PERINTIS eJournal

PERINTIS eJournal, **2017**, Vol. 7, No. 1, pp. 20-30

EGRESS TIME ANALYSIS FOR LEDANG FLOATING, PRODUCTION, STORAGE AND OFFLOADING UNIT USING EVACUATIONZ

Nur Amilia Zainudin and Mohd Zahirasri Mohd Tohir*

Department of Chemical and Envrionmental Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor Darul Ehsan, Malaysia

*Corresponding author: zahirasri@upm.edu.my

ABSTRACT

The paper proposes a Monte Carlo probabilistic model in estimating egress time from Musolla to the muster area of Ledang Floating, Production, Storage and Offloading (FPSO) unit using EvacuatioNZ software. The complexity of the egress process is associated with the behaviour of occupants throughout the egress process. Hence the objective of the paper is to quantitatively establish the endurance time of egress process by validating several components of human behaviour in the EvacuatioNZ simulation. Human behavior factors such as human re-entry after escaping and crowd behavior are taken into consideration prior simulation runs of the egress process. From the simulation, the range of evacuation times from the origin point of escape to the muster area is estimated to be between 7.17 min to 18.78 min with a mean of 11.28 min.

Keywords: *Fire evacuation, Egress time, EvacuatioNZ, Probabilistic simulation.*

1.0 INTRODUCTION

Safety of personnel and protection of costly assets are of overriding concern on all offshore oil and gas sectors i.e. of platform structure or vessels like Floating, Production, Storage and Offloading (FPSO) unit. Consequently, rigid and comprehensive demands have been placed on hazard and risk management for offshore facilities. According to United Kingdom Health, Safety and Environment (UKHSE) Regulation [1], the management and workers at all levels must analyze their own activities in detail as to understand how dangerous such scenarios can occur and develop, and to what extent the consequences of the scenarios may have. Safety and contingency measures then must be commensurate with the risk in each individual activity. The higher the risk, the more numerous and wide-ranging safety measures must be implemented. The design of facilities, the choice of technical solutions with good inherent safety characteristics and the choice of effective barriers are included in the measures to prevent undesirable incidents.

The provision of adequate facilities and provisions for the safe complete emergency Escape, Evacuation and Rescue (EER) System are one of the essential inherent safety elements for offshore facilities. The provision plays a vital role for safe operation and for use of any personnel on board (POB) in the event of a major accident in the offshore facilities. This was recognized by Lord Cullen during the public inquiry into the Piper Alpha disaster. One of the most important aspects of EER which has received scant attention until recently is human factor.

Anecdotally, it was assumed that in an emergency that "panic" or irrational behaviour is the cause of someone's acting in the incorrect manner and contributes to injury and death. In fact, studies of a number of recent incidents such as Kings Cross underground tube fire in 1987 [2] have indicated that the errors made were not due to panic but inappropriate decisions were made because of a variety of reasons including; ambiguity and confusion, incoherent instruction, time wasting actions, lack of appropriate instructions, misunderstanding of the nature of the emergency and lack of acceptance of the authority of a source of instructions.

Although adequate EER system has been installed, the ability to integrate the human behaviour into the system accurately need to be considered and not to be overlooked. Understanding on how individuals respond and behave in the case of emergency is essential as this is one of the component that can contribute to bring fire safety measure into line with individuals' needs during an incident [3]. The assessment on human behavioural in EER is a fundamental in estimation total EER time whereby this time depends on human capability to perceive and interpret danger signal and to carry out several actions before make a move to a safe place [4]. The personnel's behavioural at the initial stage of the emergency is the most important factor in determining their chance of surviving the event [4]. Hence, this paper will briefly outline the integration of human behaviour in determining the egress time from a worst-case scenario in FPSO Ledang using EvacuatioNZ software.

2.0 EVACUATIONZ

The evacuation model of EvacuatioNZ is a coarse network model incorporates the Monte Carlo approach with unlimited simulations that simulates the occupants' behaviour and the evacuation times to the exits throughout the evacuation process. The programme is written in C++ language using Microsoft Visual C++ (Version 6.0) which can simply be modified or developed for further research. Moreover, since C++ is a common language code and widely used in the engineering field hence it can be linked with other language codes if applicable easily.

