# STUDY OF OPERATOR TRAINING AND OPERATOR TRAINING SIMULATORS IN THE OIL & GAS INDUSTRY

A Thesis Submitted to the
*University of Petroleum And Energy Studies*

For the Award of
***Doctor of Philosophy***
in
Oil and Gas Management

BY

Kallakuri Ravikanth

June 2022

SUPERVISOR (s)

Dr. P.C. Bahuguna
Dr. Sanjay Shivalkar

School of Business
University of Petroleum & Energy Studies
Dehradun-248007: Uttarakhand

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## DECLARATION

I declare that the thesis entitled **STUDY OF OPERATOR TRAINING AND OPERATOR TRAINING SIMULATORS (OTS) IN THE OIL & GAS INDUSTRY** has been prepared by me under the guidance of Dr. Prakash Chandra Bahuguna, Associate Professor, School of Business, University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

**KALLAKURI RAVIKANTH**
School of Business,
University of Petroleum and Energy Studies,
Dehradun, Uttarakhand, India.
DATE: 15 June 2022

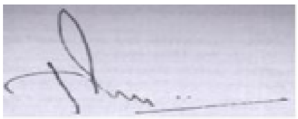
UPES
UNIVERSITY OF TOMORROW

Great Place To Work. Certified MAR 2021–FEB 2022 INDIA

## CERTIFICATE

I certify that Mr. KALLAKURI RAVIKANTH has prepared his thesis entitled "**STUDY OF OPERATOR TRAINING AND OPERATOR TRAINING SIMULATORS (OTS) IN THE OIL & GAS INDUSTRY**", for the award of PhD degree of the University of Petroleum & Energy Studies, under my guidance. He has carried out the work at the Department of Oil and Gas Management, School of Business, University of Petroleum & Energy Studies.

Internal Supervisor



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# ABSTRACT

This study is intended to identify different influences affecting the Operator Training Simulators (OTS) and efficacy of OTS training in the oil and gas industry. Operator Training Simulators are exclusively used for control room operator training. Survey method is used to collect stakeholders responces for the research objectives using questionnaire. The stakeholders consisting of operators, supervisors and managers, OTS development and process automation teams. Mixed method research methodology with case study approach is used to gather data and analysis of findings.

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method is used for the literature review. The data is analysed quantitively and qualitatively to understand the perceptions of stakeholders, validating the research design, proving the ADDIE model (Analysis, Design, Develop, Implement and Evaluate), interpreting and analysing the results. Demographic and Qualitative data is analysed using NVivo data analysis tools. Instructional design framework is adopted to test the ADDIE model by mapping the questionnaire to the stakeholder survey. ANOVA and Linear Regression is conducted by using IBM SPSS (Statistical Package for the Social Sciences) statistical tools.

Data Validity, Normality and Internal Consistency being checked by appropriate methods and found reliable. Interitem correlations established the positive relationship between different constructs of the model and paired sample tests validated the correlations between the type of industry and stakeholder role in the development, usage and efficacy of OTS models. Linear regression is to examine the significance of the ADDIE component aspects on the overall effectiveness. The correlation and regression analyses indicate that there is link between each individual components of instructional design model, ADDIE and overall effectiveness of simulation training.

The study highlights that, OTS Instructor role is significant in the design and development of training simulators, training administration, maintenance and

customization of OTS specific to each training objectives and effectiveness of the training process. The instructors are needed to be trained on the instructional design processes, up to date pedagogical tools and competency assessment methodology.

OTS developers along with the instructors are recommended to identify the necessary pedagogical features of the models, customize them to site specific requirements and carried out simulator development to enhance individual competencies, support learning abilities to elevate the skill levels of the operators.

The outcome of the survey accentuates the need to develop training simulators embedded with instructional design models to support the lifelong learning process, improve training transfer to the workplace and contribute to prevent human errors in the industry.

# ACKNOWLEDGEMENT

The journey of this research is one of the best periods in my life with many memories to cherish. I have learnt that the academic field is one great space, where continuous learning for excellence is infinite and knowledge sharing is best among many approaches for contributing to the humanity.

I would like to extend my sincere gratitude and heartful wishes to my supervisor, Dr. Prakash Chandra Bahuguna, Associate Professor, School of Business, UPES for his directional guidance, steadfast support, continuous encouragement, feedback and timely suggestions.

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During the course of this study, I was fortunate to interact with many academicians and intellectuals from different nationalities, cultural background and diverse industries to explore their vision on this subject. I am able to acquire and adapt different learning styles and training methodologies etc., through their support. I would like to thank one and all for participating in this study, providing constructive suggestions and productive feedback.

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I am thankful to my wife for her constant support, encouragement and patiently listening to my musings in this journey. It’s innocuous to say that we jointly earned this degree.

I am appreciative to my children for their little inputs, suggestions and keep motivating me in this endeavor and believing in me more than myself.

I would like to extend my gratitude to my parents and in-laws, who are always there to support me and inspire with their words.

Finally, I would like to thank the divine almighty for giving me strength, spiritual solace during many difficult times, showing the path and clearing obstacles with ease and without which I may not be able to complete this momentous journey.

गुरुर्ब्रह्मा गुरुर्विष्णु गुरुर्देवो महेश्वरः

गुरु साक्षात परब्रह्मा तस्मै श्रीगुरवे नमः

**Dedicated to all the wonderful Guru’s and my incredible country, INDIA.**

**RAVIKANTH**

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# CHAPTER 1

## 1. INTRODUCTION

The aim of this study is to "Study Operator Training and Operator Training Simulators (OTS) in the Oil & Gas industry". Control room operators have to monitor the 24/7 operations, maintain the products quality and quantity, intervene during abnormal situations and restore operations back to normal operating conditions. Operator training simulators are extensively used in the training of control room operators across the hydrocarbon industry. This study accentuates the necessity to develop operator training simulators unified with instructional design models in-order to evaluate training and anticipated results. The intention of this research is to study these attributes in the literature and in the oil and gas industry. By using an online survey to capture stake holder insights, we have tried to identify key perceptions about simulator training, their usage and efficacy to explore different ways of improving the overall process and recommendations to maintain actual process and simulator systems together as digital twins.

### 1.1 BACKGROUND OF THE STUDY

In the industry, the training sessions are generally planned after detailed discussion with training service providers, internal & external trainers and vetting the scope of work by relevant Subject Matter Experts (SME's) from the concerned departments and conceptualized, administered by the Training or Learning teams. In the training feedback and gap analysis it was found out that there is always a small gap existing for what is the expected outcome of the training and what is delivered in the workplace. The different feedback mechanisms and post training analysis are not capturing the needs of the employees and leaving them dissatisfied with some doubt in mind leading to human errors during critical operations and split-second decision making required during the oil and gas industry process control operations.

The challenges faced by organizations to manage workforce necessitating the need to bolster the existing tools towards integrating different platforms for usage thru single window access with virtualization and remote operation, educating the existing workforce with new tools and technologies, cyber security and establish uniform methodologies for easier asset management (Deloitte, 2020). There are numerous issues exclusive to technical workforce, as the workplace knowledge outdates quickly, and many workers appear skill outmodedness. It is exceptional to the staff, who are recruited due to their dedicated domain experience in the critical operational areas.

### 1.2 OVERVIEW OF OIL & GAS INDUSTRY

In the development and growth of countries, energy derived from oil and gas industry contributes significantly across the world. An growing population, financial and sustainability goals, advent of new technologies, changing geo-political landscape and ever-changing regulations are all altering the energy infrastructure.

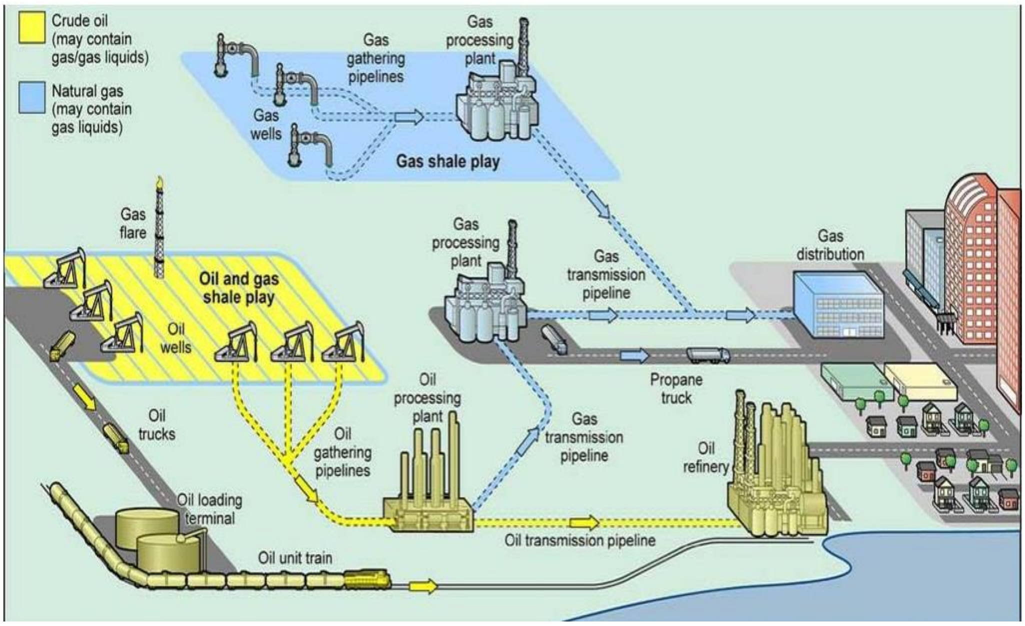


**Figure 1.1 Overview of Oil and Gas Industry**
(https://arvengtraining.com/en/the-oil-gas-sector/)

The different operations across the oil and gas industry consisting of Exploration, Extraction, Purification, Transport, Processing, Refining and Marketing of crude oil and natural gas. The intent is to produce Electricity, manufacturing of raw materials for different Petrochemicals, Plastics and Intermediate Chemicals and final end products such as Automotive fuels (Diesel, Petrol, Jet Fuel, Compressed Natural Gas, CNG etc), Cooking gas (Liquified Petroleum Gas, LPG) etc. Across the oil and gas industry (Fig 1.1), there are no of issues in developing capable and competent workforce to monitor, operate and control the processes, which are discussed in next section.

### 1.3 ROLE OF CONTROL ROOM OPERATORS

Process operators in the industry are generally divided into two main roles, namely, Field operator and Control Room Operator, based on the physical presence and job location as below.

- ❖ Field Operator, the person working inside the field or outside control room.
- ❖ Control Room Operator, the person working inside the control room.

Control room operators (Fig 1.2) play a significant role when it comes to safety of the operations and controlling the process conditions. They are the first line of defence for any process upset or problematic conditions to quickly bring the process under control. Control room operator's control, monitor, operate and maintain the process parameters. Across the industry they are also known as Process Operator, Process Technician, Control Room Officer (CRO), Panel Operator and Board Operator etc. in the processing units, refineries, chemical plants and storage facilities.

**Figure 1.2 Typical Control Room Operator on duty**
(http://www.ief-ngo.org/en/service/training/petrol/46-comp-oil-gas)

Operators are usually responsible for one or more units/processes within their operating company. They use complex procedures and operate automatic control loops that control temperature, pressure, composition and flow rate using Distributed Control Systems (DCS) and continuous monitoring of the operations. They should be in a position to go through number of graphic pages in the DCS, monitor process changes, respond to the changes and act to the abnormal conditions using standard operating procedures, equipment manufacturer references and instructions.

## 1.4 ROLE OF OTS

Training simulators are used in chemical operations and process trainings, industrial safety components design, process modelling and testing. They are also used in aviation, shipping, military, and health agencies etc. They provide an alternate substitute in replicating the very hazardous and often complicated situations. Actual operations of these process are too unsafe to replicate for practicing the operations and be competent in the highly stressful factory situations (Burke et al., 2007). The competencies of the operators are able to maintain with appropriate training of the replicated scenarios and practice them repetitively using a simulator.

The main purpose of training in the simulator is to impart self-confidence among the staff and improve their capability to accomplish tasks during hostile situations (Stetz and Hunt, 2006). Further the behaviour of the operator is influenced by many external factors like work surroundings, personal factors and environment, which necessitates human factors should be considered while designing a simulated process (Vilela et al., 2020). Manca et al., debated widely about the concept simulator training and the probable benefits of employing them to train the workers in dealing with the aforesaid situations. Operators have to act quickly to an abnormal situation, determine problems, identify and quickly plan tactics to mitigate the issue. The operator intellectual capability and ability to response are strongly interlinked with each other (Manca et al., 2013).

Training can be defined as the strategic knowledge contribution that teaches the workforce in what way they can accomplish the tasks and other imminent work. Learning in the workplace improve productivity across organizations while educating positive attitudes towards growth and development of competencies. Most of the time the training is more focused on what needs to be done to carry out the work, rather than the application of skills. By applying suitable learning stratagems, the operator training can be improved further. One can select them based on the requirements of the target group and theme or simulation process to be trained or configured in the training simulator.

## 1.5 OVERVIEW OF THE STUDY

Operator Training Simulator’s (OTS) are extensively used in the hydrocarbon industry for training the control room operators for start-up, shutdown, normal operations, planned and un-planned events along with abnormal situations. Simulator training offers thoughtful learning process for process logics and control systems. It provides an overview to precisely identify process issues before they intensify to stoppage of the process and loss of production. Due to various organizational issues, operator training simulators are not continuously updated to modern features and over the time become out-dated.

The training effectiveness of the individuals or across operations teams in the hydrocarbon industry is not studied in the perspective of the stakeholders. Most of the industrial accidents and near misses from the literature are attributed to operator errors and other human factors while insufficient or lack of appropriate training, training effectiveness, lack of lessons learnt practice etc., related to either learning/training transfer are identified as one of the many root causes in the incident closing or corrective action reports. With many similarities (in terms of criticality and high-risk operational processes running incessantly by few people) in Military, Health, Mining, Nuclear, Transport and Aviation industries etc., who are using simulation as a training tool, the training transfer studies in these areas are also applicable to the training simulators in the hydrocarbon industry. This inculcated an interest in the present research, to find out how to improve the overall operator learning process and OTS trainings by using appropriate training approaches and instructional design models.

The central research problem as derived from literature and research gaps is to “Study different Operator Training Simulators (OTS) models, economic benefits, usage, efficacy and its role to prevent human errors as per the stakeholder expectations in the oil and gas industry".

This study is carried out in conjunction with OTS stakeholders to gather their feedback through an online survey. The data is analysed by using qualitative and quantitative data analysis procedures together, supplementing each other.

## 1.6 THESIS STRUCTURE

The current thesis is structured over five chapters, namely 1. Introduction, 2. Literature Review, 3. Research Methodology, 4. Data Analysis and 5. Conclusions and Recommendations.

These chapters will provide comprehensive discussion of this study on the basis of review of literature, theoretical framework, methodology, analysis of the data collected, findings, recommendations and inferences addressing the stakeholders community. The stakeholders perceptions to improve upon the existing processes and usage is deliberated. Below is the summary of each chapter.

Chapter-1 narrates the introductory part of the thesis consisting of overall nature of this study, key stakeholders, overview of the industry and the research process.

Chapter-2 consists of the review of literature carried out to understand the current situation in the academic and industrial literature, thematic analysis, key instructional design process, methodology, research tools and basis of analysis.

Chapter-3 presents the methodological approach towards the research topic, study design, data gathering and analysis methods along with justification for their selection.

Chapter-4 consists of data analysis, findings for each research objective and their inferences along with detailed summary of results.

Chapter-5 presents the conclusion of different research questions. Contribution of this study for the overall benefit of society at large, their applicability to oil and gas industry and along with other industries is discussed.

## 1.7 KEY FINDINGS

The results indicate that instructional design models should be coupled with simulator model development to increase the OTS usage and effectiveness. There is linear correlation between ADDIE model (Analysis, Design, Develop, Implement and Evaluate) components and training effectiveness and learning transfer to the workplace. Linear regression equations derived can be used to validate the sessions to increase effectiveness.

The study highlights that the OTS instructor role is the key to succeed in the design and development of training simulators, administration, maintenance and customization of OTS specific to each training objectives and effectiveness of the training process.

Reskilling the instructors with instructional design and competency management certifications might help industry to organize eloquent sessions with proven pedagogy and learning methodology.

OTS developers along with the instructors are recommended to identify the necessary pedagogical features, customize them to site specific requirements and carried out simulator development to enhance individual competencies, support learning abilities to elevate the skill levels of the operators.

## 1.8 EPILOGUE

The introductory part of this described in this chapter along with the motivation and contextual basis to this research. Further it offers an overview of the industry and key personnel associated to this study. The main stakeholders and their roles along with brief summary of thesis is described. The overall thesis structure, its alignment to the research objectives are deliberated along with slight description of each chapter. Finally, key findings of this study and possible improvements required to enhance the OTS training with reference to the stakeholders and industry at large are shortly summarized.

# CHAPTER 2

## 2. LITERATURE REVIEW

### 2.1 INTRODUCTION

This chapter narrates the overall imprint of the Literature Review (LR) process applied to this research, literature review methodology, summary of the themes grouped from the literature and thematic analysis of academic and industrial literature.. The review of instructional design models applicable to this study is carried out with reference to the research design. The gaps are further analysed to formulate research questions, objectives and ways to address them through different methodology. The findings with reference to the operator training and efficacy of operator training simulators are summarized.

### 2.2 METHOD

The literature is reviewed by adopting the Systematic Literature Review (SLR) process methodology. SLR is the systematic, clear and predictable method for exploring, classifying, appraising and correlating the existing literature work carried out by academicians and different researchers (Okoli et al., 2010) into the research framework.

Systematic review is a process in which we can use clearly planned approaches to gather information and produce conclusions form the studies that are intended to address a clearly formulated research question. This can also be used as a basis for writing methodical appraisals of literature for further research and with clearly defined objectives other than assessing interventions (Moher et al., 2015). This brings structure to the review rather than browsing through the automated reviews of data bases. In this review, the different key phrases and words recurring from literature, training industry and commonly available databases are collected, and detailed information is sought from online and offline sources.

Due to the similarity of training delivered in various businesses, like Aviation, Automobiles, Finance, Chemical industry, Education, Gaming, Medical, Military, Mining, Marine (includes shipping), Nuclear, Oil & Gas (includes Petrochemicals) and Power sectors, their usage of training simulators, training effectiveness, reduction of human errors due to training interventions are being looked upon in the literature.

The sources of online databases include and not limited to white papers from the industry, manuscripts from ScienceDirect, Emerald Insight, Google Scholar, ResearchGate, Taylor & Francis journals, Wiley Online Library, SpringerLink, SAGE Publications, Inderscience Publishers along with relevant doctoral thesis from scholars through online libraries commonly available through the internet. The study was made to include the most articles possible, but the present research also not to claim that the database is also not complete. The primary literature review findings are analysed, papers are filtered to refine the keywords to analyse data and further they are combined under different themes to enhance the scope for further research.

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method is used as basis for this review (Fig 2.1). PRISMA is an evidence-based methodology where, different set of items are collated for reporting the systematic reviews providing the meta-analysis of existing research (Page et al., 2021). This is primarily focused on reporting of literature reviews and evaluating the effects of interventions. This is used for expanding an understanding of primary reasons, thoughts and inspirations among the different stake holders. To ensure the validity of the systematic review process, the scholars should be able to prepare a clear, comprehensive, and precise explanation of why the review is carried out, what they are doing with it, their intended results and contribution to literature at large in a sequential manner (Moher et al., 2009).

The study was made to include the most articles possible, but the present study also not to claim that the database is also not complete. Based on the literature review around 200 articles using PRISMA protocol, the manuscripts are grouped as per themes and further analysed by using NVivo data analysis tools.

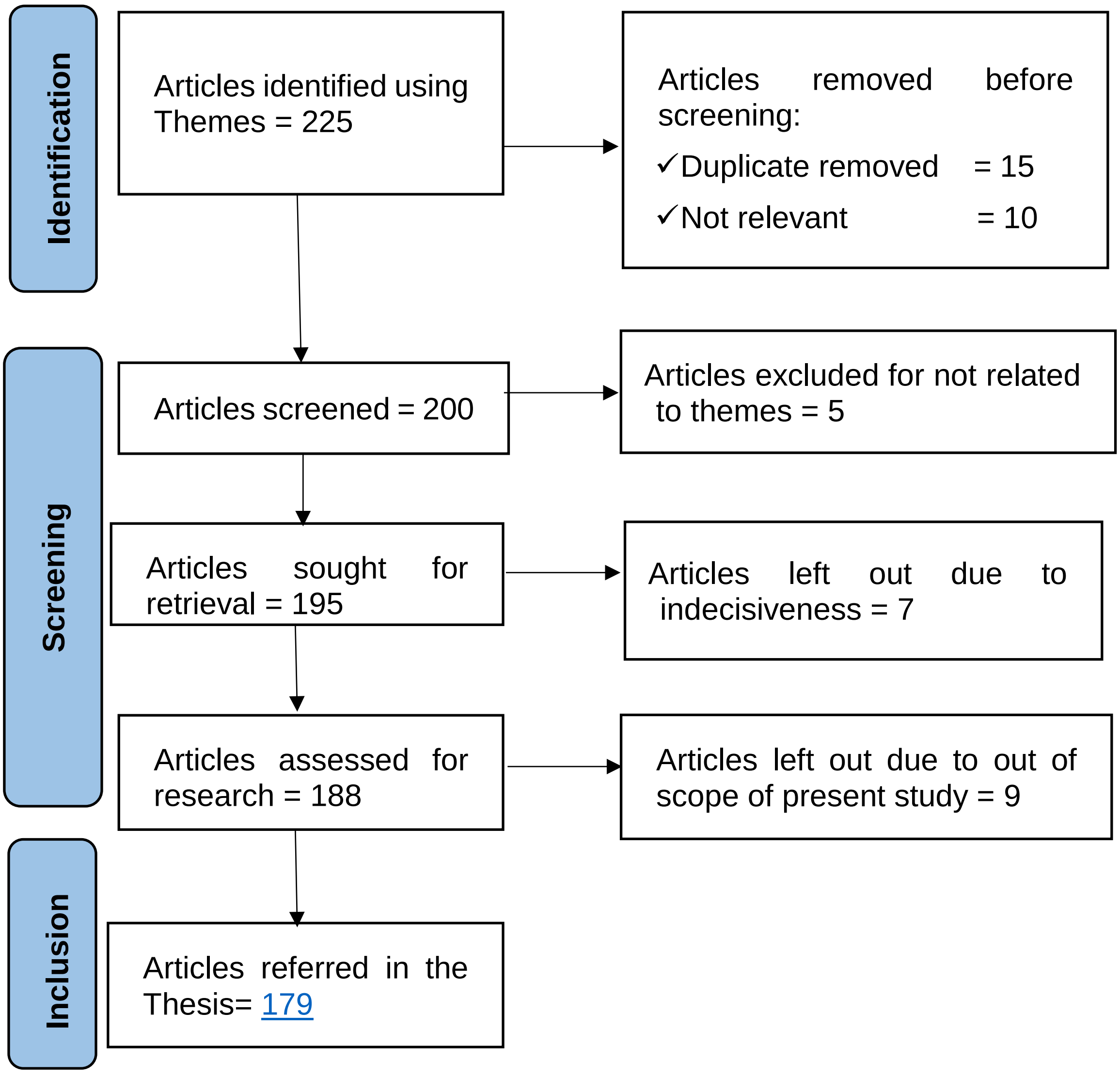


**Figure 2.1 Literature review by PRISMA method**

(Source: https://estech.shinyapps.io/prisma_flowdiagram/)

### 2.2.1 LITERATURE REVIEW USING NVIVO

NVivo (2021 version) from QSR International is an Qualitative Data Analysis (QDA) tool to analyse the literature review papers and thematic analysis. The gaps and key findings, inferences from the literature review are analysed using NVivo tools. They provide visual connections, patterns and themes so that researchers can visualize and analyse the connections and write in more apposite manner (Booth et al., 2018).

The word cloud output query in NVivo is applied to most frequent words in the literature review papers. Words like ‘OTS’, ‘Practice’, ‘Process’, ‘Activities’, ‘Act’ and ‘Change’ as shown below (Fig 2.2) displays that the words appearing in more font size, bold and highlighted are directly correlated to appeared frequently and words like ‘operator’, ‘communication’, ‘scenarios’, ‘simulator’ etc., which are smaller in size appeared less relative to others and the shaded words like ‘programming’, ‘connectivity’, ‘functionality’, ‘automated’ etc are present the lowest frequency in the word frequency query.

By repeating this exercise with grouping of words like exact matches, words with synonyms, generalizations etc., we can be able to identify the “key words”. Further as per the frequency and no of words present in most of the papers, we can map further using coding and analyse them as theme and subthemes to explore the gaps and we can broaden the literature search as needed.

