturing industry and for construction industry one to three months. The above are based on the observations and review experience of the construction projects and operating plants in the span of 16 years by the author.The author also observed that the safety culture progression from Level – 1 to Level -4 is very rapid (one to two months) for construction projects. The jumping of levels may not be sequential or orderly. It can be abrupt as a new contractor may join the construction work and land into severe / disabling injury in a short time due to inadequacies in the safety management system. The apex level (Level 5- Catastrophic) indicates failure of all protective and defence layers reflects in severe injuries / fatalities at regular intervals, in –breeding negligence, built –up over confidence at multiple levels, out-of-control contract management system, etc. This is a total failure of safety culture in an organisation an alarming stage, for construction activity /industry the cycle (week to a month) is very short as compared to manufacturingindustry (one to three months). This is based on the observations and review experience of the construction projects and operating plants in the span of 15 years by the author. The author also observed that the progression from Level – 1 to Level -4 is very rapid (1-2 months) for construction projects.

The apex of the pyramid depicts the situation(s) where the preventive measures have failed and the incident / accident is at the threshold, whereas the base of the pyramid also mentions about few deviations / failures wherein the safety management system can continue to survive. There is no clear cut distinction between Lag and Lead indicators. The extent of overlapping cannot be estimated. The margin of barriers between Lead and Lagindicators is hairline, only fortune plays a pivotal role. The construction management should not rest/ bank on fortunes, they should believe in realities. The wisdom always prevails in preventing a severe / fatal injury.The researchers say that “Another inadequacy common to Lead and Lag indicators is that neither measure essential leadership attributes, communications and desired safe behaviours as necessary elements of safety culture and safety performance”.

The typical parameters of Lead indicator (**P**) which are positive, proactiveand injury / accident preventive efforts are required to be taken by the organisation :

- Safety improvement programs
- Efforts to reduce risks
- Management and supervisors visits to work places
- Near misses reporting culture
- Safety promotion programs
- Compliance to established and approved procedure
- Safety education and training to all levels
- Periodic meetings / interactions and agenda between inter plant / project authorities and with contractors.
- Pre-job meeting / tool box meetings and reviews involving supervisors and managers.
- Preventive checks / inspections of plant, machinery, equipment, tools, etc.
- Timely completion of safety tasks
- Mock up exercises, desk top practices, drills, etc.

The typical parameters of Lag indicator (**R**) which are negative, reactive, review and corrective actions which should be in place to prevent recurring injury / accident:

- Injuryfrequency rates
- Injury Severity rates
- Incident rates.
- Mean time between two accidents
- Longest accident period
- No of un safe behaviour/ acts observed / reported
- Inspection / Audit Findings and Metrics
- Accident reviews, status on corrective measures
- Lessons Learned from accidents in the same site.
- Adequacy of preventivemeasures, etc.

The above are typical parameters of Lead (P) and Lag(R) indicators. The Safety Culture Score or Index (S) for any

organisation is the sum of Lead indicator (P) and the Lag indicator (R). The Ps are positive indicators (+ value) and Rs are negative indicators (-value). In general, Ps are qualitative in nature and Rs are quantitative. The efforts have been put by the author to quantify the parameters within the indicators so that a score for the each of the indicators is available. Quantitative values are preferred because of their objectivity and ease of interpretation. An exercise has been carried out to evaluate the safety performance by a point system. A point system is based on 0-100 scale. The value assigned to Pis , average of the three elements which are factored for 100 points which has positive value (+) and for R the value assignedis average of two elementsfactored for 100 points this has negative value (-). The SafetyCulture Score / Index(S) is the sum of the above two (i.e P&R). The net value is positive, if thepreventive, positive and proactive measures exceed the reactive and negative measures or vice versa. This is a good quantitative measure of safety performance of an organisation for the purpose of assessing, ranking, rewarding, etc.

Mathematically, the Safety Culture Score / Index **(S)** is represented as,

$$S = P + R \text{------} \quad (1)$$

This implies that S can have values ranging from 0 to 100. Theoretically, when value of P is less than R (i.e P<R), a negative value of S is possible, where proactive measures are totally absent. This means that a negative value of safety culture is equivalent to the absence or no safety culture in the organisation, hence negative value of S is equal to zero.Thus the range of S can be expressed ($0 \leq S \leq 100$).

C.Computation of Safety Culture Score

An attempt is made by the authors to assimilate the information on performance of safety management system obtainedfrom 30 units which consists of Operations (11units), Production (10 units), Research &Development (7 units) and Construction (2projects/units) over a period of last two years (2015 & 2016) to arrive at a Safety Culture Score /Index. The above units are spread over different parts of India with a diverse technologies, geographically different sites, varied workforce &languages, diversified culture, conservative customs and traditions, etc. The study conducted is comprehensive and harmonized to an uniform scale.The information is based on 5 indicators of which 3 are Lead Ps (P1, P2 and P3) s) and 2 are Lag Rs (R1and R2). All five indicators are based on performance of Safety Management System (SMS). The Psare, Establishment of SMS (P1), Sustainability of SMS (P2) & Safety Knowledge Management (P3). The Rs are, Accident Management (R1) and Compliance Management (R2). The 100 points of each indicators are divided into various elements. The above indicators can be applied to all industries like operations, processing, servicing, research and development, construction, etc.

