*Journal of Energy and Safety Technology*

JEST

RESEARCH ARTICLE Open Access

# The Survey And Perspective Of Human Factors Associated With Maintenance Activity

Dari Alharran[1], Vitushana Nagalingam[1], Norafneeza Norazahar [1,2]*, Arshad Ahmad[2], Norhisham Bakhary[3,4], Nur Hazirah Noh@Seth[5]

[1]Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malaysia
[2]Centre of Hydrogen Energy, Institute of Future Energy, Universiti Teknologi Malaysia, 81310 Johor, Malaysia
[3]Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Johor, Malaysia
[4]Institute of Noise and Vibration, Universiti Teknologi Malaysia, City Campus, Jalan Semarak, 54100 Kuala Lumpur, Malaysia
[5]School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia, 81310 Johor, Malaysia

*Corresponding author: norafneeza@utm.my*

**Article History**

Received: October 29, 2021 Received in revised form: July 18, 2022 Accepted: July 24, 2022 Published Online: December 1, 2022

**Abstract**

Maintenance is to keep equipment in good condition for performance during the operation process; ineffective maintenance may have a negative effect on the machinery's or plant's performance. Inadequate maintenance can shorten the life of equipment and plant and, consequently, have a potentially high risk of incidents or accidents. The complexity of maintenance tasks, poorly written maintenance procedures, fatigue among workers, lack of training and refresher training, or inadequate safety barriers are examples of ineffective maintenance programs. This paper presents a survey on human factors associated with maintenance activities in oil and gas plants in the United Arab Emirates (UAE). The questionnaire comprises four performance-shaping factors (PSFs): experience and training, procedures, time and stress, and work process. Ninety-three respondents from the maintenance companies of the oil and gas industry participated in the survey. The responses show that both experience and training could improve the workers' skills and the success of the maintenance tasks. The results also indicate that training and education of maintenance workers are imperative and that experienced workers can handle abnormal situations. The responses suggest that both experience and training could improve the workers' skills and the success of the maintenance tasks. The maintenance activities are now adapting to Industry 4.0; however, human factors may still be present. Thus, it is appropriate for future research work to include the effectiveness of Industry 4.0 in maintenance activities while considering the presence of human factors.

***Keywords:*** *Human Factor; Maintenance; Human Error; Performance Shaping Factors; Risk-based Inspection.*



## 1.0 INTRODUCTION

Major accidents in process industries are often caused or linked to human errors and human factors. Apart from studying the human factors, maintenance activities can be studied to link the relevant and possible human factors with these maintenance activities. Maintenance is considered a crucial activity within a facility. The main objectives of maintenance activities are to ensure the smooth operation of an industrial system and preserve the equipment in a satisfactory condition for the performance of the intended functions.

Maintenance activities will be carried out by the maintenance personnel hired by the organization; if the maintenance personnel is affected by any human factors, the maintenance activities will also be affected. Any mishap in the maintenance procedures will bring negative implications upon many of the other workers, even though they do not have any relevance to the maintenance team. This is how maintenance issues arise in a plant. For instance, if the organization fails to provide proper tools for maintenance activities, the personnel will not be able to carry out the task safely and properly. They will have to use the

readily available tools provided and proceed. This is very unsafe as the maintenance job cannot be done correctly. Hence, the organization, which is part of the human factors, affects the maintenance activities of the plant indirectly.

Maintenance activities often require tasks, such as replacement, testing, inspection, cleaning, and adjustment, to keep the equipment in good condition for performance during the operation process and to comply with regulations. Any organization or company should apply for an efficient maintenance program by maintaining the equipment before its failure, thus, avoiding the cost of failures and possible revenue loss. Generally, applying an effective maintenance program can increase the equipment's lifetime and, subsequently, reduce the overall repair cost. Therefore, maintenance activities play a vital role in minimizing the risk associated with several work activities and ensuring the continuity of the operation process [1],[2].

Several standards, such as API-510, API-653, API-570, and API-580, have been published by the American Petroleum Institute (API). API organizes inspection intervals based on equipment life, consequences of failure, degradation rate, and environmental impact. The latest methodology is risk-based inspection built on API-580 and API-581. The main assumption of this methodology is that risk continues to be acceptable between two planned maintenance or inspection intervals. However, this condition may not hold true in a complex, fast-changing, or degrading engineering system [3].