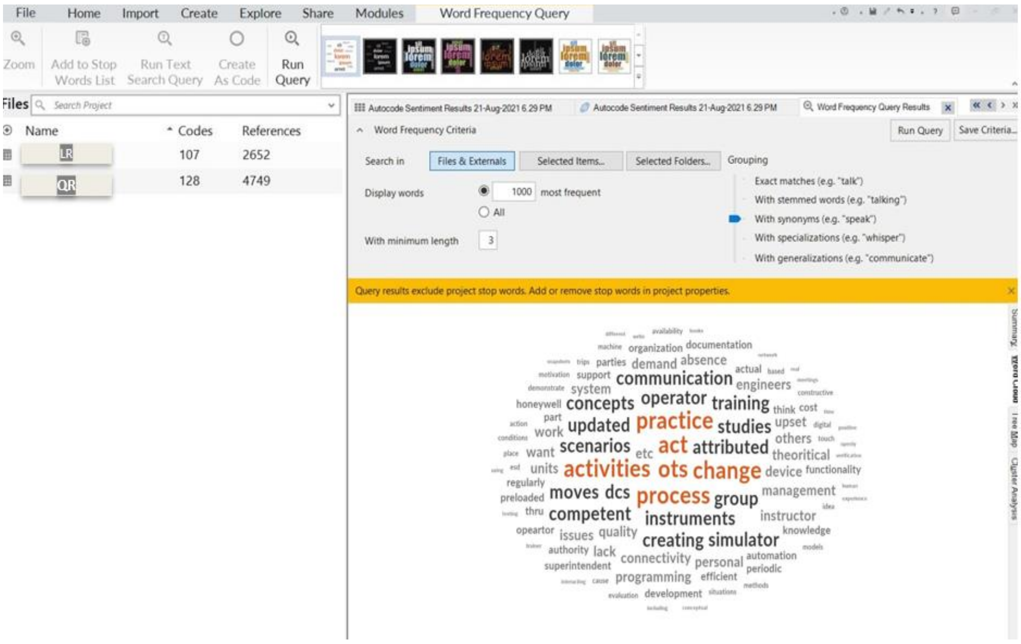


**Figure 2.2 Word cloud showing keywords**

(Source: NVivo from literature review by Author)

Combining the qualitative data analysis with coding and there by generating the key words or themes is important steps to explore the literature for the relevance, applicability and authenticity to progress on the research objectives. Themes are built in patterns derived from data set to search answer to research questions. Thematic analysis emphasize the social, cultural and individual influences over the same topic among the researcher(s) and literature which can be validated from similar areas of interest (Michelle, 2020).

**Coding**

A code can be a name, phrase, term or expression that can be tagged for a segment of existing text. The code labels data like a keyword describes an article (Maria, 2019).Coding is the process by which basic research information can be transformed to make it compatible for statistical and computer assisted analysis.

Coding is one of the methods of linking the singular data to ideas of expression at different levels of concept, such as descriptive, topical themes, and systematic impressions. Using automatically labelled codes in NVivo, one can apply an extraction pattern learning process to automatically generate patterns representing subjective expressions in a visual arrangement (Fig 2.3).

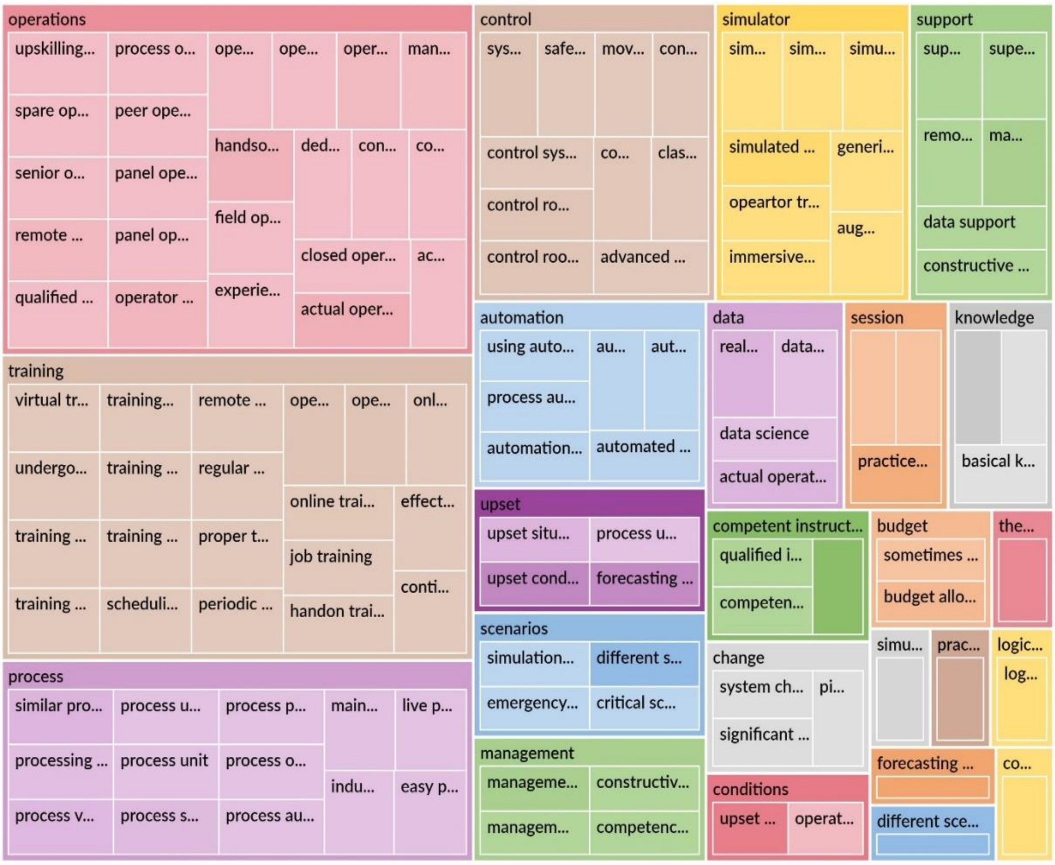


**Figure 2.3 Themes & subthemes by no of coding references**
(Source: NVivo from literature review by Author)

Visual coding is carried out to map similar topics in same colour, which can be used to mark passages for review. Items and words compared by number of coding references and tree map output visualizes that the larger rectangle is with highest coded words tabulated with the text representing themes and subtext (subthemes) representing relationship with the themes. These will help us to provide guidance in interpretation and demonstrate the coded themes and subthemes to validate findings, produce discussions with evidence and write reviews based on the literature or surveys and interviews. This also help in data captured in phrases and words for revisiting for future updates and revisions.

The 'most frequent words used from the cloud' and 'most frequent words linked to others thru clusters' can be used for conceptual correlations (In this research, NVivo is customized to use Pearson correlation coefficient as -1 = least similar and 1 = most similar while running the software) between them and help us in writing the review of literature and analysis.

Based on the above methodology, the main themes (Fig 2.4) identified for further analysis are, 1. Human Errors in Process Control, 2. Process Operator Training, 3. Operator Training Simulator (OTS) Training, 4. Training Effectiveness and 5.Training Transfer & Learning Transfer. Each theme is analysed from literature to identify gaps and summarize inferences, presented with details in the next section, titled Thematic Analysis.

## 2.3 THEMATIC ANALYSIS

Thematic analysis is the methodical technique of simplifying the data into smaller text and unifying them by labelling discrete explanations and citations with suitable codes, to facilitate the sighting of noteworthy phrases. Thematic analysis is the process of identifying unique patterns within large data set by browsing through the manuscripts with reference to the research questions (Moria, 2017).

A Theme can be defined as an explanation of a belief, practice, need, or any other phenomenon that is discovered from the data. These are emerged while searching literature for correlated conclusions and we can be able to trace them multiple times across different researchers and data sources. The themes can also be enhanced by broader search outlook through qualitative analysis software (NVivo) by coding of words, key phrases by their significance. The overall spread of the literature review is plotted in Fig 2.4 and the below table (Table 2.1) display the themes with their search outlook in the literature and validation of themes from literature through similar researchers. Individual themes are analysed further in next sections.

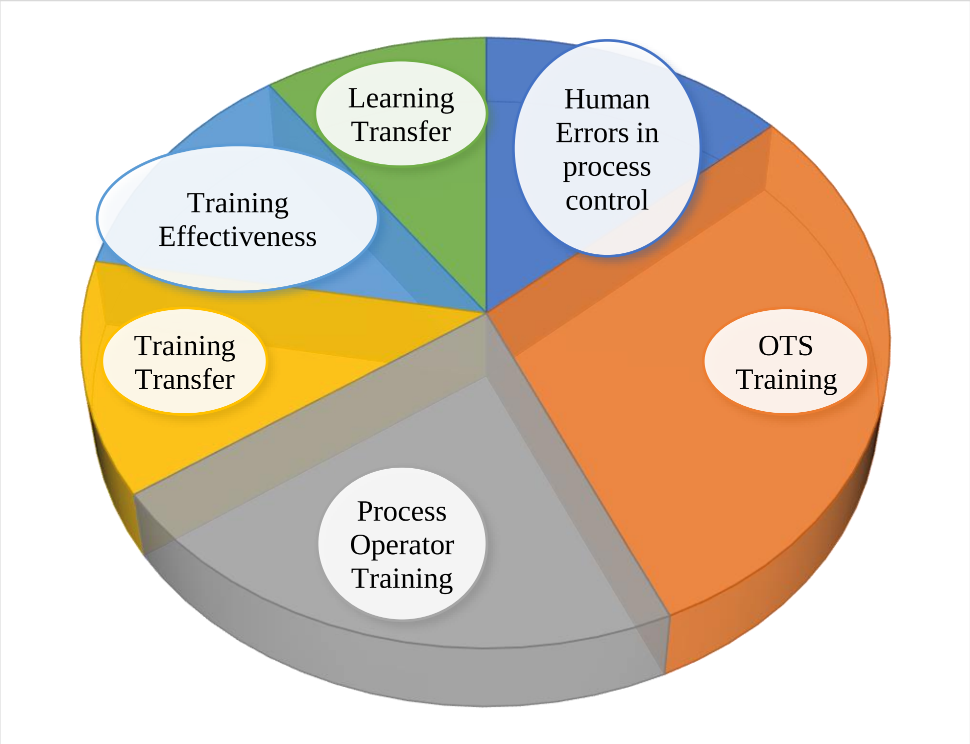


**Figure 2.4 Themes vs Percentage of articles from Lit. Review**

(Source: Author compilation from literature)

**Table 2.1 Themes with References**

| Themes | Search Outlook in the Literature |
|---|---|
| Human Errors in Process Control<br>(Annette et al., 2009 and Lemay, 2008) | ✓ Human errors in process control<br>✓ Situational awareness during process control<br>✓ Conditions leading to the events/accidents<br>✓ Process Incidents involving human errors |
| Process Operator Training | ✓ Operational errors during the process control |

| | |
|---|---|
| (Komulainen et al., 2018 and Tichon et.al, 2003) | ✓ Operator Competency<br>✓ Training of Operators in the Oil & Gas Industry |
| Operator Training Simulator Training<br>(Stetz et al., 2006) | ✓ OTS Usage, limitations and Modelling<br>✓ Underutilization of OTS<br>✓ Instructor role and responsibility<br>✓ Simulation Complexity<br>✓ Process Modelling |
| Training Effectiveness (Baldwin, 1988 and Barnard et al., 2001) | ✓ Effectiveness of training<br>✓ Training evaluation methods<br>✓ Training feed back<br>✓ Competency & Skills improvement |
| Training Transfer & Learning Transfer<br>(Patle et al., 2016 and IAEA, 2004) | ✓ Training transfer through simulation<br>✓ Training & learning transfer methods<br>✓ Applying knowledge in workplace<br>✓ Enhancement of the current practices |

### 2.3.1 HUMAN ERROR IN PROCESS CONTROL

Every major loss in the industry is a combination of an exceptional and multifaceted contributions from the faults and failures of automated systems, legacy issues, management failures, human error, and other emergency events. The improper handling of operating units by the operating staff is identified as one the many root cause of hazardous conditions and contributing to incidents (Patle et al., 2016).

Numerous process safety studies and researchers pointing out to inappropriate management of change procedures and conclude that accidents comeback repeatedly due to lack of usage of anecdotal data, unable to apply the lessons that are available from accident investigation and their corrective action reports (Antonovsky et al., 2013, Annette et al., 2009).

Le May (2008) studied the lessons learned from accidents in different literature and analyse that the main three causes attributed to human factors, contributing to human errors are (Lemay, 2008),

1) Poorly trained Operational personnel

2) Lack of Staff Competency

3) Deficiency of safety culture across the organization

He further investigate that organizations are required to provide adequate training and ensure competence in the workplace so that failures by human errors can be prevented by appropriate drills. The training preferably using a training simulator, there by demonstrating the staff's ability to perform in a safety critical task or during process emergencies, reliably without escalating the situation. Peoples contribution towards these accidents are in the range of 70-90% and Abnormal Situation Management consortium, Texas-USA mentions that there is no or insufficient time to check the work carried out by the operators due to lack record and lessons learnt data. This is consequential to raise of human errors in operational facilities and is described as a major source to many lop-sided conditions (Walker-2011). The management perspective for any hazardous job is limited to check how the performer is managed and the embedded organizational processes to carry out the work. The conflicting and imperfect decisions within the organisation can be lessened if the supervisory staff are enough knowledgeable in identifying the key tasks and support the worker (Gordon, 1998). The less than expected performance of control room operators can be considered as one of the key factor to conclude that why many industrial control schemes fail to deliver intended results during the emergencies and process upsets (Li et al., 2011).

Below is the summary of literature review for this theme.

**Table 2.2 Literature Review Summary-THEME.1**

| Source/Author with Reference | Year | Inference | GAP |
|---|---|---|---|
| Christou. M and Konstantinidou. A | 2012 | Production of situational tools and defining | Addressing incidents at an operational level |

| | | | |
|---|---|---|---|
| | | effective control measures to respond is needed | is not studied and how to simulate the scenarios in training of operators |
| Antonovsky, A et al. | 2014 | Precise enquiry tools identify incidents related to human factors should be part of organizational tools | Assessment of illustrative samples across the staff can be a basis of unfairness in the study |
| Salvendy and Karwowski | 2011 | Ideal balancing of operational procedures and rules are key to prevent fatal errors | Bigger variations in operators decision making during irregular situations and process upsets are difficult to identify |
| Dhillon and Liu | 2006 | Human intervention is the biggest causation factors for direct causes for accidents | The study is not aimed at different industries |
| Antonovsky et al. | 2015 | Human factors could be based on the factors | The number of plant stoppages within a given |

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|---|---|---|---|
| | | that are found to frequently contribute to failures in complex systems | period was the basis for assigning a relative reliability level |
| Mrugalska et al. | 2016 | * Abnormal situations are due to poor personnel selection and training *Operators need to attentive to process conditions | How to address abnormal situations and training interventions are not mentioned |
| Mrugalska et al. | 2016 | Situation Awareness model framework is necessary for gaps | Studies are desirable on effectiveness of training |
| Mathis | 2014 | Approaches to plan, track progress and implementing should also focus why those approaches are deployed | Limited no of participants in the sample as 30. Failure to involve younger employees due to their less experience |

| | | | |
|---|---|---|---|
| Bott, G and Tourish, D. | 2016 | Incidents can be viewed as an organizational phenomena and to assume creative and practical study, and analysis using (i) interviews, (ii) questionnaires, (iii) forms | Researchers should find hypothetical outlines for descriptive accidental data |
| AICHE | 2015 | Employees are unprepared for a complex process upset at the facility and no formal training on control systems | * Competency levels of the staff operating during the time of accidents<br>*Research about their training & experience in operating these units |
| Peres et al. | 2016 | The study identifies several factors like absence of training, competency roadmap and lack of workplace preparedness | Training on how to implement Standards and Regulations: Better methodology for identifying root causes of incidents |

| | | | |
|---|---|---|---|
| Rachael, Gordon | 1998 | Human errors from skill and knowledge based can be eliminated by competency management and training | Focusing on accidents feedback for lessons learnt trainings |

### 2.3.2 PROCESS OPERATOR TRAINING

Most industrial accidents investigation pointing to operational errors and loss of process control. The processes in the oil and gas business is such that in all the operations, there are probable risk due to the hazardous nature of the constituents being mined, treated and transported (Marsh Audit-2017).

Emerson Automation Solutions, USA in a white paper on dynamic simulation business case in 2018 compared process operator training with a typical airplane pilot training in terms of managing variables and operations involving complicated automation processes. They further emphasized that having an operator training and competency system can uncover potentially catastrophic issues in the automation system or operations of the plant (Emerson, 2018).

Invensys technologies, now taken over and known as Schneider Electric in its white paper (Invensys, 2013) cited that, in terms of industrial accident percentage, the second-highest source of accidents in plant operations are attributed to operational errors, involving process operating personnel and control room operators. Theoretically these can be easily controlled by proper training, competency management and increased foresightedness from operators and supervisors.

They observed that the console operators needed more console experience and training in dealing with these situations, which never arise before. Fully trained operations personnel, with knowledge how to operate within the technical environment and have in-depth know how of the plant processes are indispensable for safe, reliable and efficient plant operation, especially in critical situations & abnormal conditions.

Below is the summary of literature review of this theme.

**Table 2.3 Literature Review Summary -THEME.2**

| **Source/Author with Reference** | **Year** | **Inference** | **GAP** |
|---|---|---|---|
| Salman et al. | 2014 | Non-standard conditions and accident situations can result in totally diverse actions, which might be ignored in the initial design | Control the possible stages of automation, operator response, workload and training of operators |
| Manca et al. | 2012 | The nature of tasks and challenges, which are faced by the operators, are different in their significance, sensitivity, physical and mental requirements | * Needs to find ways to training operators based on reproducible and effective evaluations<br>* Measuring the human factors automatically during the training exercise |
| UK HSE Report | 2015 | Console operators required precis control experience and training to effectively tackle human issues induced by training and competency | There is need for a unit-specific hands-on training planned with instructional design tools and effective measurement of results |

| | | | |
|---|---|---|---|
| Annette et al. | 2008 | All methodologies scrutinized for simulator training are based on adaptive transfer | Research to validate that simulators will follow the learning design<br>Error training on the design in process control environments |
| Manca et al. | 2014 | Limitations of present training policies linked to the training aims formulated by the instructor needs to be achieved | A "one-size fits-all" methodology is not suitable for simulator training, and we have to create tools for measuring the effectiveness |
| Salman et al. | 2015 | Importance of designing training methods for unplanned tasks and improved training methodology to mitigate incidents | To explore, the relation between training and situational awareness with probable enhancements |
| Jayanti et al. | 2011 | Model validation has to be carried out by independent experts to ensure fidelity and effectiveness of the system with reference to real system | A methodical unified testing and configuration helps in building a useful Training Simulator |

| | | | |
|---|---|---|---|
| Manca | 2011 | Creating detailed training methods and design strategies for the Industry based on instructional design principles | The paper didn't specify what kind of models and training systems can be integrated with process control and applicability from other areas where an opportunity exists to apply this research |
| Salman et al. | 2015 | Bridging the gap between the highly demanding human machine interfaces and analysing the effectiveness of training methods | Further research activities to progress the operator performance using advanced training methodologies and pedagogy |
| Aveva | 2013 | Benefits of OTS are multiple along with faster start up, enhanced facility integrity and increased production performance, faster production start-up and restart after a shutdown | Economic impacts of not having the training simulators on similar processes and industry vide cases. |
| Invensys | 2014 | OTS coupled with VR tools enhances the operator adaptability to any situations | Behavioural aspects are not considered. |

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|---|---|---|---|
| NASA | 2015 | The simulated situations and inflight anomalies are highlighted to make the case preparations to meet the events are critical for the mission | Knowledge gained during exercises to be applied to analyse the efficacy of control systems training |
| Peres et al. | 2016 | Procedural usage and Organizational factor are interrelated. | Research in human interaction considering workers observations and response |
| Rachael, Gordon | 1998 | In the unintended scenario there was a significant collaboration between procedural tasks but not the number of errors committed | Evaluations of electronic procedures to be conducted within a system that systematically varies the type of task operators perform |
| UKHSE Report | 2005 | Training can be rooted by an organised arrangement for corrective actions in a timely manner | Incorporating best operating practices into the OTS training methodologies and planning |
| UKHSE Report | 2005 | Procedures alone are not sufficient to deliver best results and they have to be practiced improving human performance. | An functioning procedure assembled prior to training to discuss operator error and its impact on training is missing |
| Monica and Levente | 2012 | Simulator guaranteed an effective training of | The case study is focusing on the FPSO |

| | | | |
|---|---|---|---|
| | | the operators during initial start-up, operational testing and optimisation of automated control loops | crude separation unit only and other processes/industries are not captured |
| Roos | 2002 | Critical events are considered from a human perspective, then the criticalness becomes the key issue | How critical incidents and personnel decisions having key influence on the reliability of operations |
| Hotblack | 1995 | Effective logging of data immediately from the process upsets help to produce lessons learnt exercises and configure simulation cases to training. | Plant operating personnel are always not finding the time to sit down and log instances that could be attributable to future simulator training and lessons learnt exercises |

### 2.3.3 OPERATOR TRAINING SIMULATOR TRAINING

Plant operations these days are challenging due to process complexity, high operating costs involved in operations, reduced profitability due to low oil prices and increasing competition. The industry is always looking for highly trained and qualified staff to operate the facilities. The ever-increasing and continually improving computerised systems in the process control leading to processes that are more multifaceted for the operators to follow and execute the operating changes (Donald, 2016). Consequently, these heavily automated controls tend to reduce human interventions.

The implementation of new control loop or a process with improved automation leads to some sort of complexity in operations. This can be one of the point resulting in system acquaintance issues confronted by the staff, as they accustomed to earlier versions and habitual in handling the operations. The ARC advisory group survey about OTS best practices and recommendations revealed that more than 80% of the participants, consisting of top & middle management, instructors and operators across the world, believes that simulation-based learning is viewed as a strategic component of the overall training policy of the company (ARC Survey, 2015).

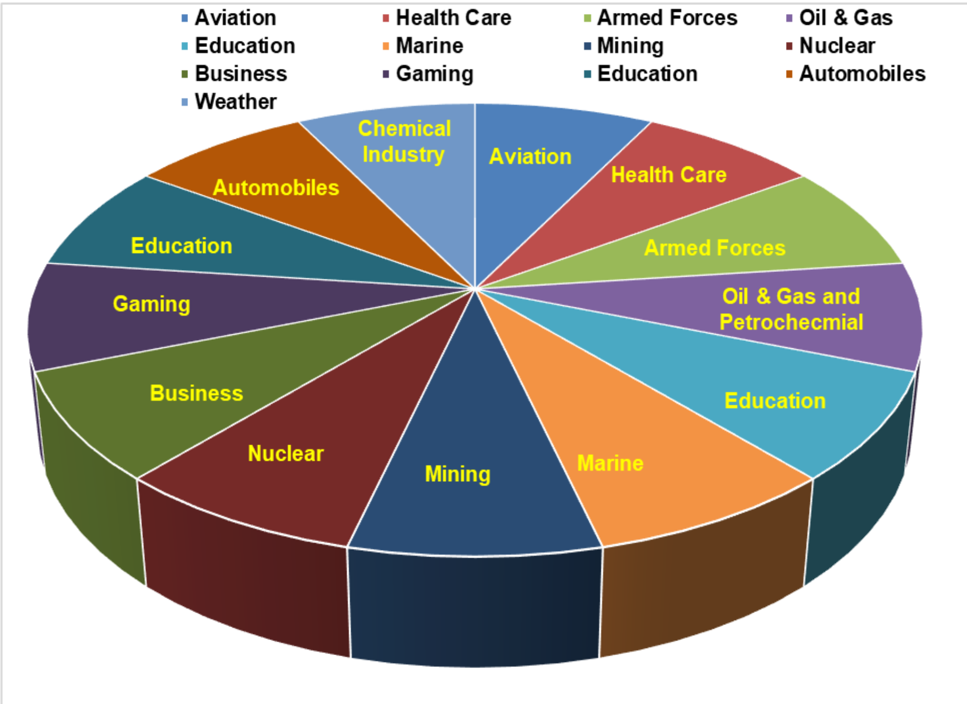


**Figure 2.5 Major Simulation training usage across different sectors**

(Source: Author, compiled from SPSS analysis)

Simulators are preferred choice for exercise and drill in many sectors like Aviation, Oil and Gas Industry, Nuclear Industry, Battle field management, Medical and First responders training (Fig 2.5) because they provide an innocuous substitute in reproducing the high-risk and practical training scenarios. The actual interpretations of these situations are too expensive and very unsafe for the staff to repetitively practice in responding to the workplace conditions (Tichon et.al, 2003).