Generally, this model is a node-based whereby each component of the building is treated as an individual node. The maximum number of occupants in the node is calculated based on the dimension of each node that has been specified. For conservative estimation, the travel distance in the model is represented by the length from the corner of one room to the center of the other room. Ko [5], Xiang [6] and Teo [7] has done a systematical validation of EvacuatioNZ by carrying out a various component testing to verify the performance in order to provide satisfactory results such as door queuing and movement on stairs. Based on the validation, the model can produce comparable results to hand calculation. The version used for this research is EvacuatioNZ version 1.2.

2.1 Input Files

MAP, POPULATE, SIMULATION, SCENARIO, PERSON TYPE and EXIT BEHAVIOUR are six elements used as input files. Basically, these files can be divided into two categories; physical aspects and behavioural aspects. MAP, POPULATE, SIMULATION and SCENARIO are related to the physical aspects to the defined scenarios while PERSON TYPE and EXIT BEHAVIOUR are related to the behavioural aspects of the occupants concerned. These files are formatted in Extensible Mark-up Language (XML), which is correlated to the Hyper Text Mark-up Language (HTML). Hence to reduce the possibility of input errors, it is advisable for the user to have a basic knowledge of using these types of language codes [8].

2.2 Output Files

Three major output files are generated by the current EvacuatioNZ named CONNECTIONS, LOG ACTION and NODES in Comma Separated Values (CSV) file and can directly be imported into the Excel worksheet for users to further analyse the probability distributions for risk assessment. Further, a detailed description for each simulation is provided in LOG file. These includes the time when the simulation is run, input and output files status, number of evacuees and the total evacuation time. The flow of occupants through each connection are recorded in the CONNECTION file. It then shows the use of each exit path during evacuation event. The NODES file on the other hand offers similar information to the CONNECTIONS file but it is highlighted for each node to allow the user to observe the potential of blockage in the building and identify further the usage of each node in respect to the occupant quantity for an egress system. The probabilities of several actions that are anticipated to be performed by the occupants during the evacuation are recorded in the LOG ACTION file. The probabilities calculated is then add up to 100 percent at each time step. Additionally, several other output files regarding occupant pre-evacuation time are available in the PERSON TYPE file; total evacuation times for batch runs simulated via SCENARIO file; and log files with detailed individual movement generated in the POPULATE file [8].

3.0 METHODOLOGY

The simulation and analysis of the egress time was conducted using EvacuatioNZ Software Version 1.2 which uses Monte Carlo network evacuation model in producing statistical distributions of egress times of each personnel evacuating in the event of fire. The software was able to collect results from repeated simulations of a specified scenario in a relatively brief time [8].

3.1 Determining Governing Design Scenario

In reality, there are unlimited amount of evacuation scenarios can be formed since there are a lot of factors are associated such as the geometry of the building, the number of people evacuating the building, type of person, etc. There is always an uncertainty on what situation the evacuees would be in. Hence, for this work, the worst possible scenario imagined is selected to be the starting point for simulation purposes.

A conventional method for calculation of evacuation time is by taking the area of farthest point, highest elevation and the lowest elevation to the muster area. However, the debate about whether the farthest point can be considered as worst-case scenario for the evacuation time calculation has gained fresh prominence with some arguing that the worst-case scenario should be measured based on other factors as well. Peculiar to contemporary textual sources, the relative importance of human behaviour in coping the emergency escape and evacuation process proposed and gave an idea to conduct the evacuation time estimation in a slightly different method.

Thus, specifically for this study, the point of evacuation origin is selected based on the highest number of personnel and the most crowded the area can be at a certain time. Based on ‘Project Manning Distribution Data’, maximum 30 personnel will attend the FPSO during normal operation. Moreover, the Manning Distribution Data [9] specifies that each personnel spend most of their time at the Accommodation Block generally. Therefore, as a conservative approach it is probable to assume that all these 30 people are gathered in the Musolla at the C Deck of Accommodation Block suggested there is an event which required everyone to be presented there. Therefore, Musolla is selected as point of origin during the emergency event for the governing case scenario instead of any other farthest point to explore the significance.