The consequence of ineffective maintenance can shorten the lifespan of equipment or plant, cause injuries to workers liable to perform maintenance tasks, and lead to accidents or incidents. Accidents during maintenance could occur due to mechanical failures, the complexity of maintenance tasks, poorly written maintenance procedures, fatigue among workers, lack of experience and refresher training, inadequate safety systems and barriers, and poor safety culture in the companies or organizations. Quite often, many organizational factors were identified or addressed as latent errors leading to the failure of maintenance activity. Organizational factors may include inadequate time to perform the required tasks, incomplete work processes because 'work-in-done' and 'work-as-imagine' are different, safety standards not understood, bad equipment design and insufficient financial resources to provide training to maintenance workers [4],[5],[6],[7],[8].

Human factors associated with maintenance activities contribute to major accidents. These human factors are miscommunication, wrong application of devices, and unsafe working habits. Job factors, such as working double shifts, workers having more work than they could handle, unclear relationships in reporting and conflict in work planning, and inadequate work standards are also the immediate causes of the accidents. In short, failure during maintenance may occur primarily due to human factors, organizational factors, and a lack of methods to establish a safe maintenance process.

This paper presents a survey on human factors' effects on maintenance workers. The survey work is described in Section 2.0, while the analysis of responses is discussed in Section 3.0. The research work and survey were conducted in early 2020, towards the end of 2020, and the researchers have limitations and outreach.

## 2.0 SURVEY WORK

### 2.1 Designing questionnaires

Performance shaping factors (PSFs) are used as a basis for designing questionnaires concerning the maintenance activity in the oil and gas industry. Eight performance shaping factors are time, stress and stressors, the complexity of tasks, workers' experience and training, procedures, ergonomics and human-machine interaction (HMI), fitness for duty, and work process [9]. The structure of the questionnaire is designed as in Table 1. It consists of three main sections—A, B, and C. The body of the questionnaire is in Section B, with sub-sections comprising questions related to PSFs.

**Table 1: Structure of the survey questions related to maintenance activity**

| Sections | Sub-sections | Items | Format for feedbacks |
|---|---|---|---|
| A | | Background of respondents | Categorical |
| B | 1 | Work experience and training | Likert scale:<br>1 – Strongly disagree,<br>2 – Disagree,<br>3 – Neither disagree nor agree,<br>4 – Agree, and<br>5 – Strongly agree |
| | 2 | Procedures for maintenance | |
| | 3 | Time for maintenance work | |
| | 4 | Work process | |
| C | | Comments or suggestions | Open-ended answers |

### 2.2 Distributing questionnaire

All questionnaires were prepared in a Google Form (https://forms.gle/BLGSdoMBycoCzziZ8). The link to Google Form was shared with and emailed to two companies (Companies A and B) located in the United Arab Emirates (UAE), where the co-author resides. The nature of the business of both companies is maintenance works in the oil and gas industry. The employees or maintenance workers were given a month to respond to the questions in the Google Form. The research and questionnaire distribution were conducted during the global pandemic of COVID-19 in June 2020.

### 2.3 Analyzing responses

The maintenance workers' responses from companies A and B were collected through Google Forms in MS Excel. The responses were then imported into and analyzed using the Statistical Package for the Social Sciences (SPSS) software version 26. All the Likert-type questions were considered ordinal data.

## 3.0 RESULTS AND DISCUSSION

Ninety-three maintenance workers participated in the survey by answering the questionnaire in Google Forms. Eighty-seven respondents were male, and six respondents were female. The analysis of responses is described in Sections 3.1 to 3.5.

### 3.1 Respondents' backgrounds

Figure 1 shows that fifty-nine respondents were between 31 to 40 years old, twenty-one were between 20 to 30 years old, and thirteen were above 40 years old. Next, Figure 2 presents a chart of respondents' highest education level. Many respondents (57%) have a bachelor's degree as their highest education level. Only nine respondents (10%) completed high school but had no tertiary education. The respondents' years of work experience varied from each other, as illustrated in Figure 3. Twenty-nine respondents (31%) have one to five years of work experience in maintenance, followed by twenty-two respondents (24%) with six to ten years, and nineteen respondents (20%) have 11 to 15 years. The participation of maintenance workers in the survey also included eight respondents with less than one year of work experience.

