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Original Article

Statistical Data Analysis in Emergency Management Elements of Indian State of Tamil Nadu Manufacturing Industries Utilizing LPG

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ABSTRACT

Introduction: Process safety is becoming more difficult as requirements increase. When balancing quality, volume, and safety on a budget, major accidents are unavoidable. The inability of organizations to absorb unwelcome and unanticipated disruptions is a major contributor to complacency and a decline in safety attitudes. The inability of industries to interpret standards impedes self-regulation.

Methods: A total of 50 emergency management element (EME) questionnaires were developed to evaluate the state of an industry. These questionnaires were categorized as first aid, personal protective equipment (PPE), communication systems used in plants, safety education and training, occupational hygiene and health, management systems on accident reporting, safety and health, analysis and investigation, and procedures and protocols. From 32 LPG industries in Tamil Nadu districts, information for all 50 questions was gathered and the statistical tool "Analysis ToolPak" in Excel 2010 was used to analyze the data.

Results: This study conducted a comprehensive statistical analysis of various aspects of industrial on-site emergency planning. The questionnaire's reliability was determined using Cronbach's alpha test. Utilizing descriptive statistics, t-tests for means, one-way ANOVA, and histograms, statistical evaluation was conducted. Encouragingly, all the results were favorable, providing compelling evidence that the LPG-utilizing industries in various regions of Tamil Nadu, India, are exceeding safety requirements.

Conclusion: In conclusion, the findings suggest that improved legal frameworks, laws, and implementation of EME in communication systems can greatly enhance the development of safety in plants, fire protection, and emergency health services. These measures can significantly reduce the occurrence of accidents and improve the response time to emergencies, ultimately saving lives and reducing property damage.

Keywords: EME, Fire Protection, Safety

Introduction

Safety is defined as the state of being free or protected from danger, accident, hazard, injury, damage, or risk.[1] It relates to the minimizing of human-hazard contact in an industrial setting and is primarily concerned with preventing physical harm to people or property. An emergency is defined as an accident or incident with the potential to cause serious damage or death. It might cause major property damage, interrupt manufacturing and factory activities, and have a harmful influence on the environment.[2-4] Major accidents with fire,[5] explosion,[6] and toxic releases can happen in factories, and those that store and handle chemicals that pose fire, explosion, and toxic hazards above a threshold level are known as "Major Accident Hazard (MAH) Factories.[7]

The main technical and functional requirements of a new Complex Emergency Management System (known as SiGES) that was constructed in July 2003 at the Porto Marghera petrochemical complex, close to Venice, were outlined.[8] On the property, nine chemical manufacturing facilities produce a wide range of potentially dangerous substances, including ethylene, propylene, butadiene, chlorine, vinyl chloride, hydrogen cyanide, toluene di-isocyanate, hydrogen fluoride, etc. Local policies for industrial risk prevention in Italy were discussed in some detail.[9] They updated the document, and then a genuine accident happened to highlight the planning's shortcomings. As part of their report, they also mentioned that the lessons learned from this experience suggested some multi-organizational directions and methodological approaches for future studies on risk management and communication.

HSEM, a sophisticated multilayered emergency management system, was defined.[10] According to their information, the HSEM is a thorough model that considers risk assessment, disaster prevention, mitigation, and preparedness. Additionally, they stated that this model was thought to be dynamic and capable of maintaining multiple interdependencies between events, actions, actors, context, and the other elements of the process. The accident emergency management system at the chemical industrial park was analyzed.[11] It detailed the parallels between the immune system and the accident emergency management system in terms of their current environments, action objects, functions, and adjustment mechanisms. As a result, they were able to improve the accident emergency management system in chemical industrial parks and analyze how well it performed overall.

The study focused on disaster simulation and its relationship to emergency management and contemporary simulation, enhancing its assistance to first responders, the dynamic response to crisis evolution, as well as the improvement in training and management of safe routing and handling of injured people.[12] To federate multidisciplinary models for industrial plant emergency management, a new line of research into the use of interoperable simulation was created with the introduction of these components. A Petri-net based simulation approach is suggested examination of the fire emergency response preparedness, which is structured to combat one of the flames but can handle multiple fires.[13] They discovered that while the distribution strategy based on fire severity is generally preferable to the average distribution, there are some circumstances where it is more effective. Additionally, it was stated that the various backup staffing strategies had been contrasted and that the fire conditions also affected how well the backup staffing was working.