For example,

The Ps(+ve) are,

1. Establishment of SMS (P1)has 5 elements such as 1) identification and appointment of key personnel responsible for safety and health, 2) Reporting system, investigation and analysis of events, near misses, etc, 3) Work methods like Permit to work system, etc for all works, 4) Hazard identifications techniques available and employed and 5) SMS documentation. The 100 points are distributed equally with equal weightage (20%) between them.
2. Sustainability of SMS (P2) has 5 elements, they are 1) Fixing authority, accountability, responsibility for safety and empowering the key personnel, 2) Participative and co-operative efforts for safety through committees, work groups, etc, 3) Performance evaluation of SMS through monitoring and control of all activities at the organisation including commitment by managementat all levels, 4) Training and assessment of SMS and 5) Periodic safety exercises and drills. The 100 points are distributed equally with equal weightage (20%) between them.
3. Safety Knowledge Management (P3) has 2 elements which are 1) Safety promotional activities like competitions, contests, awards, prizes, etc for the best safety campaigns as well as Awareness programs on hazards and control, life style management, positive health aspects, etc. and 2) Learning from latest trends and developments in occupational safety and health technologies, accidents happening at other places, preventive actions for recurrence, etc. The 100 points are distributed equally with equal weightage (50%) between them.

The Ps value of a unit is an average of PI, P2 and P3. The computed value of Pfor each unit is shown in TABLE 2.

The Rs(-ve) are,

1. Accident Management (R1) has 2elements, they are 1) Reporting and recording of all accidents / injuries through an effective system and 2) Computation of accident rates (frequency rate which is number of injuries per million man hours worked, severity rate means number of man days lost per million man hours worked, incident rate number of people injured per thousand exposed to the hazard/ risk, etc. The 100 points are distributed equally with equal weightage (50%) between them.
2. Compliance Management (R2) has 3 elements, identified as 1) Non- Compliance and follow up for closure to SMS requirements, 2) Non- Compliance and follow up for closure to legal and regulatory recommendations/ requirements and 3) Offences, penalties regulatory / legal actions, public complaints, etc. The 100 points are distributed with the weightage of 40 %, 40% & 20% respectively.

The Rs value of a unit is an average of R1 and R2. The computed value of R for each unit is shown in Table 2

In the Table 2, O (Operating Unit means the organisation involved in operating various systems and producing electric power), P(Processing Unit means the organisation involved in production of chemicals, fabricated engineering products, etc using chemical, mechanical and metallurgical processes), R&D (Research & Development Unitmeans the organisation involved in carrying of research and developmental activities utilizing latest and advanced science and technologies) &C (Construction Unit means construction of a large scale heavy engineering infra-structure industries deploying intensive and extensive resources like work forces, finance, etc.)

Table 2. Typical safety culturescore / index for different industries

Unit	Lead Indicators Ps (+)			Av Lead Indicators (P1+P2+P3)/3	Lag Indicators Rs (-)		Av Lag Indicators (R1+R2)/2	Safety Culture Score / Index	Stage
	P1	P2	P3	(+)(P)	R1	R2	(-)(R)	S=(P)+(R)	
O - 1	96	92	94	94	12	18	15	79	S
O - 2	90	94	92	92	14	20	17	75	S
O - 3	79	75	80	78	20	16	18	60	M
O - 4	72	76	78	75	25	15	20	55	E/D
O-5	87	89	79	85	19	25	22	63	M
O -6	75	70	70	72	28	24	26	46	E
O - 7	63	68	64	65	30	26	28	43	E
O- 8	89	90	85	88	32	28	30	58	M
O- 9	84	86	79	83	26	22	24	61	M
O-10	91	93	92	92	25	21	23	69	M
O-11	86	87	89	87	22	20	21	66	M
P -1	78	75	78	77	26	22	24	53	D
P -2	79	80	78	79	23	17	20	59	M
P -3	77	80	75	77	28	22	25	52	D
P- 4	72	76	74	74	22	20	21	53	D
P- 5	73	78	74	75	29	23	26	49	D
P- 6	78	76	75	76	25	23	24	52	D
P- 7	85	82	83	83	30	26	28	55	E/D
P- 8	70	68	74	71	32	28	30	41	E
P- 9	72	70	65	69	26	20	23	45	E
P- 10	74	78	77	76	28	24	26	50	D
R&D -1	75	74	82	77	20	18	19	58	M
R&D -2	72	74	72	73	24	20	22	51	D
R&D -3	80	73	71	75	29	25	27	48	D
R&D -4	65	58	60	61	22	18	20	41	E
R&D -5	70	68	66	68	28	20	24	44	E
R&D -6	66	64	72	67	30	20	25	42	E
R&D -7	76	75	72	74	18	12	15	59	M
C-1	84	82	84	83	24	20	22	63	M
C-2	80	78	80	79	30	26	28	51	D

