# An Analysis of the Effect of the Implementation of an Integrated Management System (IMS) on Work Ergonomics in an O&M Power Plant Company

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**Abstract.** Ergonomics has developed significantly for the prevention of related accidents. Its implementation, however, depends on the existing management system within a company. The integrated management system (IMS) is frequently implemented in industry, which is an integration of ISO 9001, ISO 14001, and OHSAS 18001. The objectives of this research were to analyze the effects of IMS implementation on work ergonomics and to find the influencing factors. The methods used were the 4x4 method for investigating accidents; interviews; and a questionnaire for workers and managers at an electricity company. The subjects were divided into three levels, namely: top management, middle management, and workers. Logistic regression was used to analyze and estimate the effects of one or more management variables on ergonomics related accidents. The results showed that the implementation of IMS has supported work ergonomics very well based on the average scores, which ranged from 2.99 to 3.38. The logistic regression showed that the most influential IMS on work ergonomics was the Do (D) of Deming's PDCA cycle, whereas the most influential parameter for ergonomics accident prevention was Policy (P) and Do (D) at the top management level.

**Keywords:** *environment; ergonomics; management system; occupational health and safety; quality.*

## 1 Introduction

According to Nurmianto [1] ergonomics is a science that, when applied harmoniously within the work environment, will achieve high productivity and efficiency through the optimum use of human capabilities. Conventional ergonomics approaches focus on design development between human operators and machines. However, over time ergonomics has been brought into a broader field and it has grown into an important component of health and safety in relation to work incidents.

Data from the Bureau of Labor Statistics of the United States in 2011 show that accidents due to ergonomic factors caused by musculoskeletal disorders

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(MSDs) were 387,820 cases with an incidence rate of 38.5. They also reveal that in general, ergonomics related accidents amounted to 33% of the total non-fatality cases in the United States. This is quite surprising because ergonomics tend to be seen as trivial, but apparently contribute to as much as one-third of the total number of accidents. The lack of data and records of occupational accidents makes it difficult to get the number of ergonomic related accidents in Indonesia. Nevertheless, from the point of view of safety culture, which tends to ignore ergonomic factors, it can be expected that the number of such accidents will be quite high.

Wilson [2] found that organizational errors are often the root cause of operator errors and man/machine failures. In addition, the interface systems must match the operators' capabilities. Therefore, according to Nouri [3] there is a need for integrated design between health, safety, environment and ergonomics. The Domino theory suggests that occupational injuries are influenced by two main things: people and work environment. Ergonomics as a factor related to humans as well as machines has an important role in preventing accidents. But for preventive purposes, analysis of ergonomics should include not only man and machine, but also physical, cognitive and organizational ergonomics. The objective of this research is therefore to find the impacts of integrated quality management on ergonomics and to show a method of finding out what needs be continuously improved and how it should be done to reduce accidents due to ergonomics.

Ergonomics requires a management system that supports its implementation and continuance within a corporate organization. One management system widely used within organizations is the Integrated Management System (IMS), which is a combination of the three international management system standards: QMS of ISO 9001, EMS of ISO 14001, and OHSMS of OHSAS 18001. According to Haddad, *et al*. [4] IMS is, in principle, a combination of management systems in the form of procedures, personnel responsibilities, audit processes, and evaluation areas. Casadesús, *et al*. [5] found that companies with IMS of ISO 9001 and ISO 14001 show better performances than those without IMS. Based on the research by Griffith, *et al*. [6], the IMS framework has a positive influence on the environmental performance of an organization. However, to determine whether IMS is also able to provide a positive influence on the implementation of ergonomics in a company, it is necessary to conduct further research.

## 2 Methodology

### 2.1 Materials and Methods

This research was conducted at an electricity company, PT. X. This is the operator and maintenance services company of a coal-fired power plant in Indonesia. This company has been certified for integrated ISO 9001, ISO 14001 and OHSAS 18001, called Integrated Management System (IMS), for 3 years. The subjects were divided into three levels namely: top management, middle management, and workers. The number of respondents in each category was determined using a proportionate stratified random sampling. The total number of respondents was 159, consisting of 9 at the top management level, 30 at the middle management level, and 120 at the worker level.