The research on how the NEMS handled problems with group decision-making during times of crisis was finished in 2016.[14] To identify elements that hinder or support collaborative sense-making, it looks at several recent crises in China. They discovered a lack of professionalization, misaligned plans with crises, a lack of accountability, and fragmented leadership. It is further stated that the newly constructed NEMS finds it challenging to develop a shared understanding of a crisis because of these crucial factors. The information in a few gathered emergency scenarios was evaluated utilizing the CA approach.[15] That was the overarching pattern they found in the scenario descriptions. Additionally, most scenarios were designed to enhance response-related capabilities. The prevention and recovery capabilities, among other crucially important needed capabilities, were disregarded.

A novel methodological approach to simulating human errors in emergencies was proposed.[16] After researching the various aspects of human behavior that can affect operator reliability. They created a brand-new model based on the combination of fuzzy cognitive mapping methods and the Analytic Hierarchy Process (AHP), a multicriteria method for planning and deriving meaning from complex decisions. A detailed examination and evaluation of the occurrences of injuries, illnesses, and accidents at industrial sites, with a classification of the results based on the danger and salubrity of the manufacturing process.[17] They enabled users to assess the level of industrial and workplace safety continuously and impartially. They ultimately concluded that the implementation would significantly contribute to a thorough approach to the objective of raising safety levels at industrial sites.

Developed numerous strategies for utilizing big data in emergency management by merging the general design of the big data system with safety science ideas (EM).[18] Additionally, they showed that such techniques are repeatable and generalizable, allowing for the broad use of big data technology in the creation of operational applications across numerous EM industries. They stated that the safety risk monitoring and early warning system of hazardous chemicals established by the Ministry of Emergency Management, PRC further validated the viability of those technologies. A risk assessment approach for evacuating during hazardous cloud emissions was proposed.[19] They introduced the vulnerability model and accident probability to assess hazards. There was also a case study of the risk analysis of finding shelter in neighborhood residential dwellings in China.

The research on domino effects brought on by unintentional incidents, natural disasters, and intentional attacks over the previous 30 years was examined.[20] For the purpose of presenting the applicability of the current modeling methodologies and management tactics, a comparison study is done. They stated that to prevent and lessen domino effects, future studies should focus on strengthening the safety and security of chemical industrial regions and identifying key difficulties in the industry.

Following the establishment of the MEM, a bus accident in Chongqing's Wanzhou District was investigated.[21] Examining the issues that arose during the MEM's rescue procedure. To improve China's emergency management system, respond to incidents effectively, and safeguard public safety, they subsequently suggested making successful tactical improvements. In the process industry, emergency planning based on AI has been summarized.[22] They claimed that data-driven AI facilitates effective management of emergency planning. Traditional techniques were also unable to accurately extract features for emergencies.

To comprehend the variations in factors affecting health and safety that Korean workers may experience depending on their line of work, in particular to pinpoint the variations by employment type in terms of health status, the likelihood that workers will wear protective equipment, access to manuals on emotional expression, and information on risk factors affecting health and safety According to them, to improve the safety environment as primary health care providers by understanding factors related to the health and safety of part-time workers, the health and safety manager will require education and consultation, manual development, and early intervention.[23]

The threat zones have been calculated and potential scenarios of benzene dispersion from a poorly situated gas station in the city of Douala have been modeled.[24] The predicted threat zones are more dangerous for the gas station's employees, who are also significantly exposed to nearby homes and social infrastructure. If more research is done to examine the combined effects of gasoline emissions, it may be possible to determine whether the effects of benzene and other chemicals combined have cumulative or synergistic effects.

Examining the process safety management readiness system in major accident-prone factories that handle and store hazardous chemicals is the goal of this study. The creation of a questionnaire, data collecting, and statistical analysis of the LPG sectors are used to complete this study. In Excel 2019's "Analysis ToolPak," statistical techniques were employed to analyze the data. The article identifies gaps in the current on-site emergency planning at MAH Factories that handle and store hazardous chemicals and offers suggestions for strengthening emergency management components.