Table 3. Performance based safety culturestaging

Score(S) Criteria	Safety Culture Stage	Transition Stage and Period
<40	Incipient(I)	Needs immediate action to establish Safety Management System
40- 55	Evolving (E) / Developing(D)	Improvement (1 to 2 years)
56-70	Managing / Maintaining (M)	
71-89	Strengthening/ Sustaining(S)	Reinforcement (3-5 years or more). Generally not anticipated for Construction Industry
> 90	RObust (O)	

The typical Safety Culture Score / Index (**S**) is calculated and tabulated for all the 30 units as above. It is observed that the value of **S** ranges from 41 to 79. Based on the **S** value the stages of safety culture prevailing in a unit can be graded for the understanding of the safety performance**.** It is noted during the course of study that the above units are highly diversified in technologies, functions, management styles, etc. Effort is made to arrive at common, uniform and basic occupational health and safety requirements and the safety management system prevailing in the unit to measure the safety performance and the working culture. Based on the above stages are identified for each unit. The criteria for the stage is the present position and the scope for further improvement not for the purpose of rewarding or ranking the units.

D.Stages of Safety Culture Performance Assessment

The authors have surveyed and reviewed the open literature and information available on the stages of safety culture in various organisations including high reliability organisations like space, nuclear, aviation, hydrocarbon processing industries. In general, the stages varied from 3 to 5 in different organisations depending on the activities and functions. The authors observed from the global scenarios, that safety culture is a phenomenal process and takes considerable time i.e about more than 20 years to move from stage to stage i.e evolve, develop, manage, improve, maintain, strengthen and sustain. The industries at large are still in managing and improving stages and have long journey to travel. In case of construction industries due to their short project life cycle (normally 5 to 10 years for mega-projects from conception to completion), they cannot afford to have long gestation periods like manufacturing or production units to achieve sustainable safety culture. Construction industry should look for a rapid development in 3 stages like Evolving / Developing as Stage 1, Managing / Maintaining as Stage 2 and Strengthening / Sustaining as Stage 3. The initiation to transition from one stage to other shall not be more than 6 months. This is based on author's experience with project management and safety performance of 8 mega construction projects that have been completed in the last 15 years in India. The project should at least reach Stage 2 in less than a year so that the safety performance can be improved during the process of construction in the coming years. The principal contractor shall be held responsible under the contract management system to strictly comply with the requirement. In order to facilitate the development of robust safety culture at early phase of construction, during the evaluation and selection of contractors the availability of Safety Management System or Occupational Safety Health System shall be the primary criteria for awarding the work. This shall ensure safety conscious work environment throughout the construction stage of the project.

A trial effort is made to fit the appropriate stages for the typical 30 units whose safety culture assessment is done and data is presented above in Table 2. The Table 3 gives the score based criteria for arriving at the present stage. Interpreting the above Table 3, we can conclude that with the data available with authors the S value less than 40 is very rarely seen at the project early stages. This can a happen when sub-, sub – contractors resort to works in the site because of no safety culture as the construction progresses. The authors also observed that the fall of score can happen at any stage due to frequent incidents / events, recurring severe injuries, over-confidence, complacency, negligence, blaming culture and non-caring attitude of project management. These are the signs and symptoms of deteriorating or degrading safety culture of the organisation which should be detected and checked, corrections / corrective actions should be taken immediately. The authors inferred that maintaining a score in the range of 70-80 had been a challenge in the construction industry. The level of 60-70 should be maintained throughout the gestation period of the project, which is sign of good safety culture.