Primary data were collected through field observation, interviews, and questionnaires. Field observation consisted of routine and daily inspection by using our five senses, also known as a walk-in survey. Interviews were conducted to obtain information directly from respondents in order to learn about the working conditions, the type of jobs performed, and complaints arising due to inconvenience of ergonomics in their work area. Interview questions were based on the Caution Zone Checklist from the Washington State Ergonomic Checklist [7]. The questionnaires in this research were developed from the IMS principles: (1) Policy, (2) Plan, (3) Do, (4) Check, and (5) Action. As for assessing the ergonomics aspect, the questions were developed according to the Ergonomic Checkpoint Checklist [8] from the International Ergonomic Association, Kodak Ergonomic Design for People at Work [9] and the Industrial Accident Prevention Association (IAPA) [10]. The acquired data were scored using the Likert Scale, as shown in Table 1.

**Table 1** Likert scale score.

| Type of Response | Score |
|---|---|
| Disagree | 1 |
| Slightly Agree | 2 |
| Agree | 3 |
| Strongly Agree | 4 |

To be able to measure the effect of work ergonomics on accidents, the likelihood of injury or accident, worker complaints about musculoskeletal disorders and physical stress were collected and assessed for the years 2007-2012.

The cause of accidents was found using the 4x4 accident investigation technique. This technique was developed to support safety professionals in the

USA, who decided to shift safety from engineering to management based on the domino theory, which proposes not to stop at unsafe acts and/or unsafe conditions but find the root cause of an accident, i.e. managerial faults.

Secondary data obtained were: (1) organization structure, (2) number of employees, (3) documentation and regulatory compliance to the IMS certification requirements, (4) environmental management, (5) work accidents, and (6) risk analysis and data in the form of Hazard Identification Risk Assessment Determine Control (HIRADC). The integrated IMS model can be seen in Figure 1.

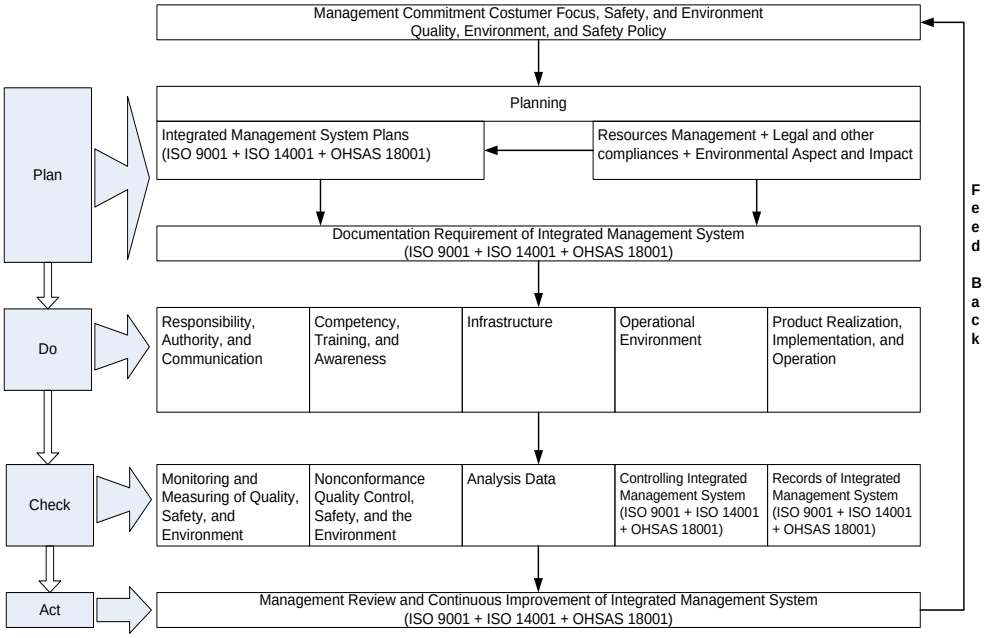


**Figure 1** PDCA model of Integrated Management System [11].

## 2.2 Data Analysis

The data obtained were analyzed using logistic regression, which is a mathematical model to analyze the relationship between independent factors, in this case, ergonomic related accidents as affected by IMS, expressed as Eq. (1) [12]:

