



## Statistical Analysis of LPG data in Manufacturing Industries for Management System Elements

C. Gnanasekara Baburao<sup>1</sup>, T.Srinivas<sup>2,\*</sup>, A. Anitha<sup>1</sup>, R.K. Elangovan<sup>3</sup>, R. Govindarajan<sup>1</sup>

<sup>1</sup>Department of Chemical Engineering, Hindustan Institute of Technology & Science (HITS), Chennai, India

<sup>2,\*</sup>Department of Chemical Engineering, B V Raju Institute of Technology, Narsapur, Medak, India

<sup>3</sup>Directorate General, Factory Advice Service and Labour Institutes (DGFASLI), India

[\\*dr.t.srinivas85@gmail.com](mailto:dr.t.srinivas85@gmail.com)

### Abstract

Process safety is becoming more difficult as requirements increase. When balancing quality, volume, and safety on a budget, major accidents are unavoidable. A major cause of complacency and safety attitude decline is a lack of organisational resilience to absorb unwanted and unforeseen disturbances. The inability of industries to interpret standards impedes self-regulation. LPG Industries from various districts in Tamil Nadu (Hosur, Vellore, Coimbatore, Thiruvallur, Chengalpattu, Kanchipuram, Chennai, Madurai, Sivaganga, Madukkarai, Trichy, Salem, Tuticorin) were inspected and data was collected for this study. To assess the state of an industry, 50 questionnaires were created. 50 questionnaires were classified as Management System Elements, which were further classified as Safety, Health, and Environment Policy, Safety & Health Organization, First Aid, Personal Protective Equipment (PPE), Communication System used in plant, Safety Education and Training, Occupational Hygiene & Health, Management Systems on Accident Reporting, Safety and Health, Analysis and Investigation, Procedures and Protocols. 50 questionnaires from all thirty-three industries were statistically analysed. All the results were positive, indicating that safety in performance in LPG industries in various districts of Tamil Nadu, India is above average. The consequences of strengthened

regulations, legal systems, and implementation related to PSM are the extremely essential methods to be needed to enhance improvement.

**Keywords:** Management System Elements; Safety; Health; Environment Policy; Personal Protective Equipment;

**Introduction:**

In general terms, safety refers to the state of being free or protected from harm, accident, hazard, injury, damage, or risk (1). In an industrial environment, it refers to the reduction of human-hazard contact and is primarily concerned with preventing physical harm to persons or / and property. An emergency is as an accident or incident that has the potential to result in serious injury or death. It may result in considerable property damage, significant disruptions to manufacturing and factory operations, and may have a negative impact on the environment (2,3,4). Major accidents involving fire (5), explosion (6), and toxic releases (7) can occur in factories, and those that store and handle chemicals that pose fire, explosion, and toxic dangers in excess of a threshold quantity are referred to as Major Accident Hazard (MAH) Factories.

Theophilus et al. [8] described the fail to notice human considerations in the existing system and describe an integrated process safety management system (IPSMS) model derived from a review of all remaining PSM frameworks. They discovered that the prototype, which uses the CHECK, ACT, DO, and PLAN structure, also includes an execution approach. They concluded that the IPSMS offers both a practical and a theoretical structure for managing, measuring, and analysing process safety management systems.

Shamim et al. [9] have created a useful mathematical tool for quantitatively evaluating the execution of established lagging and leading metrics in chemical industries. They reported that the tool would allow for further academic concern and may immediate future researchers toward empirical conclusions for long-term safety implementation via the proposed conceptual framework.

Yiu et al., [10] et al. analysed the benefits and challenges of SMS. They discovered that the top four benefits were safer working conditions, fewer worker injuries, incorporating safety management into project management, and enhanced project management. Putting safety as a lower priority due to organisational cultural differences, high worker turnover, tight project schedules, subcontractor obstruction, and inactive SMS implementation by project team members constituted the top five obstacles.