5. RESULTS AND DISCUSSION

Construction work has been increasing in developing and undeveloped countries over the past few years. With an increase in this type of work occupational fatalities have increased (OSHA Data & Statistics / Commonly Used Statistics, 2017). A recent study (Hinze *et al*., 2013) published in the US has found serious shortcomings in using traditional lag indicators for measuring safety. In contrast, Leading indicators can predict future levels of safety performance. The results of the study also indicate that the reactive Lag type indicators which are based on consequences of the accidents / injuries, lackinformation on preventive measures to improve the safety performance. Lead indicators are pro-active type of indicators or precursors which indicate efforts of the construction organisation in preventing the severe / fatal injuries by an effective and efficient management controls in place. The Lead indicators give the status on healthiness of the active and passive defence layers built in the organisation. The authors attempted to quantify the safety performance through the computation of the Safety Culture /Index (S) which the composite mix/ combination of Ps & Rs which is a good metric. The valueof S at any point of time is an indicator of the stage of safety culture prevailing in the organisation. Currently there are no standard national or international safety effectiveness indicators that are accepted by the construction industry. The challenge is that quantitative survey instruments developed for measuring safety culture and/ or safety climate are inherently flawed methodologically and do not produce reliable and representative data concerning attitudes to safety. Measures that combine quantitative and qualitative components are needed to provide a clear utility for safety effectiveness indicators. Construction sector looks for a definitive and determined indicators for the positive performance assessment of safety culture. The Ps and Rs of this study can also be effectively considered as essential factorsfor improving safety performance. The computation method can be used as a reliable and tangible way of measuring safety culture. This paper proposes that the accurate measurements / metrics of safety effectiveness and safety culture is a requirement for assessing safe behaviours, safety knowledge, effective communication and safety performance in a construction industry. A personal study by author on analysis of trends of around 30 units involved in manufacturing, construction and other allied activities over a period of 16 years (2001-2016) reveal that the hierarchy of contributors for severe / fatal injuries are fall from height, struck by/ against and electrocutionwhich account for more 95% injuries. The construction management should adopt a strong safety management system to establish a robust/ resilient safety culture. This is in agreement with the studies conducted by researchers worldwide in both the developed and developing countries at all parts of the globe. The effective performance of safety is determined by the safety culture Score / index (S) which is an indicative of safety culture.

The construction industry shall maintain a safe and healthy, humanework environment. Managers and supervisors should be held responsible for the establishment and maintenance of good health and safety practices. A systemic approach towards safety shall bepromoted and enforced through empowerment throughout the organisation. To bethe most effective organisation safety practices should be clearly communicated to all levels through signboards, meetings, training programs etc. Work descriptions and performance criteria should clearly indicate that healthy and safepractices are part of the employeesexpectations. Performance appraisals, at all levels should evaluate theemployees conformance to health and safety practices and recognize good health and safety practices. A step further, each employee should be made to understand from the outset of the project that failure to observe goodsafety practices may subject the employees to disciplinary action up to and including possible termination. A recordable, safe and successful story in construction history is completion of the London Olympic Park which was, completed in 4 years in 2012 with around 12,500 workers, clocking up 62 million hours of work with an Accident Frequency Rate of 0.17 per 100,000 hours and with zero fatalities. It's an example of what can be done, if we plan, train and remain vigilant (Source: Courtesy British Safety Council, Bechtel, Helen Binet and ODA(Olympic Delivery Authority) (http://www.theb1m.com/ video/health-and-safety-in-construction-a-visual-history).

Updated June 28, 2017. This is the embodiment and testimony of a robust safety culture in construction. This research work istargeted to improve the working conditions of those temporary work forces in all parts of the world who assemble in the process of building permanent industries / structures / institutions and earning their lively hood get injuries and succumb, due to their poverty, illiteracy, unawareness of hazards and combined with their own ignorance. These injuries could have been prevented had there been a positive safety culture with an effective hazard communication and commitment towards safety by the construction management. Of late, the concept of safety culture has been attracting the attention and is in the focus of the academicians, researchers, practitioners, industrialists, government, public, stakeholders, pressure-groups, etc, nationally and internationally

6. Conclusion

Construction has been accredited as a hazardous workwith high potentiality for severe and fatal injuries. Customarily, historically and traditionally the safety performance of any industry had been measured by Lag (R) metrics such as incident rate, frequency rate, severity rate, injury index, etceven with different namesglobally indicating only the past. Measuring Leadindicators is consistent with Injury Free work

place philosophy, because, unlike Lag indicators (injury rates), measuring metrics (Lead(P) Indicators) for safetyperformance are available beforehand so that injuries can be prevented. The safety culture Score / Index(S) is a good indicator of the safety culture prevailing in the industry. The author's experience and the studies by other researchers worldwide from time to time also unveil that the inattention, lack of care, management oversight, inadequate commitment, no work supervision, lack of awareness and training on hazards, underestimating the hazard, inadequacies in legislation process and control,etc are the contributors for the severe /fatal accidents in construction.

It is concluded that to develop a strong safety culture in the construction process, the organization must be well informed on hazards and continually learning. This involves on ways and means to analyse incidents to reveal all issues and wanting to learn from near misses before they become accidentsThe workforce must be encouraged to realize that all incidents are worth reporting. Reporting systems should be effective. The organisation should discourage blame- game, which is hard to do. A good checks and balance on compliance with procedures is essential. The organisation shall strive to improve its safety performance with changes as and when needed / demanded. We should remember that safety is a neveran ending journey and should pursue good safety practices relentlessly, whatever the situation or condition the future dictates.

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