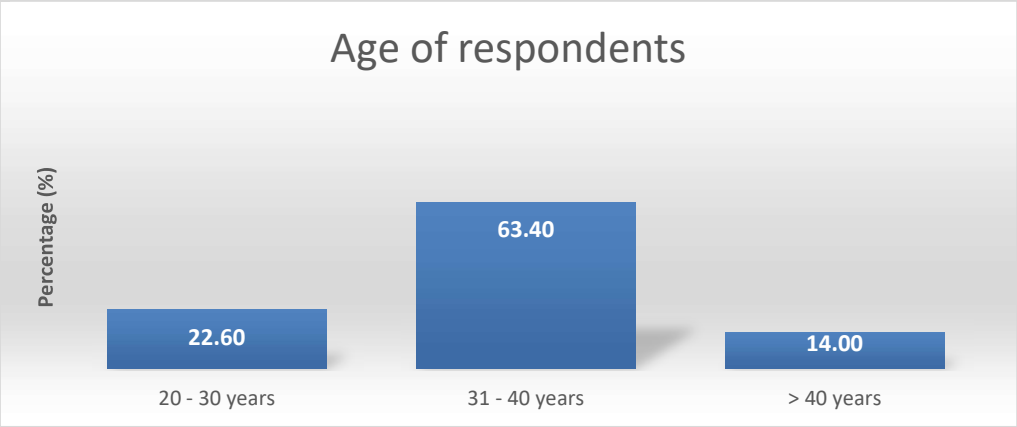


**Figure 1**: Respondents' age based on categories.

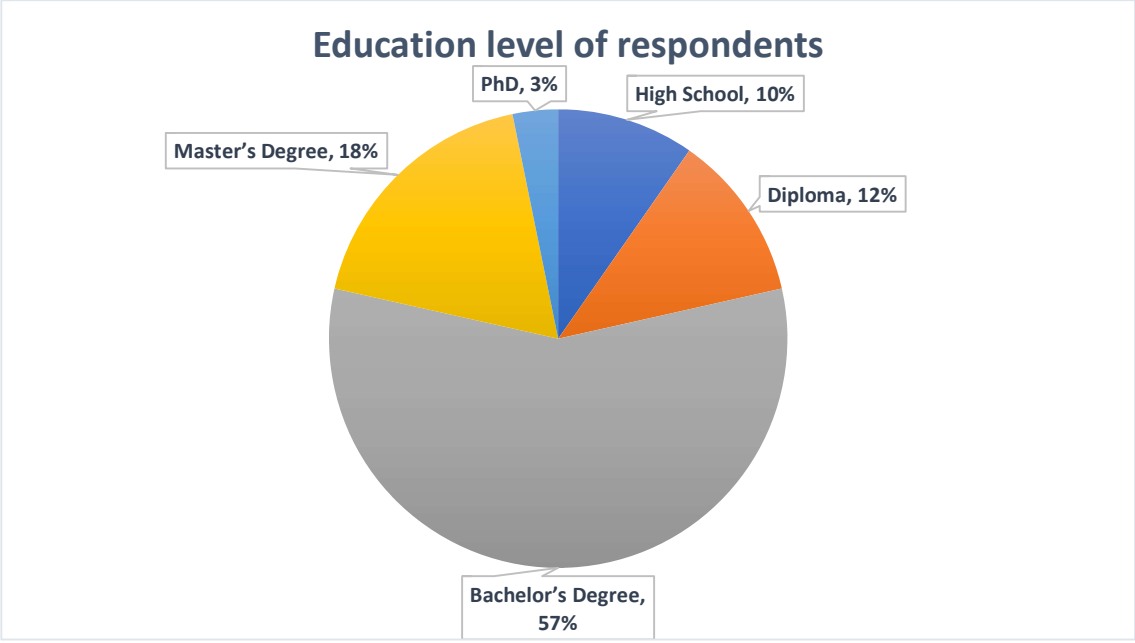


**Figure 2**: Respondents' education level.

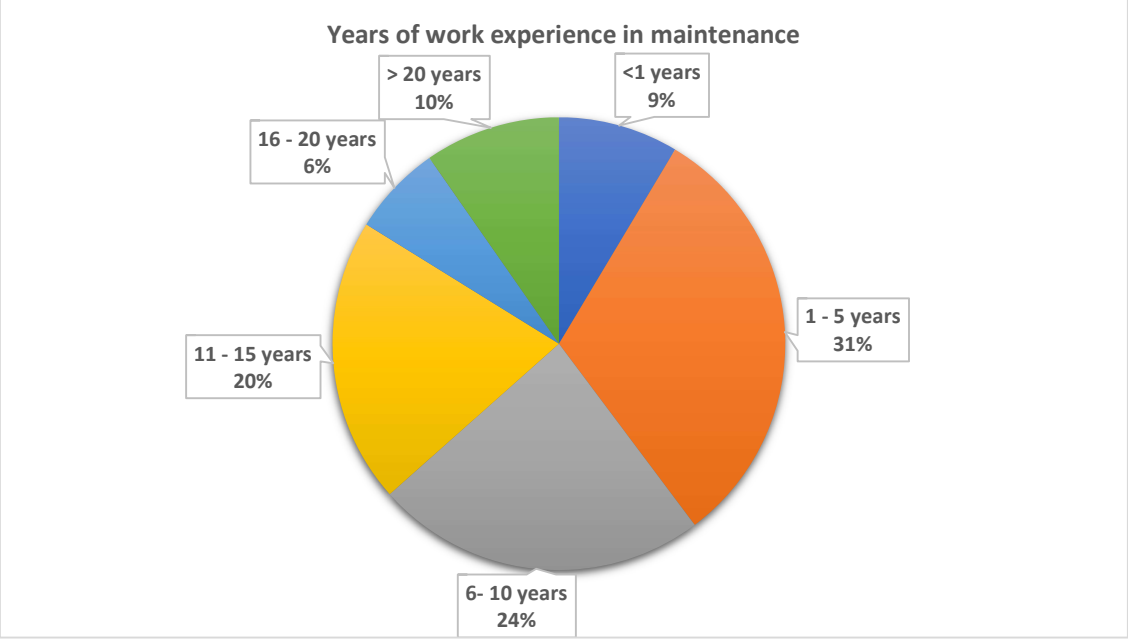


**Figure 3**: Respondents' years of work experience in maintenance work

### 3.2 Work experience and training in maintenance activities

Table 2 lists the questions in Part 1 of Section B: The workers' work experience and training associated with maintenance tasks. Referring to Figure 4, thirty-three respondents strongly agree, and thirty-eight respondents agree that only experienced workers can do maintenance activities for abnormal situations or conditions. Sixty-five respondents strongly agree that training before the maintenance tasks could prevent workers from performing unsafe acts. A similar number of respondents also reported that good training would prepare workers for possible situations while maintaining plants or machinery. Fifty-five respondents strongly agree, and thirty-four respondents agree that workers with vast experience in maintenance tasks have a good understanding and knowledge of the plant or machinery. For Question 1.5, twenty-seven respondents reported that they neither agree nor disagree that less-experienced workers cannot handle abnormal situations. Only one respondent did not answer Question 1.5. Thirty-three and thirty-nine respondents strongly agreed and agreed, respectively, that novice workers should attend training as provided by the company. Twenty-four respondents reported that they neither agree nor disagree that the company provided refresher training in equipment and maintenance procedures to experienced workers.

**Table 2**: Questions related to work experience and training (Section B, Part 1).

| No. | Questions |
|---|---|
| 1.1 | Maintenance tasks of abnormal situations are done by experienced workers only. |
| 1.2 | Training plays a vital role in reducing unsafe acts while performing a task. |
| 1.3 | Good training makes employees well-prepared for possible situations. |
| 1.4 | A high level of experience provides workers with extensive knowledge and practice in a wide range of potential scenarios. |
| 1.5 | A worker with a low level of experience cannot handle an abnormal situation. |
| 1.6 | Novice workers must attend all training in maintenance provided by the company. |
| 1.7 | The company provides refresher training on the maintenance of equipment/assets and procedures to experienced workers. |

