Assessment of Safety Culture Maturity Level in Production Area of a Steel Manufacturer

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Abstract. Safety culture is widely known to have the ability to encapsulate all factors including perception, psychology, and attitude. This ability serves as an important role for organizations in occupational safety and health. Further, this ability is used as an effort to reduce the risk of accidents. One of the efforts made is to measure the level of maturity of the safety culture in the steel manufacturer production area by involving the variables of safety culture, namely commitment, leadership, responsibility, competence, engagement & involvement, information & communication, risk, and organizational learning. This study aims to measure the level of safety culture maturity in the activities production area of steel manufacturers. Data collection was carried out by distributing questionnaires with a purposive sample of 107 workers. Two expert judgments are involved as determinants of the safety culture variable weights using the AHP (Analytical Hierarchy Process) method. The results showed that the level of safety culture maturity in the production area of steel manufacturer was 3.64, which falls in the proactive category. The priority for improvement of safety culture variables starts from the leadership to the information & communication.

Keywords: Analytical hierarchy process, Occupational safety and health, Safety culture, Safety culture maturity level

1. Introduction

Steel manufacturing is an industry where safe working procedures are important, as workers face many risks due to the nature of the job [1]. One of the steel manufacturing in Indonesia is a steel manufacturer in the Sidoarjo district which is engaged in the steel smelting industry. Steel manufacturer is a steel smelting company that was founded in 1976. The raw material used in the production process is scrap which is then processed into steel billets and steel wire rods. The production process at the steel manufacturer consists of SMS (Steel Melting Shop) and RML (Rolling Mill). Every implementation of steel production activities at steel manufacturers, especially in each SMS and RML production area has the potential to cause danger resulting in work accidents.

Work accidents that occur in the manufacturing industry, especially in smelting furnaces can pose various undesirable risks. This is because the work environment in the manufacturing industry has a work environment that creates many risks such as the nature of the work, hot and noisy environmental conditions, as well as heavy routine work tasks and the risk of accidents both injury and burns [1]. Research conducted by Holmes explains that accidents are defined as any unplanned event that results in injury or ill health of people, or damage or loss to property, plant, materials or the environment or a
loss of a business opportunity [2]. Problems faced by this research, there are accident data that occurred in the steel manufacturer production area during the 2014 - 2018 period revealed that there was an increase in the number of work accidents in 2018 if we were compared to the previous 4 years with 10 case. Work accidents experienced by steel manufacturer workers in 2018 have severe a higher rate of severe work accidents than in previous years. Severe work accidents experienced by fractures in the ankles, middle and index fingers and stab wounds on the right foot caused by being exposed to the workpiece. According to [5] with the enhancement occurrence of work accidents, a work safety culture is needed as a safety that is felt, assessed, and prioritized in an organization.

An organization has a varied safety culture and must have a strong commitment [4] so that the safety culture can affect safety [1]. Just like Borwn say in [1], there have been several previous studies on safety in manufacturing that have focused on behavior, attitudes, climate, or culture with the results showing that culture can form the basis for unsafe attitudes and behavior. Safety culture can be widely known for its ability to encapsulate all factors including perception, psychology, attitude and managerial. This is what makes one an important component of organizational culture that discusses individual safety, safety performance, and several things that are prioritized by safety organizations [5], [6]. The development of the safety culture model concept has been carried out by several researchers including [7]. Safety culture in an organization is assessed by using three aspects of indicators namely personal aspects, behavioral aspects, and situation aspects, while [8] safety culture is assessed by the P2T model namely people, procedures, and technology models. [9] Argues that modeling in safety culture is multi-dimensional, there is no consensus regarding the dimensions used, depending on the safety culture model it uses. The research that was done uses nine components or dimensions, namely: leadership, communication, organizational goals and values, supportive environment, responsibility, learning, trust in people and systems, resilience, engagement.

