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Analytical Hierarchy Process Based Fire Emergency Response for Off-Shore Platform

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Abstract:-This study is aimed at developing an Analytical Hierarchy Process based fire emergency response for off-shore platform. The study area was limited to the Niger Delta region of Nigeria. Structured questionnaires were the major instruments employed for data collection with a total study population of 570 respondents randomly sampled among oil and gas companies. Analytical Hierarchy Process (AHP) was the methodology employed for model development for effective operations of an emergency fire response system. The output from the analyses showed that Administrative factors should be given the highest priority (53.5%) with respect to developing an effective emergency fire response system, this was followed by engineering/design factor (26.6%), human factor (11.2%) and finally legal/other factors (8.7%).

Keywords:-Emergency Fire Response System, Administrative Factors, Human Factors, Engineering/Design Factors, Analytical Hierarchy Process.

I. INTRODUCTION

The world experienced the worst oil rig disaster recorded in the history of man on July, 1988 with death toll of one hundred and sixty-seven (167) out of the two hundred and thirty-two(232) people on board. Literature has it that the initial cause of the incidence was a gas leak (Netfirms, 2015). Since then, emergency and disaster response have gained increased attention. Fire Emergencies occur in spite of sophisticated and advanced measures put in place to prevent fires. However, when they occur, the minimization of loss, protection of personnel, asset, and the environment can be achieved through proper implementation of an appropriate emergency response plan. Response to these emergencies will depend on the capabilities and scope of the existing manpower and resources available. In offshore oil field operations, fire disasters are known to be of low frequency of occurrence but have high severity of impact. In onshore operations, they occur more often with equally devastating consequences. The key factor to a rapid response in an emergency situation is the effectiveness of communications, procedure and training (Moore, 2008).Without prompt emergency response intervention, impacts to lives, environment and property escalate. The accident public enquiry report (Cullen, 1990) revealed that bad communication and administration hitches were major causes of the accident. There are multiple reasons for success or failure of emergency response management. However, one of the obvious reasons is that of response time. The time it will take for personnel to recognize and respond to the fire alarm triggers and ultimately arrive at safe place or muster point and time for the fire response team to mobilize and intervene in a fire emergency will determine the chances of survival of workers exposed to the fire. Thus, this study is aimed at developing an operational model for setting up as effective emergency fire response system as applied to basically off-shore platforms.

II. MATERIALS AND METHODS

A. Study Area

The study area for this study was limited to the Niger Delta region of Nigeria. The Niger Delta region occupies about 7.5% (70,000 Km2) of the total land mass of Nigeria. It is bounded on the south by the Gulf of Guinea within the Atlantic Ocean and on the east by Cameroon. It lies on coordinates 05º 19' 34" N, 06º28' 15" E. This region is the hub of oil and gas exploration in Nigeria. It comprises of nine States: Akwa-Ibom, Rivers State, Bayelsa, Cross River, Delta, Edo, Imo, Abia, and Ondo State. This region generates about 90% of Nigeria's foreign exchange earnings (Akalonu et al., 2017), thus making it the main stay of Nigeria's economy. Figure 1 present map of Nigeria showing the region of the Niger Delta and the States within it.

Fig. 1: Map of Nigeria showing the region of the Niger Delta and the States within Them.

B. Data Collection

Data collected for this study were with the aid of oral interview, personal observations and questionnaires distributed to respondents (570 persons) actively involved in oil and gas exploratory activities (international and national oil companies). The collected data has to do with the pair-wise comparison of factors in relation to oil platform administration, design, policies, onboard communication, fire response procedures / drills, and general fire safety awareness. Table 1 presents the judgments rating scale employed for the pair-wise comparison by the respondents.

Scale of relative importance	Verbal/Logical Judgments	Explanations
1	Equally preferred	Two activities contribute equally to the objective
2	Equally to Moderately	When a compromise is needed
3	Moderately preferred	Experience and judgments slightly favour one activity over the other
4	Moderately to strongly	When a compromise is needed
5	Strongly preferred	Experience and judgments slightly favour one activity over the other
6	Strongly to very strongly	When a compromise is needed
7	Very strongly preferred	An activity is strongly favoured, and its dominance is demonstrated in practice
8	Very strongly to extremely	When a compromise is needed
9	Extremely preferred	The evidence favouring one activity over another is of highest possible order of affirmation

Source: Saaty (2008)

Table 1: Comparison/Judgment Scale

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Majority of the sampled respondents were workers with job specifications usually on oil platforms with an average work experience of three years. These job specifications include Health, Safety and Environmental (HSE) officer, riggers (tool pushers, electricians, mudlogger), top management staff (Rig managers and supervisors) and rig crane operators.