Methods

The complexity of process safety is increasing as higher standards are established. The industry's incapacity to comprehend these regulations hinders self-governance. For this study, the emergency management element questionnaire was developed considering MAH factories' requirement for on-site emergency planning. The Emergency Management Elements were categorized into ten categories (Figure 1).

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 data for all 50 questions were gathered from these factories through coordination and on-site visits. The collected data were analyzed using the statistical tool "Analysis TookPak" in Excel 2010. The questionnaire was evaluated statistically for descriptive statistics, t-test for means, one-way ANOVA, and histogram.

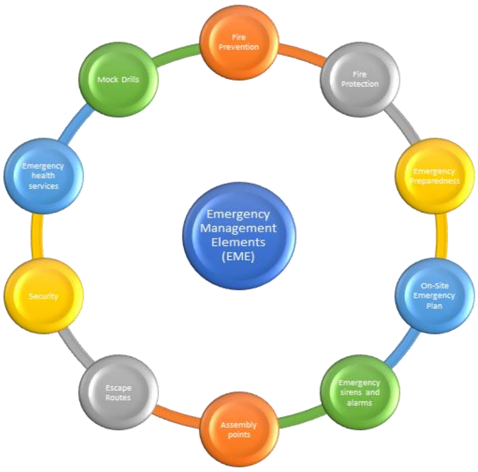

Figure 1: Emergency Management Elements

Results

The questionnaires used in this study were classified into several categories, including first aid, personal protective equipment (PPE), communication systems in industrial plants, safety education and training, occupational hygiene and health, accident reporting management systems, safety and health analysis and investigation, as well as procedures and protocols. Data for all 50 questions were collected and examined from 32 LPG industries located in the districts of Tamil Nadu.

For the data analysis, the statistical tool "Analysis ToolPak" in Excel 2010 was employed. This study conducted a comprehensive statistical analysis of various aspects of on-site emergency preparedness in industries. The reliability of the questionnaire was assessed using Cronbach's alpha test. Subsequently, descriptive statistics, t-tests for means, one-way ANOVA, and histograms were utilized to evaluate the questionnaire statistically.

The topics of Emergency Sirens and Alarms, as well as Escape Routes, exhibited a normal distribution with mean, median, and mode values converging to zero. Conversely, other topics displayed unequal means, medians, and modes, indicating skewed distributions. The topics of Fire Protection, Emergency Preparedness, On-site Emergency Plans, Assembly points, and Security yielded p-values greater than 0.05 and F<Fcrit, signifying statistical insignificance. These topics do not require improvement.

However, Fire Prevention, Emergency Health Services, and Mock drills demonstrated p-values less than 0.05 and F>Fcrit, indicating statistical significance. Thus, industries need to enhance their performance in these areas. Furthermore, the topics of Fire Prevention, Assembly points, and Emergency Health Services exhibited relatively lower skewness and kurtosis, suggesting the need for improvement in Fire Prevention and Emergency Health Services.

SHV Energy Pvt Ltd, followed by Patwari Bakers, Hindustan Petroleum Corporation, Daewon India Autoparts Pvt Ltd, and SHV Energy Pvt Ltd Tuticorin, are required to prioritize the fulfillment of the complete set of questionnaires pertaining to Emergency Management Elements (Figure 2).

