CONSTRUCTION HEALTH AND SAFETY FROM A LEAN PRODUCTION APPROACH

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Abstract

In comparison with other types of industries, the construction industry is characterized as the one with the highest ratio of occupational injuries and accidents. A large percentage of the accidents that occur could have been eliminated, minimized or prevented if the decisions in the feasibility and design phases of the life cycle had been better studied and analyzed. The principles and methods introduced by the lean construction philosophy have increased the performance of the processes at the work site, but the need to guarantee the health and safety in the labor environment is still essential. The current problem is that safety and health is not implicit within the constructive processes. It should be considered as one and not managed separately as it is currently done by many companies. This paper aims to establish the relationship between lean construction and safety and health, conducting a description of the context, a review of existing theories, a bibliometric search, and an analysis of results.

***Keywords**: Accidents; Construction; Health and Safety; Lean; Occupational*

Resumen

En comparación con otros tipos de sectores, el de la construcción se caracteriza por ser el sector con la mayor proporción de lesiones y accidentes laborales. Un gran porcentaje de los accidentes que ocurren podrían eliminarse, minimizarse o evitarse si las decisiones en las fases de viabilidad y diseño del ciclo de vida se hubiesen estudiado y analizado mejor. Los principios y métodos utilizados por la filosofía de la construcción sin pérdidas han incrementado el rendimiento de los procesos de la obra, pero la necesidad de garantizar la seguridad y la salud en el ambiente de trabajo sigue siendo esencial. El principal problema es que la seguridad y la salud no está implícita en los procesos constructivos. Se debería considerar incluida en ellos y no manejarla por separado como lo hacen actualmente muchas empresas. Este artículo tiene por objeto establecer la relación entre la construcción sin pérdidas y la seguridad y salud, llevando a cabo una descripción del contexto, una revisión de las teorías existentes, una búsqueda bibliométrica de artículos relevantes, el análisis y la explotación de los resultados y, finalmente, su interpretación y propuesta de líneas de investigación.

***Palabras clave:** Accidentes; Construcción; Seguridad y Salud; Sin Pérdidas; Laboral*

1. Introduction

Construction work is featured by a series of factors that include high labor turnover, a constantly changing work environment and conditions on site, and different types of work being carried out simultaneously by several contractors (Pellicer, 2007). Construction sites create risks not only for the construction worker but also for general public that somehow interact through or near where the construction work is being carried out. Construction is considered relatively hazardous. In construction, there are more significant injuries and lost workdays due to these injuries or illnesses in construction than in virtually any other industry (Waehrer et al., 2007).

Construction owners are looking how to make the construction process continuous and improvement by minimizing any type of waste. Lean Construction advocate to reduce or minimize waste and an effort for continuous process, the incorporation of safety is needed for secure it (Alarcón and Pellicer, 2009). Construction need safety for secure the work site and workers, Lean will improve construction by making the process efficient, and increase the productivity of the company (Saurin, Formoso, & Cambraia, 2006).

Lean Construction is a production management-based approach to project delivery through a new way to design and build capital facilities; applied to construction, Lean changes the way work is done throughout the delivery process (Ballard and Howell, 2003). Lean Construction extends from the objectives of a lean production system – maximize value and minimize waste – to specific techniques and applies them in a new project delivery process (Alarcón and Pellicer, 2009).

Implementation of Lean Production concepts into construction seems to be a major in the endeavor to eliminate accidents (Saurin, Formoso, & Cambraia, 2006). Koskela (1993) identified strategies to improve construction safety through the use of Lean Production concepts:

- Designing, controlling and improving engineering and construction process to ensure predictable material and work flow on site.
- Improving safety management and planning processes themselves to systematically consider hazard and their countermeasures.
- Improving safety related behaviors – instituting procedures that aim at minimizing unsafe acts.

Lean Construction from a point of view on Safety Management Complexity of systems favors the following (Thomassen, 2002):

- From global to local control (from directions of systems to guidelines for single units).
- From task instruction and standard operating procedures (rule–following behavior) to boundaries for acceptable performance (coping behavior).
- From analytical deduction to recognition of patterns.
- From management of actions to management of the mechanism that generates actions.