**Table 2.4 Literature Review Summary-THEME.3**

| **Source/Author with Reference** | **Year** | **Inference** | **GAP** |
|---|---|---|---|
| Tichon et al. | 2009 | Repeated practice is the root cause for better execution and motivated to repeat their simulator experience | Underutilization of OTS and expected outcomes are not measured |
| Monica et al. | 2012 | OTS is strategically important as it unlocks the benefits of hands-on approach to training and helps in the advancement of actual control systems | The validated model is applicable to only one unit and needs to be validated for all units and Process. |
| Chirgwin | 2021 | Simulator training should be repetitive at systematically to endure the skills learned and recollect during actual situation | Research is required to enumerate the longstanding benefits in a sequential or tangible method. |
| Chung | 2000 | There is noteworthy variance in training with the simulator and other trainings | OTS benefits with a clear output and reasonable framework should be modelled |
| Patle et al. | 2016 | Developing training simulators models with relationships designed for analysis | Appropriate methodology to address recurring problems and |

| | | | |
|---|---|---|---|
| | | using multiple linear regression and other statistical tools | improving their usage across the industry by using instructional design tools applicable for OTS processes |
| Tyverskoy et al. | 2011 | Proof ground of Automated systems in Power stations to learning the simulated environment | Concept wise it is not established with other sectors and industries |
| Maria | 2005 | Learning in the simulator is used as evidence for competency evaluation and training effectiveness | Proof of concept is not established to other sectors and Industries and only One Model is used to demonstrate the experience |
| Alinier | 2013 | Skills developed in a simulator are convenient to replicate in actual situations | The study is confined to only one university in a closed group of students/volunteers and needs to study the applicability in other areas |
| Komulainen and Sannerud | 2014 | The didactic model for training simulator pedagogy is successful to improve learning results. The generic models has | Multi-disciplinary collaboration is necessary in the research and development learning and |

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| | | demonstrated to be suitable for theoretical and engineering courses | assessment methods for simulator training |
| Surender | 2015 | There is substantial variation of boldness, ability in execution and acquaintance in workplace after simulation training | Confined to only maritime simulators and other areas are not studied but these can be applied to hydrocarbon industry |
| CPP | 2014 | The strategies aimed at advancing the reliability of process control facilities through both team coordination and individual expertise in process control | Future research to include, creating domain specific training tools/resources, to improve training strategies |
| Parasuraman and Manzey | 2010 | Effectiveness of automation in training will vary not only by the type of automation and the task, but also by the skill levels of the operator | The presence of an important set of deliberations in the design and establishing proper training methodology with automation is missing |
| Walker et al. | 2013 | New trainees may not be able to cope up to training transfer effectiveness and | Measuring the effectiveness of OTS and methods to |

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|---|---|---|---|
| | | Engineering measures can help manage the process, competent operators | evaluate the performance |
| Paul | 1976 | There needs to be much more emphasis upon how the reported results were achieved | The simulator training practitioners and researchers alike need more case study of simulator training applications |
| Barbara | 2002 | Training delivery mechanisms could be modernized, instruction could be improved through instructor qualification, standardization | Operators may need comprehensive guidance on what topics to train pilots and how to measure training effectiveness |
| Monica and Levente | 2015 | Work environment constraining the usage of new skills and gathering relevant research methodology to measure the outcomes | The study confined to only one organization and not applied to any other Industry |
| Robert | 2009 | Due to the increased retention of employees and to be competitive they need to be competent and to utilize skills in their work environment | The smaller sample size has limitations on the data analysis. The author not analysed similar training methods |

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|---|---|---|---|
| Tian Yongliang et al. | 2009 | Learning design models can be used to measure simulator training quantitatively | Study confined to only aircraft carrier and not applied to any other industry |
| Donald | 2016 | ✓ Minds-On/Hands-on process trouble shooting is needed with Simulation training into the process safety and operations curriculum<br>✓ After the hands-on training, students showed substantial improvement in recovering from a plant upset | *Training effectiveness is not validated in the industry and applied for engineering students in the university.<br>* Examining ways to incorporate more predictive style exercises with the use of simulators. |
| Salman and Manca | 2014 | Knowledge improvement, and performance assessment from many uncharacteristic circumstances and industrial upsets for lessons learnt exercises | Developing an online tool for involuntary evaluation of the operators in the workplace |
| Frank | 2015 | * Revised standards are expected to prevent the rate of hazardous situations.<br>* Organizations have | The method has no strict guide and weakly structured and can be aborted any time and applied |

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| | | to build up list abnormal conditions to act upon the process to practice scenarios | based on Situational Awareness |
| Rick | 2015 | Applicability and Ability of the OTS usage and Effectiveness of the training on the operations in a measurable scale | Integration of Virtual systems with the OTS evaluation methods |
| Simone and Luigi | 2015 | The efficiency of using visual and reality-based settings in training simulators contribute to improve operator performance | Effectiveness of the training and data on the training efficacy is not used due to lack of methodology |
| Rothrock | 2015 | Operators interaction in the workplace situations, and improvements to the current process systems | Integrating eye tracking features in augmented reality and develop suitable systems using pedagogical methods |
| Heffner | 1997 | Team members should be trained to for effective communication and integration between team members | Training with team perform significantly better than those trained single or alone |

### 2.3.3.1 OVERVIEW OF THE SIMULATION PROCESS

The Latin word ‘Simulare’ is the originator of the word simulate, which means ‘imitate’, ‘copy’ and the verb is initiated from, “similis”, which means ‘similar’ or ‘like’ (Shanton & Goldman, 2010). Oxford online dictionary (2022) pronounces simulation as “a situation in which a particular set of conditions is created artificially in order to study or experience something that could exist in reality” and simulator as “a piece of equipment that artificially creates a particular set of conditions in order to train somebody to deal with a situation that they may experience in reality” (Oxford, 2022).

IST, Institute of Modelling Simulation & Training, U.S.A defines simulation modelling is the development of scheming a working model of an actual or imaginary system by capturing the necessary data to interpret the result and conducting necessary experiments”. The model characterizes the process itself and simulation characterizes the reality (IST, 2021). Process models are created by simulation software by integrating graphical illustrations/interfaces by programming with chemical engineering first principles such as mass flow, temperature, pressure, level, composition etc., using thermo dynamic equations and their modelling computations using advanced mathematical tools to display the data along with site specific industrial hardware.

**How simulation helpful in real word scenarios**

Simulation is the repetitive exercise with same conditions existing in normal situations. It is expected to prepare staff to carryout tasks effectively during demanding situations (Tichon and Guy, 2013). A US National Transportation Safety Board survey (NTSB) in 2005 determined that, simulators can be used as a part of “what is going on” process of evaluating alarms, which is a tool that operators can use to evaluate the cause of the alarm and act, along with problem solving techniques. The flight simulator training provided a better understanding of the types of pilot response and evaluation practice decision-making errors originated from weather-related incidents.

**On-the-job training (OJT)**

OJT is always a key part of the learning curriculum of control room operators. OJT needs to be developed with a structure to ensure with properly defined training methodology, identification of key skills and familiarity achieved while performing the routine jobs. It needs to be supplemented with various forms of replication of work in a simulated scenario or in a training simulator, coupled with a competency system to assess that appropriate competencies have been achieved (Andy- 2010). The consequences of both precise and improper decisions should be immediately fed back to trainees giving them the opportunity to correct mistakes and learn from them (Konstantinos-2002). The general aim of simulator training is to build confidence and providing an intellectual map of persons capability to accomplish tasks during hostile conditions (Stetz. M et al., 2006).

### 2.3.4 TRAINING EFFECTIVENESS

Baldwin and Ford in their book defined training as a deliberate learning involvement which connects the personnel how to accomplish tasks in the workplace at present and possible application in future. Learning in the workplace is intended to progress the effectiveness of diverse sections while educating constructive attitudes toward business and organizational alignment across the organization (Baldwin and Ford, 1988).

Training is not only an important issue for the human resources alone, but it stands to grow in importance as the new healthcare, financial, process and environmental regulations continue to take effect and employees have a continually . Due to increased level of regulatory monitoring, growth of energy consumption, increasing population and sustainable living practices we are finding ourselves facing more challenges in the near future. There are many ways to train the staff such as In-person in the classroom, Online thru internet, Simulation, Virtual classrooms covering Self-paced interactive presentations, Computer Based Training (CBT) and Off-line simulations etc.

Training is broadly defined as an intervention focused on the identified population for the sole interest of cultivating workplace skills, changing behaviour and improving competencies. Most of the time the focus of training is more about what to know, rather than submission of what is being learnt during the training or the expected transfer or usage in the workplace. Technological support in the workplace to apply different learned things is identified as one of the important aspects to capture the transfer of learning and their by training effectiveness (Yamnill and McLean, 2001).

**Table 2.5 Literature Review Summary-THEME.4**

| Source/Author with Reference | Year | Inference | GAP |
|---|---|---|---|
| Korteling | 2015 | The training design should be embedded to determine training effectiveness and stakeholder surveys, opinion polls, trainee evaluation forms should be coupled with workplace performance checklists | * Measuring training transfer in the simulators is a complex phenomenon including design flaws and needs to be studied more<br>* How to maintain the OTS updates along with the existing systems |
| Excerpts from Hydrocarbon Processing, February- 2007 Pages 110-116 | 2007 | Validating control strategies using the OTS requires special skill and data | * To prove that the systematic use of an OTS as training tool not only for operators but also for other staff |
| Optimizing OTS performance, World Oil., Dec-2012, Pages 61-65. | 2012 | Using OTS reduced operational risk and enhanced facility integrity | The simulator vendors involvement on how the OTS can be optimized for |

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| | | | operator training is not studied |
| Bell | 2019 | Approaches into three major categories Opinion Based, simulated learning effectiveness and transfer of training | The study is limited to air combat training only and not considered in other sectors |
| Bransford | 2007 | Helping people to learn how the thoughts, behaviours are affecting in terms of organizational and cultural settings across the workplace | Workplace cross competencies and dynamics are not considered in terms of learning plans and training evaluations. |
| Subramanian and Rao | 1997 | Structured training interventions changed the expectancies of the Low Performers | The study confined to only one organization, cost-benefit or ROI in terms of the total organization are not studied |
| Salas and Janis | 2001 | Technology influenced systems are gaining importance in the organizational learning and | More research is needed to interpret the results of training effectiveness into practice and |

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| | | becoming a main method of training in the industry | uncovering why training is necessary |
| Larsen and Hepworth | 1998 | Students with higher-level skills in the practice sessions mixing with lower skills staff and assisting the latter to achieve higher levels | Study refers only to social work students alone and other streams are not considered |
| Jacqueline | 2006 | Supervisors can work in partnership with trainers or examine training content beforehand to determine tools needed on the job to enhance transfer | Small sample size and less response rate is hindering the conclusions of the study and practicability for other areas in Industry |
| NIOSH | 1999 | Studies for safe work atmosphere and to recognise factors influencing the training process by optimizing the resources | Workplace programs developed and conducted using different training methods should have similar measurements of effectiveness |
| Heffner | 2005 | Training on virtual reality simulators helped the to reduce | The non-uniform case scenarios can dilute the result and |

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| | | the time taken to complete the tasks | positively contribute to the findings |

### 2.3.5 TRAINING TRANSFER & LEARNING TRANSFER

Learning is about the learner being able to perform the tasks they have been given to execute by adapting the skills learnt during a training session (Davis, 2013). Learning is the progression of obtaining the capability to handle a situation which is not faced earlier. We can say that it is the transformation of ones behaviour, in the work-place due to some earlier experience or practice by simulated training (Ravikanth et al., 2018). The training should be focussed on the transformation, which is reproduced in a theoretical setup, flexible and consequence of a presentation, and in a way leads to reduction of automation gratification (Parasuraman et al., 2010). Due to the similar nature of training transfer & learning transfer, the studies and literature across the domain are interwoven. Based on the other works, with reference to the search outlook theme, both are analysed together.

**Table 2.6 Literature Review Summary-THEME.5**

| Source/Author with Reference | Year | Inference | GAP |
|---|---|---|---|
| Stephen | 2018 | Improved training using the OTS and procedures cross-checking to improve process safety | OTS/DCS-pathways to appear as "Digital Twins" by enabling technologies in-tandem |
| Baldwin et al. | 1988 | Training transfer depends on the generalization of learning material and maintaining skills on the job, depends on the | Need further research on interactive efforts of work characteristics, its effectiveness |

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|---|---|---|---|
| | | training design, trainee workplace | and on time utilization of skills in the workplace |
| Ghaneemah and Casimir | 2015 | * Developing an organizational culture to improve attitude to training and might increase overall training transfer in workplace<br>* Analysis of the training needs to customize training and facilitate training transfer | The generalization is uncertain due to small size and the training process sample representing only a fraction of work force and data is biased by overall positive perceptions of the respondents |
| Pilar | 2010 | Systematic evaluation of the training is needed to design a modest evaluation plan<br>than an intricate plan so that it can receive support from the organisation | In-sufficient training of instructors, who are not competent with training assessment methodologies and not being training in their usage |
| NRC | 1996 | No quantitative research is carried out in the simulator | Further studies on the optimal use of simulator |

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|---|---|---|---|
| | | effectiveness and training transfer to workplace | training and applying instructional methodology in the design of the training models |
| Westin et al. | 2015 | Improving methods and situations for a reflective training transfer to be arranged for the integration of theoretical and practical knowledge | Study confined to small group of 35 participants and no detailed statistical analysis is performed |
| Stanley et al. | 2014 | The simulation training is effective by using transfer of learning methods, effective learner engagement and self-belief in carryout the tasks | Learner focused curriculum design to engage learners at varying degrees and tasks in a given training simulation exercise |
| Daniel | 2008 | Organizations need to concentrate on data collection from different sources to avoid exaggerated results and need to | Further research activities to improve the performance of transfer of training and |

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| | | corelated the data with other methods of evaluation and employees themselves | evaluating the effectiveness for each training by instructional design process and models |
| Pertanika | 2017 | Transfer of learning depends on the multiple factors to identify whether staff are able to establish skills in their workplace | Measuring contribution to the transfer of learning and mechanism to correct the issue |
| Timothy et al. | 2017 | Constructive training transfer is regarded as the main aspect and proving it in a tangible way is a formidable challenge | Ways to optimize transfer and effectiveness and expanding training transfer outcomes |
| Sensuse et al. | 2017 | Qualitative approach is used to perform an in-depth inductive study to seek information among possible knowledge transfer | Evaluation of knowledge transfer and developing features to measure knowledge management |
| Komulainen and Sannerud | 2018 | Improvement of instructor abilities and uniform qualitative assessment across the | Instructional design features and post training |

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|---|---|---|---|
| | | trainings is needed | analysis is not marked as part of the study |
| Thérèse | 2019 | Engaging learners with clear learning goals as part of the classroom curriculum | ✓ Learners pursue knowledge and with their sub-ordinates without clear goals<br>✓ Lack of pedagogical design used in the training curriculum |
| Jinkyun et al. | 2003 | Development of counter measures to quantification of the human errors to identify the critical points | How to identify the training effectiveness, learning interventions with reference to the execution |
| Korteling | 2006 | Measurements and Evaluations focus on learning and trainee performance | Lack of dimension to training transfer and preservation of results by instructors at workplace |

| | | | |
|---|---|---|---|
| Burke and Hutchins | 2014 | The organizational background effects effectiveness of training and workplace transfer interventions | No studies on real workplace situations and staff as focal points and stakeholders as subjects for training transfer cases |
| Irene | 2008 | Learning objects helped to decide what kinds of strategies to take in each training design and different phases of transfer | Development of instructional design models to enhance student learning in a virtual environment |
| Stanley et al. | 2003 | Establishments not learning from previous incidents due to lack of incident learning and corrective action tracking systems | Over time by learning from the incidents can reduce risk and minimize losses to become a high reliability organization |

| | | | |
|---|---|---|---|
| Ibrahim and Tareq | 2014 | Staff not able to use the information expanded through training and the invest made for training and development always unable to comprehend | Association between different training issues transmission and improvements workplace |
| Tobias et al. | 2017 | Focus group dialogue depends on practices and insights to produce circumstantial data for training transmission | Researchers must define on where to deploy the focused group training technique and how to analyse the data through literature |

**2.3.5.1 CONE OF LEARNING**

Edgar Dale proposed his famous cone of learning in 1969 and hypothesized that students are able to gain the information by what they "do" as opposed to what is "heard", "read" or "observed" and his research contributed to the advancement of Cone of Experience (Dale, 1969), one of the widely used tool in the learning industry.

According to the cone of experience in learning, the most active methods of learning are at the bottom of the triangle. Learning by doing also known as "Practical learning" or "Action oriented learning" or "Simulation" and "action-learning" practices, might result in 90% retainment of performing the task. Individuals are able to learn superlative when they are able to use the perceptual learning styles based on the sensory based interactions, involving cognitive responces stimulating memory (Dale, 1969). The more the number of sensory conduits conceivable in interrelating with the training tools, the best the chance that most of them can learn from it.

As per this theory, as we progress down to the bottom layers of the cone, the better the knowledge gain and the additional information can be grasped. The instructors or instructional designers should strategize the actions to outline real or actual experiences to maximize learning transfer and retention to the workplace (Heidi, 1990).

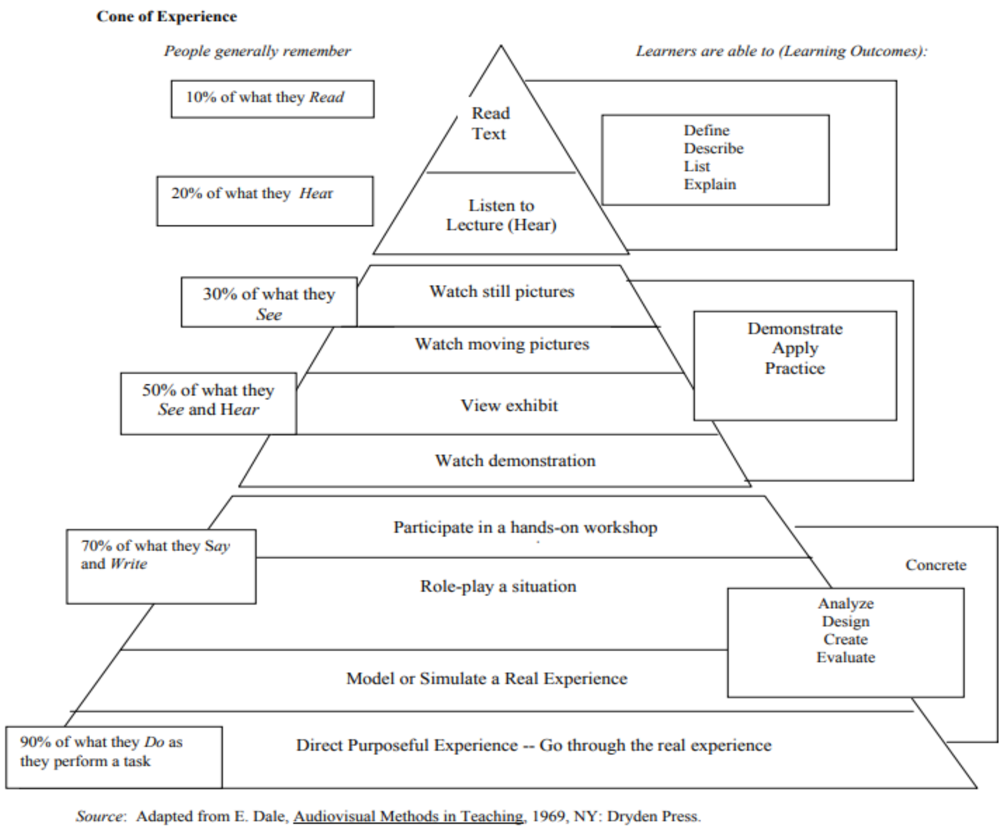


**Figure 2.6 Cone of Experience- Dale**

(https://www.queensu.ca/teachingandlearning/modules/active/documents/Dales_Cone_of_Experience_summary.pdf).

### 2.3.5.2 KOLB'S LEARNING STYLES

Kolb defined learning as the process where the knowledge is created through the transformation of experience and is based on four principles (Kolb, 1984).

The four principles can be summarized as

1) Dynamic Experimentation (Doing)
2) Intellectual Conceptualisation (Thinking)
3) Thoughtful Observation (Watching)
4) Actual Experience (Feeling)

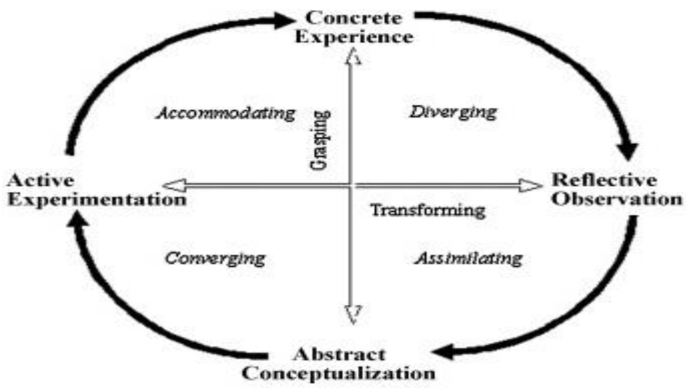


**Figure 2.7 Experiential learning cycle**

**(**https://www.sciencedirect.com/science/article/pii/S0147176708000941#fig1 ).

Learning is the process where the learner being able to perform the tasks given to them by executing and adaption of the skills learnt during the training session (Davis, 2013). Based on the above different researchers tried out theories of human learning, namely Experiential Learning Theory (ELT). ELT highlights that learning styles are merely not a psychological characteristic but a continual state resulting from synergistic transactions between the learner and surrounding atmosphere.

As per the experiential learning cycle, the learning process or knowledge is based on the combination of two dialectically correlated modes of gaining the experience –Concrete experience (CE) and Abstract Conceptualization (AC) – and two dialectically related modes of transforming experience—Reflective Observation (RO) and Active Experimentation (AE) through accommodating, diverging, converging and assimilating through the interconnection of grasping and transforming information (Simy and Kolb, 2008).

To be learned more effectively, learners can be facilitated to identify their preferred learning style and the instructor can strengthen the training curriculum by the application of the experiential learning cycles adapting to the learners as a team and facilitate the training sessions (Mcleod, 2017). The different associations of attention are in between the training method, the expected learning consequence and its intended influence on the planned exercise. In the cause-and-effect relationships, the process variables like training styles, methodology etc., are indicators such as knowledge gained and transferred into the workplace (Cohen and Colligan, 1998).

The significant issue is to identify the important necessities of training effectiveness, to understand the relationship of these items on the envisioned impact of training like transfer of new skills and abilities in the workplace. While identifying different factors responsible for transfer of training in technical domain positions through an evaluation in practice, the authors conclude that there are three important stages during the technical training transfer namely, inputs, throughputs and output along with different sublevels which can be addressed using pedagogical or instructional design methodology in the training processes (Annette et al., 2014).

## 2.4 INSTRUCTIONAL DESIGN PROCESS

Instructional Design (ID) process commences by identifying the performance issues or lack of workmanship of learners and their root causes and then able to determine whether the instruction or training is the appropriate solution. The methodical approach consists of using proven Instructional System Design (ISD) models, such as Blooms Taxonomy, Robert Gagne Conditions of Learning, Three learning theory, ADDIE, ASSURE and the Dick and Carey model etc. The ISD models identified from the literature and applicable for this study are described in the next sections.

### 2.4.1 BLOOMS TAXONOMY

Bloom’s Taxonomy is an arrangement of diverse ideas and skills that educationalists able to create such as earning objectives, such as Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation coupled as Create, Evaluate, Analyse, Apply, Understand and Remember in a hierarchal manner (Huitt, 2011). This is based on the hierarchical methodology and the higher levels learning is always depends on the skills attained at lower levels. If the lower-level skills are not properly attained and not suffice, the knowledge and skills at top levels are not able to prosper. Bloom’s Taxonomy often displayed as a graphical pyramid, and each one is built on the foundation of the previous one so that we can be able to demonstrate this hierarchy (Anderson et al., 2001). This will have an effect if the bottom level has some issue which effect the next higher levels. If the learner is not able to get the required level in the initial stages, he cannot be in a position to adapt higher levels of learning and not suitable for dynamically operating industries and suitable for educational institutions.