In the determination of the minimum sample size with respect to this study, the proportion formula (see Equation 1) as proposed by Cornish (2006) was used:

$$n_o = \frac{Z^2 pq}{e^2} \quad \text{...... (1)}$$

Where n_o = sample size; Z = 1.96, which is the level of significance and corresponds to 95% confidence level; p = maximum variability in the population assumed to be aware of fire safety response; and q = 1- p. e = percentage level of precision (±5%)

For IOC and NOC, p was assumed to be 95%.

Therefore, sample size

$$n_o = \frac{1.96^2 \times 0.95 \times 0.05}{0.5^2} = 72.99 \approx 73$$

For this study, the above estimated sample size was assumed as the minimum sample size for questionnaire distribution. However, atotal of five hundred and seventy (570)respondents were sampled from both international and national oil companies. The purposive sampling technique was applied for the choice of companies to sample while the simple random sampling technique was employed for general questionnaire distribution among respondents.

C. Data Analyses

The collected data were used to develop a model for operations with respect to emergency fire responses using Analytical Hierarchy Process (AHP). Analytical Hierarchy Process (AHP) uses hierarchical structures to model problems (starting with objectives, criteria, sub criteria, and alternatives) and then develop priorities for alternatives to aid decision making. Especially when faced with a complex problem having multiple conflicting and subjective criteria (Lai et al., 2002).For AHP model development the governing equations applied are presented by Equations 1-4 (Bovwe et al., 2016).

Equation (1) presents the structure of a pair wise comparison *matrix*, *A* which is the first step in AHP model development after the problem modeling has been established. This involves stating the major objective, criteria and sub-criteria of the proposed model (Brunelli,, 2015).

$$A = \left(a_{ij}\right)_{n\times n} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{21} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} \quad \text{...... (2)}$$

Taking each entry from the respondents as the ratio between two weights Equation 1 could be represented as Equation 2.

$$A = \left(\frac{w_i}{w_j}\right)_{n\times n} = \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{pmatrix} \quad \text{.... (3)}$$

Simplifying Equation 2, matrix A will be:

$$A = \begin{pmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{pmatrix} \quad \text{.... (4)}$$

Using Equation (3), the priority (weight) vector for criterion *j* by each respondent is given by Equation (4) as:

$$w_j = \frac{1}{n}\sum_{k=1}^{n}\left(\frac{a_{jk}}{\sum_{k=1}^{n} a_{jk}}\right) \quad \text{..... (5)}$$

For this study a web-based Analytical Hierarchy Process software developed and revised by Goepel (2016) was used as an aid in data analyses.

The develop model parameters with respect to this study are as presented. Major Criteria:

D. Model Parameters:

- *Objective Function:*

Effective Fire Emergency Response (y)

- *Major Criteria:*

  Administrative Factor (x_1);
  Engineering/Design Factor(x_2)
  Legal/other factors(x_3);
  Human Factors (x_4);

- *Sub-Criteria:*
  Training & Re-training (z_1);
  On Board Communication (z_2);
  Fire Response Procedures (z_3);
  Drilling Rig Safe Condition (z_4);
  Rig Design Layout (z_5);
  Position of firefighting Equipment (z_6);
  Fire safety policies (z_7);
  Certification & Re-certification for Fire Safety Regulators (z_8);
  Fire safety awareness (z_9); and
  Fire safety practices(z_{10}).

III. RESULTS AND DISCUSSION

A. Results

Taking the Objective function (Effective Fire Emergency Response =**y**) of the proposed model, the output from employing the web based AHP software is presented by Figure 2.