This paper aims to establish the relationship between lean construction and safety and health, conducting a description of the context, a review of existing theories, a bibliometric search, and an analysis of results. The approach of the problem is not only to analyze the relationship between topics and verify if there is an important connection between them, but to recognize which elements make a difference if there really is a connection. The paper is structured in five sections: introduction, relationship between lean construction and safety, explanation of the method, concept map that shows the link among key concepts used in the

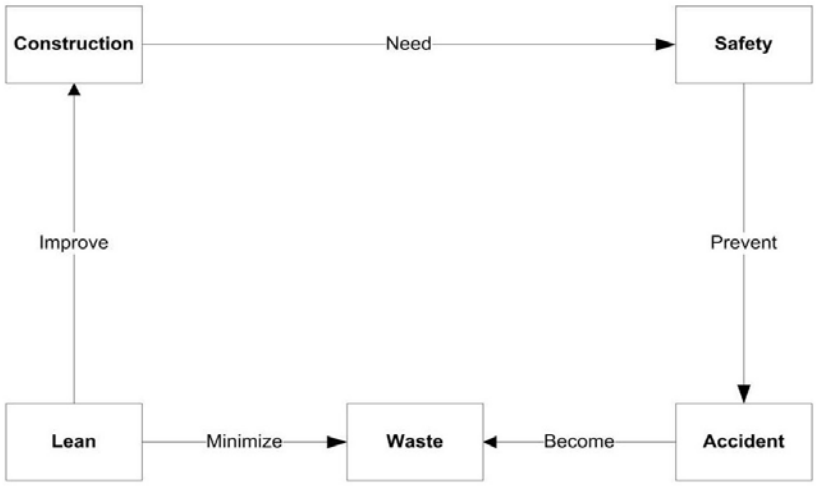
bibliometric analysis, an example of in-depth analysis of one specific part of the concept map, and conclusions.

2. Relationship between Lean Construction and Safety and Health

In general, five concepts are related regarding lean construction, on the one hand, and safety and health, on the other hand. The definition of each one is described to understand how they relate between them (Figure 1):

- Lean: Advocates minimizing waste and continuously improving.
- Safety and Health: The control of recognized hazards to attain an acceptable level of risk.
- Construction: Is the undocumented processes that take place as interplay between a complex and dynamic customer, and a complex and dynamic production system at a temporary production facility.
- Accident: An occurrence in a sequence of events that produces unintended injury, death, or property damage.
- Waste: Any inefficiency that results in the use of equipment, materials, labor or capital in larger quantities than those considered as necessary in the production of a building (Koskela, 1992).

Figure 1: Relationship between principal keywords



For understanding the flow chart, Lean Construction categorizes two kinds of waste (Bertelsen and Koskela, 2003): flow materials (overproduction, correction, material movement, processing, and inventory) and human action (waiting and motion). The first one is related to the worksite. The second one is related to human activities or performance of the workers. When a process is delayed or some elements are missing for performing an activity, the people in that area are waiting because they don't have the materials or equipment to perform their work; this time represents a type of waste. It is almost the same with motion; in this aspect people can get hurt for doing an inefficient performance or for not identifying or preventing a hazard, and this could cause an injury or an accident.

Why the injuries are waste? Because, as shown in Figure 2, they represent cost in human lives, regarding suffering as well as other costs such as compensation, lost time, low

productivity, higher employee turnover, and others. Figure 3 represents this waste in two ways: employee and company.