As did previous research, while in the research that will be conducted by using eight variables of safety culture, namely; commitment, leadership, responsibility, competence, information and communication, and organizational learning. The variables used in the study are used as a tool to measure the maturity level of safety culture in steel manufacturer companies, especially in the company's production area. One measure that can be used is safety culture maturity level. Safety culture maturity is a model that assesses the level of understanding of safety culture at every level of the organization in the company. The assessment of safety culture maturity for this steel manufacturer is assessed using five levels namely; basic, reactive, planned, proactive and resilient [10]. This study aims to measure the level of safety culture maturity in the activities production area of a steel manufacturers to describe the stages of improvement of safety culture. Furthermore, the results of measuring safety culture maturity in the study serve as recommendations for improving the safety culture in the production area of the steel manufacturers.

2. Methods
This research involves eight safety culture variables consisting of commitment (C), leadership (L), responsibility (R), competence (CO), engagement & involvement (EI), information & communication (IC), risk (RI) variables and organizational learning (OL) as a model of safety culture research [11]. Safety culture modeling with these variables is used in the assessment of the maturity level of safety culture in the production area of the steel manufacturers. The level of maturity assessment was carried out in three stages, including:

1. Assessment of the average from eight safety culture variables based on the results of the development of a safety culture questionnaire with a scale of 1-5 which was distributed to 107 workers from 224 workers in the production area of the steel manufacturer. The number of samples obtained using a purposive sample by means of inclusion and exclusion criteria. The results of the development of safety culture questionnaire have a total of 80 questions in which 40 questions are from the variable commitment, leadership, information & communication, and organizational learning (each 10 questions variable), 9 questions from the responsibility variable,
7 questions from the engagement & involvement variable, and 24 questions from risk and competence variables (each variable is 12 questions).

2. Assessment of the weights of each safety culture variable by using the AHP (Analytical Hierarchy Process) method with Expert Choice V11 software tools. This assessment was completed by experts with the rating scale 1-9 listed in table 1.

| Scale | Definition                                      |
|-------|------------------------------------------------|
| 1     | Equally important                              |
| 3     | Variable A is slightly more important than variable B |
| 5     | Variable A is more important than variable B    |
| 7     | Variable A is more important than variable B    |
| 9     | Variable A is absolutely more important than variable B |
| 2,4,6,8 | Value between the two closest numbers          |

3. Then an assessment of safety culture maturity level is carried out in the production area from the product of the average value and weight of each variable safety culture. The assessment of safety culture maturity level is assessed using five levels namely; basic, reactive, planned, proactive and resilient.

3. Result and Discussion

3.1 The Average Assessment of Safety Culture Variables

Steel manufacturer is a company engaged in the steel smelting industry located in Sidoarjo district. Research conducted on 107 workers in the steel manufacturer production area, namely SMS and RML, obtained a value average on each safety culture variable based on a questionnaire that had been distributed. The safety culture variables used in this research are commitment (C), leadership (L), responsibility (R), competence (CO), engagement & involvement (EI), information & communication (IC), risk (RI) and organizational learning (OL). The average assessment of safety culture variables is the first assessment of safety culture maturity level. The results of the assessment are shown in table 2.

| No | Department | Variables of Safety Culture |
|----|------------|-----------------------------|
|    |            | C  | L  | R  | EI | RI | CO | IC | OL |
| 1  | Department 1 | 4,13 | 3,87 | 3,99 | 3,94 | 3,93 | 3,79 | 4,03 | 4,06 |
| 2  | Department 2 | 3,58 | 3,49 | 3,74 | 3,57 | 3,55 | 3,60 | 3,65 | 3,55 |
| 3  | Department 3 | 3,64 | 3,61 | 3,59 | 3,47 | 3,45 | 3,49 | 3,43 | 3,53 |
| 4  | Department 4 | 3,85 | 3,78 | 3,92 | 3,94 | 3,84 | 3,73 | 3,87 | 3,83 |
| 5  | Department 5 | 3,48 | 3,35 | 3,51 | 3,73 | 3,68 | 4,03 | 4,09 | 3,96 |
| 6  | Department 6 | 3,45 | 3,74 | 3,73 | 3,94 | 3,78 | 3,68 | 3,98 | 3,70 |
| 7  | Department 7 | 3,46 | 3,50 | 3,62 | 3,73 | 3,83 | 3,73 | 3,66 | 3,68 |
| 8  | Production Area Steel Manufacturer | 3,65 | 3,62 | 3,73 | 3,76 | 3,72 | 3,72 | 3,81 | 3,76 |

Based on table 2 regarding the average assessment of safety culture variables, the results were obtained that the smallest value obtained by the leadership variable was 3,35 in department 5. While for the largest value in the assessment of the average safety culture variable was obtained on the commitment variable which was 4,13 in department 1. So that the average grade results - The average
safety culture variable in all production areas obtained the smallest value in the leadership variable of 3.62 while the largest value in the information and communication variable was 3.81.