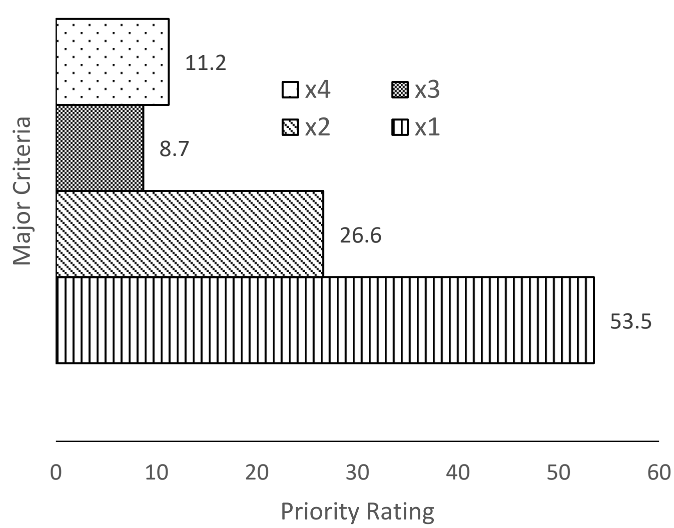

Fig. 2: Priority Rating of Major Criteria with Respect to the Objective Function.

Figures xxx presents the output from the web-based AHP software with respect to the Sub-criteria ranking as related to the major criteria

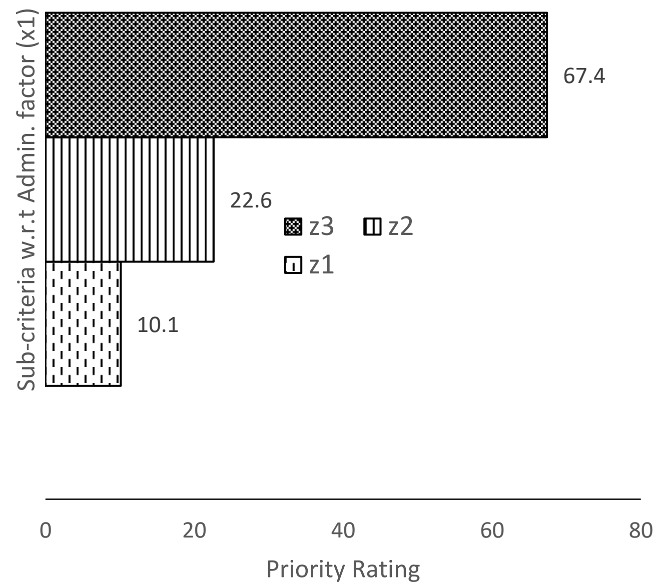

Fig. 3: Priority Rating of Sub- Criteria with Respect to the Administrative Factor.

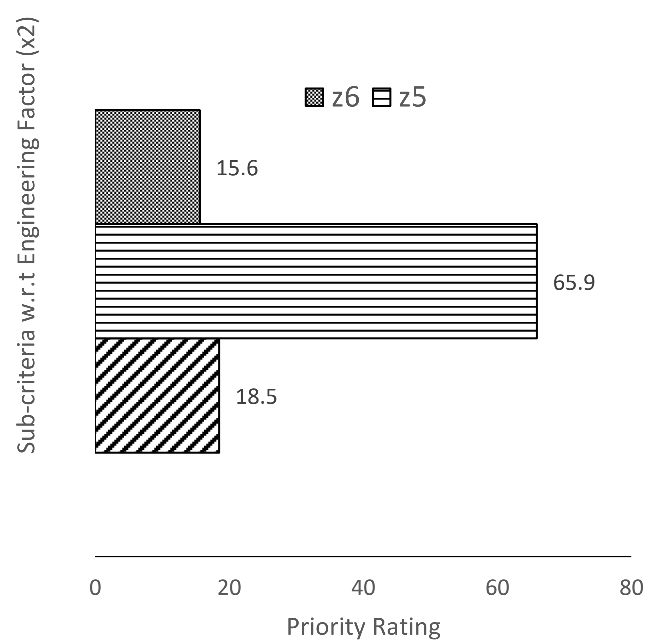

Fig. 4: Priority Rating of Sub- Criteria with Respect to the Engineering Factor.