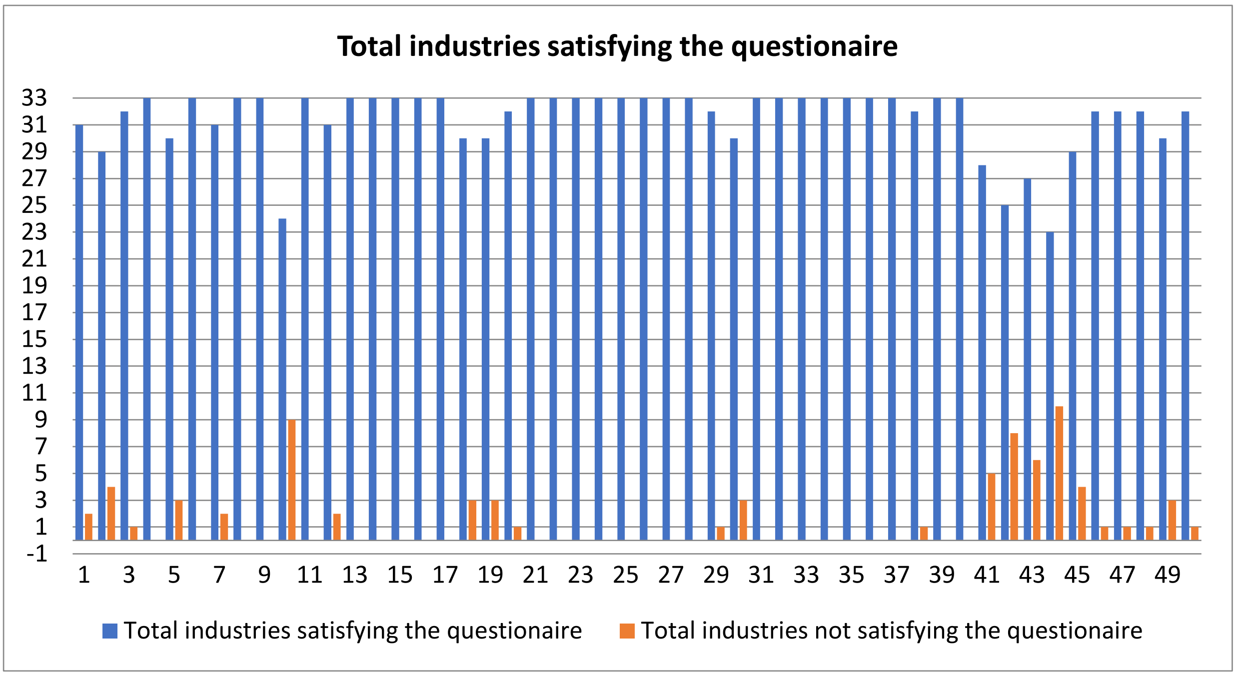

Figure 2: Total number of factories satisfying EME questionnaire

Table 1: Descriptive statistics

Parameters	Total control	Total industries satisfying the questionnaire
Mean	33	31.5
Standard Error	0	0.34
Median	33	33
Mode	33	33
Standard Deviation	0	2.43
Sample Variance	0	5.93
Kurtosis	∞	4.007
Skewness	∞	-2.063
Range	0	10
Minimum	33	23
Maximum	33	33
Sum	1650	1575
Count	50	50
Largest(1)	33	33
Smallest(1)	33	23
Confidence Level(95.0%)	0	0.69

Mean ≠ Median; SD and variance present

The data follows left skewed distribution with outliers (Kurtosis>3). This shows that all industries do not follow the same trend in the follow-up of a questionnaire. To look for the forecasted values, a confidence level with a 95% probability for the mean is calculated and reported. The data has a CI of 0.69 and hence the mean has 30.81 as the lower limit and 32.19 as the upper limit (Table 1).

In one-way ANOVA analysis, the p-value is less than 0.05 and the F value is greater than the F critic (Table 2). Hence, the null hypothesis is rejected when compared between columns and the data is statistically significant. Hence, overall data for emergency management elements need to be improved.

Table 2: One way ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	56.25	1	56.25	18.981	3.26135E-05	3.94
Within Groups	290.5	98	2.964285714			
Total	346.75	99				

Industry-wise comparison of emergency management elements

The industry-wise comparison of the different emergency management elements is given below (Table 3). The industries that satisfied all the questionnaires are as follows:

1. Control Industries
2. Covai LPG
3. Hindustan Petroleum Corporation
4. Indian Oil Corporation Ltd Sivagangai
5. Shv Energy Pvt Ltd
6. Meena LPG Industries Madukkarai
7. Shv Energy Pvt Ltd
8. Bharat Petroleum Corporation Limited
9. Meena LPG Industries
10. Patwari Bakers
11. Daewon India Autoparts Pvt Ltd
12. Dongwoo Surfacetech India Pvt Ltd
13. Hanon Automotive Systems India Pvt Ltd
14. India Yamaha Motor
15. Lotte India Corporation Limited
16. SSTP, BHEL
17. Sundaram Fastners Limited
18. Shv Energy Private Limited, Tuticorin