3.2. The Weighs Assessment Safety Culture Variables

The next assessment is to assess the safety culture variable weights using the AHP (Analytical Hierarchy Process) method with the use of expert choice v11 software. Analytical Hierarchy Process is a framework for a person in making complex problem decisions, giving an assessment based on knowledge, experience, and feelings using paired comparisons, and to obtain a set of priorities that are considered as a reasonable solution in solving problems. The assessment of the safety culture variable weights was conducted by 2 experts who were considered to have knowledge and experience in the field of occupational safety and health, especially in the area of production of PT. X. The weighting assessment of 2 experts can use the participant table by selecting the combined column in expert choice v11 software so that the results of weighting the safety culture variables are shown in Table 3.

| No | Variable                      | Expert 1 | Expert 2 | Combined |
|----|-------------------------------|----------|----------|----------|
| 1  | Commitment                    | 0.125    | 0.116    | 0.122    |
| 2  | Leadership                    | 0.137    | 0.129    | 0.144    |
| 3  | Responsibility                | 0.192    | 0.119    | 0.160    |
| 4  | Engagement & involvement      | 0.106    | 0.052    | 0.077    |
| 5  | Risk                          | 0.069    | 0.234    | 0.138    |
| 6  | Competence                    | 0.136    | 0.095    | 0.114    |
| 7  | Information & Communication   | 0.113    | 0.190    | 0.148    |
| 8  | Organizational Learning       | 0.121    | 0.066    | 0.097    |
|    | Total                         | 1        | 1        | 1        |

3.3. Assessment of Safety Culture Maturity Level

This assessment is needed to determine the level of safety culture owned by the steel manufacturer production area. There are five levels of safety culture level according to research Foster's namely; basic, reactive, planned, proactive and resilient. The safety culture maturity level assessment is formulated using equation 1 on each safety culture variable so that the results are shown in Table 4.

\[
\text{Safety Culture Maturity Level} = \text{Average} \times \text{Weight}
\]  

| No | Department     | C   | L   | R   | EI  | RI  | CO  | IC  | OL  |
|----|----------------|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | Department 1   | 0.50| 0.56| 0.64| 0.30| 0.54| 0.43| 0.60| 0.39|
| 2  | Department 2   | 0.44| 0.50| 0.60| 0.27| 0.49| 0.41| 0.54| 0.34|
| 3  | Department 3   | 0.44| 0.52| 0.57| 0.27| 0.48| 0.40| 0.51| 0.34|
| 4  | Department 4   | 0.47| 0.54| 0.63| 0.30| 0.53| 0.43| 0.57| 0.37|
| 5  | Department 5   | 0.42| 0.48| 0.56| 0.29| 0.51| 0.46| 0.61| 0.38|
| 6  | Department 6   | 0.42| 0.54| 0.60| 0.30| 0.52| 0.42| 0.59| 0.36|
| 7  | Department 7   | 0.42| 0.50| 0.58| 0.29| 0.53| 0.43| 0.54| 0.36|
| 8  | Production Area PT,X | 3.11| 3.64| 4.18| 2.02| 3.60| 2.98| 3.96| 2.54|
|    | Safety Culture Maturity Level | 3.25  |     |     |     |     |     |     |     |