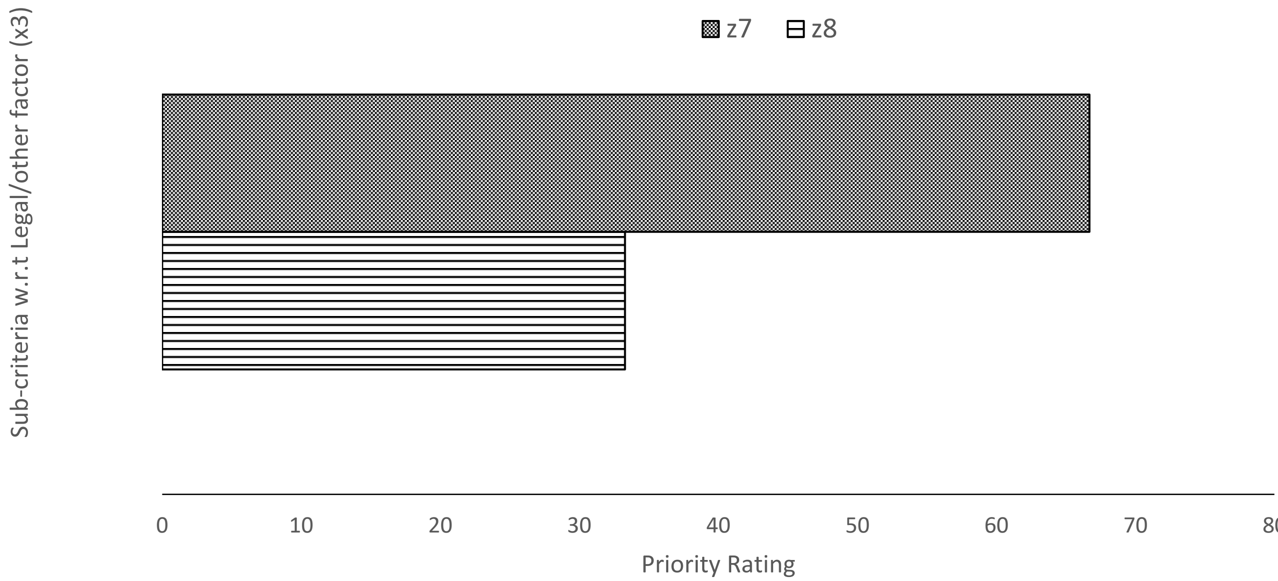

Fig. 5: Priority Rating of Sub- Criteria With Respect to the Legal/Other Factor

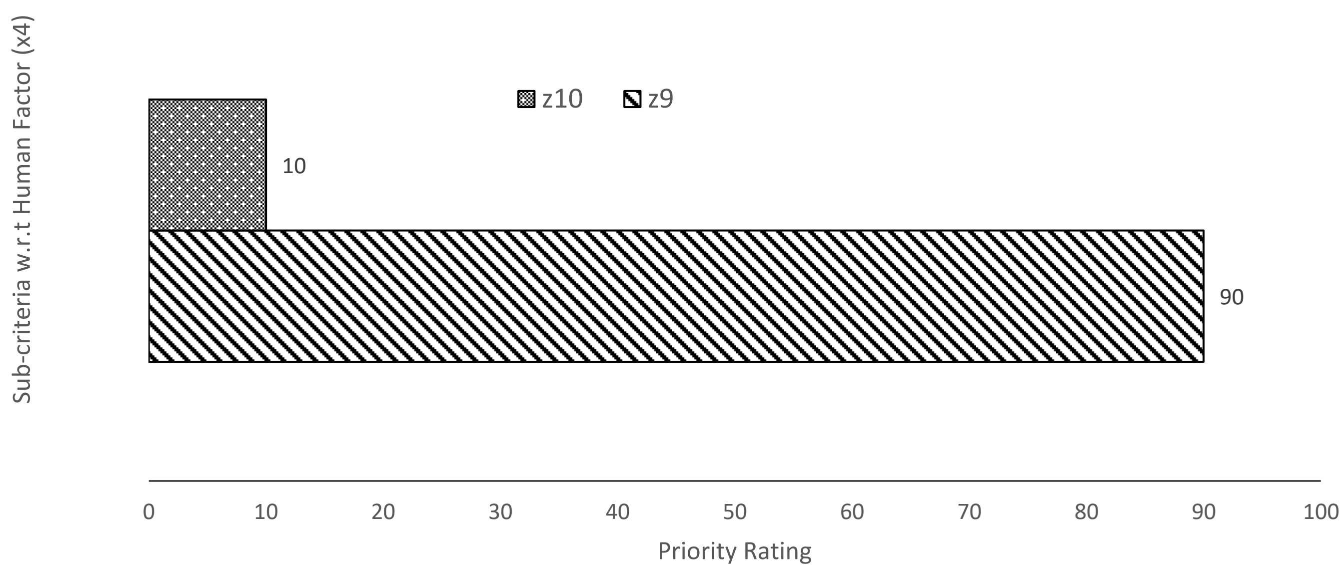

Fig. 6: Priority Rating of Sub- Criteria With Respect to the Human Factors

Finally, Figure 7 presents the assemblage of the proposed model (operations for an effective fire emergency response system) by taking the relative influences of the major criteria and their respective sub-criteria with respect to their respective priority ratings (see Table A1, Appendix A).