For this study, the simulation is limited to model for time to escape from the Musolla which is located at C deck to the muster area which is located at A deck. The graphical representation for the escape journey from the Musolla to the muster area used for the simulation are presented in Figure 1 and 2 below:

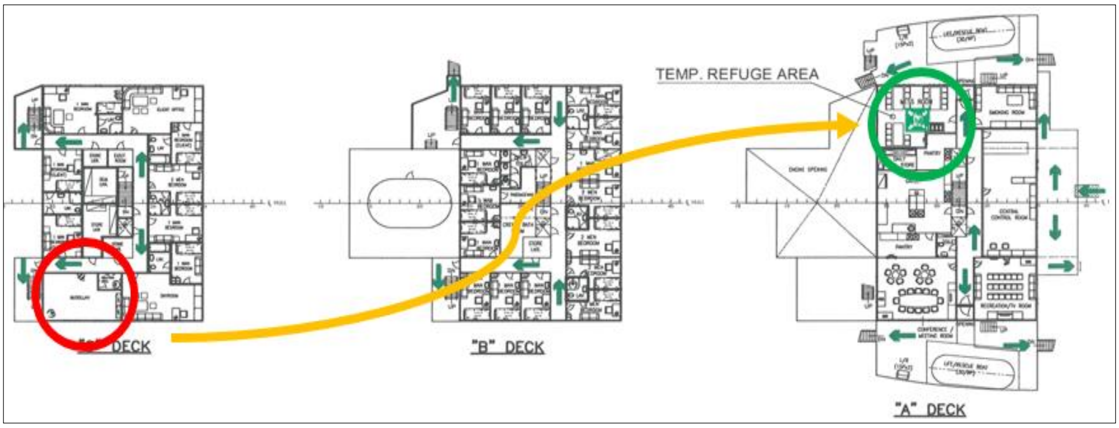

Figure 1. Layout of escape route from Musolla to the muster area.

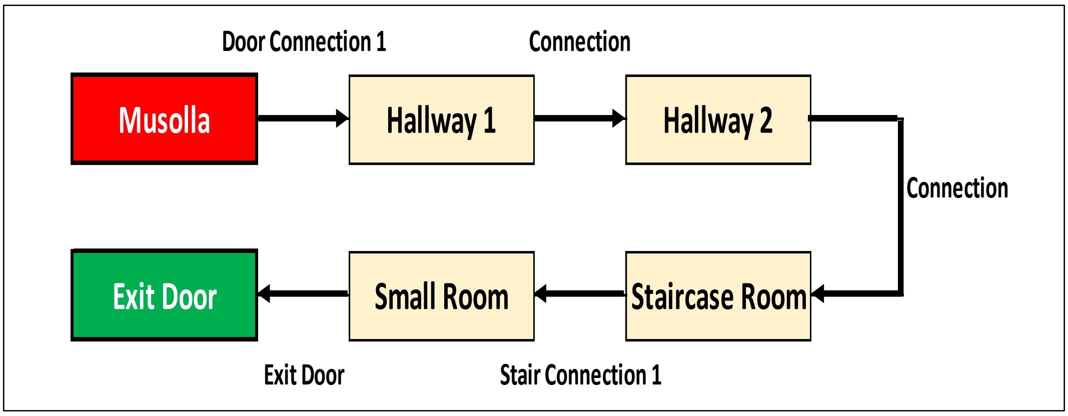

Figure 2. Graphical representation of escape route from Musolla to the muster area.

For each room, the entrance is varied between 0.6 m to 0.7 m wide with single doors. The passageway is measured to be 1.2 m while the stairways are sized with 1.2 m width and 0.25 m tread. The occupants' conditional behaviours are considered fit and healthy men with potential maximum movement speed of 1.2 m/s as default movement time [10]. The delay time for the overall occupant used in this EvacuatioNZ simulation is assumed to be zero for this particular case scenario. For this scenario, 100 iterations of simulation runs are examined without the influence of any other factors and to get a closest value to the converging output mean. In this case, the output is the average escape time of the 100 iterations.