### 2.4.2 GAGNE CONDITIONS OF LEARNING

Gagne conditions of learning is based on five major categories of learning, namely Verbal information, Intellectual skills, Cognitive strategies, Motor skills and Attitudes. This models hypothetical background deal with all characteristics of learning, and the emphasis is mostly on knowledgeable skills transfer (Gagne, 1992). Different conditions (internal and external ) are to be satisfied, which are essential for learning process. Gagne proposes that the learners must have a chance to exercise evolving solutions to solve their problems, able to learn different attitudes and are in a position to be exposed to credible training models or influential opinions (Gagne, 1992). Gagne is very influenced by Bloom’s knowledge class and separated into a different category called Verbal information and further added learning tactics known as Cognitive strategies. Gagne believed that perceptive strategies are like learning plans to the instructor and have to be prepared by using this methodology and one has to expect that the learners are adopted to the outcomes in the process of learning. These strategies are not subject or sector specific and can be applied anywhere for any situations (Wager et al., 2009).

### 2.4.3 ADDIE MODEL

ADDIE is a cyclical model containing different instructional design processes.

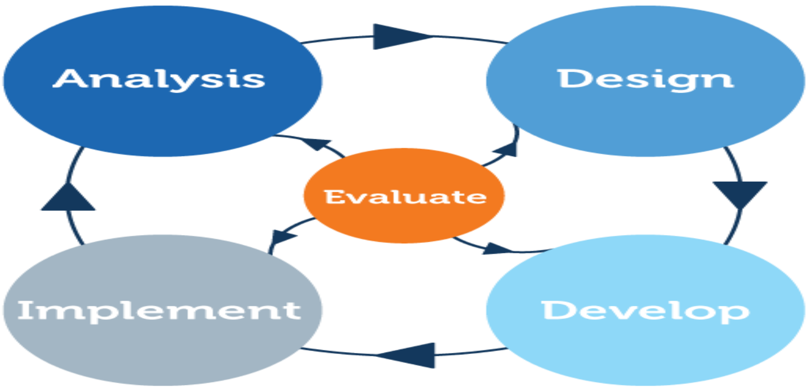


**Figure 2.8 ADDIE Model**

(https://xerte.cardiff.ac.uk/xapi_launch.php?template_id=14489&group=groupname#page1)

As shown above, they are Analysis: Overall scope of training and process, Design: User requirements (Stakeholder characteristics, specific objectives and learning strategies etc.), Development: Production of instruction and overall process, Implementation: Conducting course (Coaching & Tutoring) and finally Evaluation: Assessing and collecting data for the success or failure or possible improvements to the course in conjunction to others (which is the effectiveness).ADDIE model can be applied in the development and appraisal of training process, procedural competency, leveraging technology for expanded reach can be analysed by open-ended questionnaire and this should be prepared in the context of stake holders and the data is studied to validate the overall process conditions and improve learner knowledge and work force development (Patel et al., 2018).

The detailed information from literature about each component of ADDIE is presented below (Simone and Luigi, 2016).

❁ **Analysis** stage is to determine, who the learners are and the overall goals we are trying to achieve. One has to classify the knowledge, skills, attitudes, and behaviours that need to be taught, required amount and essential levels of content, different resources required and or available at the facilities. Further the focus is on define the goals of the instructional design process, and possible learners issues.

❁ **Design** stage is to how the content and related activities have to be sequenced and offered to learners. The objectives of each session/unit and required skills attainment or intended training outcomes to achieve for each session objectives have to be designed. What methodology one will be using to achieve each objective and how the training assessment is carried out also have to be designed in-tandem with the course materials.

- **Development** stage deals with building the course itself. This stage focuses on putting different theoretical aspects and to create tangible course materials. The instructional designer can seek information from the organizations to implement their vision into the curriculum and if possible talk to the intended learners themselves to gather their inputs to formalize the content. This inclusiveness of the stakeholders possibly enhance the overall success of training and return of investment by actual workplace transfer for the organizations.
- **Implementation** is the actual instructional delivery and training of the participants. This stage requires all the elements of the learning atmosphere that are identified, and training strategies developed using above methodology. The implementation stage should be based on appropriate pedagogical methodology that guides the delivery of the instruction.
- **Evaluation** stage is the final one to assess all the other stages to collect feedback and finetune the process. Evaluation can be divided into both formative and summative or both.

ADDIE instructional design model is regularly used in the hydrocarbon industry for developing training programs and Instructional curriculum. This can be due to the strong emphasis on the analysis and Development phase, which affects the remainder of the items. During analysis, the characteristics of the learners are determined, and training goals are identified. In addition, the overall developmental considerations include financial resources, time charter, learning limitations, and desired instructional methods. From the analysis and design stages, one can determine that the program costs which might outweigh the projected outcomes of the training.

Due to the cyclical nature of the ADDIE process, one can study each stage and revaluate before and after next stage and modify the plan/proposal to fine tune the end result. We can measure each item of the model by relevant questionnaire and analysing the feedback using appropriate analysis tools. This is very important as the instructional design process have to anticipate and evaluate the points effecting the learner performance, which can be instigated by raise of process complexity and difficult operational situations. When the participants competent and understand the processes and functioning of the complex control & safety systems they are better equipped to deal with the situations and handle the upsets (Simone and Luigi, 2016).

ADDIE is chosen as the conceptual model in the present context to evaluate the stakeholder perceptions and generalization through the survey as it runs in a cyclical process, flexible to allow everyone, at any time to revisit a particular step, and refine it as needed for the success of the overall program or individual modules or the training model itself.

## 2.5 LITERATURE REVIEW SUMMARY

To know that the training program or session effective, it needs to be well-defined in a clear evaluation criterion and gauging its impact on specific individuals or organization. It is to be tested and feedback is collected by using pre-defined methodology, either by manually or automatic means, without any bias towards the topic, instructor and other organizational issues. Training efficacy normally depends many number of paradigms, instructor competence, instructional design, time spent on training, trainee motivation, cognitive ability and competencies of individuals and organizational issues.

The objective of the training determines the most suitable condition for measuring the efficacy of training (Stetz, 2006). The key aspect of training is to prepare the trainees for the responsibilities and to accomplish the tasks in the workplace (Barnard et al., 2001). The training should focus on the change of performance, which gets reflected in the ability of perform and systematic training leading to multitasking in operations, and one can observe a decreasing trend of reduction of automation related abnormalities and its consequences (Parasuraman et al., 2010). The learner should be properly motivated and eager to involve fully in the training process. They have to identify their strength and weakness, administrative and intellectual skills and to be self-evaluative to overcome their weakness in coordination with the instructor and supervisor (Yamnil, 2001).

Simulator training will be very effective when the underlying skills are supplemented by it and can be achieved success or improvement by the sense of command during the training and learners ability to replicate in the workplace (Maschuw et al., 2008). Process safety experts suggest that part of the learning process is to memorize earlier incidents, envisage possible failure cases which are not occurred till date but probably might occur in future due to underlying risks. They can be easily preventable by possible training interventions and lessons learnt exercise involving previous incidents.

From the literature, the main elements that are crucial for appraising simulator-based training are as below.

- Methodology (how to evaluate and what tools to use)
- Criteria (how is the outcome based on)
- Objectivity (specific requirement of training session)
- Reliability (the proven method of evaluation)
- Validity (correctness of measurement)
- Fidelity (accuracy of imitation)

### 2.5.1 KEY TAKEAWAYS

- The overall training program, not only some components should be effective.
- Process simulations should the configured to meet the training requirements rather than configuring training program to fit the simulators.
- Assessment of operator competencies should be conducted using established performance methods.
- Training should be continuous till the mandatory level of competencies are attained and maintained consistently.
- Refresher training is always required to uphold the required level of

competency.

- ❖ Pre and post program evaluation and assessment at the workplace is essential to evaluate overall program efficiency.
- ❖ Conducing workplace environment, willingness to participate and positive attitude to training is important for training transfer.
- ❖ Training Strategies, organizational policies, and inspection or auditing by regulatory authorities are key points to ensure training effectiveness, ensuing transmission to workplace and compliance to standards.
- ❖ Instructional design models can be used to evaluate the training process by stakeholder feedback and analysis through questionnaire.

## 2.6 GAPS FROM LITERATURE

The lack of the systematic training is possibly one of the roadblock in improving the competencies of the staff to meet the controlling requirements of the complex automation systems (Li et al., 2011). Patel et al., in their research article on operator training process mentions that there is an essential requirement to develop enhanced methodologies, to have direct impact on the safety, productivity, profitability, stability, and controllability of the operating processes (Patel et al., 2016).

Human error is the main root cause of majority of industrial incidents and corrective actions like training enhancements and mandatory re-training with suitable simulators are the key factors in the development of advanced simulators. Training simulators enable training of the process operators on normal operations, shutdown (planned or unplanned) and different emergency conditions. They include scenarios such as start-up, shutdown and upset conditions. The scenario-based training assists the operators to address the emergency in a most efficient manner, thereby ensuring safe operation of the plant.

The demographic shift due to retiring experienced staff also requires less but inexperienced staff do more work in 24/7 critical unit operations, who needs to be trained quickly with all the nuances of process scenarios. Operator

Training Simulators include modelling and simulation of all the equipment, their designed to meet the design conditions during the configuration of the process model. Actual process graphics, process control and safety systems, alarm management and all other control strategy included in the real units.

The operator training simulator training literature is lacking with data to show the different fundamentals of simulation training to provide conducing atmosphere that inspires active learning and learner engagement in the workplace. In the industry, the training assessment and efficacy of the operators and perceptions of stakeholders are not deliberated in the viewpoint of the instructor using proven instructional design models.

### 2.6.1 THEORETICAL GAP

In the human factors research, while studying the root causes of contribution to incidents in the petroleum industry, it was observed that there is a limitation to access for operational staff to get detailed picture of incidents, lessons learnt and how to avoid them in future with training and they are more willing to report findings incognito due to weaknesses in the organizational processes and attributing culture with in their organizations (Antonovsky et al., 2014). Further, very slight, or insignificant research work is existing in view of stake holder expectations of operator training. The usage of simulators across the hydrocarbon industry in the context of human errors prevention and evaluating the perceptions and feedback with inputs from key stake holders (users and suppliers) is missing.

Judgement based assessment of the simulator sessions, models which can quantify performance assessment of the program based on training methodologies are difficult to conduct as they have an inadequate scope to measure the effectiveness. Therefore, training evaluation studies should include planned estimation by professionals or the instructor himself. This can be carried out within the context of the training and skill transfer .Survey is one of the useful instrument with overall opinions from key stakeholders by using appropriate questionnaire with clear evaluation criteria and data analysis methodology.

### 2.6.2 RESEARCH GAP

In the current academic and industrial literature, very petite or less research work is carried out on the operator training simulators, their effectiveness, usage and perceptions of key stakeholders in the oil and gas industry.

## 2.7 THEORETICAL PREMISE

In the research methodology, exploratory research is used to seek overall understanding of fundamental reasons, thoughts and motivations among the stake holders on a particular subject or event. This research adds quality and insightful information to the studies and is one of the vital aspect to investigate any new methodologies. It concurrences the researcher to be creative to understand insightful views on a particular subject.

Descriptive research design by using structured survey (Controlled questionnaire administered to seek responces and planned to prompt precise evidence for a particular event or subject) and observation (behavioural pattern of individuals, items, and trials in a methodical manner to seek information about the phenomenon of interest) is the primary data gathering tool in this study.

To measure training transfer, we need to carry out different correlational studies on the aspects of measurement scales and to have better understanding of different ways to design. It is also better to inform users the advantages or disadvantages of using one instrument over another and seek responces accordingly.

Significant levels of individual inconsistency can be observed when learners apply tasks in workplace. Further there is an changeability of individual workplace transfer which are tied to variables like motivation level and self-efficacy etc., which can be influenced by transformation by the individual himself (Schoeb et al., 2021).

There is a limitation in validating the present learning methodologies linked to these learning objectives accomplished in the simulators, as any singular approach is not an ideal resolution. More research, stake holder studies need to be carried out to identify issues and propose solutions within the framework of learning theories and instructional design (Annette et al., 2014).

**2.8 EPILOGUE**

In this chapter, the methodology of the systematic literature review process is deliberated by using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method. The main themes are presented and each one of them are briefly discussed in tandem with the literature cited in the study. Different instructional design processes applicable for OTS are deliberated and ADDIE (Analysis, Design, Develop, Implement and Evaluate) model is selected to evaluate the effectiveness. Exploratory and Descriptive research methods are used as basis for theoretical premise of this study. Survey method with questionnaire is used to collect feedback from stakeholders of the operator training simulators and mixed method research is chosen to analyse the data. Data analysis is carried out by using NVivo tools. The gaps from literature are summarized along with key takeaways within the context of this study.

# Chapter 3

## 3. RESEARCH METHODOLOGY

### 3.1 INTRODUCTION

The overall research methodology with reference to research objectives, in consideration to the study framework and as per the literature review is summarized in this chapter. This study is envisioned to identify the different training models and methodologies of operator training applicable for the OTS. The overall approach to the study and research methodology to gather stake holder perceptions along with the data collection process is described. The instrument design, strategy, data analysis along with ethics and limitations are summarised. This is intended with an overall aim "to improve operator competency, minimize human errors and maximize training productivity" of training simulators.

### 3.2 RESEARCH OVERVIEW

This study is projected to examine the key relationships between different stake holders of the OTS, like process operators, instructor, supervisors, and simulation engineers etc and ways to reduce human errors in operations and allied benefits.

The approach in this study is to examine the below attributes from different sectors in the industry, where training simulators are used for training the operating staff.

- ✓ To identify role and perceptions of key stake holders
- ✓ To explore different methods to prevent OTS obsolescence
- ✓ Explore diverse ways to minimize human errors in operations
- ✓ How best practices from others can be used in oil and gas industry
- ✓ How different efforts can be enhanced by probable intervention

### 3.2.1 RESEARCH GAP

In the current academic and industrial literature, very little research work is carried out on the operator training simulators and their usage, effectiveness, expectations and perceptions of main stakeholders in the hydrocarbon industry. Keeping in view of all this debate and from the literature review, the research of "Study of Operator Training and Operator Training Simulators (OTS) in the Oil & Gas industry" is assumed to be valuable in present environment.

### 3.2.2 BUSINESS PROBLEM (BP)

There is lack of productive simulator training of control room operators in the hydrocarbon industry and usage of operator training simulators leading to Human Errors, Loss of Production, Compliance and Environmental Issues.

### 3.2.3 RESEARCH PROBLEM (RP)

As per the current industry training practices, review of literature and as per the research gap, the research problem is defined as below.

✔There is a need to study Operator Training process and Operator Training Simulator (OTS) models, their intended benefits, usage, efficacy and their role to prevent human errors as per the stakeholder expectations across the oil and gas industry.

### 3.2.4 RESEARCH QUESTIONS (RQ)

✔RQ-1: What are different types of operator training simulators (OTS), OTS models and available training methods used in the oil and gas industry?

✔RQ-2: What are the expectations of stake holders (Instructor, Operators and Management) on the OTS training?

✔RQ-3: How OTS is being used in the training and competency of control room operators and application of OTS as a tool to reduce human errors?

### 3.2.5 RESEARCH OBJECTIVES (RO)

✔RO-1: To study different training models and methodologies on operator training applicable for the OTS.

✔RO-2: To study different challenges faced by the stake holders (Instructor, Operators and Management) and identify new approaches to OTS training.

✔RO-3: To study the efficacy and control systems knowledge acquired using operator training simulators in minimizing human errors and other economic benefits.

## 3.3 RESEARCH FLOW CHART

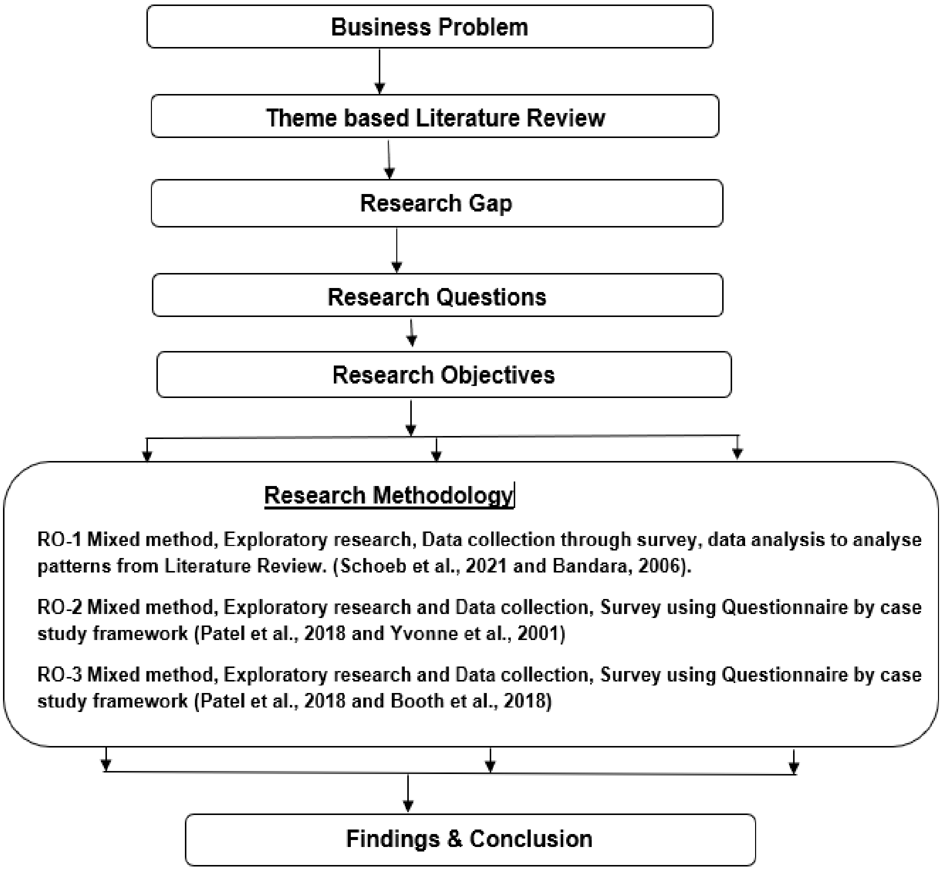


**Figure 3.1 Research Flow Chart**

(Author compilation from literature)

## 3.4 RESEARCH METHODOLOGY

This study is carried out using mixed method research methodology consisting of qualitative and quantitative ways to analyse the data gathered through questionnaire, using case study approach among different stake holders in the usage and development of operator training simulators.

### 3.4.1 PILOT STUDY

A preliminary study was done thru a pilot mission across two refineries in USA to gather preliminary data on the effectiveness of operator training simulators. This pilot study consists of 35 questions along with the demographic data of the 40 participants training with the process simulation models from Simulation Solutions LLC, USA. After the training sessions, the questionnaire is filled by different participants and data is analysed. The findings from this study are presented at the 59th International Conference of Scandinavian Simulation Society (SCANSIMS2018), Oslo, Norway.

Based on the outcome of this pilot study and further literature review, the scope is broadened in the present study consisting of more detailed questionnaire, different industry sectors (Gas Processing, Refinery, LNG, Petrochemicals and Others) covering upstream, midstream, and downstream organizations, wider demographic area of respondents (as key stake holders) envisioned across a larger population to represent the industry. These are the stakeholders with distinct knowledge about the OTS process and are associates of a specific group of operational personnel in the industry, identified by the researcher as part of the study.

Qualitative research by survey of the stakeholders (Instructors, Operators, Supervisory staff, Model Engineers/Development team) with special knowledge of simulation training across the industry. They represent the unique population who are key informants of this study. Qualitative research uses a true-to-life approach where the researcher can identify and understand the phenomena in the framework of his study specific to the research. This is the actual creation from the data set and the researcher is not able to try manipulating the subject of interest (Patton, 2001).

Questionnaire and checklists along with interviews of stake holders of the process (Trainees, Instructor and Managers) is helpful to gather data and analyse by suitable qualitative methods by planning them as cases (Yvonne et al., 2001). The self-assurance in simulator trainings is due to the fact that most studies on their efficacy are carried out on individual assessment of participants than on unbiassed trainee performance data (Salvendy et al., 2012). The actual assessment methods for simulator training is the collective analysis of post-training evaluations taken over a period time rather than a one-step approach. Through this method, the learner, instructor and supervisor remarks can collectively be used to identify performance trends and issues (IAEA-2004). The reduced incidences of accidents and resultant downtime, in the case of both personnel and equipment, means an increase in productivity, which justifies the investment on the simulators.

### 3.4.2 MIXED METHOD RESEARCH

Mixed methods research is the amalgamation of qualitative and quantitative research methodologies within one research study (Molina, 2016). The use of this type of research in industrial settings playing an significant role in the advancement of field based studies carried out through diverse methods. These are encouraging researcher's to augment scope of their business problems and understanding different research questions and probable methodologies (Molina, 2016). Using mixed methodology, one can enhance the accuracy, theoretical and intellectual abilities, seek new ways to answer the research questions. We can categorise reviews that are not recognized earlier and contributing to sharpening our methodological skills (Edwards, 2008). In the mixed method research, surveys is one of the best tools to collect the data, where the researcher gather qualitative data through forms using group of questions among the identified people or individuals having similar expertise or simply the stakeholders. The survey can be modified from an existing instrument so that it can be validated through a focused group of experts or can be through an pilot study, and then share the survey instrument to the targeted population (Creswell and Hirose, 2019).

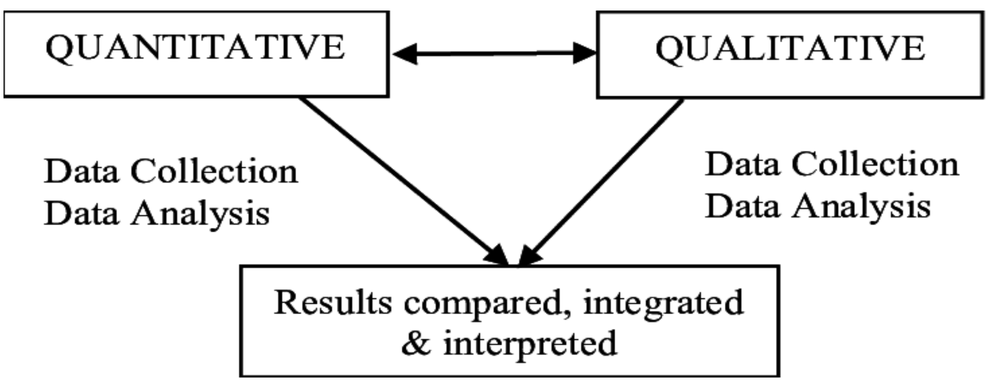

**Figure 3.02 Mixed Method Research**

(Author compilation from literature)

Quantitative scholars sometimes isolate themselves from qualitative analysis of the studies as their studies are quantifiable in nature and their findings are designed to reduce their involvement and role to qualitative aspects of their research. Patton (2021) supported the concept of scholar's contribution and involvement by deliberating in the present-day situations. They are variable in nature and the reliability in quantitative research solely resting on the research design. In the qualitative research, “the researcher himself is the instrument" and its reliability is a consequence of the validity, dependable planning and execution of openness of the study. Although consistency and legitimacy are delt independently, these two are not treated distinctly in qualitative studies and often combined as per the research design (Patton, 2001 and Golashani, 2003).

### 3.4.3 CASE STUDY APPROACH

In the case study approach, the underlying central tendency is to brighten a decision or set of conclusions by how cases are engaged, how cases are realised and what is the collective outcome. This definition thus mentions the cases as “decisions” having more emphasis to case studies. Yin (2003) described the common cases to include “people,” “organizations,” “processes,” and “events”. Case study’s exceptional strength due to its capability to deal with many varieties of evidence such as documents, articles, discussions, and explanations or a combination of all these to gather the information form cases. Cases from oil and gas industry can be based on stakeholder surveys, forms and worksheets based on the research objectives. They can be used by grouping them with objective measurements such as role, time, type of industry, position of learners and presentation (Simone and Luigi, 2016).

Case studies can be based on mixed method and the main sources of evidence normally used are citations, archives, consultations, direct annotations, contributor remarks and physical artifacts (Yin, 2003). A intellectual model of the narration by the participant in the “case” is an emic illustration of reality.

The interpretation of the same process from different cases by the researcher is the actual representation and close to authenticity.

Based on the case study research approaches used by different researchers, Jane, 2013 concluded in his research that using a different approach or fixed methodology does not define the case study. Cases can be shaped into the form of a particular study comprising different cases and they might encompass either quantitative or qualitative data or mixed methods (Jane, 2013) with true consideration of the below aspects in the research design as suggested by Golafshani are (Golafshani, 2003)

(1) The importance is on the realities and basis of simulator performance

(2) The statistical information can be easily quantified

(3) The mixed method data is for investigating the precise information

(4) The result is expressed in statistical terms with qualitative responces.