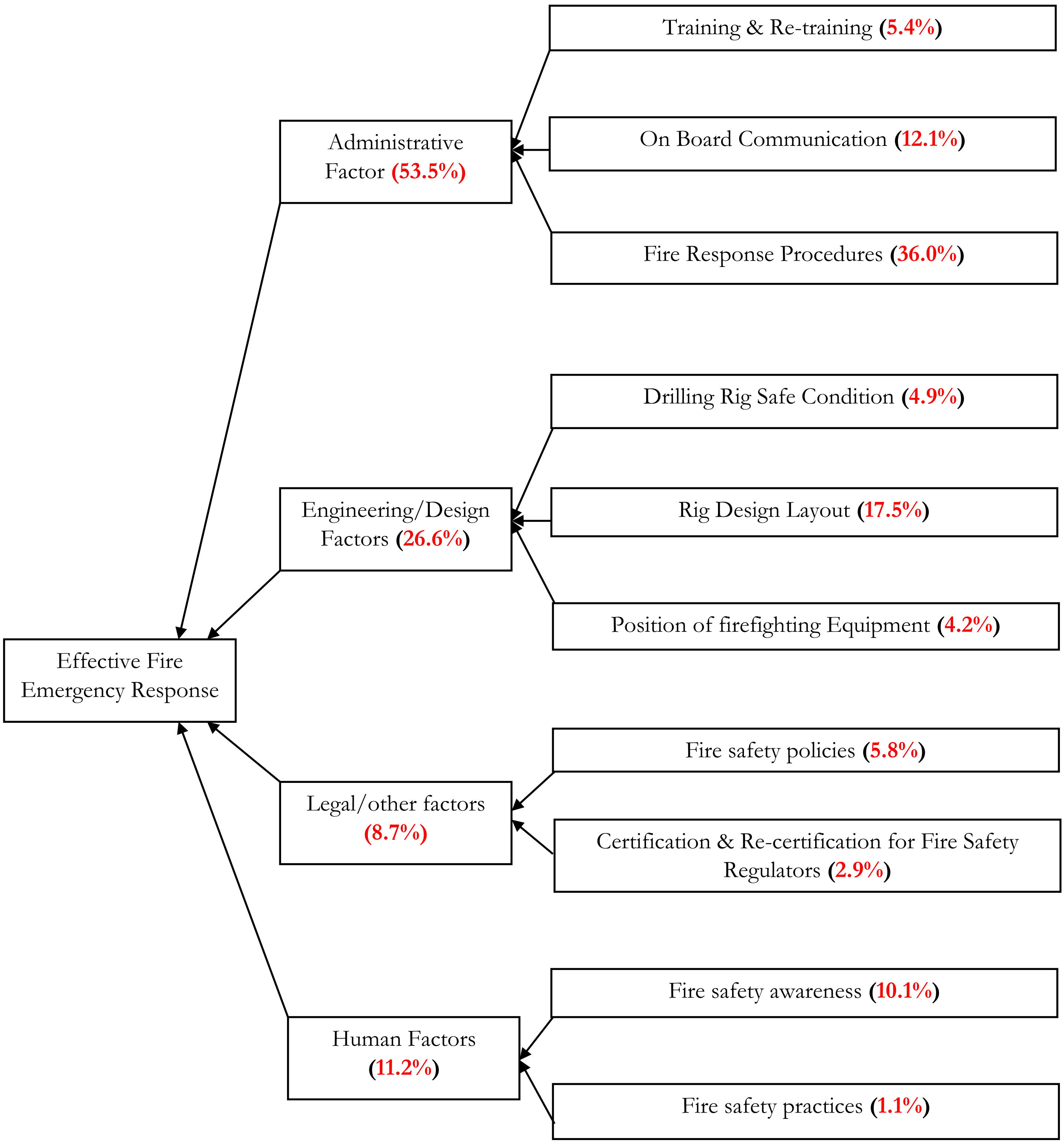

Fig. 7: Showing A Proposed Model for the Development of Operations for an Effective Fire Emergency Response System