4.0 RESULTS AND DISCUSSION

As the random start feature is turned on, the model is able to give a range of escape times as a distribution rather than a single value. There is a total of 100 simulations for the case specified as governing scenario as described in Section 3.

EvacuatioNZ produced a probabilistic escape times for each simulation. Table 1 and Figure 3 below represent the summary for cumulative escape time for 100 simulations. It describes that 100 repeated simulations produced a distribution for the escape time range from 430 s to 1127 s with the average of 677 s of escape time for all 30 personnel as specified in the POPULATE file to safely escape from the Musolla to the Temporary Refuge (TR) using the route as per MAP file.

PERINTIS eJournal, **2017**, Vol. 7, No. 1, pp. 20-30

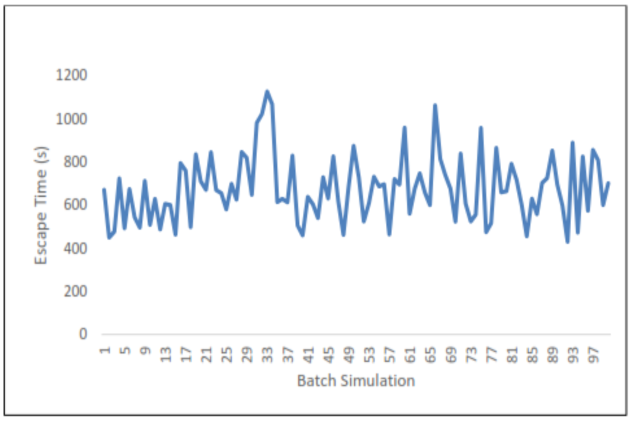

Figure 3. Escape time for governing case.

Table 1. Summary of escape time.

Batch Run	**100**
Max Escape Time (s)	1127
Mean Escape Time (s)	677
Min Escape Time (s)	430
Standard Deviation	152.09

4.1 Number of Personnel at Musolla and TR with Respect to Time

EvacuatioNZ produced a probabilistic escape times for each exit. Figure 4 and Figure 5 display a cumulative number of personnel start to escape from escape origin i.e. Musolla and arrived at safe node i.e. TR respectively for 10 simulations selected randomly which are run 10th, run 20th, run 30th, run 40th, run 50th, run 60th, run 70th, run 80th, run 90th, and run 100th all together. This small sample was chosen because of the expected meticulous process is required to exract and plot all 100 simulations. Apart from that, there are two additional graphs; Figure 6 and Figure 7 were plotted for the same setting based on maximum (run 33rd), minimum (run 92nd) and mean (run 69th).

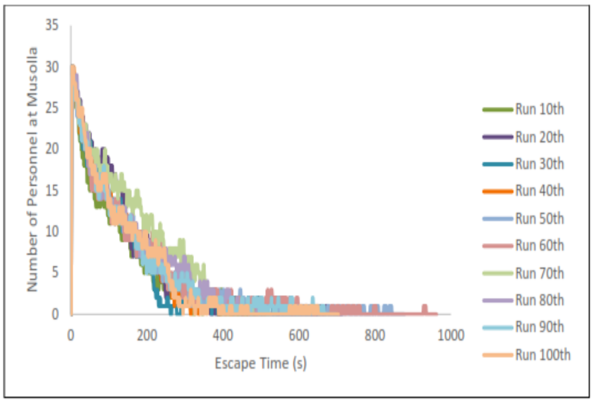

Figure 4. No. of personnel at Musolla with respect to time.

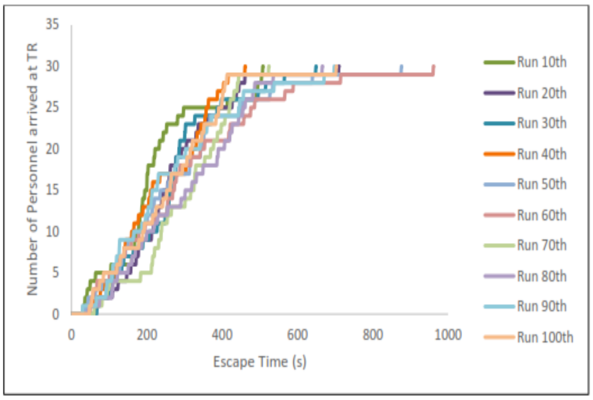

Figure 5. No. of personnel at TR with respect to time.