In this study, different cases from the industry stakeholders is carried out by survey tool and data is analysed qualitatively and quantitatively. The data triangulation techniques used in the questionnaire preparation includes:

a) Direct reflexion of the researcher within the environments of the case

b) Probing case participants for explanations and interpretations

c) Analyses of written descriptions and occurrences in the cases

The research objectives along with their adopted methodology are summarized below.

**Table 3.1 Research Objectives mapped to Methodology**

| Research Objective | Research Methodology |
|---|---|
| ✓ RO-1<br>To study of different training models and methodologies on operator training applicable for the OTS. | ➢Exploratory research, Data collection through survey, data mining to analyse patterns and Literature Review. (Schoeb et al., 2021 and Bandara, 2006) |

| | |
|---|---|
| ✓ RO-2<br>To study different challenges faced by all the stake holders (Instructor, Operators and Management) and to study new approaches in OTS training. | ➢ Exploratory research and Data collection, Survey using Questionnaire. (Patel et al., 2018 and Yvonne et al., 2001) |
| ✓ RO-3<br>To study the efficacy and control systems knowledge acquired using operator training simulators in minimizing human errors and other economic benefits. | ➢ Exploratory research and Data collection, Survey using Questionnaire (Patel et al., 2018 and Booth et al., 2018) |

### 3.4.4 VALIDITY, NORMALITY & RELIABILITY

**Validity**

Validation is the process by which we can accentuate the process justification, instead of authentication carried out through dedicated time-consuming and cross-verification processes there by establishing relationship between the investigator and the contributors (Creswell and Poth, 2013). Validity of the data, questionnaire and analysis for the qualitative and quantitative methodology is described in individually as pertinent to each section.

**Internal consistency**

Internal consistency can be defined as the extent to which all portions of the measurement tools measuring the same perception. The scales internal consistency is studied by item-to-scale correlations and within that scale, how are the inter-correlations of items (Devellis, 2003). Whenever two constructs have a direct association with each other in such a way that if one varies methodically with other, then they are said to be correlated and also termed as they are mutually associated. The mutual association and their path to relationship is characterised by an correlation coefficient such as Pearson's "r" (called are) or Spearman's "ρ" (called rho).

If a group of items are measured by a single entry, one have to accept that if each of these items correlate with the overall scale and all the items inside also positively correlated. Pearson's 'r' is used to establish the association or relationship and to distinguish whether these variables are directly correlated or inversely correlated.

In this research work, Pearson's correlation coefficient, "r" is used to establish the construct validity. As per Clark and Watson, the average inter-item correlations, 'r' can be in the range of 0.15 and 0.50. If 'r' is below 0.15, the items are too broad to construct, while if they are above 0.50, it indicates the redundancy of items on the scale (Clark and Watson,1995). By tabulating all the values are shown in a correlation matrix and we can conceptualize the relationships with the variables and this table also displays that whether these relationships are statistically significant or not.

**Normality**

Normality tests are conducted to evaluate the normality of the data collected during the study. Depending on the normality test we can be able to decide whether mean is the appropriate choice to demonstrate the central tendency of the data or not. Based on that, the means are equated using parametric tests or else medians can be used in comparison with the groups, using nonparametric methods (Mishra et al., 2019).

As described by Mishra et al., Shapiro-Wilk test and Kolmogorov-Smirnov tests can be used to validate normality of either small or medium sized samples, where the no of samples is less than 300 or $n < 300$, but both these tests are not reliable, where $n>300$ or the sample size is more than 300 (Mishra et al., 2019). If the sample size is small (our case of $n<50$), we can test the normality by using the Shapiro–Wilk test result and Kolmogorov–Smirnov test should be avoided, even though both tests are indicating that the normal distribution of the data. Based on this assumption, in this study, the normality of the data is analysed by performing Shapiro-Wilk in SPSS.

**Reliability**

Reliability is the degree by which an instrument measuring an item is giving same results if the measurement were to be taken again under the same conditions. The consistency of scores measured by the instrument is proven by its reliability. Internal consistency and reliability is estimated to judge the consistency of results across test items. As per the literature the Cronbach's 'α' (called alpha) found to be the most reliable measure to compute the internal consistency of the instrument (Paulsen and BrckaLorenz, 2017). Paired samples 't' test is carried out to understand that is there any significant difference between the identified cases, namely Role and Industry.

### 3.4.5 QUALITATIVE PARADIGM

The main intention of the qualitative research is to define or know the underlying reasons from the stakeholder perspective. The stakeholders can reasonably validate the credibility of the process and able to describe their perceptions to summarize the results.

Confirmability can be defined as the degree to which the results can be confirmed or substantiated by others to validate the findings. Validation in qualitative research can be defined as the process to evaluate the "accuracy" of the results, in the words of the researcher and the contributors. This indicates that the interpretation of the study is factual illustration of the researcher. Patton (2001) postulates that in the case studies generalizability is one important measure for excellence and is conditional to the selected cases. In this way in the quantitative research validity is very specific to the tests designed as part of the process and in qualitative research triangulation methods are used due to the nature of the study.

Creswell & Poth (2013) justified the process instead of authentication carried out through dedicated time-consuming and cross-verification processes there by establishing relationship between the investigator and the contributors using a close relationship between the researcher and the stakeholders, which is also proven in other studies (Miami, 2019). Whittemore, Chase and Mandle (2001), analysed thirteen research works about validation and came up with the significant qualitative justification measures. They classified the criteria to validate qualitative studies are (Whittemore et al., 2001).

- ✓Credibility (The results precisely describe participant views?)
- ✓Authenticity (Is different thoughts are taken into deliberation?)
- ✓Criticality (There is a factual evaluation of all aspects of the study?)
- ✓Integrity (Researcher described any limitations and they are cited clearly during the study?)

In the Qualitative study it was presumed that the scholar conveys a exclusive perception to his research (Golafshani, 2003). The researcher might expand the instrument design by repeatability to augment the studies internal consistency and, consequently prove the reliability. In this way the investigator can review, add or delete the survey items to expand the consistency, which might affect its validity. Another major concern here is to what extent this kind of amendment exaggerate the studies requirements (Muhammed et al.,2008).

Keeping in line with above works and recommendations for the validation of the survey's, the full text of the questionnaire is shared with a focus group of 6 experts from the oil and gas industry consisting of Training Specialists, Senior Managers and Automation experts. These are not invited to the survey and not part of the stakeholder participations to evade prejudiced inputs. Based on their contributions, 15 questions are reworded and 10 are removed and the rest 80 are used. The changes are reconfirmed from this focused group (with no comments) and finally transformed into the online survey using google forms. This strategy along with the check-recheck approach by the researcher provides evidence that face validity and content validity of the questionnaire is verified (Melike, 2013).

### 3.4.6 QUANTITATIVE PARADIGM

The performance of the instrument in-terms of whether it is meeting the outcomes that are expected from the research can be called the validity of the instrument. It specifies whether the instrument is meeting the ideals set by the researcher or methodology itself to judge the eminence of the tool. In the quantitative studies, the numerous types of validity measured by the researchers are face validity, content validity, and construct validity (Oktavia et al., 2018).

The respectability of the paradigms is measured to prove the construct validity of the instrument. The two types of construct validity are convergent validity and discriminant validity. Many scholars calculate the construct validity by studying correlations between the construct and additional items that are supposedly related with the construct. This measure is called as the convergent validity. If they vary independently of the construct then it is called as the discriminant validity (Oktavia et al., 2018). These two validations work in-tandem so that if we able to establish both convergent and discriminant validity, then by default the construct validity is proven (Pillai and Rajmohan, 2020). The degree of relationship amongst two measures is measured by the Correlation coefficient. One can investigate different patterns of correlations between the items or inter item-correlations between these measures to evaluate construct validity. In this study, inter item correlations are studied between each constructs of the model (ADDIE) and individual cases (Role & Industry), which are further described in Chapter 4 along with detailed analysis of objectives.

### 3.5 INSTRUMENT DESIGN

The current study is carried out by survey method using online questionnaire. The participants (stake holders) are randomly chosen from the researcher's professional network and their connections consisting of Control room operators, Supervisors, Managers, OTS training instructors, Training Specialists, OTS modelling engineers, Automation specialist and OTS developmental team. The questions type include, single and multiple choice, open and closed ended with the aim of gathering data to address the survey objectives through stakeholder perceptions using mixed method case study approach by systematic feedback.

#### 3.5.1 SURVEY RESEARCH

Survey research is one of the methods of methodology in which researcher administer a survey instrument to an identified population of individuals to gather their opinions, views, perceptions and behaviours. In this technique, investigators can gather data by using questionnaires (e.g., printed, handwritten or emailed etc.) and statistically analyse the data to pronounce trends among the responders to the survey questions. This is to test the defined research questions or simply hypotheses (Creswell and Guetterman, 2018). Researchers can also infer the validity of the data by connecting these results back to any previous research studies using review of literature methodology or cross validate in similar studies carried out in other areas. Surveys are normally designed to gather the feedback or information using items that can be quantified and analyse the findings. Investigators can embrace qualitative or open-ended questions coupled with the quantitative research study incorporating in the survey design and overall research methodology.

### 3.5.2 SAMPLING DESIGN

To estimate the sample size in this study, Yamane formula (Fig 3.1) is applied by assuming the targeted stakeholders population of 60 stake holders. This accounts to around 10 respondents from each targeted business, within the oil and gas industry domain. They are chemical industries like Utilities (Power, Desalinated, Water & Effluent treatments), Refinery, Petrochemicals, Natural Gas processing, Liquified Natural Gas (LNG) processing, Oil and Gas Production and Distribution terminals (Stephanie, 2018).

$$n = \frac{N}{1 + N * (e)^2}$$

n - the sample size
N - the population size
e - the acceptable sampling error

** 95% confidence level and p = 0.5 are assumed*

**Figure 3.003 Yamane Formula**

(Source :https://www.tarleton.edu/academicassessment/documents/samplesiz e.pdf)

This is in line with the exploratory method used for this study, some of which are carried out with a normal sample size of 50-60 participants. This is at a 95% of confidence level and margin of error (Precision) of 5% (Vogt et al., 2012). The stakeholder population consisting of OTS Instructors, OTS Development and Modelling Engineers (grouped together as OTS team), Process operators (DCS operator), both the OTS development and operations managers/supervisors are grouped together as Supervisors.

### 3.5.3 QUESTIONNAIRE STRATEGY

The questionnaire is broadly divided in to three sections to gather data. They are

1) Demographics, consisting of participants profiles (Age, nature of industry, experience, location, educational qualifications, their current role etc.).

2) OTS Training facilities, models, industry type, simulator configuration etc.

3) OTS usage and its effectiveness in the workplace and current situation in the industry.

### 3.5.4 LIKERT ITEMS AND SCALE

The questionnaire for this survey is adopted with five-point Likert scale through the responces format with verbal anchors at all points of the scale. They are mentioned here below, with their corresponding score in brackets.

- Strongly Disagree (1)
- Disagree (2)
- Neither Agree nor Disagree/Neutral (3)
- Agree (4)
- Strongly Agree (5)

These itemized scores are validated with the responces from different respondents with reference to their workplace within the industry, their current role or position as cases. To ensure reliability, the response scale is varied for 50% of the participants (while assigning the survey link) and no significant deviation is found in the responces. The skewness, normality and middle of the scale effect determines the analysis method and this way expected scale effect and statistical analysis can be carried out by using ANOVA and associations can be analysed by Linear Regression (Lant, 2013).

**Acquiescence Bias and End of Scale Bias**

Acquiescence bias, also called as “agreement bias”, is the tendency of the study responders to agree or disagree to the specific research questions or making their opinions by simply selecting the declarations without the action being a true reflection of their choice or the question itself. Agreement bias infers that there is an inclination among the individuals (Due to their internal perceptions) to agree with study questions irrespective of their ‘true’ preference or the question’s envisioned response (Orna et., al, 2010). Extreme end or end of scale response favouritism implies that people tend to choose endpoints while answering the research questions. They do not either reading the answers fully or think to choose other options and either the responces are skewed to end of the scale. Further respondents might answer questions either fully positive (Yay saying or response acquiescence) or answer questions fully negative (Nay saying), regardless of the content. This can greatly affect the questionnaires as the results appeared to be influenced by researchers (Bias, 2021).

In order to nullify these prejudice, investigators can observe the relationships between the constructs both before and after the study, possibly thru a pilot survey and administer the main survey or check the responces cross validated with literature (Podsakoff et al., 2003). The questionnaire is prepared with a combination of both open and closed ended questions with Likert items so that the survey participants have to respond without an bias towards the item (or favourable responces). Further the mixed methodology design and analysis of outcomes by qualitatively and quantitatively minimize the extreme end responces (Williams et al., 1996). All these measures are adopted in the questionnaire & instrument design and the findings are also crosschecked with literature from similar studies and validated for each objectives in the analysis section.

The questions are also grouped together to fit in the criteria for the ADDIE Model to analyse as per the participants as their Cases (Industry & Role) and also mapped to each of the ADDIE model components by coding horizontally and vertically. The full set of questionnaire is attached in Appendix-1.

### 3.5.5 DATA COLLECTION & ANALYSIS

Data collection sources in this study are divided in to two main categories, namely, Primary and Secondary sources, as detailed below.

**Primary data**

Primary data of this research is collected through an online mixed method survey, carried out from April-2021 to August-2021 using google forms. Each participant is briefed with the background of the study, confidentiality of the data being collected, its methodology is explained through a memo. Option is provided to contact the investigator and seek clarification through a conference call and 10 participants used this facility to have more information about the study. Complete guidelines to fill the questionnaire, their intended usage and confidentiality are summarized in the introductory section. Around eighty oil and industry people are shortlisted by simple random sampling and purpose sampling thru professional connections (like Research gate, Google Scholar, LinkedIn etc) and their industry references for carrying out the study without any bias towards participants. Out of them 60 people fit in the stake holders criteria and after seeking their consent, email invitations being sent for participation in the study thru google forms..

**Secondary data**

Secondary data is collected from various industry reports, websites, scholarly journals, online portals, Qatar National Library (web portal and onsite in Doha, Qatar), UPES library and scholarly articles available online in IEEExplore, Google Scholar, Science Direct, Research Gate etc.

### 3.5.6 ANALYTICAL TOOLS

1. NVivo (QSR International, version 12 of 2021) for Qualitative Data analysis

2. SPSS (Statistical Package for the Social Sciences from IBM, version 28 of 2021) for Quantitative Data analysis

### 3.5.7 ANOVA AND LINEAR REGRESSION MODEL

Analysis of Variance or simply, ANOVA is a statistical inferential technique to identify whether the mean of groups under the study are same or different.

ANOVA helps us to understand how different groups responding to a set of assumptions through Hypothesis testing. The null hypothesis is assumed that the means of the different groups are equal. the alternate hypothesis assumes that the two populations are unequal. If we can get the statistically significant result based on the study to be unequal means, it proves that implying the alternate hypothesis to be correct and to reject the null hypothesis.

Different terms used in calculating the different components to measure ANOVA and Linear Regression for data analysis (Chapter-4) are mentioned below.

ANOVA is a process by which we can test the data in such a way that how it can fit in the model. During the data postulation to calculate ANOVA, it delivers an indicator called F-ratio, to check the statistical significance of the items. We can use ANOVA in no of ways other than regression, such as identifying substantial variances between the mean scores of different groups or variation of groups on a assumed dependent variable etc.

The Standard Deviation (SD) is to quantify how different values are spread-out from the mean value.

Variance is defined as the average of the squared difference from the mean.

Standard error is the approximate difference between sample mean and population mean.

Range is the difference between largest and smallest observation.

The quartiles are the three points that divide the data set into four equal groups, each group comprising a quarter of the data, for a set of data values which are arranged in either ascending or descending order. Q1, Q2, and Q3 are represent the first, second, and third quartile's value respectively.

Inter Quartile Range (IQR) is a measure of variability, also called the midspread, being equal to the difference between $75^{th}$ (Q3) and $25^{th}$ (Q1) percentiles.

Homogeneity says that variances within all subpopulations must be equal. Homogeneity is only needed if sample sizes are very unequal. In this sample all the samples are having same size and accordingly the homogeneity is assumed to be satisfactory.

Sum of squares estimates the variance of a set of data to know spread out. It is calculated by measuring how much each case deviates from the mean (or the regression line), squaring these deviances and adding them all together. The deviances between the regression line and the data points are called residuals and by squaring them and adding together we have the residual sum of squares.

R-Square is the proportion of variance in the dependent variable which can be predicted from the independent variables and is also known as the coefficient of determination.

Adjusted R-square – As predictors are added to the model, each predictor will explain some of the variance in the dependent variable simply due to chance. The adjusted R-square tries to produce a true value to estimate the R-squared values for the population.

R is the square root of R-Squared and is the correlation between the observed and predicted values of dependent variable.

Mean Square is the sum of squares divided by their respective df. This is calculated to generate the F ratio (dividing the Mean Square Regression by the Mean Square Residual) in order to test the significance of the predicting variables of the model.

The standard error of the estimate, also called the root mean square error, is the standard deviation of the error term, and is the square root of the Mean Square Residual (or Error).

Degrees of freedom (df) is (n - k) for n observations and k groups and mean squares within (MSwithin) -basically the variance within groups, known as SSwithin / DFwithin. Df refers to the values in a study that has the freedom to vary and are essential for assessing the importance and the validity of the null hypothesis. The model degrees of freedom correspond to the number of predictors minus 1 (K-1).

The standard deviation is the square root of the variance. It represents the average distribution or data variability and adjusted to maintain the same units of measurement as the original. The standard error is the standard deviation of the sampling distribution.

Intercept is the predicted value of the outcome variable in a regression model when all of the explanatory variables have a single value, zero. If this was displayed on a scatterplot such as a simple linear regression it would be the point at which the regression line crosses, or intercepts, the zero point on the Y-axis.

**Significance of ANOVA and Regression**

The F-value is the Mean Square Regression divided by the Mean Square Residual. The p-value associated with this F value is very small (<0.001). These values are used to seek responces to the study, "Do the independent variables reliably predict the dependent variable?" so that we carry out the hypothesis testing. Higher F ratio of more than 50 indicates that the variation between groups is larger than the individual variation of groups. In such cases, it is more likely that the mean of the groups are different (Bruin, 2006).

The P-value, also known as α (alpha) level denotes to the probability that an effect or relationship has occurred merely by coincidence. It is the likelihood that an experimental outcome might happened due to the coincidental aspects such as dissimilarity in the sampling process. A p-value of less than 0.05 ($p<0.05$) shows there is less than 5% probability that the effect is seen and is predictably considered acceptable for rejecting the null hypothesis and to conclude that the effect is statistically significant. If the p-value is greater than 0.05, we can conclude that the group of independent variables does not show a statistically significant relationship with the dependent variable, or that the group of independent variables does not reliably predict the dependent variable and is predictably considered acceptable for accepting the null hypothesis and concluding that the effect is statistically not significant .

ANOVA is used to find a commonality or generalization between different variables of different groups that are not related to each other or to prove their interdependence. It is not used to make a prediction or estimate but to understand the relations between the set of variables. Regression looks for a relationship while ANOVA looks for differences in the model. In case of ANOVA evaluates the difference variables of interest and provides concurrence to the researcher. In case of regression model, it is basically used for prediction. Once you get the model, it predicts the dependent variable by giving different values of the independent variables.

Regression is a technique to predict the effect on dependent variable by the independent variables due to their interdependence or close relationship. It helps the researcher to validate the hypothesis and with evidence to conclude the test. Regression can be based on fixed variables or independent variables effecting the others. Regression analysis can be carried out with the use of single independent variable or multiple independent variables, generally known as Linear Regression and Multi-Linear Regression respectively.

**Regression Equations and Model**

We can postulate multiple models using a single regression command in the SPSS. The output tells us whether the number being reported (typically 1) and below this column shows the predictor variables (Imp, Eva, Dev, Des etc in this case) as applicable for each measurement of each other. The first value (shown as constant) represents the constant value or the Y intercept, the height of the regression line when it crosses the Y axis. In other words, the predicted value of one variable as applicable for each measurement can be used to validate others when all other variables are '0'.

"B" is called 'Regression Coefficient' and using 'B' values we can formulate regression equation thru which we can envisage the effect of dependent variable from the independent variable(s). The B values are also called as 'Unstandardized coefficients. They are measured on different scales and due to this, we need to compare them to predict ones influence on others. The standardized version of 'second B' value is called Beta (β). This is also important to measure and interpret multiple explanatory variables using regression. 't' value tells us whether the second variable is making any statistical contribution to the predictive model and can be included in the regression equation.

### 3.6 RESEARCH ETHICS

In this research all the mandatory research ethics, scientific rigour and moral principles. Ethical code of conduct is strictly followed during the research design and while performing different research activities as applicable to each activity. The individual data and consolidated data gathered in this research is only accessible to the researcher. The names of individuals, stakeholders identity and organizations are kept confidential and not accessible to anyone except the researcher. The questionnaire, primary data and stakeholders are grouped and coded alpha numerically for analysis and interpretation. The online survey is designed to participate voluntarily, and opportunity is provided to withdraw or contact the researcher for clarification, if any. The responces are not shared with anybody, and all files are password protected, securely stored in cloud storage with logging in through two factor authentication by researcher. The consolidated analysis of findings as a group or case without mentioning names is captured in the thesis and different manuscripts published as part of the study. The intellectual information is not disclosed to any third party and no authorization was provided to anyone.

### 3.7 RESEARCH LIMITATIONS

The limitation of the study includes the lesser no of samples (or responces) used in the data analysis. This in turn created restrictions on the quantifiable data across different sections of the industry to compare the data as different cases. The generalization of the conclusions might indeterminate due to the relatively small geographical sample size within the broader companies operating in the oil and gas industry. This is in turn addressed by cross sectional sampling of the stake holders from the industry to represent broader overview and gathering primary data for analysing within the research framework.

### 3.8 EPILOGUE

In this section, the complete research methodology with reference to the research objectives is aligned with the data collection method and data analysis. The research gap, business problem, research problem, research questions and research objectives are defined with the overall approach to the study. The survey design, sampling methodology and instrument design is narrated together with data collection and analysis of exploratory cases using case study methodology. Qualitative and Quantitative design along with their analytical procedures are elaborated in-tandem with the proposed statistical methods, namely ANOVA and Linear Regression. All of them are mapped with the ADDIE model and stakeholder feedback questionnaire. Ethical considerations and limitations of the research, overall strategy, data analysis and other applicable procedures of this study are elaborated in detail along with cited literature.

# CHAPTER 4

# 4. DATA ANALYSIS

## 4.1 INTRODUCTION

This chapter narrates the comprehensive data analysis from literature and data gathered through stakeholders study. They are  categorised into different sections, namely demographic data, findings and analysis of each research objective as proposed in the research methodology. Different training models and methodologies for operator training applicable for OTS are discussed in detail. ADDIE model is validated using ANOVA and Linear regression. Regression equations along with variance coefficients are derived for each construct of the model. Qualitative interpretation of the research questions is carried out by using coding, clustering and data visualization plotted along with the objectives.

## 4.2 DATA SAMPLING AND RELIABILITY

As per sampling design with a intended population (N) of 60 samples, Confidence level of 95%, Precision level of ± 5% (e=0.05) amounting to the calculated sample size (Yamane's formula) of n=51 (Stephanie, 2018). 46 people completed the full questionnaire, amounting to 90% response rate and 6 incomplete, partially filled responces are ignored.

The tendency of normality distribution is analysed by performing Shapiro-Wilk test using SPSS (Shapiro Wilk) and found that all the statistics are above 0.5 with 'p' values less than 0.05 or $p<0.05$ (Shown in section 4.5.3.2). The outcome of the test concludes that the variables follow normal distribution, and the internal consistency can be measured through Pearson's correlation coefficient, "r" to prove its construct validity. Pearson's correlation coefficient, 'r' calculate scores of responses to an item with their total scores assuming normal distribution of the variables.

**Reliability and Consistency**

The average value the "r" is found to be 0.402 (Pearsonr), and all the questionnaire is in the range of 0.25 (Likely to be useful) and 0.45 (Very beneficial) as described by Oktavia et al. The average value for all the questions is found to be 0.402. As it is greater than 0.35 ( or $r>0.35$) we can confirm the validity is strong and is beneficial for the study (Oktavia et al., 2018).

As per the data analysis, the Cronbach's 'α' value found to be 0.928 (All cases, where $n=46$) and 0.815 (Excluding 6 random cases or $n=40$) and for each question and Cronbach's 'α' value is in the range of 0.775 to 0.960 (for all the individual questionnaire). This shows that the questionnaire has high level of internal consistency.

The unidimensional reliability with pairwise cases (Role and Industry) is 0.785 with an upper and lower bound of 0.865-0.785 respectively and all are $\geq 0.70$, which is the acceptable for good internal validity, consistency, and inter-rater reliability (Basu, 2016).