Based on table 4, the safety culture maturity level assessment in the steel manufacturer production area is 3.25 where the value is included in the planned category. The results obtained from table 4 are a numerical data value using the AHP method so that the resulting value has an uncertain value,
meaning that the value is presented in order of scale and criteria so that it has more subjective properties. Evaluation with criteria that do not have certainty and subjective assessment requires a concept fuzzy. One of the concepts fuzzy that can be used TFN (Triangular Fuzzy Number). According to [12] the TFN (Triangular Fuzzy Number) method is a method special class of fuzzy numbers whose members are defined by three main numbers expressed as (l, m, r) with namely the lowest value, middle value, and highest value. The use of the TFN method is illustrated by the safety culture maturity level scale contained in table 5 and the results of the TFN for safety culture maturity level in the steel manufacturer production area are in table 6.

| Scale | Safety Culture Maturity | TFN₁ | TFN₂ | TFN₃ | Information |
|-------|-------------------------|------|------|------|-------------|
| 1     | basic                   | 1    | 2    | 1    | basic       |
| 2     | reactive                | 1    | 2    | 3    | reactive    |
| 3     | planned                 | 2    | 3    | 4    | planned     |
| 4     | proactive               | 3    | 4    | 5    | proactive   |
| 5     | resilient               | 4    | 5    | 5    | resilient   |

Table 5. Safety Culture Maturity Level with The TFN Method

| No   | Variable               | TFN₁ | TFN₂ | TFN₃ | Average |
|------|------------------------|------|------|------|---------|
| 1    | Commitment             | 2,676| 3,663| 4,554| 3,615   |
| 2    | Leadership             | 2,622| 3,608| 4,471| 3,547   |
| 3    | Responsibility         | 2774 | 3763 | 4557 | 3665   |
| 4    | Engagement and involvement | 2,756| 3,744| 4,590| 3,673   |
| 5    | Risk                   | 2,714| 3,699| 4,574| 3,644   |
| 6    | Competence             | 2709 | 3,699| 4,551| 3,630   |
| 7    | Information & Communication | 2,803| 3,793| 4,602| 3,702   |
| 8    | Organizational Learning | 2,728| 3,721| 4,580| 3,654   |

| Safety Culture Maturity Level | 2,723 | 3,711 | 4,560 | 3,641 |

Table 6. Assessment Results Safety Culture Maturity Level

Figure 1. Triangular Curve Membership Chart of Safety Culture Maturity Level
Based on table 6 the assessment of the level of safety culture variables at the safety culture maturity level of the steel manufacturer production is a variable leadership 3.547 and the highest value is owned by the information & communication variable with a value of 3.705. Termination of the proactive category owned by production area steel manufacturer by using a triangular curve membership chart. From this research, the safety culture maturity level rating of the steel manufacturer production area is 3.64 where the value is included in (or belongs to) the proactive category. For this value of 3.64 we can see from Fig 1 that the corresponding score obtained for proactive value is 0.64, and its corresponding score for planned value is 0.36.

Hudson explains that the proactive category at the level of safety culture maturity is that there is improved performance, something that is not expected to be considered a challenge [13]. The involvement of workers seems to have begun to take the initiative and doesn't carry out too orders from the leadership regarding safety factors. The concept of Hudson's safety culture maturity model proves to be a useful tool for the organization in assessing its safety culture. But the model proposed by Foster has a difference where the concept of the model created has a direct relationship to the standards of the company's own management with safety culture categories that have also been established. So in the proactive category proposed by [10], there is a target setting where senior managers are involved in determining safety and in overseeing managers are responsible for the results of safety activities that are made to meet and on target. In this case, the proactive categorization in the steel manufacturer production area is obtained through observations that the manager of the production area department and the manager of occupational safety and health are jointly responsible for the safety culture with proof that every month a supervision is held in the form of safety patrol, providing safety-related training and occupational health, there are standard operating procedures in every production activity, as well as integrated safety audits in accordance with research from Foster. However, the facts that occur in the plant there are still some workers sometimes still violate the rules of OSH which are caused by the lack of strict action from the manager of the production area department. This needs to be considered given that the improvement of safety culture still needs to be done in improving the safety culture in the production area of steel manufacturers to achieve resilient levels.