PERINTIS eJournal, **2017**, Vol. 7, No. 1, pp. 20-30

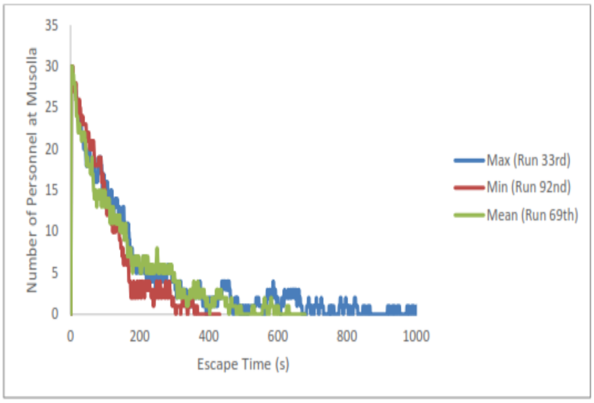

Figure 6. No. of personnel at Musolla with respect to time (max, mean, min).

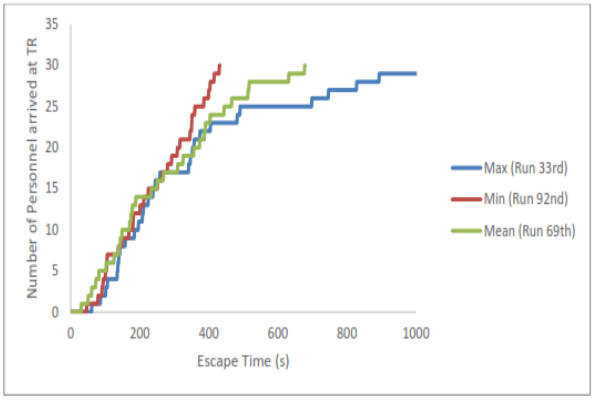

Figure 7. No. of personnel at TR with respect to time (max, mean, min).

It can be seen that there is a clear trend of decreasing for the number of personnel at Musolla with respect to escape time in Figure 4 and Figure 6 and the trend shows vice versa for the number of personnel at TR in Figure 5 and Figure 7. These clearly indicate the link between both nodes are inversely proportional as an evidence that personnel are escaping themselves to the safe exit. Additionally, what stands out in the Figure 4 and Figure 6 is, the number of personnel apparently fluctuated throughout the escape time which is somewhat counterintuitive. However, since the EvacuatioNZ considered the human behaviour in the simulation, this result suggest that the personnel might re-enter the Musolla after escaping from the room. This suggestion is in line with the research by Kuligowski et al. [11].

Interestingly, based on the graph, the trend of fluctuation could not be seen from the number of personnel entering safe node (TR) in Figure 5 and Figure 7 which shows smooth inclination without flux as compared to Figure 4 and Figure 6. This result provides new insights into the re-entry behaviour where the behaviour is set-up merely at the early stages of the escape process in which personnel still in the state of confusion and contemplated on decision to be made as demonstrates from the behaviour of personnel to exit Musolla while as time goes on, personnel eventually have confidence to escape without anticipate re-entering and turn back to the origin point.

4.2 Movement Distribution of Random Personnel (Agent #15)

As for individual movement study, one person i.e. Agent #15 was picked randomly out of thirty personnel to study the movement distribution of the person throughout the escape process. This was done by taking out the simulation from 10th, 20th,30th, 40th, 50th, 60th, 70th, 80th, 90th, and 100th run of the simulation. Figure 8 illustrate the escape times in relation to the node area to examine the flow of personnel throughout the escape route from the origin point of escape i.e. Musolla to the safe exit i.e. TR. Figure 9 and Figure 10 were obtained by excerpt the data from run 10th and run 60th respectively to compare the movement distribution.