$$\log \frac{p}{1-p} = \beta_o + \beta_1 \text{policy} + \beta_2 \text{ plan} + \beta_3 \text{ do} + \beta_4 \text{ check} + \beta_5 \text{ action} \quad (1)$$

$$Y = \alpha + \beta_1 \text{policy} + \beta_2 \text{ plan} + \beta_3 \text{ do} + \beta_4 \text{ check} + \beta_5 \text{ action} \quad (2)$$

The probability equation is [13]:

$$p = \frac{1}{1+e^{-(\alpha+\sum \beta_i X_i)}} \quad (3)$$

where:
p = probability,
Y = log (p/1-p),
$\beta_i$ = regression coefficient,
$\alpha$ = intercept value, and
$X_i$ = management variable values/scores.

## 3 Results and Discussion

### 3.1 Respondent Profiles

The questionnaires for the respective respondent profiles were pre-tested for their validity and reliability, and distributed in 6 departments, i.e. Finance & Administration, Human Resources, Environmental, Maintenance, Operation, and Engineering. Out of the 162 distributed questionnaires 158 (97.5%) were returned.

### 3.2 Assessment of IMS Implementation as Impacting on Work Ergonomics

The average values of the scores for the top management, middle management, and workers were all above 2, indicating that work ergonomics within IMS were supported quite well, as can be seen in Table 2.

**Table 2** Scores of impacts of IMS implementation on work ergonomics.

| Parameter | Top Management | Middle Management | Workers |
|---|---|---|---|
| Policy | 3.28 | 3.28 | 3.11 |
| Plan | 3.44 | 3.50 | 3.08 |
| Do | 3.33 | 3.20 | 2.96 |
| Check | 3.39 | 3.21 | 3.05 |
| Act | 3.44 | 3.14 | 2.75 |
| **Average** | **3.38** | **3.27** | **2.99** |

Table 2 shows that the highest score was obtained for the Plan variable at the middle management level, with a score of 3.50, indicating that this management level is the most influential on ergonomics execution. This value supports the fact that the IMS planning process mostly comes from middle management, while workers only contribute ideas. As for the top management level, the planning process mostly serves as managerial decision-making based on risk assessment.

The lowest value of IMS implementation towards work ergonomics was shown by the Action variable at the worker level, which was equal to 2.75, indicating that there is low worker participation in corrective action.

This interpretation is in line with the workers' assessment of the Do variable, scoring 2.96, the lowest value. Scores for both the Do variable and the Action variable at the worker level were the lowest, showing that IMS implementation of ergonomics at this level still needs to be improved.

## 3.3 Assessment of Ergonomics Complaints Based on Functional Organization

Assessment of ergonomics complaints was conducted based on the checklist of ergonomics complaints from the Industrial Accident Prevention Association (IAPA), which was divided into two categories, see Tables 3 and 4, and Figure 2.

**Table 3** Meanings and score values of ergonomic complaints.

| Value | Meaning |
|---|---|
| 1-3 | Ergonomic problem is found to be a significant complaint (there is an ergonomic-problem) |
| > 3-4 | Ergonomic problem is not found to be a significant complaint (there is no ergonomic-problem) |

**Table 4** Recapitulation of ergonomic complaint scores.

| Parameter | Top Management | Middle Management | Worker |
|---|---|---|---|
| Cognitive Ergonomics | 3.00 | 3.07 | 3.15 |
| Physical Ergonomics | 3.53 | 3.11 | 3.00 |
| Total Ergonomics | 3.42 | 3.10 | 3.01 |

The ergonomic assessment showed that for cognitive ergonomics the highest score value was at the worker level, namely 3.15, while the lowest score was at the top management level, indicating discomfort. This value is in line with the fact that although top management level has less physical workload, the magnitude of work responsibility results in a high stress level.