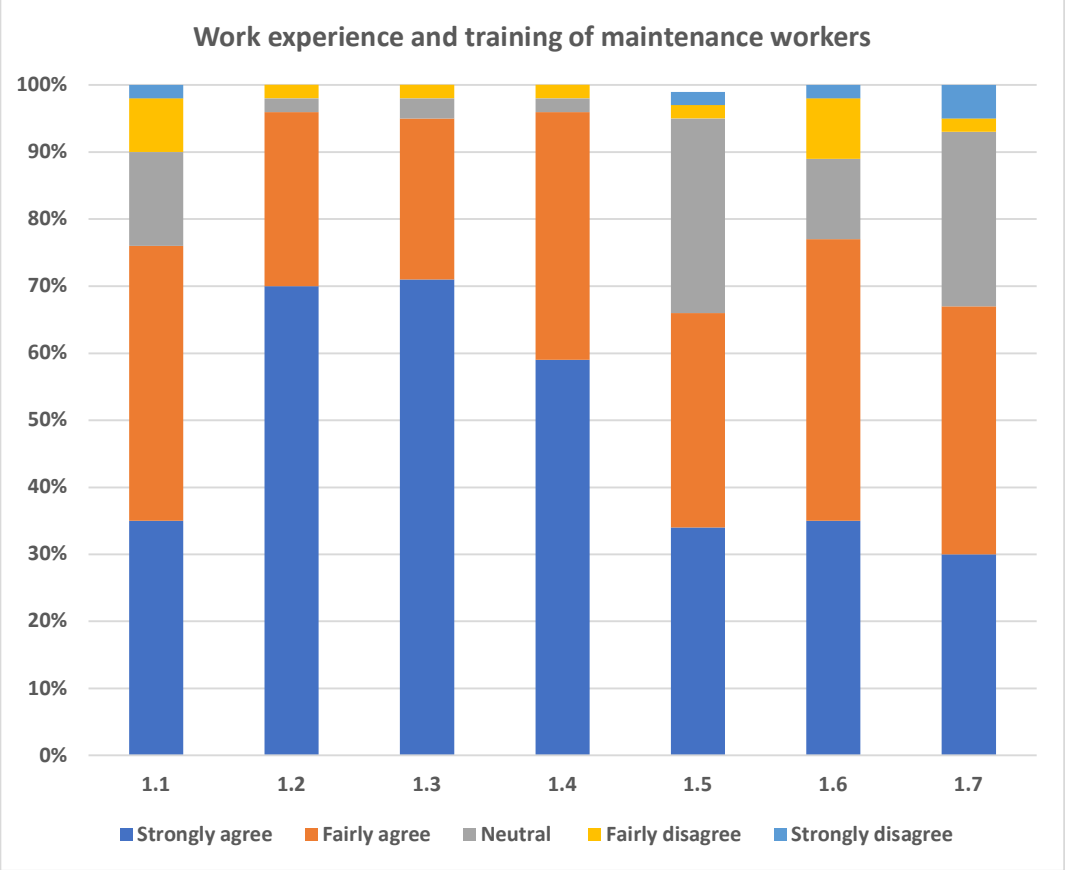


**Figure 4**: Responses of workers' experience and training in maintenance tasks.

### 3.3 Procedures for maintenance activities

Questions related to maintenance procedures are listed in Table 3. Based on the questions, Figure 6 presents the analysis of the responses from the workers. Sixty-seven and fourteen respondents strongly agree and agree that proper written procedures could help workers perform maintenance tasks safely. Thirteen respondents neither agree nor disagree with the availability of written procedures. Question 2.2 shows that sixty and thirty respondents strongly agree and agree that inadequate information on maintenance procedures could lead to incidents or accidents. Question 2.3 asked respondents about the potential of an incident or accident if performing maintenance tasks without procedures. Fifty-eight respondents strongly agree, and twenty-five respondents agree with Question 2.3. Similar responses can be observed for Question 2.4. The feedback on Question 2.5 is interesting—sixty-nine respondents strongly agree that they always read the procedures before performing maintenance jobs—because it is the highest among all questions in Part 2. Question 2.7 shows a mixed perception of understanding some steps in the procedures. Nineteen respondents admitted that they took shortcuts in some steps to have work done within a short time.

**Table 3**: Questions related to procedures for performing maintenance activities (Section B, Part 2)

| No. | Questions |
|---|---|
| 2.1 | An accurately written procedure ensures workers can perform all job tasks safely. |
| 2.2 | Inadequate information in the procedure may lead to an accident while performing the task. |
| 2.3 | Performing any task without written procedure increases the likelihood of an undesired event. |
| 2.4 | An accurate procedure plays a vital role in decreasing the likelihood of an undesired event. |
| 2.5 | Sometimes I do not read all information in the procedure. |
| 2.6 | The procedure should be formally written down in an attractive way. |
| 2.7 | Sometimes I do not understand some steps in procedures. |
| 2.8 | I take shortcuts to some steps in procedures to have work done in a short time. |