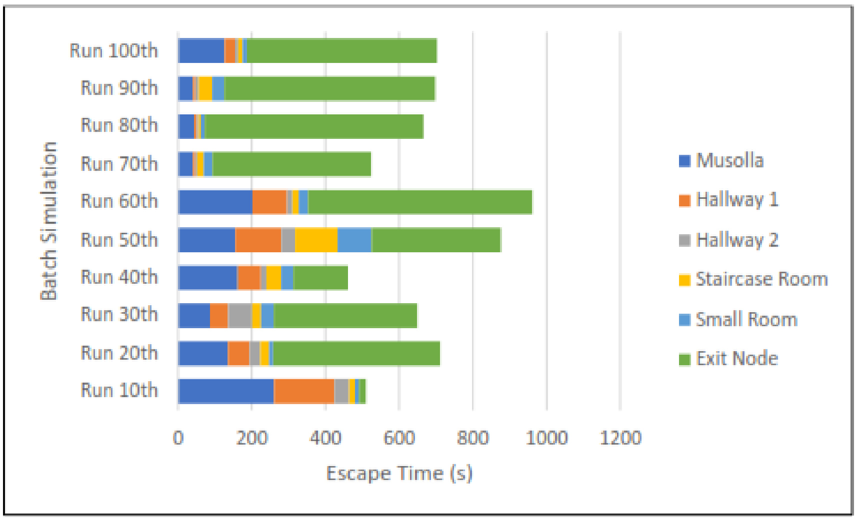

Figure 8. Movement distribution of agent #15.

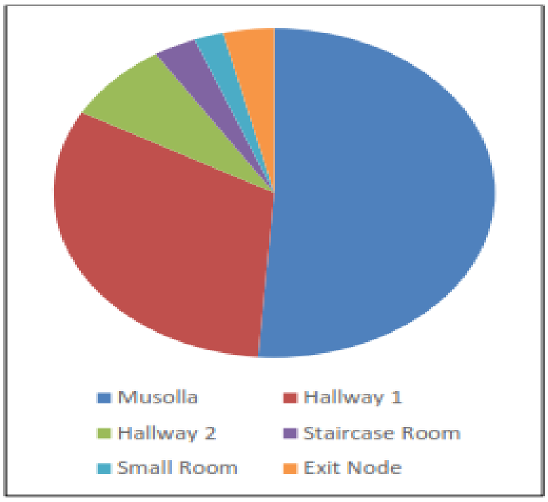

Figure 9. Movement distribution of agent #15 at run 10th.

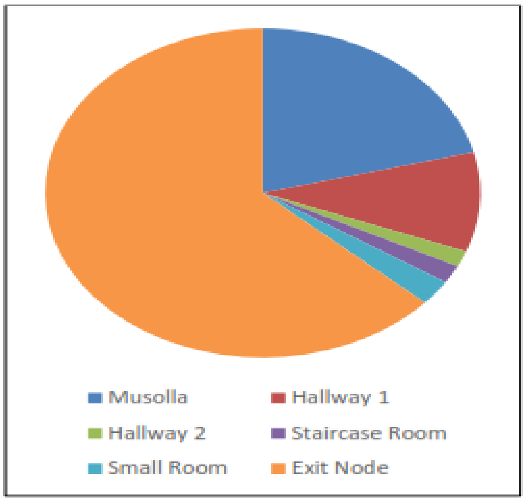

Figure 10. Movement distribution of agent #15 at run 60th.

It is apparent from the graphs above that the movement distribution of Agent #15 is varied distinctly from one run to another. However, what is striking about the data in this graph is Agent #15 spent most of his escape time in the exit node, assuming he is waiting for the last person to enter the exit node except for Run 10th which proposed that Agent #15 among the last person to enter the TR as shown in Figure 9.

The second higher escape time is denoted by the escape time of Agent #15 at Musolla. This is possibly due to high density of the escape origin point which consequently lead to slow traffic at the node and its connecting line. Additionally, work by Nilsson and Fahy [12] suggests re-entry and crowd behaviour might be among the reason of the longer escape time at the Musolla node. The escape time for node Hallway 1, Hallway 2, Staircase Room, and Small Room are observed to be not statistically significant as compared to escape time at Exit Node and Musolla particularly due to shorter distance of the node and its connection line. Taken together, these results suggest that there is a positive association between the length of the escape route (node) to the escape time. Overall, this pattern to a certain extent is believed apply to all 30 personnel.