**4.3 DEMOGRAPHIC DATA ANALYSIS**

The participants of the survey include different stakeholders of the OTS industry consisting of Instructors, Development and Modelling Engineers (grouped together as OTS team), Process operators (grouped together as DCS operator), both the OTS development and operations managers/supervisors are grouped together as supervisors. The participants working in different Chemical industries like Utilities (Power, Desalinated, Water & Effluent treatments), Refinery, Petrochemicals, Natural Gas & Liquified Natural Gas (LNG) processing, production and distribution terminals. The overall demographic data from the survey respondents is shown in Fig 4.1 and analysed below.

Majority (33%) of the respondents are from Natural Gas, Liquified Natural Gas industry which are predominantly modern hydrocarbon industries in comparison to the refinery and petrochemicals industries due to value chain of the process LNG is offering as a green fuel among the fossil fuels and one of the most sought-after hydrocarbon across the world for power generation and usage as an urban transportation fuel. OTS development and modelling team (18%) is minimal to respond as these are highly specialized and normally supply multiple industries and companies.

The participants are spread across Middle East (grouped from UAE, Qatar, Kuwait and Bahrain), India, Asia Pacific (grouped from Singapore, Malaysia, Indonesia) & China, Europe (grouped from France, Italy, Norway, Germany, Romania) and Americas (grouped from Mexico, USA, Venezuela).

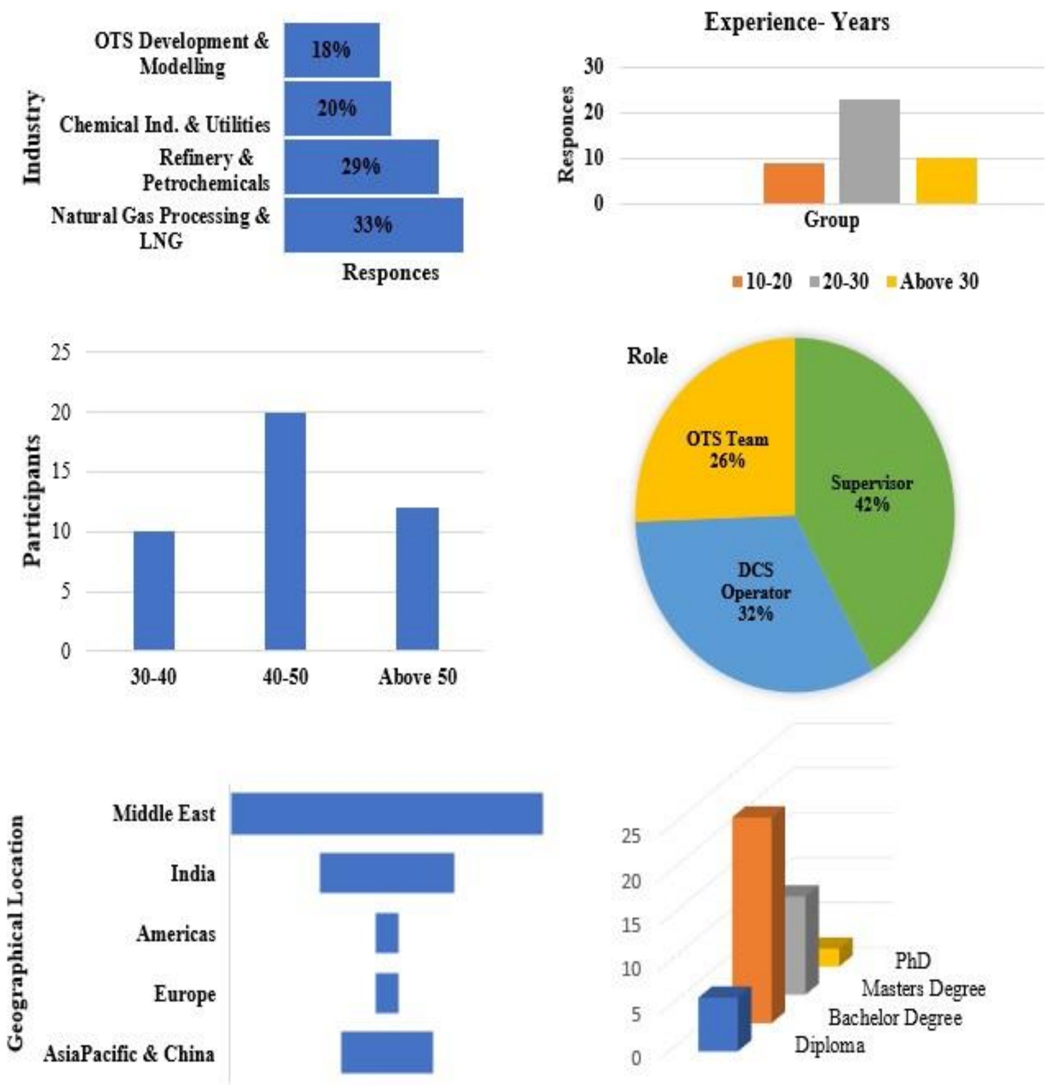


**Figure 4.1 Demographic Data of Participants**

(Source: Author, compiled from Quantitative analysis)

Stake holders from Middle Eastern organizations, being the largest suppliers of Crude oil and Liquified Natural Gas products to the world markets contributed maximum no respondents in this study. This might be due to the overall complex nature of industries and abundance of all hydrocarbon industries present in a single location and with multiple nationalities from the world working in a single region across large industrial cities operating through respective national companies like Saudi Aramco, Abu Dhabi National Oil Company (ADNOC), GASCO-UAE, Qatar Energy, Qatar Gas, QCHEM, Kuwait National Petroleum Corporation (KNPC), Petroleum Development Oman (PDO), Oman LNG etc.

The participants average age is around 45 years and majority of them in the age bracket of 40-50 years. They are having an average industrial experience of 25-30 years across different geographies and industry. The educational qualifications of participants are ranging from basic Diploma (Mechanical and Chemical) and Bachelor's degree, mainly operators and supervisors and Master's degree (Chemical engineering) and PhD holders (mainly OTS modelling/development team).

## 4.4 RO-1 FINDINGS AND ANALYSIS

- ✓ R.O-1 is to study different training models and methodologies on operator training applicable for the OTS.

NVivo (2021 version) from QSR International is used as the Qualitative Data Analysis (QDA) tool to analyse the literature review, thematic analysis of qualitative data from the survey responses, mapping and validating the questionnaire. Data from the literature and general observation made through the cases was further tested with qualitative data gathered through the survey. The gaps and key findings, inferences from the literature review are analysed using NVivo tools. They provide visual connections, patterns and themes so that researchers can visualize and analyse the connections and write in more apposite manner (Booth et al., 2018).

### 4.4.1 OTS SUPPLIERS AND MODELS

As per the literature review in conjunction to RO-1, below are the large-scale Operator Training Simulator providers and their software models used in the industry.

1) UniSim® Design Suite, Honeywell (UniSim® Design UniSim Design Suite | Honeywell)
2) Aspen HYSYS® Dynamics, Aspen Technology, Inc. (Operator Training Simulator Deployment | AspenTech)
3) Operator Training Simulator (OTS), Yokagawa, (Operator Training Simulator | Yokogawa Electric Corporation)
4) Petro-SIM, KBC by Yokogawa (SIM Reactor Suite | Refinery Simulation Software | KBC)
5) AZprocede, Logical simulation tools from Azprocede (AZprocede - Séries de modèles, logiciel AZprocede)
6) OmegaLand OTS & MIRROR PLANT, Omega Simulation Co., Ltd. (OTS ┃ Solution ┃ Omega Simulation Co., LTD)
7) ChemCad for Oil and Gas, Chemstations (Oil & Gas Chemical Process Simulation Software | CHEMCAD (chemstations.com)
8) AVEVA™ Operator Training Simulator, AVEVA (Operator Training Simulators – Empower operators to run a plant in any conditions | AVEVA)
9) INDISS Plus®, Dynamic simulation platform by CORYS (Custom Operation Training | CORYS)
10) JADE High-Fidelity Simulators, JStation™ JADE™ GSE Systems (Simulation Solutions - GSE Solutions)
11) K-Spice®, Kongsberg multipurpose dynamic simulator (K-Spice Process simulation - KONGSBERG DIGITAL)
12) Operator Training Simulator, Mobatec (Mobatec - Next Generation Operator Training Simulator)

13) TSC Sim, OTS-Operator Training Simulators (TSC - Operator Training Simulator (OTS) (tscsimulation.co.uk)

14) TSC Sim, MPDS-Multi Purpose Dynamic Simulators (TSC - Life Cycle Multi-Purpose Dynamic Simulators (tscsimulation.co.uk)

15) VisSim, Visual Solutions (Process Control | VisSim and Real-Time Simulation | VisSim )

16) ProSimulator OTS, Sim Infosystems (Simulation - Process Plant Simulator & Power Plant simulator | Process Simulation (siminfosystems.in)

From the survey responders we can note that UNISIM training simulator software continued to be the market leader with 63% respondents using the OTS supplied by Honeywell Process technologies as per the data compiled by the survey and shown in Fig 4.2. All other suppliers are having market share in the range of 5-10% usage across the industry, which is in conjunction with the literature review (Fighte, 2007). This might to be due to ease of the package usage, advanced user and modelling interface, able to integrate with any control systems (DCS) suppliers with UNISIM and process design software integration with Honeywell's own graphic builder, graphic design and interface display driving UNISIM being numero-uno position in the OTS industry.

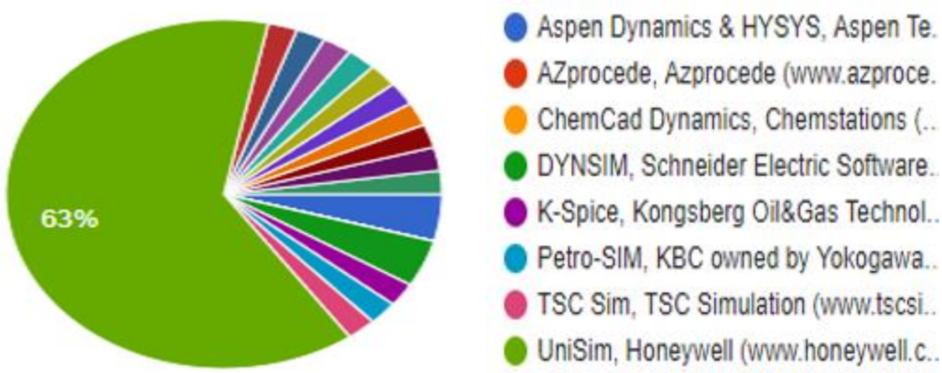


**Figure 4.2 OTS market share by suppliers**

(Source: Author, compiled from Quantitative data analysis)

### 4.4.2 OTS METHODOLOGIES AND TYPES

Training simulator categories can be classified depending on the generic usage, modelling criteria and process requirements. Each methodology and type is discussed in this section with reference to the literature.

#### 4.4.2.1 UNIVERSAL CLASSIFICATION

Simulations can be broadly divided in to three types, such as Live, Virtual and Constructive; where in the model represents a process or pattern nearer to reality using mathematical reproduction of original item (IST, 2021). Live simulations are similar to simple gaming and doing hands on operations by mimicking or imitating or pretending the exercise.

Virtual simulation is carried out by programming the actual system in an computer operated graphical interface, replicated with time-based operations similar to actual process (Medical, Operator training, Aviation/Flight, Industrial machinery like Crane, Forklift and Driving simulators etc.).

Constructive simulation is carried out by charting the simulation based present or previous value by extrapolation or predefined statistical models (Weather forecasts like Wind, Snow and Temperature etc.). They can also be divided into Physical aspects (Design and Engineering features) and Psychological aspects (Functionality, Task and Difficulty level etc). We cannot achieve better training transfer and there by effective results in training, by solely raising the engineering features and fidelity of a simulator, but one has to improve the overall features along with instructor ability to execute these complexities (Jen and Edward, 2016).

#### 4.4.2.2 FIDELITY

Fidelity is the mark or label where in the training simulator imitates the reality. Generally, simulator suppliers labelled them as 'low', ‘medium’ and 'high', by modelling conditions to show that how close they characterise 'real life' situations (Tverskoy et al., 2011). These types of simulators include and not limited to generic low, medium and high-fidelity, dynamic high-fidelity, immersive, virtual, immersive and virtual reality and small unit-based models that are suitable for mobile applications. Many researchers agree about the importance of fidelity in simulation and further narrates that the primary importance should be given the learning objectives and skill development for effective transfer of learning than the simulator configuration in itself.

Low fidelity models are very modest models connected to the control system elements. The aim here is to link control systems with the help of pre-defined models coming from a very modest prototype, not often linked to any safety systems or logics. Engineering equipment like valves, exchangers, turbines, pumps and compressors etc are modelled in this way to gain understanding and familiarize with the operations and are suitable to academic institutes, design validation and suitable to small equipment supply companies.

Medium fidelity models are normally developed from elementary chemical engineering equations up to the point defined by the limit of complexity in both mathematical and thermodynamical aspects. They are limited to one or more unit-based processes like a dehydration unit, gas purification and gas/oil separation units etc. Some of them are driven by data and therefore more precise depending on the design basis parameters and complexity of the process. These have inadequate application outside their distinct areas. They are appropriate for limited operational purposes and to test control loops and not suitable for complex interlinked or multi feed processes involving integrated operations and thermodynamic responces. These models are acceptable for smaller units and have a lower price tag compared to others. However, their application is limited in cases of a more complex processes due to the advent of more complex process design (sometimes licensed by reputed engineering companies or patented with O&G majors) in terms of efficiency of process and sustainable development designs to limit emissions etc.

High fidelity models are the most used versions, where precisely designed process models related to highly complex units involving integrated process operations like natural gas processing, crude refineries and petrochemical complexes. They are distinctive due to the application of rigorous process modelling using dynamic simulators such as Unisim, Hysys, Dynsim etc. They are also integrated with emergency shutdown systems and up to date with the process design of the actual plant. It is very important in the initial stages of development for adapting a clear-cut definition towards the process representations and their intended usage. We have to be mindful to different complexities and challenges brought into the OTS operational environment and the capability of instructor(s) to maintain the systems without the help form the engineering supplier on a continuous basis. This is due to the difficulties related to mathematical models, process licenses, thermodynamic and mass balancing of the units along with convergence complications involving highly automated logics.

#### 4.4.2.3 PROCESS REALITY

The range of different training simulators covers unit based, customized and generic process models of the operating units. They are generally classified as normal, virtual and augmented models either in a 2D or 3D field environment. The virtual and augmented models are extension of generic simulators integrated with 3D models of the site configured using specialized interfaces. Due to the higher amount of programming and interface integration, the virtual and augmented models are costlier than others.

Augmented Reality (AR) is a method that overlays a computer aided generic depiction into the real world. AR illustrations can be realised by the use of specially designed goggles, mounted helmets, 3-D (three-dimensional) monitors and hand-held devices (Karlsson et al., 2017). Virtual reality (VR) is the process of integrating the reality-based computer simulation and modelling that enables the individual to interact with an artificially developed 3-D imaginary or another sensory setting, imitating the real-world rendition (Lowood, 2021). Both the methods replicate reality by use a kinaesthetic equipment such as augmented goggles, audio-visual and surrounding environment using multimedia devices. The more advanced the skills learner is having like experience in the industry, using similar simulator for other units etc., then the new simulator have to be developed as per the anticipated skill achievement and to enhance skill transfer (Jen and Edward, 2016). The instructor has to recreate scenarios by mixing the experienced crew with in experienced or less experience crew so that the real task is captured during the simulation session by peer learning and persuasive discussions.

#### 4.4.2.4 PROCESS DESIGN

In the OTS industry, the simulator process models are further divided based on the integration of Process Control Systems (PCS) with or without Process Safety Systems (PSS). PSS can be further classified in to ESD [Emergency Shut Down] & EDP [Emergency De-Pressurization] depending on their end functionality and intended use. For simplification and cost perspective, the training model can be modelled purely for control system training and process safety system is simplified and is not recommended for complex and critical processes. The PCS can be modelled in an integrated way by combining all in one single interface. Complex processes like Refinery, LNG and Petrochemicals etc., often use isolated models limited to one particular process due to the complexity of integrated process and different process design due to constant upgrading or adding new facilities. In that case, it is recommended to have different instructors for different processes to add training value as the single instructor cannot manage different OTS and train many operators effectively. The interfaces, graphics, navigational and operational tools for instructor and operators remains same for isolated or integrated models and boundary conditions are often allowable to be varied by the instructor. The process models are proprietary for each operating company based on first principles of chemical engineering and thermodynamics coupled with computational models, often licensed for each user/company.

### 4.4.3 OTS USAGE

Number of studies on the training simulator effectiveness are based on the individual assessment of trainees than the actual performance of operators in the DCS, training transfer to workplace and competency assessment based on proven methodology (Salas et al., 2006). One need to develop rigorous tools, which are adaptable to continuously changing and automation driven working environment (Chirgwin, 2021). These attributes validate with earlier findings of different researchers that the procedures can be optimized to insist on critical points, reinforce learning by repeated practice and then the chances of errors are less, as the operators already practiced and be confident in executing the complex tasks (Riloff & Janyce, 2003).

As per the findings, the OTS is mainly used in the industry by the order of

- ❖ Regular operator training (90%)
- ❖ Conceptual studies and what if scenario testing (62%)
- ❖ Control Logic programming and testing of control systems (55%)
- ❖ Procedural verification and validation (50%)
- ❖ Process feasibility studies (40%)

Data from operational errors, basic technical knowledge, logical relationships between different scenarios, forecasting unit upsets and practice, technical knowledge revision along with improvements in process modelling further validate the fact that the simulator training can also be used for identifying recurring human errors or operational mistakes taking place while implementing a procedure or testing a control loop etc and the lessons learnt should be shared across different organizations to increase awareness.

**OTS training days**

The average no of days offered for simulation training per calendar year is shown in Fig 4.3. As per findings, more than 60% organizations allocate at least 10 days for simulation training in two sessions of five days each. Around 30% organizations allocating more than 10 days of training are mostly from middle eastern, encouraging the vocational training and regulatory requirements to invest more in developing homegrown talent and manpower rather relying continuously on overseas professionals.

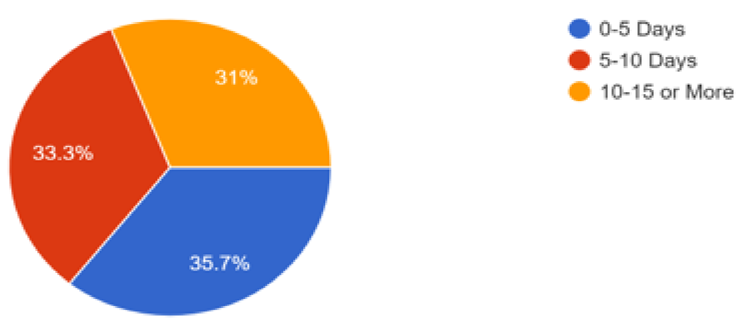


**Figure 4.3 No of days of OTS training across the organization**

(Source: Author, compiled from survey data)

The no of training days in India and other Asian countries are in between 0-5 days, which might be due to under investment in their manpower, no regulatory requirement and staff having high methodological knowledge in dealing with process upsets due to robust technical education and apprenticeship.

Organizations allocating 10-15 days are based in Europe and other advanced countries showing their commitment to learning and compliance due to strong regulatory requirements for insurance and sustainable initiatives. The most common practice observed in the Middle East (where most complex and advanced oil and gas ventures are located) is dedicated 10 days of training to operators per year, embedded in their training calendars and reported through annual sustainability reports.

### 4.5 RO-2 FINDINGS AND ANALYSIS

- ✓ R.O-2 is to study different challenges faced by all the stake holders (Instructor, Panel Operators and Management) and identify new approaches to OTS training.

To address this objective different set of questionnaire (Appedix-1) mapped to individual items in the ADDIE model (Analysis, Design, Develop, Implement and Evaluate) are used to gather stakeholder responses. SPSS is used to analyse the quantitative data and NVivo is used for the qualitative data (For coding and mapping etc,) as described in Chapter-3, Research Methodology (Section 3.4.5 & Section 3.4.6). SPSS is used to analyse internal consistency, reliability, normality, correlations between items and inter-item correlations between the variables, ANOVA (Analysis of Variance) and Linear Regression. Each of them are described envisioned with the objectives as below.

#### Descriptive Analysis

Role of respondents (Coded as R1, R2 and R3) and Industry (Coded as C1, C2 and C3) for descriptive analysis of components from the survey responses is shown in Fig 4.4. Industry cases (spread across different industries in oil and gas domain) and Roles (Key stakeholders of OTS) as an individual entity and paired together for correlation analysis and plot the relationship maps related to each item (Lant, 2013). The interrelation between Industry and Role along with their relationship count is shown in Fig.4.5. The thickness and size of the lines shows that greater responsibility lies with the instructor & OTS team with reference to the simulation model development and configuration as this affect the overall life cycle usage and effectiveness of training imparted by the simulator. The items with highest relationship count shows that there is greater responsibility lies with the instructor and OTS team with reference to the simulation model development. $C_2$ is having direct relationship with $R_1$ and $R_2$ symbolizing that no supervisory responces from NG and LNG Industry. $C_1$ and $C_3$ having direct relationship $R_1$, $R_2$ and $R_3$ due to complexity of processes in comparison with $C_2$. Roles $R_1$ and $R_2$ having more direct relationship count with industry cases $C_1$ , $C_2$ and $C_3$.

| **Frequency Table** | | **Frequency** | **Percentage** |
|---|---|---|---|
| **Industry** | Chemical Industry & Others (C1) | 17 | 36.96% |
| | Natural Gas Processing & LNG (C2) | 13 | 28.26% |
| | Refinery & Petrochemicals (C3) | 16 | 34.78% |
| **Role** | Operator (R1) | 14 | 30% |
| | Instructor & OTS Development team (R2) | 19 | 41% |
| | Supervisor & Manager (R3) | 13 | 28% |
| **Central Tendency** | | **Mean** | **S. D.** |
| **Industry** | Chemical Industry & Others (C1) | 1.8 | 0.745 |
| | Natural Gas Processing & LNG (C2) | 2.11 | 0.937 |
| | Refinery & Petrochemicals (C3) | 2.17 | 0.835 |
| | Total Mean | 1.98 | 0.866 |
| **Role** | Operator (R1) | 1.76 | 0.752 |
| | Instructor & OTS Development team (R2) | 1.92 | 0.9 |
| | Supervisor & Manager (R3) | 2.19 | 0.655 |
| | **Total** | 1.96 | 0.767 |

**Figure 4.4 Descriptive Statistics (Industry and Role)**

(Source: Author, compiled for data analysis using SPSS)

We need to consider the complexity of the case (like Chemical Industry & Others, Natural Gas Processing/LNG and Refinery & Petrochemicals) and get feedback from the specific site personnel as per their role (Operator, Supervisor or Manager, Instructor and OTS development team). Further Role and Industry based statistical data is mapped to the individual ADDIE components to understand the relationship between each component and the interconnection between type of industry (due to the complexity of each type) and nature of operational role in the development and usage of OTS as a strategic training tool for operator trainings.

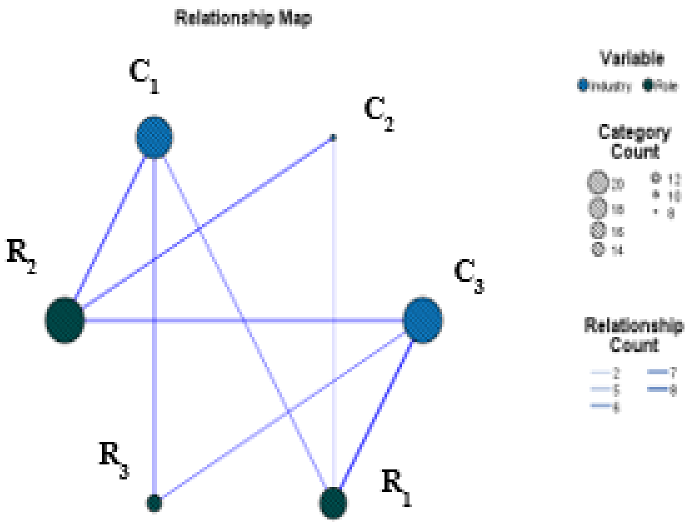


**Figure 4.5 Case & Role relationship map with variables**
(Source: Author, compiled from SPSS)

We can conclude that the instructor role is pivotal to coordinate the developmental aspects of simulator and effective customization of OTS including control room operators. This will further enhance the site staff being more proactive to attend the training, being involved from the system development and motivate learning culture across the organization.