Nwankwo et al. [11] create a reasonable structure to aid in the choice of a proper and suitable PSM system for particular industry segments in the interior the process industry. According to the researchers, Based on the findings of the investigation, it was determined that there is not yet a PSM system that is suitable for use across the board in the process industry.

Shanmugam et al. [12] investigated process safety management (PSM) execution between Malaysian major hazard installations (MHI), providing an evaluation of recent PSM execution wisdom. They discovered that a characteristic percentage of 40% of major hazard installations in Malaysia had PSM execution wisdom levels that were below the like predefined conventional wisdom levels.

Nordin et al. [13] used a System Dynamic Model to improve the construction safety management system at the project level (SDM). Their findings demonstrated that the factors have a relationship and interact with one another. The discoveries of this analysis are anticipated

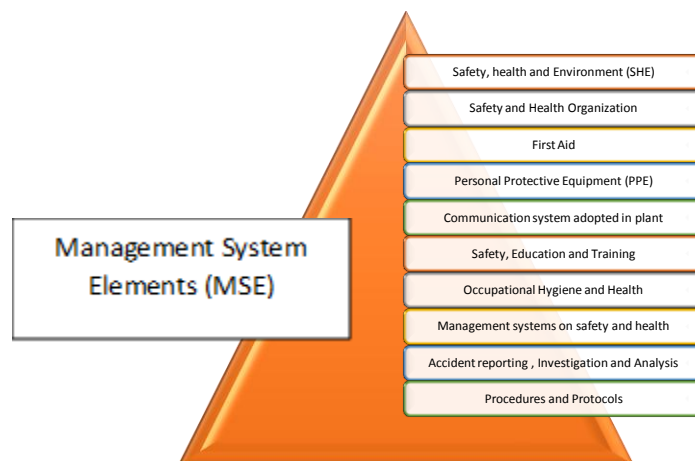
to help identify the most effective corrective actions that can be used to reduce the number of construction accidents in Malaysia.

Wang et al. [14] gathered and developed FPE data from the standpoint of report expose and utilized the blended weight cloud prototype to assess the occupational health and safety management level (OHSML) of 69 listed companies in China's energy industry from 2009 to 2019. The findings were as follows. (1) The OHSML of most listed companies in China's energy industry was even at the minimal end.

Despite several statutory requirements for emergency planning factories, the occurrence of workplace emergencies demonstrates the current process safety management system's shortcomings [15, 16, 17]. The purpose of this study is to examine the process safety management preparedness system in Major Accident Hazardous Factories that handle and store dangerous chemicals. This study is accomplished through the development of a questionnaire, data collection, and statistical analysis related to LPG industries. The analysis used statistical tools from the "Analysis ToolPak" in Excel 2019 to analyse the data. The paper highlights shortcomings in existing on-site emergency planning at MAH Factories that handle and store dangerous chemicals and makes recommendations for improving management system elements.

## **Material and methods**

The questionnaire was developed in light of MAH factories' requirement for on-site emergency planning. The surveys were divided into two categories: Management System Elements (MSE) and Emergency Management Elements (EME). The Management System Elements (Fig. 1) were further categorized into ten categories.



**Fig. 1.** Management System Elements

### **Participants and Procedure:**

The approved questionnaires were classified as YES/NO/Comments, and their status was gathered from the 32 registered factories. The study examines MAH facilities in the Indian state of Tamil Nadu that handle dangerous chemicals. The factories included in this study were