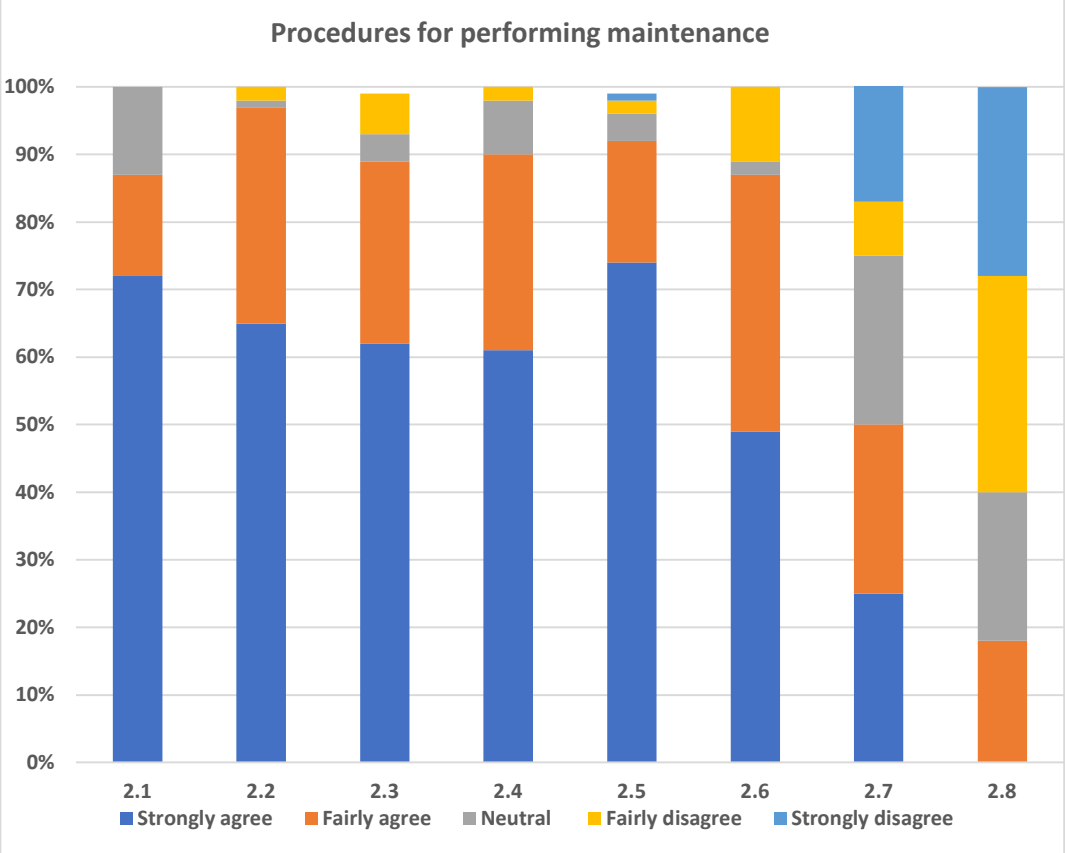


**Figure 5**: Responses of worker's on procedures for performing maintenance tasks.

### 3.4 Time and Stress

Time is essential to maintenance: pre, during, and post. Thus, time and stress can be correlated; for example, inadequate time to complete maintenance activities effectively contributes to stress for workers and companies. The maintenance activities and time are indeed related to the financial resources. Such situations directly contribute to the increment of stress among workers and the management of companies. Questions related to time and stress are provided in Table 4. The responses to the questions are presented in Figure 6. Questions 3.1 to 3.6 show that respondents strongly agree, between 35% to 54%. About 30% to 47% responded 'Agree' for Questions 3.1 to 3.6.

**Table 4**: Questions related to time and stress while performing maintenance activity (Section B, Part 3).

| No. | Questions |
|---|---|
| 3.1 | A short time (to perform a task) can affect a worker's ability to think clearly. |
| 3.2 | A short time increases the likelihood of committing errors. |
| 3.3 | A short time increases the level of stress. |
| 3.4 | There is enough time for important communication at team briefings and shift handovers. |
| 3.5 | High levels of stress impact the ability to focus on the task. |
| 3.6 | A normal level of stress helps to achieve good performance. |