### 4.5.1 INTERNAL CONSISTENCY & RELIABILITY

For each variable pair, only cases with valid data for both variables are used to compute the reliability and case summary statistics using the SPSS. The overall reliability for all cases as per Cronbach's α is 0.928. For the paired case of industry and role, the Cronbach's α found to be 0.765, the overall of 'α'for questionnaire is in the range of 0.766-0.942. The Cronbach's α after excluding six cases is around 0.815, as shown in Fig.4.6. Items with Cronbach's $\alpha \geq 0.70$ is acceptable for good internal validity and consistency and as all the items is above 0.7 (Basu, 2016), as all the Cronbach's α are greater than 0.70, we are assured that all the items are having good internal consistency and reliability.

| Case Processing Summary- Reliability | | | |
|---|---|---|---|
| | | N | % |
| Cases | Valid | 40 | 86.7 |
| | Excluded[a] | 6 | 13.3 |
| | Total | 46 | 100 |
| Cases | Cronbach's Alpha | No of Items | |
| All Cases | 0.928 | 46 | |
| Excluding | 0.815 | 40 | |

**Figure 4.6 Reliability (Cronbach's** α)
(Source: Author, compiled Quantitative analysis using SPSS)

### 4.5.2 HYPOTHEIS TESTING, ADDIE MODEL & CORRELATIONS

The cases under each category are mapped in such a way that with each one construct selected as a dependent variable and others become as independent variables for analysing validity and reliability of the model as suggested by Hair in their research based on linear regression analysis of Likert items (Hair et al., 2019). The responders are grouped as pair of cases as Industry (Ind) and Role. Their descriptive statistics are shown in Fig 4.6 and their summary of responces from survey are captured in Fig 4.7. They are subjected to correlational analysis and paired sample 't' test for hypothesis testing. This is to understand is there any significant difference between the role and industry in the usage and developmental aspects of training simulators.

**Hypothesis Testing (Paired Samples)**

Paired samples 't' test is carried out to understand that "is there any significant difference between cases such as Role and Industry and is there any significance difference in the inter-item correlations". There is strong correlation between the role and industry as the correlation calculated by Pearson's r is 0.238. This is found to be in the "acceptable range" as 'r'>0.15, this way we can conclude that both of the items are positively correlated (Navidinia et al., 2015 and Basu, 2016).

The hypothesis testing statements for the pair is formulated as below.

The null hypothesis

$H_o$: "There is a significant difference between Industry and Role in the development of the operator training simulator models".

The alternate hypothesis

$H_a$: "There is a no significant difference between Industry and Role in the development of the operator training simulator models".

| Paired Sample Statistics | | | | |
|---|---|---|---|---|
| Case | Mean | N | Std. Deviation | Std. Error Mean |
| Industry | 1.98 | 46 | 0.866 | 0.129 |
| Role | 1.96 | 46 | 0.767 | 0.114 |

| Paired Samples Correlations | | | | |
|---|---|---|---|---|
| | n | Correlation | Significance | |
| | | | One-Sided p | Two-Sided p |
| Industry & Role | 46 | 0.238 | 0.058 | 0.115 |

| Paired Differences | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Case | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | t | df | Significance | |
| | | | | Lower | Upper | | | One-Sided p | Two-Sided p |
| Industry - Role | 0.022 | 1.011 | 0.151 | 0.282 | 0.326 | 0.147 | 45 | 0.442 | 0.883 |

**Figure 4.7 Paired Statistics (Industry & Role)**

(Source: Author, compiled from Quantitative analysis using SPSS)

There is no significant difference in the Industry (M=1.98 & S.D=0.866) and Role (M=1.96 & S.D= 0.767). Conditions: n=46, t (45) =0.147, p=0.883 for $\alpha$=0.05.

Based on the above data analysis, we can reject the null hypothesis and accept the alternate hypothesis.

### 4.5.3 ADDIE MODEL ANALYSIS

Each component/variable under the ADDIE is coded consequently to analyse the responces using the SPSS, consisting of Analysis: Ana-1 to Ana-6, Design: Des-1 to Des-5, Develop: Dev-1 to Dev-5, Implement: Imp-1 to Imp-5 and Evaluate: Eva-1 to Eva-7, consisting of 28 questions, in Appendix-1.

### 4.5.3.1 INTER-ITEM CORRELATIONS

The responces are grouped into their constructs to calculate the components such as Mean, Central Tendency, Variance and Linear Regression to validate the model inter-item relationship and correlations.

| Cases | | Analysis | | | | | | Design | | | | | Develop | | | | | Implement | | | | | Evaluate | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Industry | Role | Ana-1 | Ana-2 | Ana-3 | Ana-4 | Ana-5 | Ana-6 | Des-1 | Des-2 | Des-3 | Des-4 | Des-5 | Dev-1 | Dev-2 | Dev-3 | Dev-4 | Dev-5 | Imp-1 | Imp-2 | Imp-3 | Imp-4 | Imp-5 | Eva-1 | Eva-2 | Eva-3 | Eva-4 | Eva-5 | Eva-6 | Eva-7 |
| Ref.Pet | Spr | 4 | 4 | 4 | 5 | 3 | 1 | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 4 | 5 | 5 | 5 | 3 | 4 | 3 | 5 | 4 | 5 | 3 | 4 | 4 | 4 | 5 |
| Ref.Pet | Spr | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 5 | 4 | 5 | 5 | 1 | 4 | 4 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Ref.Pet | Spr | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 |
| Chem Othrs | Spr | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 1 | 4 | 4 |
| NGP | OTS | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| NGP | Spr | 5 | 5 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 3 | 3 | 5 | 5 | 5 | 3 | 5 | 5 | 5 | 5 | 2 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Ref.Pet | Opr | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 4 | 5 | 5 | 4 | 4 | 4 | 4 | 4 |
| Chem Othrs | Spr | 5 | 5 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| NGP | Opr | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 4 |
| Chem Othrs | Opr | 5 | 2 | 2 | 4 | 3 | 3 | 2 | 5 | 5 | 4 | 1 | 2 | 3 | 2 | 4 | 4 | 4 | 2 | 4 | 2 | 4 | 4 | 5 | 4 | 4 | 4 | 2 | 4 |
| NGP | Opr | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Ref.Pet | Opr | 4 | 5 | 4 | 4 | 3 | 3 | 4 | 4 | 5 | 4 | 2 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 |
| Ref.Pet | OTS | 5 | 5 | 4 | 4 | 5 | 3 | 5 | 4 | 5 | 3 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 5 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Ref.Pet | Spr | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 5 | 5 | 4 | 3 | 4 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 4 |
| NGP | Opr | 4 | 4 | 5 | 5 | 5 | 3 | 5 | 5 | 5 | 4 | 5 | 4 | 4 | 3 | 4 | 5 | 3 | 5 | 3 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| NGP | Opr | 5 | 5 | 5 | 5 | 5 | 5 | 3 | 2 | 5 | 1 | 1 | 5 | 5 | 5 | 5 | 5 | 1 | 5 | 4 | 2 | 5 | 5 | 5 | 5 | 5 | 1 | 1 | 3 |
| NGP | OTS | 5 | 3 | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 4 | 2 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 1 |
| Ref.Pet | OTS | 5 | 5 | 5 | 5 | 5 | 2 | 5 | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 4 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 1 |
| Ref.Pet | Spr | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 1 | 1 | 5 | 5 | 5 | 1 | 4 | 1 | 4 | 3 | 3 | 1 | 5 | 5 | 5 | 5 | 1 | 4 | 5 |
| Chem Othrs | Spr | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 |
| Ref.Pet | OTS | 5 | 5 | 3 | 5 | 5 | 2 | 5 | 5 | 5 | 4 | 4 | 5 | 4 | 4 | 5 | 4 | 1 | 5 | 3 | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 |
| Ref.Pet | Opr | 4 | 5 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 4 | 4 | 3 | 3 | | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Ref.Pet | Spr | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 1 | 4 | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 1 | 4 | 5 | 5 | 5 | 5 | 4 | 5 | 5 |
| Ref.Pet | Opr | 4 | 4 | 4 | 4 | 5 | 3 | 4 | 5 | 5 | 4 | 3 | 5 | 5 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 4 | 4 | 4 |
| NGP | Spr | 5 | 5 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 1 | 1 | 5 | 4 | 5 | 1 | 5 | 3 | 5 | 2 | 3 | 1 | 5 | 5 | 5 | 5 | 1 | 1 | 1 |
| NGP | Spr | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 1 | 1 | 5 | 5 | 5 | 5 | 5 | 1 | 5 | 1 | 1 | 5 | 5 | 5 | 5 | 5 | 1 | 1 | 5 |
| NGP | OTS | 4 | 4 | 4 | 4 | 5 | 2 | 3 | 4 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 2 |
| Ref.Pet | Opr | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| NGP | Spr | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 2 | 4 | 4 | 4 | 4 | 2 | 2 | 5 | 4 | 2 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 3 |
| NGP | Opr | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Ref.Pet | OTS | 5 | 5 | 3 | 3 | 3 | 1 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 1 | 4 | 4 | 4 | 3 | 3 | 3 | 4 | 3 | 5 | 3 | 3 | 3 | 3 | 3 |
| NGP | Opr | 4 | 4 | 5 | 5 | 4 | 5 | 4 | 5 | 4 | 1 | 4 | 2 | 4 | 4 | 5 | 5 | 4 | 3 | 5 | 4 | 5 | 4 | 5 | 5 | 5 | 5 | 4 | 4 |
| NGP | OTS | 5 | 5 | 5 | 4 | 5 | 5 | 3 | 5 | 5 | 2 | 5 | 5 | 5 | 4 | 2 | 4 | 5 | 4 | 3 | 3 | 4 | 5 | 5 | 4 | 5 | 4 | 5 | 4 |
| NGP | OTS | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 2 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 3 |
| Chem Othrs | Spr | 4 | 3 | 3 | 4 | 1 | 4 | 4 | 4 | 4 | 3 | 2 | 4 | 4 | 4 | 4 | 3 | 4 | 3 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 2 | 2 |
| Ref.Pet | Spr | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 1 | 1 | 5 | 5 | 5 | 1 | 3 | 1 | 5 | 1 | 1 | 1 | 5 | 5 | 5 | 5 | 1 | 1 | 5 |
| NGP | Spr | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 |
| NGP | Opr | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| NGP | Opr | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 5 | 1 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Ref.Pet | OTS | 5 | 4 | 5 | 4 | 5 | 5 | 4 | 4 | 5 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 4 | 5 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 |
| Chem Othrs | Spr | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 1 | 1 | 5 | 5 | 4 | 1 | 1 | 1 | 5 | 4 | 3 | 1 | 5 | 5 | 5 | 5 | 1 | 1 | 5 |
| Ref.Pet | OTS | 5 | 5 | 5 | 5 | 5 | 5 | 5 | | 4 | 5 | 3 | 5 | 5 | 4 | 5 | 5 | 5 | 3 | 2 | 1 | 4 | 5 | 5 | 4 | 5 | 4 | 4 | 5 |
| NGP | Spr | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Chem Othrs | Spr | 4 | 4 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

**Figure 4.8 Industry and Role Responces with ADDIE Model**

(Source: Author, compiled from Quantitative analysis)

The internal consistency of a scale is studied by calculating item-to-scale correlations and intercorrelations of items encompassing the scale (DeVellis, 2003). As per Clark and Watson, the average of inter-item correlations measured using Pearson's 'r' can be in the range of 0.15 and 0.50 and whatever below 0.15 will be too far-reaching and whatever values above 0.50 indicates redundancy of items within the scale (Clark and Watson,1995).

As seen in Fig 4.9, we can confirm that all the inter-item correlations are within the average with very few are just above 0.50 and only one is below 0.15. This is due to the fact that the scales might contain constructs which are predominantly intercorrelated, having very slight variations. This is realistic as they are from the finest constructs (for example, Ana and Imp, Imp and Dev) of the survey and each of the variables are corelated to each other with in a reasonable range of 0.05 between each other (Paulsen and BrckaLorenz, 2017). This is practically acceptable for online surveys of this size (Curtin et al.,2020). Detailed analysis and explanation about the variance and regression is mentioned in the next section.

| Descriptives (n=46) | | | | | 95% Confidence Interval for Mean | |
|---|---|---|---|---|---|---|
| Model | Mean | Std. Error | Variance | SD | Lower | Upper |
| Ana | 4.2704 | 0.06207 | 0.173 | 0.41365 | 4.1463 | 4.3955 |
| Dev | 4.2133 | 0.07134 | 0.229 | 0.47856 | 4.0696 | 4.3571 |
| Des | 4.1889 | 0.06837 | 0.21 | 0.46864 | 4.0511 | 4.3267 |
| Imp | 3.6689 | 0.0928 | 0.388 | 0.62252 | 3.4819 | 3.8559 |
| Eva | 4.2444 | 0.07216 | 0.234 | 0.48409 | 4.099 | 4.3899 |

| Inter-Item Correlation Matrix | | | | | |
|---|---|---|---|---|---|
| | Ana | Imp | Eva | Dev | Des |
| Ana | 1 | 0.233 | 0.376 | 0.552 | 0.008 |
| Imp | 0.233 | 1 | 0.379 | 0.313 | 0.502 |
| Eva | 0.376 | 0.379 | 1 | 0.545 | 0.553 |
| Dev | 0.552 | 0.313 | 0.545 | 1 | 0.349 |
| Des | 0.408 | 0.502 | 0.553 | 0.349 | 1 |

| Summary Item Statistics | | | | | | |
|---|---|---|---|---|---|---|
| | Mean | Min | Max | Range | Max/ Min | Variance |
| Item Means | 4.068 | 3.736 | 4.289 | 0.553 | 1.148 | 0.053 |
| Item Variances | 0.269 | 0.215 | 0.391 | 0.177 | 1.824 | 0.005 |
| Inter-Item Covariances | 0.089 | 0.04 | 0.158 | 0.198 | 3.945 | 0.004 |
| Inter-Item Correlations | 0.345 | 0.133 | 0.573 | 0.706 | 4.32 | 0.054 |

**Figure 4.9 ADDIE & Inter-Item Correlation Matrix**

(Source: Author, compiled from Quantitative analysis using SPSS)

#### 4.5.3.2 ANALYSIS OF VARIANCE AND PERCEPTIONS

The study of individual items is an essential element to understand the relationship to each other and to infer the supporting data using circumstantial analysis as described in Chapter-3, Section 3.5.7. In the instrument design, number of constructs associated to specific paradigm are organised in open phrases as questions to stakeholders to respond. The analysis the score of the all the items of a constructs are combined to generate composite score and plot the results for interpreting the findings.

**Descriptives and Normality**

The central tendency of the findings can be measured by three main measures, namely mean, median, and mode. Measuring the dispersion is an alternative method to visualise the spread of data (variation) in the gathered data.

| Descriptives | | | Statistic | Std. Error |
|---|---|---|---|---|
| Ana | Mean | | 4.2704 | 0.062 |
| | 95% Confidence Interval for Mean | Lower Bound | 4.1453 | |
| | | Upper Bound | 4.3955 | |
| | 5% Trimmed Mean | | 4.2891 | |
| | Median | | 4.3333 | |
| | Variance | | 0.173 | |
| | Std. Deviation | | 0.41635 | |
| | Minimum | | 3 | |
| | Maximum | | 5 | |
| | Range | | 2 | |
| | Interquartile Range | | 0.5 | |
| | Skewness | | -0.573 | 0.354 |
| | Kurtosis | | 0.914 | 0.695 |
| Dev | Mean | | 4.2133 | 0.071 |
| | 95% Confidence Interval for Mean | Lower Bound | 4.0696 | |
| | | Upper Bound | 4.3571 | |
| | 5% Trimmed Mean | | 4.2284 | |
| | Median | | 4.2 | |
| | Variance | | 0.229 | |
| | Std. Deviation | | 0.47856 | |
| | Minimum | | 2.6 | |
| | Maximum | | 5 | |
| | Range | | 2.4 | |
| | Interquartile Range | | 0.6 | |
| | Skewness | | -0.432 | 0.354 |
| | Kurtosis | | 0.625 | 0.695 |
| Des | Mean | | 4.1889 | 0.068 |
| | 95% Confidence Interval for Mean | Lower Bound | 4.0511 | |
| | | Upper Bound | 4.3267 | |
| | 5% Trimmed Mean | | 4.1955 | |
| | Median | | 4.1667 | |
| | Variance | | 0.21 | |
| | Std. Deviation | | 0.45864 | |
| | Minimum | | 3.17 | |
| | Maximum | | 5 | |
| | Range | | 1.83 | |
| | Interquartile Range | | 0.5 | |
| | Skewness | | -0.132 | 0.354 |
| | Kurtosis | | -0.109 | 0.695 |

| Descriptives | | | Statistic | Std. Error |
|---|---|---|---|---|
| Imp | Mean | | 3.6689 | 0.093 |
| | 95% Confidence Interval for Mean | Lower Bound | 3.4819 | |
| | | Upper Bound | 3.8559 | |
| | 5% Trimmed Mean | | 3.6938 | |
| | Median | | 3.8 | |
| | Variance | | 0.388 | |
| | Std. Deviation | | 0.6225 | |
| | Minimum | | 2 | |
| | Maximum | | 5 | |
| | Range | | 3 | |
| | Interquartile Range | | 0.6 | |
| | Skewness | | -0.882 | 0.354 |
| | Kurtosis | | 0.846 | 0.695 |
| Eva | Mean | | 4.2444 | 0.072 |
| | 95% Confidence Interval for Mean | Lower Bound | 4.099 | |
| | | Upper Bound | 4.3899 | |
| | 5% Trimmed Mean | | 4.2428 | |
| | Median | | 4.1667 | |
| | Variance | | 0.234 | |
| | Std. Deviation | | 0.4841 | |
| | Minimum | | 3.33 | |
| | Maximum | | 5 | |
| | Range | | 1.67 | |
| | Interquartile Range | | 0.75 | |
| | Skewness | | 0.333 | 0.354 |
| | Kurtosis | | 0.87 | 0.695 |

**Figure 4.10 ADDIE Descriptives**
(Source: Author, compiled from SPSS analysis)

They are different type of measures of variation, namely Variance, Standard Deviation (SD), Semi-Quartile Range, Standard error etc., and Shape (by Skewness and Kurtosis). All of them are analysed together using SPSS for Linear Regression and ANOVA (as described in Chapter-3, Sec 3.5.7).

Skewness can be defined as the degree of ‘asymmetry’ or ‘deficiency of symmetry’ in the normal distribution and Kurtosis is to quantify the 'peakedness' of the distribution. A distribution is called approximate normal if skewness or kurtosis (excess) of the data is between − 1 and + 1 (Mishra et al., 2019). As evident from Fig 4.10, all the variables data for Skewness and Kurtosis were within the range of -1 to +1. These data is commonly used to pronounce the explanations to measure the dominant inclination, known as measures of central location. These are used to discuss the characteristic value from the data.

**Tests of Normality**

Normality tests are the main deciding factors to agree whether we can use mean as the demonstrative value of the data or not.

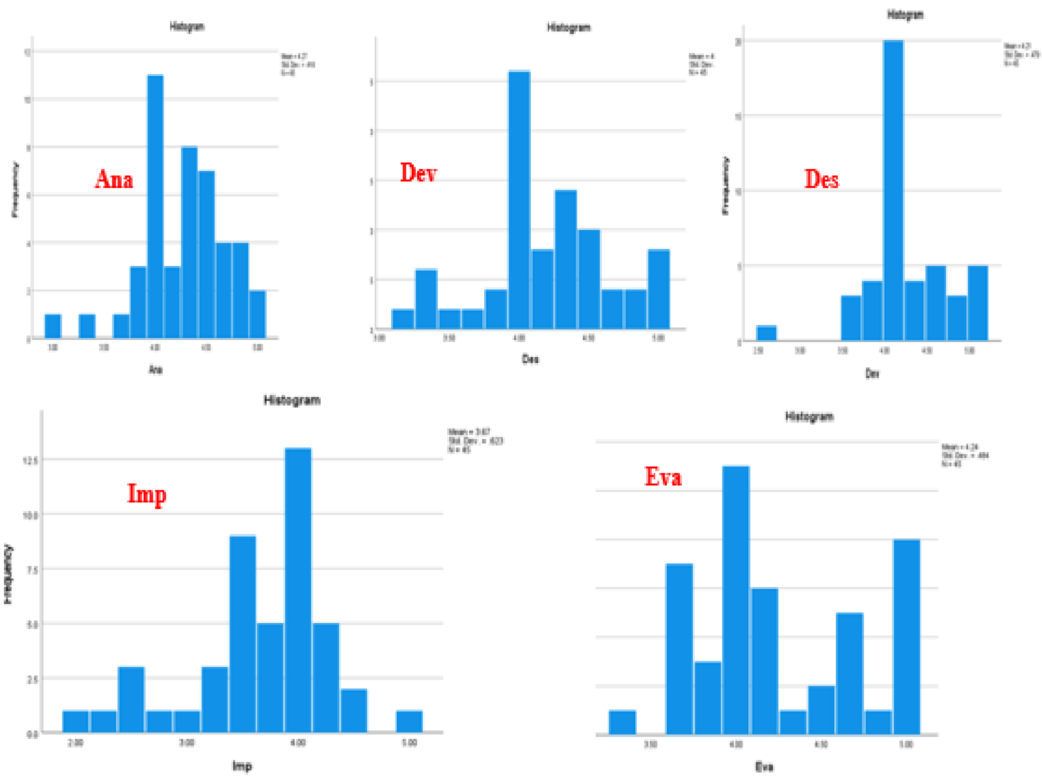


**Figure 4.11 Histograms of ADDIE Components**
(Source: Author, plotted from SPSS analysis)

If the normality is proven, we can use the means of the responces to compare the data using parametric tests or else we can use medians by comparing the groups, through non-parametric methods. The normality tests such as Shapiro-Wilk test and Kolmogorov-Smirnov test etc., are recommended for small sized samples, where the sample size, n is less than 300 (n < 300), but these tests are not reliable for larger samples. If the sample size is less than 50 (or n<50), we should use Shapiro–Wilk test and Kolmogorov–Smirnov test result must be avoided, even though both of them indicating the data is normally distributed (Mishra et al., 2019).

Q-Q plots are used to compare the quantiles of our statistics against the quantiles of the anticipated distribution. This is the quick and visual way to assess whether a variable is normal or not by using the 45-degree line. If the data adheres nearer or close to the line, it's normal or it is not. All the histography generated by using the model data are within the -2 and +2 standard deviations of the mean and the corresponding visual interpretation is shown in Fig 4.11 as histograms. Further from the QQ plots generated by SPSS (Fig 4.12), in which all the observed values (x-axis) are following the 45-degree line of the expected normal (y-axis) and the deviations are also in the acceptable limits and the data is normally distributed.

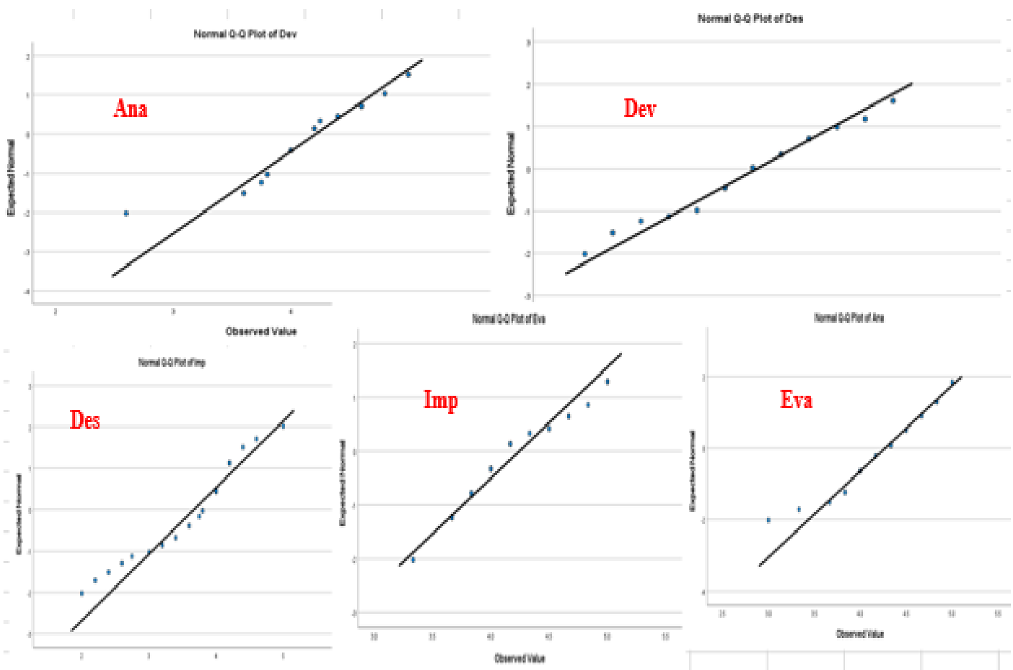


**Figure 4.12 Q-Q plots**
(Source: Author, compiled from SPSS analysis)

**Hypothesis testing for Normality (Shapiro-Wilk Test)**

The normality can also be determined by comparing the value of the Standard Deviation (SD) with the Mean. If SD is less than half mean (i.e., CV <50%), data is presumed to be normal. This is one of the fastest technique to test normality and can be used when the sample size is around 50 or less.

| ADDIE Components | Shapiro-Wilk | | |
|---|---|---|---|
| | Statistic | df | Sig. |
| Ana | 0.951 | 45 | 0.053 |
| Dev | 0.917 | 45 | 0.063 |
| Des | 0.951 | 45 | 0.058 |
| Imp | 0.913 | 45 | 0.057 |
| Eva | 0.903 | 45 | 0.061 |

**Figure 4.13 Test of Normality**
(Source: Author, compiled from SPSS analysis)

As per Mishra et al., the Shapiro–Wilk test is suitable test for samples less than fifty or n <50 and based on this assumption, test is performed for normality (Mishra et al., 2019). If the p ≥0.05, the null hypothesis can be rejected and alternate hypothesis can be accepted and proved that the data is normally distributed (Kim, 2013).