Figure 2: Relationship between Lean and Incidents

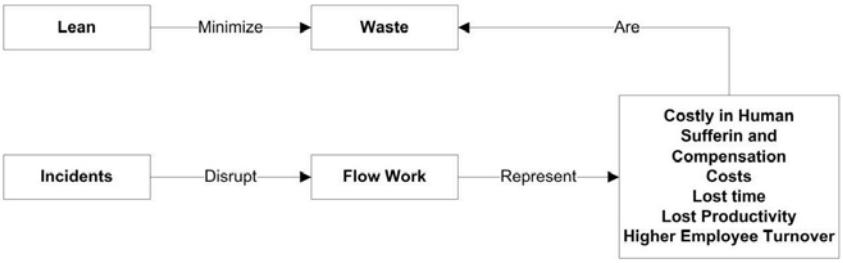
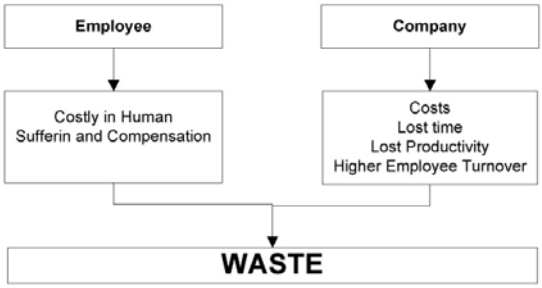


Figure 3: Waste Points of View



3. Method

This research is based on a bibliometric study that consists on a quantitative and qualitative analysis from the scientific data. In this context, the initial search covers books, papers, thesis, etc. The diversity of the information is shown in the nature of the documents and also in the resources used to obtain them: general database, specialized database, searchers, virtual information, libraries and others.

An exploratory search was planned to start the investigation and to get an approximation to the subject. Finding the keywords for the systematic search was essential in order to proceed. The keywords used were: Lean; Construction; Safety; Health; Culture; Risk; Accident; Prevention; Production; Last Planner; Continuous Improvement Programs. The databases used for the systematic search were: Web of Science and Engineering Village. Two additional journals, very specialized in Lean literature applied to construction, which were not in either of these databases, were also used: Proceedings of the International Group for Lean Construction (IGLC) and Lean Construction Journal (LCJ). The search was performed in English for papers published until the 31st of December of 2010.

The search was divided in two groups and the analysis was made according to the results obtained in each search. Level 1 begins with the search of documents in the databases of Web of Science and Engineering Village. Level 2 contains the journals LCJ and IGLC. For each level a search was made with these combined keywords.

A total of 95 papers were discovered in the search; however, 14 of them were duplicated, thus removed from the list. After reading and analyzing the remaining 81 papers, only 22

were useful for this study. There is no much information about the topic. Nevertheless, the following analysis will be focused on these 22 papers.