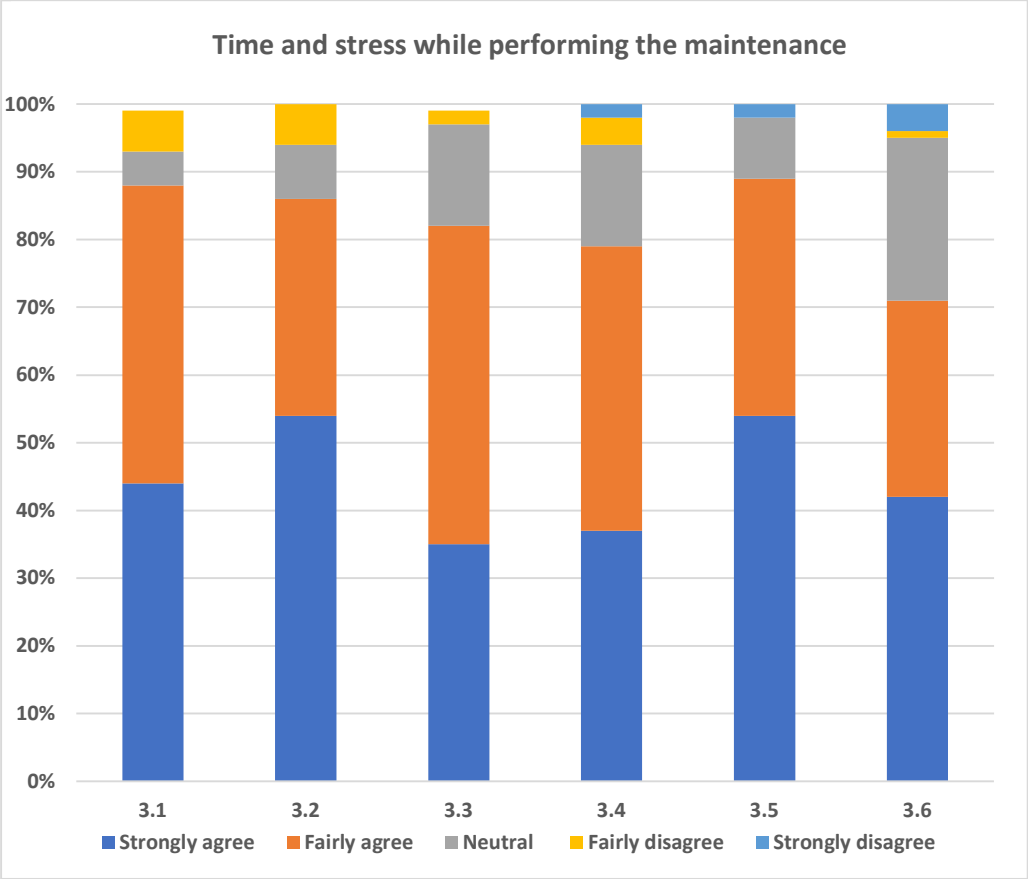


**Figure 6**: Responses of workers' on time and stress while performing maintenance tasks.

### 3.5 Work processes for performing maintenance

Work process refers to aspects such as communication, safety culture, work planning, and management policies. Table 5 shows eight questions about the work process of maintenance activities. The responses to every question are illustrated in Figure 7. Seventy-one respondents strongly agree that effective communication could prevent workers from making errors. Responses to Question 4.4 are varied: "I need more time to understand or be on the same page with other people or supervisors." Eleven respondents strongly agree, forty-two agree, twenty-one neither agree nor disagree, nine disagree, and ten strongly disagree. The same varied responses are observed for Question 4.5: "It was easy to report to management about problems or issues that they encounter when carrying out work." Sixty-three respondents provided a positive perspective of a manager who spent some time on the shop floor and spoke about safety and health. Fifty-two respondents strongly agree that management's commitment is crucial to a positive health and safety culture. Question 4.8 has varied responses or perspectives regarding non-compliance to safety regulations and the cost.

**Table 5**: Questions related to the work process for performing maintenance activities (Section B, Part 4)

| No. | Questions |
|---|---|
| 4.1 | Effective communication between all employees reduces the likelihood of errors. |
| 4.2 | Developing the communication skill of all employees help in reducing the likelihood of making errors. |
| 4.3 | To perform tasks safely, you should encourage them to ask for confirmation, clarification, and repeat the information. |
| 4.4 | I need more time to understand or be on the same page with other people or my supervisor. |
| 4.5 | It is easy to report to management of problems or issues that I encounter when carrying out work. |
| 4.6 | A good manager spends an adequate amount of time on the shop floor (where the people are) and speaks about safety and health. |
| 4.7 | Senior management commitment is crucial to a positive health and safety culture. |
| 4.8 | Non-complying with safety regulations would reduce the overall cost. |