Table 3: Industry-wise comparison of emergency management elements

Industry Parameters	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Mean	1	0.92	0.88	0.92	0.78	0.88	0.878	0.9	0.88	0.82	0.94	0.96	0.98	0.939	0.96	0.98	0.98	0.94
Standard Error	0	0.039	0.046	0.039	0.059	0.046	0.047	0.043	0.046	0.055	0.034	0.028	0.02	0.0346	0.028	0.02	0.02	0.034
Median	1	1	1	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	1	1	1
Standard Deviation	0	0.274	0.328	0.274	0.418	0.328	0.331	0.303	0.328	0.388	0.240	0.198	0.141	0.242	0.198	0.141	0.141	0.240
Sample Variance	0	0.075	0.108	0.075	0.175	0.108	0.109	0.092	0.108	0.151	0.058	0.0392	0.02	0.059	0.0392	0.02	0.02	0.058
Kurtosis	∞	8.534	3.974	8.534	-0.061	3.974	3.803	5.792	3.974	0.989	13.12	22.331	50	12.787	22.331	50	50	13.124
Skewness	∞	-3.193	-2.412	-3.193	-1.394	-2.411	-2.377	-2.750	-2.412	-1.718	-3.821	-4.841	-7.071	-3.778	-4.841	-7.071	-7.071	-3.821
Range	0	1	1	1	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	0	0	0
Maximum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sum	50	46	44	46	39	44	43	45	44	41	47	48	49	46	48	49	49	47
Count	50	50	50	50	50	50	49	50	50	50	50	50	50	49	50	50	50	50
Largest(1)	1	1	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	0	0	0
Confidence Level (95.0%)	0	0.078	0.093	0.078	0.119	0.093	0.095	0.086	0.0933	0.110	0.068	0.056	0.0402	0.0698	0.056	0.0402	0.040	0.068
F		4.261	6.682	4.261	13.821	6.682	6.836	5.444	6.682	10.756	3.128	2.042	1	3.195	2.041666667	1	1	3.128
p-value		0.042	0.011	0.042	0.0003	0.011	0.0104	0.0217	0.011	0.0014	0.0800	0.156	0.320	0.0770	0.156	0.320	0.320	0.080
F-crit		3.938	3.938	3.938	3.938	3.938	3.939	3.938	3.938	3.938	3.938	3.938	3.938	3.939	3.938	3.938	3.938	3.938

Discussion

When comparing the mean, median, and mode, it is observed that the median is equal to the mode. However, the mean deviates for industries that do not adhere to the entire questionnaire. The standard deviation (SD) is higher for SHV Energy Pvt Ltd, indicating a larger sample variance. Furthermore, Hanon Automotive Systems India Pvt Ltd, SSTP, BHEL, and Sundaram Fastners Limited exhibit higher kurtosis, indicating the presence of outliers and skewed distribution.

Daewon India Autoparts Pvt Ltd, Dongwoo SurfaceTech India Pvt Ltd, Hanon Automotive Systems India Pvt Ltd, India Yamaha Motor, Lotte India Corporation Ltd, SSTP, BHEL, Sundaram Fastners Limited, SHV Energy Pvt Ltd Tuticorin have p-values greater than 0.05 and F<Fcrit. Consequently, the null hypothesis is not rejected, indicating statistical insignificance when these industries are compared. Hence, there is no significant need for improvement in these industries.

On the other hand, Covai LPG, Hindustan Petroleum Corporation, Indian Oil Corporation Ltd Sivagangai, SHV Energy Pvt Ltd, Meena LPG Industries Madukkarai, SHV Energy Pvt Ltd Tuticorin, Bharat Petroleum Corporation Ltd, Meena LPG Industries, Patwari Bakers exhibit p-values less than 0.05 and F>Fcrit, leading to the rejection of the null hypothesis. Therefore, the data is found to be statistically significant when compared with control industries. These industries need to improve their adherence to the questionnaire.