4. Concept map

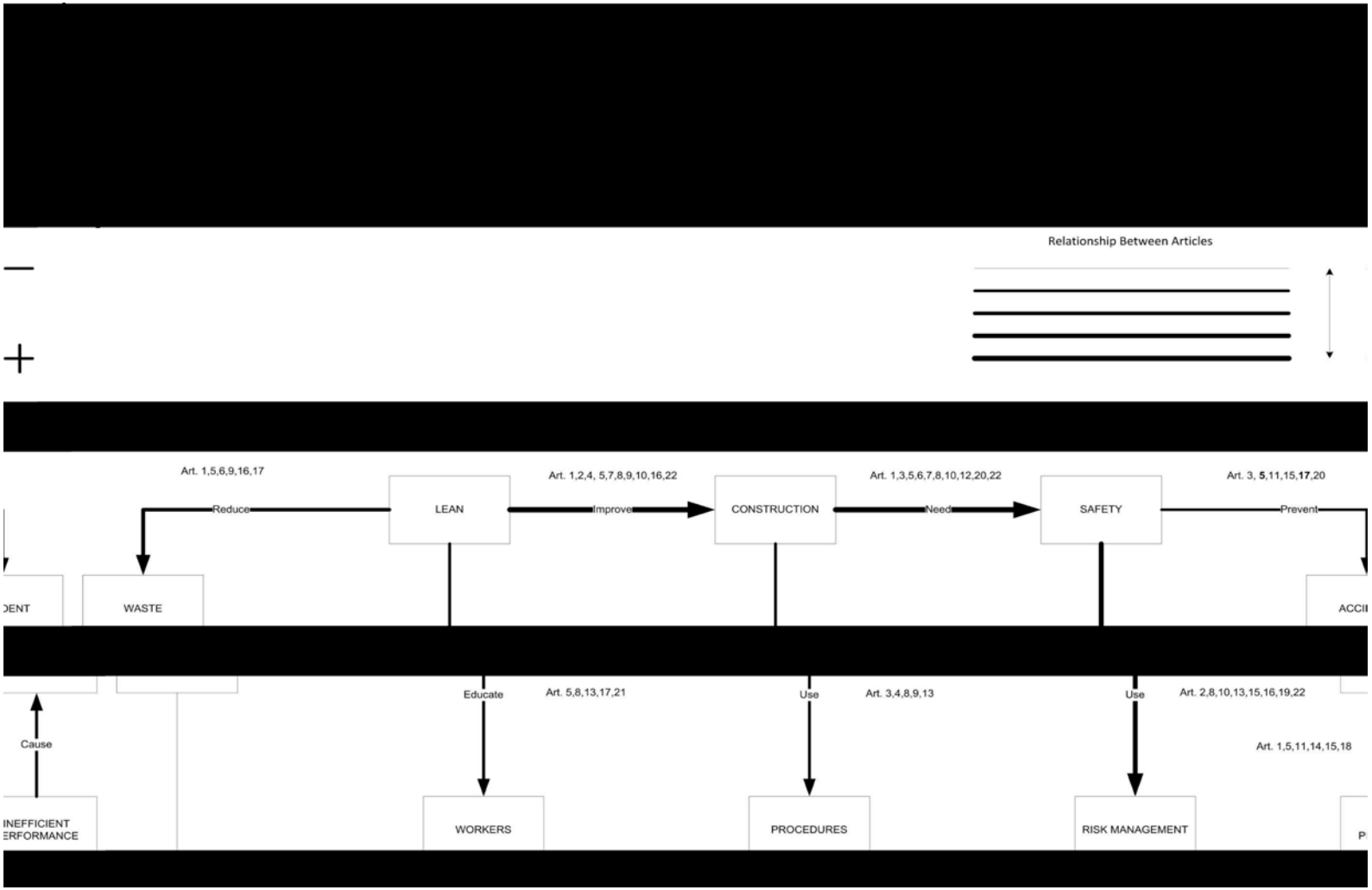
The relationship between concepts was based in the analysis of these 22 papers. It generated a concept map that shows the relationships among concepts. The concepts are shown in boxes and linked through labeled arrows in a downward-branching hierarchical structure. The relationship between concepts is articulated with linking verbs. The thickness of the linking lines represents how strong the relation is. The technique used to visualize these relationships is called Concept Mapping (Novak and Cañas, 2006).

After developing the relationship between concepts, an in-depth analysis was made of each of the relationships. First, the description of the relationships among the topics was explained, considering the papers that were supporting these links and referencing them accordingly. Later, the appreciation of the lean input is analyzed and commented, considering specially its contribution to the construction industry. Figure 4 shows the concept map whereas Table 1 includes the information needed in order to locate the referenced paper in the concept map. In Section 5 an example of the analysis is provided (Figure 5).

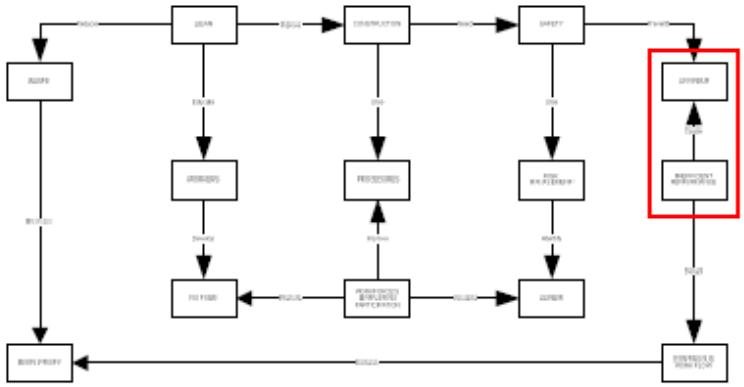
Table 1: Correspondence between the references listed in the concept map