The highest average value for physical ergonomics was shown by the top management level, i.e. 3.53, while the lowest score was shown by the worker level at 3.00. Both values are consistent with the physical workload of each level, in which workers have the greatest load, so that workers have more physical-ergonomics complaints.

The average score of total ergonomics complaints showed that the highest value was 3.42 at the top management level and the lowest was 3.01 at the worker

level. These average values indicate that the worker level has more ergonomic problems and complaints than the top and middle management levels. Hence, many ergonomic problems need to be overcome within the company.

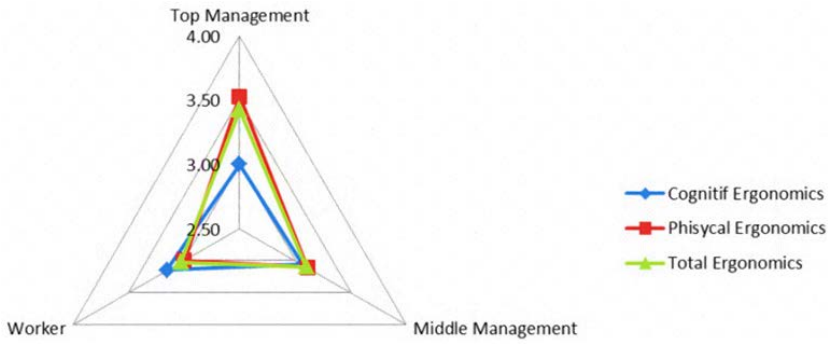


**Figure 2** Ergonomics complaints based on stratification of functional organization.

The logistic regression analysis (see Table 5) did not show any variable significantly affecting ergonomics ($p \geq 0.05$). The most influential seemed to be the Do variable at the worker level, hence the most important role due to their most forefront jobs. The least affected was the Checks parameter at the middle management level, which does not involve ergonomics and thus there is no need to revise procedures.

**Table 5** Logistic regression analysis of IMS implementation towards ergonomics.

| No. | Parameter | Top Management | | | Middle Management | | | Workers | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Sig | Exp(B) | B | Sig | Exp(B) | B | Sig | Exp(B) |
| 1 | Policy | 0.8141 | 0.2207 | 0.5230 | 0.2550 | 0.8480 | 1.2900 | 0.0830 | 0.8430 | 1.0860 |
| 2 | Plan | 0.7454 | 0.6172 | 0.5545 | 0.3060 | 0.7140 | 1.3580 | -0.4660 | 0.4610 | 0.6270 |
| 3 | Do | -0.7972 | 0.3581 | 1.6630 | -1.7660 | 0.4520 | 0.1710 | -2.3540 | 0.0310 | 0.0950 |
| 4 | Check | -0.3446 | 0.3643 | 1.2683 | 0.9780 | 0.4720 | 2.6590 | -1.1040 | 0.1030 | 0.3320 |
| 5 | Action | 0.1281 | 0.7648 | 0.9098 | 0.8570 | 0.5320 | 2.3560 | -0.1960 | 0.6940 | 0.8220 |

## 3.4 Assessment Analysis of Accidents due to Ergonomics Factors

To be able to relate accident causes to ergonomics, values 0 and 1 were assigned on the following conditions, see Table 6:

**Table 6** Meaning of value score in accident analysis.

| Value | Meaning |
|---|---|
| ***PDCA score as the cause of accident*** | |
| 0 | There is unconformity |
| 1 | There is no unconformity |
| ***Ergonomic accident score*** | |
| 0 | Not an accident due to ergonomic factors |
| 1 | Accident caused by ergonomic factor |

Under these terms, the PDCA scores were determined by the average value. If this is closer to 0, the parameter is increasingly important as a cause of the accident, while the reverse is true if it is closer to 1, as shown in Table 7 and Figure 3.