4.3 Movement Distribution at Specific Time

This section is concerned with the cumulative number of personnel spread along the nodes. Figure 11 to Figure 14 were plotted against two variables; number of personnel and batch simulation; at specific time, t = 100s, 200s, 300s and 400s respectively to demonstrate a strong and consistent association between the time and cumulative number of personnel at specific node.

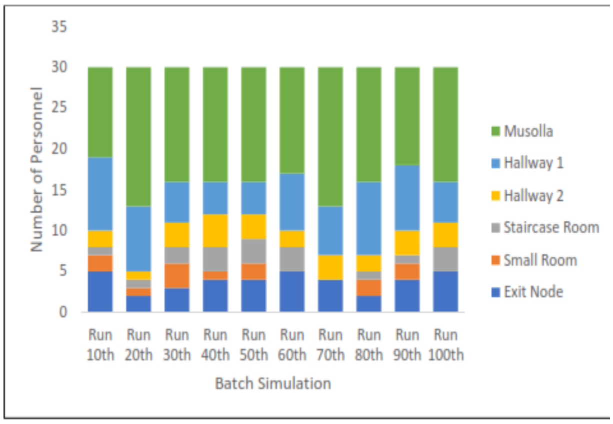

Figure 11. Movement distribution at t=100s.

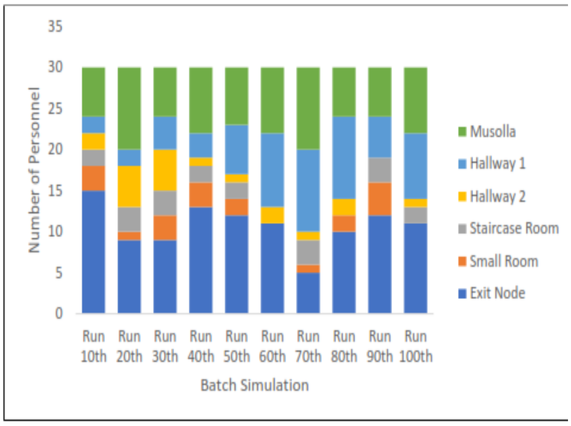

Figure 12. Movement distribution at t=200s.

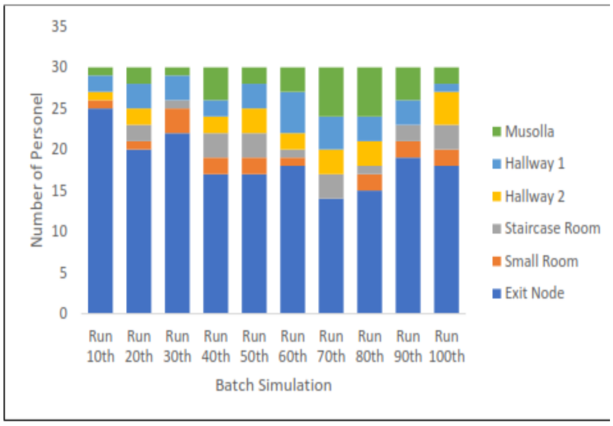

Figure 13. Movement distribution at t=300s.

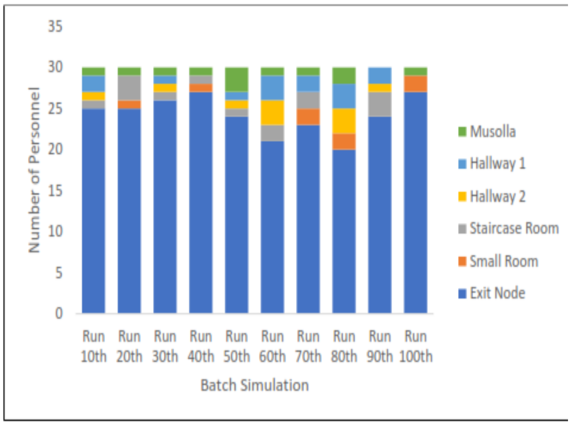

Figure 14. Movement distribution at t=400s.