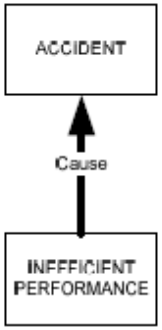
No.	References
1	Howell et al. (2000)
2	Young (1996)
3	Teo, Ling and Chong (2005)
4	Court et al. (2009)
5	Nahmens and Ikuma (2009)
6	Bae and Kim (2007)
7	Jang and Kim (2007)
8	Razuri, Alarcon and Diethelm (2007)
9	Chen, Reichard and Beliveau (2007)
10	Saurin et al. (2002)
11	Walsh and Sawhney (2004)
12	Schafer et al. (2008)
13	Saurin, Formoso and Guimaraes (2001)
14	Saurin, Formoso, and Cambraia (2006)
15	Saurin, Formoso, and Cambraia (2004)
16	Sacks, Rozenfeld and Rosenfeld (2005)
17	Narang and Abdelhamid (2006)
18	Mitropoulos, Cupido and Namboodiri (2007)
19	Mecca and Masera (2000)
20	Abdelhamid and Everett (2002)
21	Chinda (2009)
22	Davis (2009)

Figure 1: Concept Map



5. Detailed analysis of "The accident – Inefficient performance" relationship





DESCRIPTION	REF.	LEAN INPUT
The inefficient performance of workers is the main cause of accidents in the execution of an activity. The human behavior is the manner of acting a person evaluating the situation and making a decision to act. Decisions or acts made by workers are consequence of the experience that they have or receive. Human errors can happen because of inappropriate or undesirable human decision or behavior that reduces the performance of the activity by making unproductive actions.	5	Safety performance is ultimately dependent on the avoidance of unsafe acts by workers.
INPUT APPRECIATION		**PROPOSAL IMPROVEMENT**
Safety performance of workers will improve the process by making safer environments because the prevention of accidents will be present when the activities are performed. The inefficient performance of workers could lead to accidents or to create unsafe situations that might disrupt the work flow because the process will stop to take care of the problem or situation in the work site. Accidents represent costs in human lives, suffer and other costs such as compensation, waste of time, low productivity, higher employee turnover and others aspects that are considered waste in lean. The education for workers is one of the keys to prevent inefficient performance by let them know what they have to do and what are the possible hazards that can appear while they are working.		**The rotation of workers can develop accidents?** Inefficient performance can cause accidents; also the rotation of workers can compromise the performance of the process, because when new workers arrive they could have the experience but the line of work is different so it can compromise the workers' safety. In order to avoid this problem, specific teams could be subcontracted in certain activities to develop prevention measures. The rotation of workers is construction is very common and that's why it is so difficult to perform safely in the construction site because the new workers may not have education on safety and health.

6. Conclusions of the analysis of the concept map

1. LEAN improves CONSTRUCTION: Lean tries to reduce waste and achieve a continuous improvement system for increasing productivity. The contribution of Lean to construction is to control that the excess of material and waste are removed and the work site is clear for the next team to arrive with all the safety measures in place. Safety is no longer just a matter obeying rules but of taking charge of the safety and health of the workers.

2. CONSTRUCTION needs SAFETY: Construction needs safety to prevent accidents / incidents in the work zone. Workers need training to identify and manage risks. Safety can reduce or eliminate hazards but the workers need to be trained and motivated to participate in this process. Lean approach in safety are based in safety programs, continuous improvement programs, using visual methods, project planning and others tools in order to reduce the accident rate.

3. SAFETY prevents ACCIDENTS: Lean Construction is an effort to develop safety measures to be included in their system, with the use of some measures like planning for safety equipment, safety supervision, and identify critical activities that help prevention of hazards and safety of workers. These techniques are already in use in the construction industry; these aren't new forms of managing safety but Lean is trying to achieve an integrated system that could manage safety and production at the same time.

4. LEAN reduces WASTE: Processes must be controlled to detect operations or steps not needed because this can be disrupting the process instead of helping it. The importance of controlling process is crucial for the continuous work flow; the improvement of the activities will increase the efficiency and quality of the procedure becoming almost the best way to develop it. Workers perform a really important role in construction process; they are the principal elements in the production line to accomplish the product.

5. INEFFICIENT PERFORMANCE causes ACCIDENT: Workers inefficient performance could lead to accidents or create unsafe situations that might disrupt the work flow because the process will be stop to take care of the problem or situation in the work zone. Workers must be educated and trained to prevent the disruption of process by teaching them to performance adequately. The education for workers is one of the main keys to prevent inefficient performance by letting them know what they have to do and what are the possible hazards that can appear while working.