**Table 7** Recapitulation of ergonomics accident score.

| Parameter | Top Management | Middle Management | Workers |
|---|---|---|---|
| Policy | 0.47 | 0.63 | 0.80 |
| Plan | 0.48 | 0.52 | 0.96 |
| Do | 0.53 | 0.37 | 0.47 |
| Check | 0.50 | 0.51 | 0.65 |
| Action | 0.80 | 0.93 | 0.80 |
| Average | 0.55 | 0.59 | 0.73 |

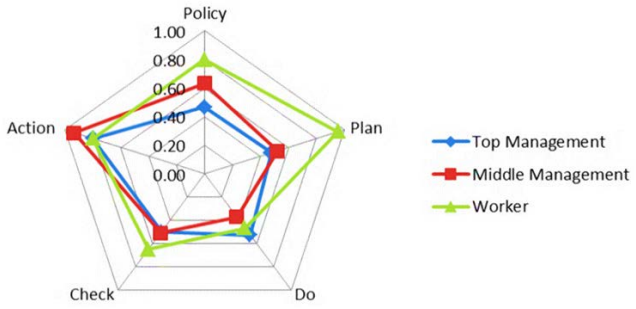


**Figure 3** Ergonomics accident root cause based on functional level. The lower the average value, the higher the probability of the cause, and vise versa.

The average scores for the 30 accident cases showed that the highest average value as the cause of an accident was for the Do variable at the middle management level, equal to 0.37, while the lowest was 0.96 at the worker level for the Plan variable. However, observations found that workers are not directly involved in planning, therefore this only indicates that workers understand the importance of planning and running the appropriate work that has been planned by their employer. Hence, the most influential variable for prevention of accidents would be the second highest average value, held by the Action

variable at the middle management level, which was equal to 0.93. By looking into the highest and lowest averages at the middle management level, it can be concluded that its functional level has a more dominant role than the other levels in the causation and/or prevention of occupational accidents at PT. X

Logistic regression analysis showed that there was no variable that significantly affected ergonomic accidents ($p \geq 0.05$), see Table 8. The most important role in ergonomic accident prevention is for middle management, but according to Kouabenan [14] middle management often shows little concern for accident prevention, focusing more on meeting production objectives. The parameter that had no effect in reducing accidents was policy at the top management level. Arifin [13], who studied decision-making processes, claims that decisions depend largely on top management commitment, while the proper implementation of policy is more important for accident prevention at the other functional organization levels.

**Table 8** Logistic regression analysis of ergonomics accidents.

| No. | Parameter | Top Management | | | Middle Management | | | Workers | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Sig | Exp(B) | B | Sig | Exp(B) | B | Sig | Exp(B) |
| 1 | Policy | -202.9200 | 0.9940 | 0.0000 | -2.0760 | 0.1060 | 0.12500 | -3.5570 | 0.2150 | 0.0290 |
| 2 | Plan | 24.2560 | 0.9970 | 3.42E+10 | 0.8440 | 0.6120 | 2.32400 | -9.7470 | 0.3990 | 0.0000 |
| 3 | Do | -134.1790 | 0.9950 | 0.0000 | -1.4090 | 0.4580 | 0.24400 | -0.6410 | 0.8190 | 0.5270 |
| 4 | Check | 202.1760 | 0.9950 | 6.37E+87 | 0.6110 | 0.7710 | 1.84300 | 6.2830 | 0.2350 | 535.3080 |
| 5 | Action | 110.3250 | 0.9950 | 8.19E+47 | -19.3130 | 0.9990 | 0.00000 | 3.4270 | 0.0510 | 30.7760 |

## 4 Conclusions and Recommendations

Based on the results of this study, it can be concluded that the implementation of the IMS has supported work ergonomics very well. This was proved by the average scores $\geq 2$, ranging from 2.99 to 3.38. Logistic regression analysis showed that the most influential parameter in the application of ergonomics is the implementation (Do) parameter at the worker level, while the most important role in the prevention of ergonomics accidents is for middle management.

It can be recommended that companies should periodically assess their performances to be able to continuously improve their performances. The results of the logistic regression analysis and other methods used in this study could be improved if data on accidents within companies was saved for a longer period, such that the significancy of the analysis could be obtained.

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