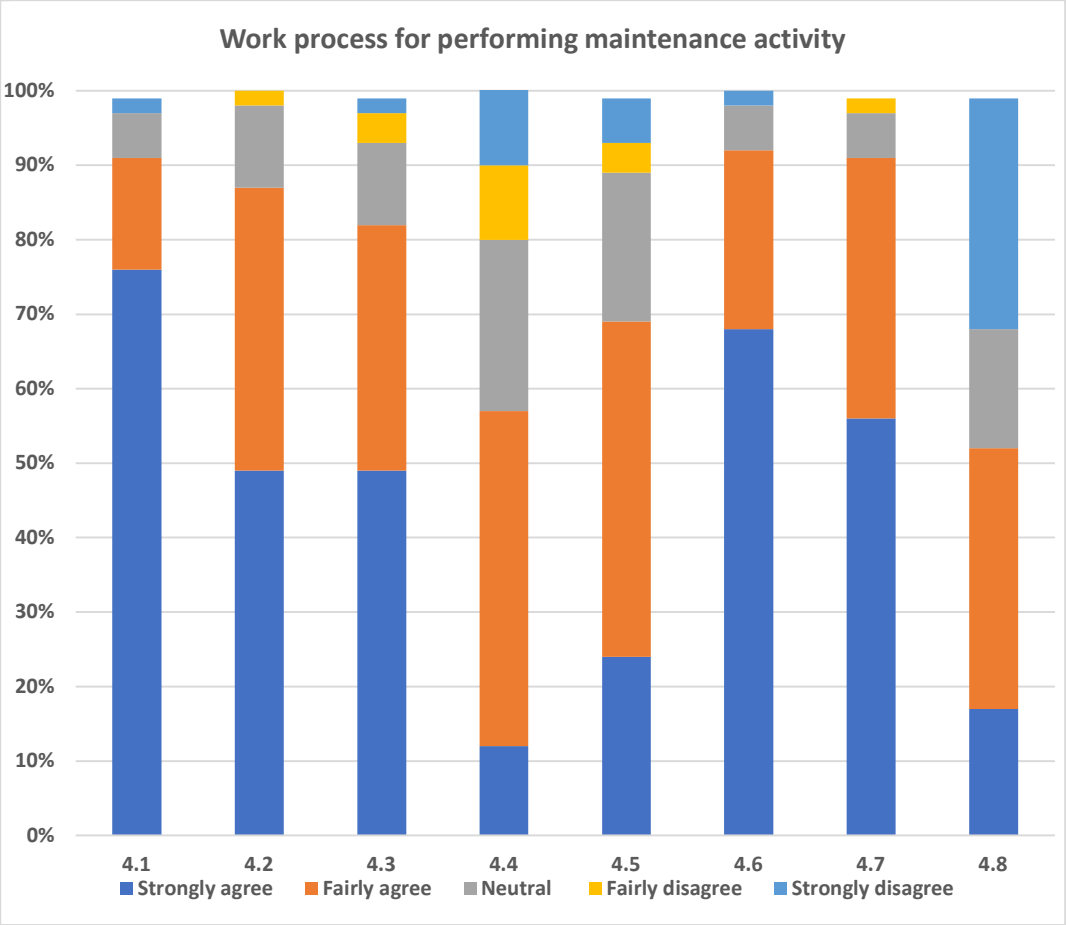


**Figure 7**: Responses of workers on the work process for performing maintenance tasks

## 4.0 CONCLUSION

The survey identifies potential human factors associated with inspection and maintenance activities of the oil and gas industry in the United Arab Emirates (UAE). Ninety-three maintenance workers participated in the survey by answering the questionnaire provided in Google Forms. The survey comprises four performance shaping factors (PSFs): experience and training, procedure, time and stress, and work processes. The responses show that both experience and training could improve the workers' skills and the success of the maintenance tasks. The results also indicate that training and education of maintenance workers are imperative and that experienced workers can handle abnormal situations. The survey results also concur with other researchers regarding the importance of proper and understandable work procedures [4], [10]. Moreover, limited maintenance time could increase stress levels [11], [12].

It is recommended that the procedures are written effectively and attractively to facilitate workers' understanding of them. Procedures prepared in pictorial form could be helpful to workers in grasping the procedures rather than a written format. Furthermore, supervisors should be responsible for verbally conveying the procedures to the workers to ensure their understanding. Novice workers are found to be incapable of understanding work procedures since the understanding is found to be influenced by one's experience. Accordingly, novice workers must be mentored or coached by experienced employees. Companies should also conduct training, refresher training, and regular coaching for novice workers to gradually develop their skills [13]. The safety and health procedures and communication should be improved to reduce the likelihood of mishaps.

The research work (i.e., questionnaire distribution, recruitment, participation, and data collection) was conducted during the early lockdown due to the global pandemic. Such situations limited the time and outreach to the industry in distributing the questionnaire and receiving participation. Consequently, the numbers of respondents are small and cannot be generalized. Furthermore, the research was limited to two maintenance Emirate companies (namely Sharjah and Abu Dhabi) out of seven.

As a recommendation for better research work or survey on human factors and maintenance activities, researchers should

i) increase the sample size,
ii) develop hypotheses related to the use of Industry 4.0 and how it affects workers and the maintenance work, and
iii) relate human factors and maintenance activities to the existing acts or standards.

The maintenance activities are now adapting to Industry 4.0; however, human factors may still be present. Thus, it is appropriate for future research work to include the effectiveness of Industry 4.0 in maintenance activities while considering the presence of human factors in any industry.

**Acknowledgments**

Firstly, the authors would like to thank those who helped distribute the survey related to this study and those who participated in it too. Secondly, the authors thank Universiti Teknologi Malaysia (UTM) for the financial support. The cost center number of the research funding is Q.J130000.3551.06G00. The research work is a project of a trans-disciplinary grant (UTM-TDR 42) vot no.: Q.J130000.3509.05G98.

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