6. INEFFICIENT PERFORMANCE disrupts CONTINUOUS WORK FLOW: The unsafe acts must be controlled and eliminated to prevent disruption in the process, workers bad performance are the reason for inefficient work flow. Designing, controlling and improving the process promotes predictable material and work flow on site. The deviations from procedures need to be detected and bring the performance back to stable zone work to secure the process and prevent accidents.

7. CONTINUOUS WORK FLOW increases PRODUCTIVITY: To increase production, it seems evident to multiply the number of workers, but increasing the number of workers does not always result in increased productivity. Intensive training, education, and skills can help in increasing the productivity level of workers. A good safety measure can increase productivity but finding them is a hard thing to do; another safety measure is to educate workers that this is for improvement of their safety at work.

8. WASTE decreases PRODUCTIVITY: Any situation that requires a solution is becoming waste since the process stops either the material flow or human actions. The objective is to maximize the proportion of value added activities, while removing waste and reducing incidental activities that could disrupt the process. Moreover, human actions are more difficult

to control because the worker's performance can be done either efficiently or not. Workers must be trained and educated to prevent any situation that can lead to decrease productivity; experience and education are important to achieve this goal. To eliminate waste every process must be analyzed and assessed, checking its safety performance also.

9. LEAN educates WORKERS: Lean education improves the knowledge to the workers by making the necessary steps to perform each activity. This will improve the performance of the workers; however, safety concepts have to be taught to keep the workers safe of any situation that could cause an accident or an incident.

10. CONSTRUCTION uses PROCEDURES: To achieve a work flow in the construction process the inefficient supply of materials has to be indentified in order to prevent site operations from not flowing smoothly. Poor design information from the prime contractor has to be identified also in order to avoid a large amount of re-work. Taking care of the safety and health of the workers will make the process safety because they will focus on their work and they will be cautious of possible hazards that could affect the entire environment.

11. SAFETY uses RISK MANAGEMENT: The mission of risk management is to protect the workers, the environment, the property, the financial means, and other resources at the construction site. Risk management goals are to reduce risk through proactive and innovative control applying claims management practices, maintaining financial stability and keeping a safe, productive workforce.

12. WORKERS develop CULTURE: The key to develop a lean culture is not just applying a lean principle or tool. Workers need to focus, involve and be motivated when applying principles and practices to approach a culture. To achieve a Lean Culture, five principles must be applied: Specify value, identify the value stream for each product, make the product flow without interruptions, let the customer pull value form the producer, and pursue perfection. Adopting a culture is a long process and workers have to assimilate procedures and rules to perform better at the construction site.

13. RISK MANAGEMENT identifies HAZARD: There are three basic steps that should be taken into consideration: identifying the hazard, assessing the risk, and controlling the risk to ensure a safe condition. In order to identify hazards, there are some points to consider: identify hazards and the controls required for each activity, assist in formulating relevant and effective safe methods, guide new workers in the typical hazards, and check and identify all specific hazards in safety documentation.

14. WORFORCE'S MOTIVATION AND PARTICIPATION can identify HAZARDS: Workforce can improve the construction process by making work to be completed with the resources available for each activity: the expected workload must be determined; resources must be allocated; activities will make the amount of work expected to be completed within a specified amount of time; the training and motivation will make workers to participate in their activities and make them efficient and qualified in their specific activity.

15. WORFORCE'S MOTIVATION AND PARTICIPATION promotes CULTURE: The most profound culture change occurs when the organization's strategies become the job of the workers. Then the workforce is engaged in the discussions and solutions for growing an organization at the onset. The result is that workers take responsibility for the outcomes, take pride in its success, and see managers as resources of change.

16. WORFORCE'S MOTIVATION AND PARTICIPATION visualize HAZARDS: The efforts of the worker should be to develop a role for members of the workforce in the hazard identification process. It is recommended that the workforce be involved in: development of the hazard identification process; forming the team and workshop scheduling; relevant workshops; reviewing the workshop results; implementation of any actions arising from the process, and assisting in providing feedback of workshop outcomes.

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