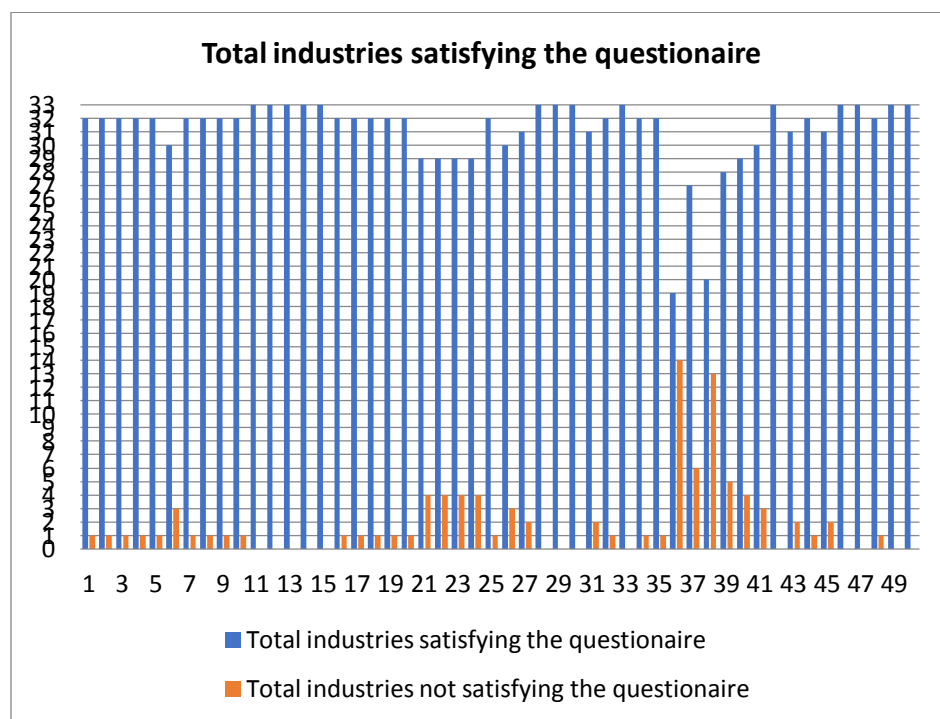
1. M/s. Coromandel International Ltd, Thiruvallur;
2. M/s. Covestro (India) Private Limited, Cuddalore;
3. M/s. Chennai Petroleum Corporation Limited, Chennai;
4. M/s. Exide Factories Limited, Hosur;
5. M/s. JSW Steel Limited, Steel Plant, Mettur;
6. M/s. Kothari Petrochemicals Limited, Thiruvallur;
7. M/s. The metal powder company limited, Madurai;
8. M/s. Manali Petrochemicals Limited, Chennai;
9. M/s. Nova Carbons India Private Limited, Tirunelveli;
10. M/s. Orchid Pharma Limited, Chennai;
11. M/s. Daimler Industry;
12. M/s. Stahl India Pvt Ltd, Kanchipuram;

13. M/s. Abilash chemicals and Pharmaceuticals Private Limited, Madurai;
14. M/s. Tamil Nadu Petroproducts Ltd, Chennai;
15. M/s. TANFAC Factories Ltd, Cuddalore;
16. M/s. SPIC Limited, Tuticorin;
17. M/s. DCW Limited, Tuticorin;
18. M/s. Greenstar Fertilizers Limited, Tuticorin;
19. M/s. Greenstar Fertilizers Limited, Tuticorin, TN3451;
20. M/s. Kilpauk Water Works, Chennai;
21. M/s. Alpha Amins (Private) Limited, Thiruvallur;
22. M/s. Chennai Petroleum Corporation Limited, Thiruvallur;
23. M/s. Balmer Lawrie & Company Limited, Thiruvallur;
24. M/s. Madras Fertilizers Limited, Thiruvallur;
25. M/s. NTPC Tamil Nadu Energy Co Limited, Thiruvallur;
26. M/s. Clariant Chemicals (India) Limited, Kanchipuram;
27. M/s. Tamil Nadu Industrial Explosives Limited (TEL), Vellore;
28. M/s. Lloyds Insulations (India) Limited, Thiruvannamalai;
29. M/s. Asian Paints (India) Limited, Cuddalore;
30. M/s. Bayer Material Science Private Limited, Cuddalore;
31. M/s. Neyveli Lignite Corporation Limited, Cuddalore and
32. M/s. Chemplast Sanmar Limited, Salem.

The data for all 50 questions were gathered from these factories through coordination and on-site visits. Following that, the binary data was subjected to additional statistical analysis.