From all the graphs above, it has been conclusively shown that as the time is extended, the number of personnel muster at the safe exit node is increasing and in contrast shows the decreasing number of personnel at the Musolla node, which implied that personnel are escaping to the TR via the assigned escape route.

Additionally, this result established the correlation between the density of the personnel with the flow of the personnel to the specific node. As for example, this can be seen from Figure 11 at t = 100 s, comparatively from run 10th and run 20th, 11 and 17 number of personnel at the Musolla node respectively. However, from Figure 12 at t = 200 s, it can be seen that the number of personnel reducing to 6 (reduced by 5) and 10 (reduced by 7) respectively. Corresponding to this, the percentage difference is calculated to be 45% and 41% which verify that at the high density of population, the traffic flow is slower. The graph plotted also presented that the escape time at Hallway 1, Hallway 2, Staircase Room and Small Room contribute merely small percentage from the total escape time simulated for all simulations that have been run.

5.0 CONCLUSION

Returning to the objectives posed at the beginning of this paper, the escape time were estimated which take into consideration human behaviour and have been discussed thoroughly throughout the report. Pertaining the outcomes from EvacuatioNZ simulations, the escape time from the origin point i.e. Musolla to the muster area is calculated to be 18.78 min, 11.28 min, and 7.17 min for maximum, mean and minimum time required respectively which the time calculated already take into consideration the human behaviour as discussed earlier. Since this scenario was deemed as the worst-case scenario, it can be concluded that the maximum evacuation time to be around 19 min. This serves as a safe refuge time for the whole area of the vessel. Therefore, by this work shows that by applying an evacuation simulation, a total safe refuge time is able to be predicted.

REFERENCES

[1] UKHSE. (1995). *A methodology for hazard identification on EER assessments*. Health and Safety Executive - Offshore Technology Report, OTH 95 466 (HSE Books 96).

[2] Carvel, R. (2016). A review of tunnel fire research from Edinburgh. *Fire Safety Journal* (in press).

[3] Percy, C., Chen, Y. F., Bibi, A., Coles-Jordan, D., Dodson, E., Evans, T., & van der Bruggen, M. (2011). The contribution of human psychology to disaster management: mitigation, advance preparedness, response and recovery. *Disaster Management and Human Health Risk II*, 195-208.

[4] Kobes, M., Helsloot, I., de Vries, B., & Post, J. (2010). Exit choice, (pre-)movement time and (pre-)evacuation behaviour in hotel fire evacuation — Behavioural analysis and validation of the use of serious gaming in experimental research. *Procedia Engineering, 3*, 37-51.

[5] Ko, S. (2003). *Comparison of Evacuation Times Using Simulex and Evacuation NZ Based on Trial Evacuation*. Master's Degree in Fire Engineering. University of Canterbury, New Zealand.

[6] Xiang, X. P. (2007). *Predicting Evacuation Time from Lecture Theatre Type Rooms.* Master's Degree in Fire Engineering. University of Canterbury, New Zealand.

[7] Teo, A. P. Y. (2001). *Validation of an Evacuation Model Currently Under Development.* Master's Degree in Fire Engineering, University of Canterbury, New Zealand.

[8] Spearpoint, M. (2017). EvacuatioNZ Emergency Movement Software. Retrieved from https://evacuationz.wordpress.com/

[9] Project Manning Distribution Data (2017). Internal document from Ledang FPSO.

[10] Fitzgerald, B. P., Green, M. D., Penington, J., & Smith, A. J. (2001). A Human Factors Approach to The Effective Design of Evacuation Systems. *I. Chem. E. Symposium Series No. 122*. IChemE.

[11] Kuligowski, E.D., Gwynne, S.M.V., & Kinsey, M.J. (2017). Guidance for the model user on representing human behavior in egress models. *Fire Technology* 53: 649.

[12] Nilsson, D., & Fahy, R. (2016) *Selecting Scenarios for Deterministic Fire Safety Engineering Analysis: Life Safety for Occupants*. In: Hurley M.J. et al. (eds) *SFPE Handbook of Fire Protection Engineering* (pp. 2047 - 2069). Springer, New York, NY