Recommendations for improvements given in the production area of steel manufacturers can be given as follows such as role models on leadership variables, conducting audits to maintain company commitment in safety culture, as well as on competency variables always checking all production equipment. To guarantee workers from work accidents, the recommendation on the risk variable is to provide a warning alarm that indicates a process failure or natural disaster. Furthermore, recommendations given to organizational learning variables regarding safety culture are discussions between the SHE Department and the production area department regarding safety, and as a form of responsibility for safety culture, safety patrols should be carried out. The involvement and participation of workers to improve safety culture in the production area of steel manufacturers is very important, therefore, a reward and punishment system is needed. In order for workers to understand the culture of workplace safety, the recommendation for information and communication variables is to conduct safety education directly to workers. For this research, the priorities for improving safety culture must also be applied more to the variable leadership because it has the lowest safety culture maturity value when compared to other variables. The flow of improvement in the safety culture in the steel manufacturer production area can be suggested starting from the variables of leadership, commitment, competence, risk, organizational learning, responsibility, engagement & involvement, and information & communication.

4. Conclusion
The level of safety culture maturity in the production area of steel manufacturer has a value of 3.64 where the value is included in the proactive category. The lowest level of safety culture variable assessment on the safety culture maturity level of steel manufacturer production area is the variable leadership 3.562 and the highest value is owned by the information & communication variable with a
value of 3,725. The priority of improving safety culture in the production area of steel manufacturer production is on the leadership variable because it has the lowest value in the assessment of safety culture maturity level. So that the flow of safety culture improvement to reach the generative category in the production area of steel manufacturer starts from leadership, commitment, competence, risk, organizational learning, responsibility, engagement & involvement, and information & communication.

5. References
[1] Nordlof, H., 2015. Safety Culture and Reasons for Risk Taking at A Large Steel Manufacturing Company Investigating The Worker Perspective. Safety Science, 73, pp. 126-135
[2] Tarik, B., and Adil, H.A., 2018. Occupational Health and Safety in The Moroccan Construction Sites: Preliminary Diagnosis. International Journal of Metrology and Quality Engineering, 9(6), pp. 1-9.
[3] Corrigan, S., Kay, A. and Ryan, M., 2018. Human Factors and Safety Culture: Challenges and Opportunities for the Port Environment. Safety science.
[4] Hopkins, A., 2006. Studying Organisational Cultures and Their Effects on Safety. Safety Science, 44(10), pp. 875-889.
[5] Choudhry, R.M., Fang, D. and Mohamed Sherif., 2007. The Nature of Safety Culture: A Survey of The State of The Art. Safety Science, 45(10), pp. 993-1012.
[6] Machfudiyanto, R. A., Latief, Y., Arifuddin, R. and Yogiswara, Y., 2017. Identification of Safety Culture Dimensions Based on The Implementation of OSH Management System in Construction Company. Procedia Engineering, 171, pp. 405-412.
[7] Cooper, M. D., 2000. Towards a Model of Safety Culture. Safety Science, 2(36), pp. 111-136.
[8] Reniers, G. L., Cremer, K. and Buytaert, J., 2011. Continuously and Simultaneously Optimizing an Organization’s Safety and Security Culture and Climate: The Improvement Diamond for Excellence Achievement and Leadership in Safety & Security (IDEAL S&S) Model. J. Cleaner Prod, 11(19), pp. 1239-1249.
[9] Lingard, H., Zhang, R., Harley, J. and Blismas, N., 2014. Health and Safety Culture, Construction Work Health and Safety Project, Centre for Construction Work Health and Safety Research. Melbourne: RMIT
[10] Foster , P, and Hoult, S., 2013. The Safety Journey: Using a Safety Maturity Model for Safety. Minerals, 3, pp. 59-72
[11] Hermawan, E., 2018. Structural Equation Modek Dimensions Of Safety Culture In Operational And Maintenance Services of Coal Fired Power Plant. Thesis Ph.D., Surabaya: Institut Teknologi Sepuluh November.
[12] Yang, H., 2008. The Evaluation For Cooperative Partner Selection Based on TFN-AHP. Fifth International Conference on Fuzzy Systems and Knowledge Discovery, pp. 203-207.
[13] Hudson, P., 2007. Implementing A Safety Culture In A Major Multi-National. Safety Science, 47, pp. 697-722.