B. Discussion

The output of the developed but proposed model for operations with respect to fire emergency response showed that for notable improvement in efficiency of the fire response system top priority should be given to Administrative factors (x_1 = 53.5%). These factors has to do with training & retraining, on board communication, fire response procedures but with the procedure for response to fire emergency by management toping the priorities with respect to administrative factors. It is interesting to note that training and retraining contribute the lowest (5.4%) compared to all the proposed administrative factors. This implies that as much as training and retraining has its place in the overall success of a fire emergency response system, on board communication effectiveness and adherence to laid down fire response procedure is critical. At the heart of the Alpha Piper incident of 1988, was communication issues and shunting of established procedures (NSC, 2013). This finding is in agreement with the study of Narimannejad et al., (2015) who worked on emergency response management native model to reduce environmental impact in an oil and petrochemical industry using AHP. Engineering/design factors (x_2) ranked second (26.6%) in the order of priority when it has to do with influencing factors for efficient fire emergency response. With respect to the engineering /design factor, rig design layout ranked the highest (17.5%). This supports the clamoring for operators to modify their platform designs so as to improve efficiency response efficiency in fire emergency situations. Such modifications should include expansion of the width of the traffic routes, especially those leading to muster points or safe havens, making the stair risers and landing less steep to support escape during emergency.

With respect to the developed but proposed model for the development of an efficient fire emergency response system, the influence3 of the human factor to its success ranked third (11.2%). Awareness of fire safety and its practices contribute weightings of 1.1and 10.1%, respectively with respect to their influence on human factor as far as efficient fire safety response is concern. Awareness talks about knowledge and exposure to fire safety through shared resources and learning experiences. It also involves how work related conditions will affect the situational awareness of a worker in the course of carrying out his job task and it might affect his response to fire emergency. The least contributing factor with respect to the developed but proposed model was legal/other factors (8.7%).

IV. CONCLUSION

The following conclusions were drawn from this study:

- When it has to do with effective emergency fire safety response system, Administrative factors should be given the highest priority.
- With respect to administrative factors, fire response procedure ranked the highest and should be considered of almost importance during the development of a fire emergency response system in order to achieve a notable level of emergency fire response.
- The safety design/ layout of an offshore platform ranked the highest with respect to engineering / design factor of an emergency fire response system for offshore platform.
- When it has to do with human factor with respect to efficient fire safety emergency response system, the awareness level of the personnel on board is of highest priority.

V. RECOMMENDATION

For the development of operations for an effective fire emergency response system for offshore platforms, this study recommend that administrative factors be given topmost priority, followed by engineering/design factor, then human factor and finally legal/other factors.

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APPENDIX A

Summary of AHP Model Output

<table>
<tr><td rowspan="10">Effective Fire Emergency Response (y) =100%</td><td rowspan="3">Administrative Factor (x_1) = 53.5%</td><td>Training & Re-training (z_1) =5.4 (10.1%)</td></tr>
<tr><td>On Board Communication (z_2) = 12.1 (22.6%)</td></tr>
<tr><td>Fire Response Procedures (z_3) = 36 (67.4%)</td></tr>
<tr><td rowspan="3">Engineering/Design Factors (x_2) = 26.6%</td><td>Drilling Rig Safe Condition (z_4) =4.9 (18.5%)</td></tr>
<tr><td>Rig Design Layout (z_5) = 17.5 (65.9%)</td></tr>
<tr><td>Position of firefighting Equipment (z_6) = 4.2 (15.6%)</td></tr>
<tr><td rowspan="2">Legal/other factors (x_3) = 8.7%</td><td>Fire safety policies (z_7) = 5.8 (66.6%)</td></tr>
<tr><td>Certification & Re-certification for Fire Safety Regulators (z_8) = 2.9 (33.2%)</td></tr>
<tr><td rowspan="2">Human Factors (x_4) = 11.2%</td><td>Fire safety awareness (z_9) = 10.1 (90.0%)</td></tr>
<tr><td>Fire safety practices (z_{10}) = 1.1 (10.0%)</td></tr>
</table>

Table A1: Resultant from AHP Model with Respect to Effective Fire Emergency Response