Journal of Engineering and Technology

ISSN 2180-3811 eISSN 2289-814X https://jet.utem.edu.my/jet/index

DOI: https://doi.org/10.54554/jet.2025.16.1.004

ENHANCING HUMAN FACTORS ENGINEERING (HFE) IN FRONT-END ENGINEERING DESIGN (FEED) THROUGH VALVE CRITICALITY ANALYSIS

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Article History:
Received Date: 21 November 2024
Revised Date: 8 April 2025
Accepted Date: 1 June 2025

Keywords: Front-End Engineering Design, Human Factors

Abstract— Human Factors Engineering (HFE) is an interdisciplinary field that studies the interactions between humans, their tasks, and the broader organizational systems. Its goal is to improve both human performance and system efficiency. In the Front-End Engineering Design (FEED) phase, a critical challenge lies in designing and positioning key components like valves to ensure their functionality and ease of maintenance. Poor valve design and placement can result in safety hazards, inefficiencies, and increased operational risks. To address this issue, this paper explores the integration of Valve Criticality

Engineering, Valve Criticality	Analysis (VCA) within the HFE framework during the FEED stage. The approach involves classifying valves according to their criticality, evaluating their operational roles, and assessing the potential consequences of valve failures. This classification aids in making informed decisions about optimal valve design and placement. Findings from applying VCA during the FEED stage indicate that categorizing valves by their criticality enhances the identification of high-risk components, improves operational safety, and reduces human factor-related risks when introduced early in the design phase. This work presents a novel methodology that strengthens safety and operational effectiveness while offering a template for future projects.

I. Introduction

Human Factors Engineering (HFE) plays a vital role in improving workers' safety, efficiency, and welfare in high-risk industries, particularly in Oil and Gas (O&G). Even minor mistakes can lead to operational inefficiencies, unsafe working conditions, and catastrophic outcomes in such environments. Human error from poor decision-making to communication breakdowns and cognitive limitations is a leading cause of accidents. HFE aims to reduce these risks by optimizing system performance with human capabilities, ultimately preventing incidents and improving operational efficiency.

Recent reviews of HFE in the O&G industry show that while significant strides have been made, there are still gaps in understanding and addressing human performance challenges, particularly in the context of the evolving digital landscape of

Industry 4.0. New technologies are reshaping the way humans interact with machines, leading to the rise of Operator 4.0 and the increasing integration of automation. However, as Industry 4.0 is still in its early stages, research on human work in this context is sparse. Although several studies have focused on specific aspects, such as offshore drilling, a holistic approach to HFE that covers broader O&G operations is still underdeveloped.

II. Methodology

Valve Criticality Analysis (VCA) should be conducted in a workshop format led by a qualified HFE specialist, usually from an external consultancy. Before the workshop, valves should be pre-identified through Piping and Instrumentation Diagrams (P&IDs) and categorized based on pre-determined criteria. During the workshop, feedback from the team will help verify the classifications, which will then be marked on the P&IDs with corresponding identification codes and colors as described in Table 1. The criteria used to evaluate the valves include their importance in process control, their role in ensuring safety and operational reliability, and the frequency with which the valve is accessed for operation or maintenance.

Additionally, five questions should guide the classification process:

1. Is the valve critical for process control?
2. Is it crucial for safety?
3. Is it prone to frequent failure?
4. Would difficulty in accessing the valve cause significant issues?
5. How often is the valve operated (e.g., more than once every six months)?

III. Results

A sample VCA workshop findings worksheet for the SIPROD Preparation stage is shown in Table 2. The methodology for VCA is summarized in Figure 1. Table 3 summarizes the valve's criticality classification for SIPROD Platforms.

Table 1: Valve Category and Description

Valve Category	Criteria	P&ID Mark-up ID & Colour
Category 1	Valve that essential to normal or emergency operations where rapid access is essential. Those valves are valves that critical for safety or operations, and used frequently for routine operation and maintenance, and particularly large valves (greater than 610 mm in diameter or length).	C1 (RED)
Category 2	Valves that are not critical for normal or emergency operations but are used during routine maintenance and operation activity.	C2 (YELLOW)
Category 3	Valves that are critical for operations or routine maintenance and are frequently used for particular tasks like commissioning, start-up, shutdown, or rarely performed maintenance tasks.	C3 (GREEN)

Table 2: Sample of VCA findings worksheet

No	Valve Description	Essential		Failure		Frequency			Category	Remark
		Process Control	Safe guarding	High frequency	Serious consequence	> Once every 6 months	< Once every 6 months	Rare		
WELLHEAD (Drawing No.: XXX)										
1	Pressure Indicator from Gas Lift Header into an inlet of the Wellhead	Y				Y			C1	
2	Pressure Switch Low from the Gas Lift Header into an inlet of the Wellhead,	Y				Y			C1	