**Results and discussion**

The data were analysed using the statistical tool "Analysis TookPak" in Excel 2010. This study conducted a statistical analysis of all aspects of on-site emergency preparation in industries. Cronbach's alpha test was used to determine the questionnaire's reliability (18). Later, the questionnaire was evaluated statistically for descriptive statistics, t-test for means, one-way ANOVA, and histogram. Total comparison for management system elements shown in Fig. 2.



**Fig. 2.** Occupational hygiene & health questionnaire vs number of industries

**Table 1:** Descriptive statistics

	Total control	Total industries satisfying the questionnaire
Mean	33	31.1
Standard Error	0	0.4
Median	33	32
Mode	33	32
Standard Deviation	0	2.82

Sample Variance	0	7.93
Kurtosis	#DIV/0!	10.49
Skewness	#DIV/0!	-3.03
Range	0	14
Minimum	33	19
Maximum	33	33
Sum	1650	1555
Count	50	50
Largest(1)	33	33
Smallest(1)	33	19
Confidence Level(95.0%)	0	0.80

Comparing the mean, median and mode, it follows skewed distribution (negative skewness). Higher kurtosis value indicates outliers. Standard deviation and hence variance present. This represents all industries do not follow same trend in follow up of a questionnaire. To look for the forecasted values, confidence level with 95% probability for the mean is calculated and reported. The data has CI as 0.80 and hence the mean has 30.3 as lower limit and 31.9 as upper limit.

**Table 2:** One way ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	90.25	1	90.25	22.77	6.38756E-06	3.94
Within Groups	388.5	98	3.964285714			
Total	478.75	99				

F and p-values are calculated to decide the significance as F statistic compares the joint effect of all the variables together (Table – 2). Here, p-value < 0.05 and F value is greater than F critic and hence null hypothesis rejected when compared between columns and the data is statistically significant. Hence, overall industries have to strictly abide by the rules set for Emergency Management Elements.



**Interpretation for Topic wise comparison:**

Mean, median and mode are equal and followed normal distribution for Topics Safety, Health and Environment Policy, First Aid, PPE, Occupational Hygiene and Health and confidence values are zero. Hence, statistically insignificant and above-mentioned topics need not to be improved. Topics Safety Education and Training and Procedures & Protocols have  $p > 0.05$  and  $F < F_{crit}$  and statistically insignificant. Topics need not to be improved.

Topics Safety & Health Organization, Communication System adopted in plant, Management systems on safety and health, Accident Reporting Investigation and analysis follows unequal Mean, median and mode and follows skewed distribution. Besides, Safety & Health Organization and Communication System adopted in plant have 5 as kurtosis and hence Outlier present and hence need to be improved. Also, Safety & Health Organization, Communication system adopted in plant, Occupational Hygiene and Health, Management Systems on safety and health, Accident Reporting Investigation and analysis have  $p < 0.05$  and  $F > F_{crit}$ , statistically significant and need to be improved in satisfying the questionnaire. Hence, the above-mentioned topics need to improve on satisfying the questionnaire.

Also, Patwari Bakers followed by Daewon India Autoparts, Covai LPG, Indian Oil Corporation Limited, Sivagangai need to focus on satisfying the entire questionnaire set for Management System Elements.

**Industry-wise Comparison:** Industries satisfied all questionnaire were (Table – 3)

1. COVAI LPG
2. DAEWON INDIA AUTOPARTS PRIVATE LIMITED
3. INDIA YAMAHA MOTOR
4. LOTTE INDIA CORPORATION LIMITED
5. HINDUSTAN PETROLEUM CORPORATION
6. INDIAN OIL CORPORATION LTD SIVAGANGAI
7. MEENA LPG INDUSTRIES MADUKKARAI
8. SHV ENERGY PVT LTD
9. SSTP, BHEL
10. SHV ENERGY PRIVATE LIMITED, TUTICORIN
11. EICHER MOTORS TLD
12. ROYAL ENFIELD
13. MEENA LPG INDUSTRIES
14. PATWARI BAKERS