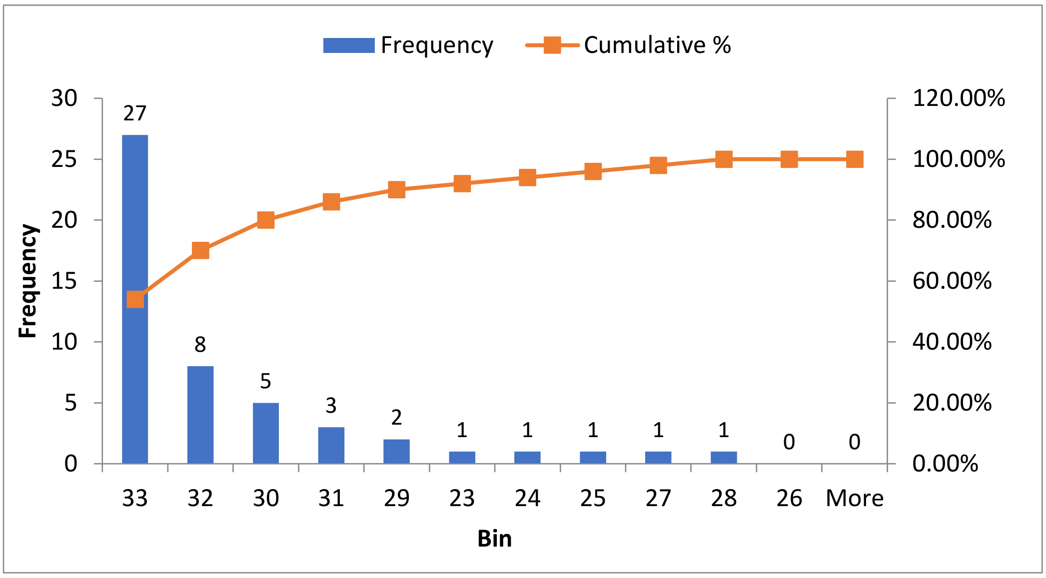

Figure - 3. Histogram for emergency management elements

The first two bars in the histogram above indicate that 35 questionnaires were followed by at least 32 industries or more (Figure 3). The remaining 15 questionnaires must be improved overall. They are as follows:

1. Have all the fires/incidents been investigated and corrective actions taken?
2. Whether the fire load study conducted in the plant?
3. Whether the flammable substances are periodically removed from the plant?
4. Do you have fixed or automatic firefighting installation(s) in your plant?
5. Are all self-closing fire doors in good condition and free from obstructions?
6. Whether the on-site emergency plan has been approved by CIF/DISH
7. Whether the updated emergency plan approved by CIF/DISH periodically?
8. Whether the fire NOC obtained from the fire department?
9. Whether an alternate assembly point is identified and specified?
10. Whether the plant has an Occupational health center? Is it under the control of a medical officer?

11. Whether the Occupational Health Centre has adequate paramedical staff?
12. Whether the Occupational Health Centre equipped with all facilities and antidotes?
13. Whether the plant maintain a dedicated Ambulance van for use in case of any emergency?
14. Whether nearby hospital facilities are available for emergency medical care?
15. Whether all the Truck and vehicle drivers and cleaners are involved in the onsite emergency mock drills

Analyzing overall data, most of the questionnaires were satisfied. However, a little more improvement is required.

Conclusions

Upon analyzing the entire data statistically, it is observed that the mean value is not equal to the median value and therefore the data is asymmetrically distributed. The mean value of YES status is lesser than its median value for some items and greater for some items. Hence, the items of YES status distributed are not symmetric about the mean but skewed left or right. The data points deviate from the sample mean and hence there exists standard error and variance values described. Confidence Interval values are calculated to explain the reliability of the estimate and likely to contain a value of an unknown population parameter and to check whether the predictions fall within this confidence interval.

Overall, the industries Covai LPG Pvt Ltd, Hindustan Petroleum Corporation, Meena LPG Industries Madukkarai, SHV Energy Pvt Ltd, Meena LPG Industries and Patwari Bakers have p-value less than alpha value (0.05) and F is greater than Fcrit and reject the null hypothesis. Hence, the data is statistically significant compared with control. Hence, the above-mentioned six industries need to be improved in satisfying the questionnaire set on Emergency Management Elements.

Overall, four topics Communication Systems adopted in the plant, Fire Protection, Emergency Health Services in Emergency Management Elements need to be improved.

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