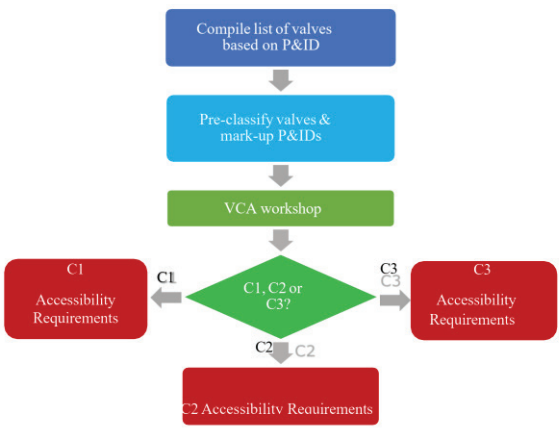

Figure 1: VCA Process Flow

Table 3: Number of C-1, C-2 and C-3 valves for SIPROD Platforms

No	System	Classification			
		C-1	C-2	C-3	Total
SIPROD Platform					
1	SIPROD Preparation	42	6	5	53
2	Rig Up	6	3	0	9
3	Well Tie-in	32	3	0	35
4	Rig Down	0	1	0	1

A. Design Requirements for the Selection, Location, and Orientation of Valve Operators and Actuators

The space between the handwheel/valve stem and surrounding obstacles for easy valve operation should meet specific distance requirements. As shown in Figure 2, a minimum clearance of 75 mm is necessary between the outer edge of the valve handwheel and any obstacle within its range of motion. For maintenance, the distance between valve flanges and obstructions must be at least the bolt length plus 25 mm to allow the use of tools and proper torque application.

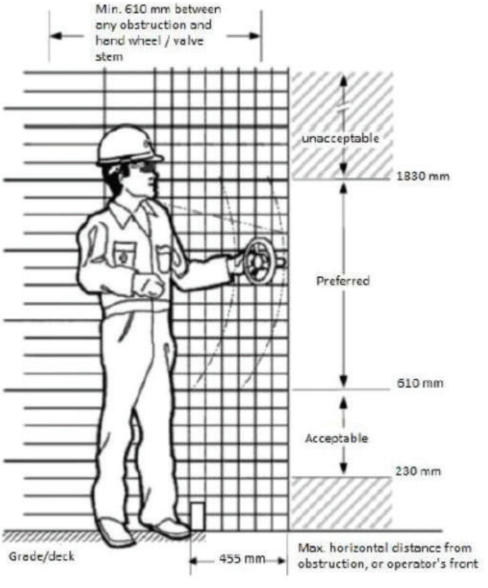

Figure 2: Mounting height operated valves with horizontal stems

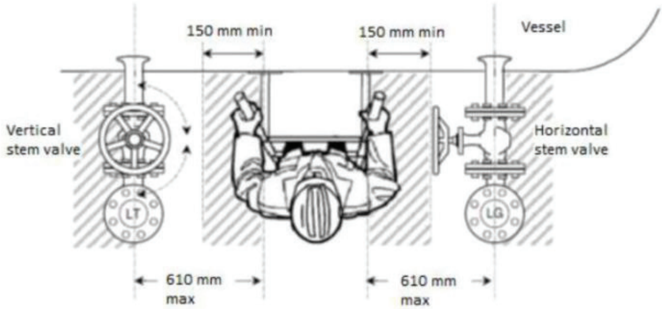

Figure 3: Minimum and maximum lateral reach distances required for handwheel-operated level instruments, gauge nozzles, or valves mounted on the side of a vessel

Additionally, when standing space is required for maintenance, as shown in Figure 3, a minimum clearance of 460 mm is necessary between a flange and surrounding structures such as walls or guardrails.

IV. Conclusion

The application of VCA during the FEED stage proves that classifying valves based on their criticality leads to better identification of high-risk components, enhances operational efficiency, and ensures safer designs by reducing human factor-related risks. Proper valve placement ensures that operators have easy access for operation, inspection, and maintenance, preventing the need for unsafe workarounds. Furthermore, the integration of Valve Criticality Analysis contributes to workforce safety by considering operators' physical capabilities when designing valves. Implementing proactive safety management systems that continuously monitor human factors risks, combined with predictive analytics, can help prevent safety incidents and improve overall project success.

V. Acknowledgement

This study was funded by the Universiti Teknologi Malaysia (UTM) through the Fundamental Research Grant (Q.K130000.3856.22H17), the Ministry of Higher Education

(MOHE) under the Fundamental Research Grant Scheme (FRGS) (Grant No.: FRGS/1/2019/TK03/UTM/02/ 14 (R.K130000.7856.5F205)), and the Faculty of Artificial Intelligence, Universiti Teknologi Malaysia (UTM). The support provided was instrumental in the success of this study.

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