**Table 3: Control industries compared with other units for their variations.**

Industry Number	Control industries	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mean	1	0.82	0.92	0.94	0.94	0.84	0.86	0.92	0.86	0.92	0.88	0.94	0.94	0.92	0.54
Standard Error	0	0.055	0.039	0.034	0.034	0.052	0.050	0.039	0.050	0.039	0.046	0.034	0.034	0.0388	0.0712
Median	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mode	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Standard Deviation	0	0.39	0.279	0.240	0.240	0.370	0.351	0.274	0.351	0.274	0.328	0.240	0.240	0.274	0.503
Sample Variance	0	0.15	0.0759	0.058	0.058	0.137	0.123	0.075	0.123	0.075	0.108	0.057	0.057	0.0751	0.253
Kurtosis	0	0.99	8.539	13.124	13.124	1.726	2.684	8.534	2.684	8.534	3.974	13.124	13.124	8.534	-2.057
Skewness	0	-1.72	-3.199	-3.821	-3.821	-1.912	-2.140	-3.193	-2.140	-3.193	-2.412	-3.821	-3.821	-3.193	-0.166
Range	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Minimum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sum	50	41	46	47	47	42	43	46	43	46	44	47	47	46	27
Count	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Largest(1)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Smallest(1)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Confidence Level (95.0%)	0	0.11	0.078	0.068	0.068	0.105	0.099	0.078	0.099	0.078	0.093	0.0682	0.0682	0.078	0.143
F		10.76	4.261	3.128	3.128	9.33	7.977	4.261	7.977	4.261	6.682	3.128	3.128	4.261	41.741
p-value		0.00144	0.042	0.080	0.0800	0.0029	0.00574	0.0416	0.00574	0.0416	0.011	0.080	0.080	0.042	4.04745E-09
F-crit		3.94	3.938	3.938	3.938	3.938	3.938	3.938	3.938	3.938	3.938	3.938	3.938	3.938	3.938

**Conclusions:**

Comparing the mean, median and mode, Median is equal to mode. Mean deviates for industries which do not follow all the questionnaire. SD is higher for Patwari Bakers Pvt Ltd, Madurai and hence sample variance. So, data variation is higher for Patwari Bakers Pvt Ltd, Madurai. Kurtosis and hence outliers high for Renault Nissan Automotive India Pvt Ltd. it follows skewed distribution.

Dongwoo SurfaceTech India Pvt Ltd, Bharat Petroleum Corporation Ltd, Renault Nissan Automotive India Pvt Ltd and Saint Gobain India Pvt Ltd have  $p > 0.05$  and  $F < F_{crit}$ . India Yamaha Motor, Lotte India Corporation Ltd, Eicher Motors Ltd, Royal Enfield has greater than 3 kurtosis in negative direction and greater skewness. Besides,  $p > 0.05$  and  $F < F_{crit}$  and hence, null hypothesis is not rejected and statistically insignificant when the above-mentioned industries were compared. However, these eight industries compared with control industries in terms of satisfying the total questionnaire to be followed in the industries. These industries are better than other industries to satisfy the questionnaire.

Ten industries namely Daewon India Autoparts Pvt Ltd, Meena LPG Industries Madukkarai CB17877, SSTP BHEL, Meena LPG Industries CB16595, Covai LPG, Hindustan Petroleum Corporation, Indian Oil Corporation Ltd Sivagangai, SHV Energy Pvt Ltd, SHV Energy Pvt Ltd, Tuticorin and Patwari Bakers have  $p < 0.05$  and  $F > F_{crit}$  and hence null hypothesis is rejected and hence data is found to be statistically significant to compare with control industries.

Hence, Management Systems on safety & health in Management System Elements need to be improved.

### **Declarations**

#### **Conflict of interest**

The authors declare that they have no conflict of interest.

#### **Data access statement**

No data's are attached.

#### **Ethics statement**

This work solely belongs to authors own research work.

#### **Funding statement**

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