Null Hypothesis
$H_o$: “the data is not from normally distributed population”.
Alternate hypothesis
$H_a$: “the data is from normally distributed population”.

As all the ‘p’ values in Shapiro-Wilk test (Fig. 4.13) are more than 0.05, we can be in a position to conclude that the null hypothesis is rejected, and alternate hypothesis is accepted. This way normal distribution of the data is confirmed to proceed further for ANOVA and Linear Regression.

### 4.5.3.3 MODEL ANALYSIS AND HYPOTHESIS TESTING

Model summary from the linear regression model output in SPSS is shown in Fig 4.13. First each one of the ADDIE components (namely Ana, Des, Dev, Imp and Eva) is kept as dependent variable while the others are selected as independent variables (or constant) to calculate ANOVA. This is to identify the correlations, validity, variance and relationship between the items and to prove the practicality of the model within the context of this study and validate the ADDIE model.

| Depedent Variable | Indepedent Variable | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|---|
| Ana | Des, Dev, Imp, Eva | .687[a] | 0.472 | 0.419 | 0.36788 |
| Des | Eva, Ana, Imp, Dev | .674[a] | 0.455 | 0.4 | 0.38996 |
| Dev | Eva, Ana, Imp, Des | .712[a] | 0.507 | 0.458 | 0.36833 |
| Imp | Des, Ana, Dev, Eva | .601[a] | 0.362 | 0.298 | 0.52426 |
| Eva | Ana, Des, Imp, Dev | .719[a] | 0.518 | 0.469 | 0.33745 |

**ANOVA**

| Depedent Variable | Indepedent Variable | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|
| Ana | Des, Dev, Imp, Eva | Regression | 4.831 | 6 | 1.208 | 8.924 | <.001 |
| | | Residual | 5.413 | 40 | 0.135 | | |
| | | Total | 10.244 | 46 | | | |
| Des | Eva, Ana, Imp, Dev | Regression | 5.074 | 6 | 1.269 | 8.342 | <.001 |
| | | Residual | 6.083 | 40 | 0.152 | | |
| | | Total | 11.157 | 46 | | | |
| Dev | Eva, Ana, Imp, Des | Regression | 5.578 | 6 | 1.394 | 10.279 | <.001 |
| | | Residual | 5.427 | 40 | 0.136 | | |
| | | Total | 11.004 | 46 | | | |
| Imp | Des, Ana, Dev, Eva | Regression | 6.229 | 6 | 1.557 | 5.666 | <.001 |
| | | Residual | 10.994 | 40 | 0.275 | | |
| | | Total | 17.223 | 46 | | | |
| Eva | Ana, Des, Imp, Dev | Regression | 4.888 | 6 | 1.222 | 10.731 | <.001 |
| | | Residual | 4.555 | 40 | 0.114 | | |
| | | Total | 9.443 | 46 | | | |

**Figure 4.14 Model Summary-ANOVA**

(Source: Author, compiled from SPSS analysis)

**Association between Dependent and Independent Variables**

As per the data the overall model is "fit" with the data selected as dependent and independent (constants or predictors) variables. For the case of Ana as dependent variable, with Des, Dev, Imp and Eva as constants, we can see from the $R^2$ value that there is 47.2% variance in Ana scores that can be predicted from Des, Dev, Imp and Eva. Similarly, the variance of Des scores that can be predicted from Ana, Dev, Imp and Eva is 45.5%, the variance of Dev scores that can be predicted from Ana, Des, Imp and Eva Is 50.7%, the variance of Imp scores that can be predicted from Ana, Des, Dev and Eva is 36.2% and the variance of Eva scores that can be predicted from Ana, Des, Dev and Imp is 51.8%. This shows the dependency of each item over the other and need to integrate each one of them during the configuration, modelling of training simulators and to improve their usage.

**Hypothesis testing (Independent & Dependent variables)**

As we chose the 'α' as 0.05, all the coefficients with a p-value of 0.05 or less than 0.05 are said to be statistically significant (i.e., The null hypothesis can be rejected by postulating that 'α' is pointedly diverse from zero). Based on this assumption one can accomplish that "the independent variables reliably predict the dependent variable".

Null Hypothesis

$H_o$: "the independent variables are not reliably predicting the dependent variable".

Alternate Hypothesis

$H_a$: "that the independent variables are reliably predicting the dependent variable".

Based on the above statements and analysis, 'null hypothesis' is rejected and 'alternate hypothesis' is accepted.

The strength of association between each one of them cannot in a position to represent the amount of which the specific independent variables are related to the dependent variable. Therefore, we need to analyse constituents of the 'Coefficients table' along with other parameters to understand the interrelationships, plot the regression equations by coefficient analysis and overall fit of the model as described in Chapter-3, Sec 3.5.7.

**Coefficients table**

This table from SPSS (Shown in Fig 4.15) gives us the values of the regression line. We can use the parameter estimates to establish the unique association between the variables (Dependent and Independent) or the variability of one among the other through a mathematical equation. These evaluations describes the increase in Ana scores that would be predicted by a unit increase in the others. This is evident from the data (Fig 4.15) that for every regression equation, namely Ypredicted = b0 + b1*x1 + b2*x2 + b3*x3 + b3*x3 + b4*x4) can be made, where b is the constant and b1-b4 are the coefficients of the independent variables and x1-x4 are the coefficients of the dependent variables (as shown under the "B" value in Fig 4.15 under the heading unstandardised coefficients).

| Coefficients[a] | | | | | | |
|---|---|---|---|---|---|---|
| Model | | Unstandardized Coefficients | | Standardized Coefficients | t (B/St. Error) | Sig.(p) |
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 2.399 | 0.582 | | 4.121 | <.001 |
| | Imp | -0.242 | 0.104 | -0.313 | -2.32 | 0.026 |
| | Eva | 0.34 | 0.164 | 0.326 | 2.076 | 0.044 |
| | Dev | 0.534 | 0.134 | 0.553 | 3.996 | <.001 |
| | Des | -0.221 | 0.145 | -0.231 | -1.527 | 0.035 |
| a. Dependent Variable: Ana | | | | | | |
| 1 | (Constant) | -0.169 | 0.695 | | -0.243 | 0.056 |
| | Imp | 0.2 | 0.106 | 0.25 | 1.877 | 0.058 |
| | Des | 0.12 | 0.148 | 0.121 | 0.811 | 0.042 |
| | Ana | 0.535 | 0.134 | 0.516 | 3.996 | <.001 |
| | Eva | 0.201 | 0.17 | 0.186 | 1.186 | 0.022 |
| a. Dependent Variable: Dev | | | | | | |
| 1 | (Constant) | 1.432 | 0.701 | | 2.043 | 0.048 |
| | Imp | 0.192 | 0.114 | 0.239 | 1.692 | 0.038 |
| | Ana | -0.249 | 0.163 | -0.238 | -1.527 | 0.035 |
| | Eva | 0.543 | 0.161 | 0.5 | 3.367 | 0.002 |
| | Dev | 0.135 | 0.166 | 0.134 | 0.811 | 0.042 |
| a. Dependent Variable: Des | | | | | | |
| 1 | (Constant) | 1.732 | 0.951 | | 1.82 | 0.056 |
| | Ana | -0.491 | 0.212 | -0.379 | -2.32 | 0.026 |
| | Eva | 0.249 | 0.242 | 0.185 | 1.028 | 0.031 |
| | Dev | 0.405 | 0.216 | 0.324 | 1.877 | 0.052 |
| | Des | 0.348 | 0.205 | 0.28 | 1.692 | 0.05 |
| a. Dependent Variable: Imp | | | | | | |
| 1 | (Constant) | 0.283 | 0.636 | | 0.445 | 0.054 |
| | Imp | 0.103 | 0.1 | 0.139 | 1.028 | 0.031 |
| | Dev | 0.169 | 0.142 | 0.182 | 1.186 | 0.042 |
| | Des | 0.407 | 0.121 | 0.442 | 3.367 | 0.002 |
| | Ana | 0.286 | 0.138 | 0.298 | 2.076 | 0.044 |
| a. Dependent Variable: Eva | | | | | | |

**Figure 4.15 Model Summary-ANOVA Coefficients**

(Source: Author, compiled from SPSS analysis)

The independent variables which are not significant, we have to see whether the coefficients are not significantly different from zero. We have to consider these values, while interpreting the coefficients (with 't' and 'p' values to see their significance). In our case all the variables where $p<0.05$ and are not statistically significant. The variables having 'p' values higher than 0.05, from the Fig 4.14, we have to seek further research with larger sampling across different industries that can be used while building the model. These parameters can be further analysed using multiple regression analysis and the model can be build up through factor analysis, which are out of purview of this study.

These estimates express the relationship between the independent variables and the dependent variable. Due to the linearity of the model, we can envisage from AnaPredicted that for every unit increase in Imp, there is a drop of -0.242 in Ana value (due to the negative value of Imp) or for every unit increase in Eva, there is an increase of 0.34 in Ana value.

Similarly, from DevPredicted we can see that for every increment in Imp, an corresponding raise of 0.2 in Dev value (due to the positive value of Imp) or for every increment in Imp, there is corresponding raise of 0.2 value in Ana and for every corresponding raise in Des, there is an increment in 0.12 of Dev value, 0.535 times Ana and 0.201 times Eva values in Dev etc. We can generalize the same with other variables namely DesPredicted, ImpPredicted and EvaPredicted etc as shown in Table 4.2.

**Table 4.1 ADDIE Equations from Regression Model**

| |
|---|
| Ana**Predicted = 2.399+-0.242Imp+0.34Eva+0.534Dev+-0.221Des** |
| Dev**Predicted = -0169+0.200Imp+0.12Des+0.535Ana+0.201Eva** |
| Des**Predicted = 1.432+0.192Imp+-0.249Ana+0.543Eva+0.135Dev** |
| Imp**Predicted = 1.732+-0.491Ana+0.249Eva+0.405Dev+0.348Des** |
| Eva**Predicted = 0.283+0.103Imp+0.286Ana+0.169Dev+0.407Des** |

### 4.5.4 EFFECT OF SIZE AND POST HOC TESTING

As per the review of literature, analysing the data using ANOVA and linear regression, we can generalize that the statistical significance of the data mostly depends on the size of the sample. Statically, minor differences can be significant in very huge samples and large effect sizes may not be statistically significant with small size samples (Nikerson, 2000). Effect of size measurements for unconditional independent variables might be having spontaneous understanding and is simple to assess them for data validation (Tunks, 1978).

The most popular effect size measures for analysis of variance models are found to be $\eta^2$ (Eta-Squared), $\omega^2$ (Omega Squared) and $\varepsilon^2$ (Epsilon Squared). We can have the spontaneous explanation of the amount of variance described through them. One of the weakness in Eta Squared is that it is a biased measure of population variance. This bias can be very small for larger sample sizes, but for the minor samples an impartial effect size measure is measured through Omega Squared (The Analysis Factor).

| **ANOVA Effect Sizes Note: Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.** | | **Point Estimate** | **95% Confidence Interval** | |
|---|---|---|---|---|
| | | | **Lower** | **Upper** |
| Case | Eta-squared $\hat{\eta}^2$ | 0.07 | 0 | 0.22 |
| | Epsilon-squared $\varepsilon^2$ | 0.026 | -0.048 | 0.183 |
| | Omega-squared $\omega^2$ (Fixed-effect) | 0.025 | -0.047 | 0.18 |
| | Omega-squared $\omega^2$ (Random-Effect) | 0.013 | -0.023 | 0.099 |

| **ANOVA** | | | | | |
|---|---|---|---|---|---|
| Case | Sum of Squares | df | Mean Square | F | Sig. |
| Between Groups | 2.30 | 4 | 1.154 | 1.58 | 0.218 |
| Within Groups | 30.67 | 42 | 0.73 | | |
| Total | 32.97 | 46 | | | |

**Figure 4.16 ANOVA effect sizes**

(Source: Author, compiled from SPSS analysis)

Soner in his study about the effect sizes described that we could obtain negative estimates in some experimental conditions (i.e., small effect size magnitude). These may be considered a disadvantage of $\varepsilon^2$ and $\omega^2$ estimates, although both measures give unbiased estimates of all experimental conditions (Soner, 2015). For a presumed population in the study, $\omega^2$ is the effect size measurement, or the degree of association. We can estimate the variance in the responses accounting from the explanatory variables and they can vary between ±1 (Glen, 2021).

Eta-squared ($\eta^2$) is the proportion of variance accounted by a factor. Eta - squared is the choice for Anova and indicates small effect if it is greater than 0.01 or $\eta^2 > 0.01$, medium effect if it is greater than 0.06 or $\eta^2 > 0.06$ and if $\eta^2 > 0.14$ indicates we can assume a larger effect.

Similarly, Omega Squared ($\omega^2$) estimates small effect if it is equal to 0.01 or $\omega^2 = 0.01$, medium effect if it is equal to 0.06 or $\omega^2 = 0.06$ and if $\omega^2 = 0.14$ indicates it effects a very large effect. This way the proportion of variance in the outcome variable is accounted for by an effect of the entire population (Karen, 2021) as shown in Fig 4.16.

Omega Squared is the unbiased estimate of population variances and is always lesser than Eta Squared and we can see that $\eta^2$ and $\omega^2$ values are in the range of small and medium scale bias not much impact on the results due to sample size effect.

**Post-hoc Testing**

Post-hoc tests are carried out to manage the group wise error rate while executing various pairwise evaluations. In other words, they test whether the difference between each possible pair of means is statistically significant or not (Ruben, 2021). One has to conduct a post hoc test when the p-value for the ANOVA is statistically significant, that is $p<0.05$.

In this study, the p value between the groups is greater than 0.05 (Table 4.3) and as such post hoc testing is not required as suggested by Ruben and Stephane (Ruben, 2021 and Stephane, 2021). As the p-value is not statistically significant, it indicates that the means of all the groups are not different from each other. This way we can conclude that the post-hoc test is not required to carryout to find out which groups are different from each other and do pairwise calculations.

### 4.5.5 PERCEPTIONS AND CENTRAL TENDENCY

Case and Role responces for Likert scale based responces are shown in Fig 4.8, which summarises the stakeholder responces for individual questionnaire. The central tendency (Mean) of and the observations or perceptions of key stake holders for each question mapped to RO-2 is presented below.

**Table 4.2 Summary of Perceptions**

| Codes | Questionnaire | Mean | Perceptions |
|---|---|---|---|
| Ana-1 | Completing the OTS trainings helped in understanding the classroom training information in an effective way | 4.5 | Perceived effective as OTS is one of the proven tool to visualise the theoretical learning |
| Ana-2 | While using the OTS, one is expected to learn new concepts that will help during their job | 4.3 | New concepts in OTS helps on the job performance |
| Ana-3 | OTS training challenged my decision-making skills during emergency conditions and process upsets | 4.1 | Perceived effective by application of skills |
| Ana-4 | OTS training helped us to be more assured in carrying out operational changes to supplement process safety and reduction of Human Errors | 4.4 | Improvement in process safety due to OTS training, with a possible decrease of human errors during process control |
| Ana-5 | There is noteworthy variation in the process control and self-confidence levels before and after OTS training. | 4.3 | Improvement due to training is perceived effective using OTS |

| | | | |
|---|---|---|---|
| Ana-6 | The skills learned from simulator training reflected the actual happenings in your job | 3.2 | Perceived effective |
| Des-1 | Simulator based training is viewed as a Strategic component or Key Performance Indicator (KPI) for operations by the management | 4.3 | Making OTS as a KPI indicates management support to recognize its importance across organization |
| Des-2 | Debriefing, Feedback and Group discussion during training are valuable to sustain learning | 4.2 | Perceived effective to include debriefing and feedback sessions are part of design of the training |
| Des-3 | One need to upgrade the OTS continuously along with the real plant like Digital Twins | 4.5 | Continuous updates result in effective performance |
| Des-4 | During the training, Automatic feedback of training allows trainees to be more independent | 3.0 | Not in favour or Neutral for automatic feedback of the sessions |
| Des-5 | Simulation training assessment is effectively used as a Skill verification tool for advancements and job ladders | 3.5 | Not in favour or Neutral to use OTS as a testing tool for promotions etc. as it biased towards instructors |

| | | | |
|---|---|---|---|
| Dev-1 | Simulation is the only effective tool that is needed for console operator training | 4.2 | Perceived effective for hands-on training |
| Dev-2 | It is advisable to take part in OTS training as part of a multi-disciplinary team | 4.3 | Perceived effective |
| Dev-3 | Automatic feedback communication modelled with performance indicators to enhance efficiency of training | 3.7 | Not much in favour or near neutral for automatic performance measurements, mainly due to bias nature of the OTS developer |
| Dev-4 | In your opinion, operator's groundwork and self-study of exercises during training helps them to be accurate and have meaning full sessions | 3.2 | Not in favour or Neutral due to little effect of training due to self-preparation, rather preparation by the instructor himself is more efficient |
| Dev-5 | Operators are generally familiar with the concept of simulation and its limitations | 3.9 | Perceived effective as the operators are to familiarise the concepts incorporated from the design itself |
| Imp-1 | It is effective to undergo simulation training as part | 3.0 | Not in favour or Neutral for taking part as group to |

| | | | |
|---|---|---|---|
| | of team within the same shift, operational group | | minimize no of participants in same session |
| Imp-2 | The instructor helped me to think critically and bring a refresh change for actual operations | 4.2 | Perceived effective to critical analysis by the instructor through an honest opinion |
| Imp-3 | I learned as much from observing my peers actively involved in the simulated environment | 4.1 | Peer learning is an effective strategy to be implemented |
| Imp-4 | In the OTS Training, the results are derived on the process outcomes without a clear relationship to specific competencies | 2.9 | Perceived in-effective as the outcomes are clearly defined with specific outcomes |
| Imp-5 | Providing regular feedback Improves performance and there by simulator training effectiveness | 4.2 | Regular feedback improves performance by the correction of errors |
| Eva-1 | We feel more confident to recognize changes in the actual plant process conditions after OTS training | 4.1 | Perceived confident in executing new modifications and tasks |
| Eva-2 | Simulator training can improve the performance of operators in managing control room emergencies | 4.6 | Perceived confident in executing emergency tasks |

| | | | |
|---|---|---|---|
| Eva-3 | OTS empowered to make critical interventions and developed an effective understanding of control loops and safety logics | 4.3 | Improve understanding and performing critical operational tasks |
| Eva-4 | Having the opportunity to introspect myself on the simulator, It improve my skills and performance | 4.4 | Introspection of handling complex tasks and improve competency |
| Eva-5 | The contribution of the employees trained on simulators resulted in effective performance across organization | 3.9 | Improvement in overall organizational performance by training transfer to workplace |
| Eva-6 | After the OTS training, the operator's actions have improved safety of control room operations | 4.5 | Improved confidence in executing emergency tasks and effectiveness of operator competencies |
| Eva-7 | We are more confident in the ability to report information more accurately to superiors and there by contributing to process efficiency | 4.1 | Perceived confident in reporting and managing self |

**Summary**

These relationships and variability of one among the others proves that the ADDIE model can be used as an instructional enterprise tool during the configuration of simulator models in tandem with process and thermodynamic models. ADDIE model can be used in any phase of the developmental process for its evaluative and cyclical nature. As the training models vary across the industry due to the changing nature of the industrial processes, the OTS developer has to work in tandem the OTS instructor and management in developing the models and finetune the modelling parameters, graphics and navigational tools, evaluative instruments available with the licensed models customized to measure the outcome of the training process and ways to store the data (training history, training performance tables, event summary, evaluative trends and corrective actions list etc.) with in the simulator environment. The narrative qualitative summaries of the stakeholders are further analysed with literature in the next section

### 4.5.6 OTS USAGE AND CHALLENGES

OTS usage, challenges and limitations faced with in the organizational or developmental context is very important to identify and one needs to be properly addressed to maximize return of investment. This is to keep up the functionality of the system as needed for operations training. The below passages summarise many opinions for the improvement and effective usage of the training simulators.

**OTS Functionality**

More than 90% of the participants responded that lack of competent instructors, motivation from management to encourage learning culture, no separate manhours/training days for OTS training and no clear organizational guidance are main causes for lack of OTS utilization within their organizations.

Above 45% of the respondents says that there is a proper maintenance plan to upkeep the OTS, 32% mentioned that they are not aware of the maintenance issues and followed by 10% of those cannot say. Having a proper maintenance plan and keeping up the updated models is the key requirements and one of the major factor to prevent OTS obsolescence.

The top five reason for non-functionality of the OTS after the commissioning stage to normal operations is mainly due to

1. No proper updating and maintenance of process models (60%)
2. Lack of budgetary support (31.5%)
3. Lack of motivation and management support (27.3%)
4. Availability of Qualified Instructors (26%)
5. Lack of coordination between automation and operations (20%)

**OTS Utilization**

To improve the utilization of OTS one has to develop tools to take data directly from actual system in the form of snapshots feeding into the simulated environment. This capability of transferring the data and modified by the instructors as scenarios to practice an actual shutdown or retrieved operational data from the past transfer to OTS along with continuous online support from vendors OTS engineers.

Lack of management support and Motivation are mentioned as key barriers to the transfer of training. After undertaking a simulation training course, the stakeholders feel that they can analyse the process better in upset conditions, able to integrate theoretical concepts into hands-on operations, can train the others through focused mentoring.

By virtue of their operational background, the instructors are not properly trained on training evaluation, pedagogical design and competency assessment tools. More than 90% of respondents agreed that the management needs to address this very urgently and rather than train the trainer course, full-fledged instructional design training and assessment certifications should be considered for the instructors using pedagogical tools.

There is lack of consensus on the usage of virtualized OTS with 3D field models and Immersive Simulators among the participants as they feel that they are not suitable for larger sized/integrated units as the piping/process arrangement is too complex to navigate. They are more suitable for offshore and unmanned installations and isolated units located in remote places where physical presence is minimal, and where On the Job Training (OJT) cannot be imparted in the location.

To measure knowledge transfer across the organization the operators need to be aware of as to whom to consult for the immediate help or assistance during continuous operations with the idea of bringing in fresh outlook or opinion. The operators seek to control the process with opinion from the Supervisor (69.6%), manage himself by recollecting earlier trainings (40%), Panel operator in the other areas (29%), OTS Instructor (35%) and Plant manager (18%). This reinforces the fact that the management must train the supervisors along with the operators as a group so that they are also well versed with the critical control system operations and approachable to control room operators as the time duration for decision making is very limited and is within 1-2 minutes.

**Cross Customization**

While developing the simulation models, the OTS engineers can adapt diverse methods in modelling the process models and adapt the same approach to similar thermodynamic models or configuring unit operations where commonality is found (for example., a boiler producing steam using Natural gas as fuel can be easily adapted as a process model generating steam from Coal or Fuel oil etc., by changing some specific inputs and process dynamics rather than remodelling the entire contents and keeping the same turbo generator configuration with final output changes suitable to the company). This is one way of standardizing the model specific to the company and same can be used either within the company or similar processes in other organizations.

### 4.6 RO-3 FINDINGS AND ANALYSIS

✔R.O-3 is to study the efficacy and control systems knowledge acquired using operator training simulators in minimizing human errors and other economic benefits.

To analyse this objective, diverse set of open-ended and multiple-choice questions are mapped into the survey form. They consists of 27 open & close ended, ranking and descriptive type questions for gathering the stakeholder responces (Appendix 1). The questions are further validated from the literature review. NVivo (2021 version) is used as the data tool to analyse the survey responces, , data visualization by clustering of different responces, coding of the data by identifying different pattern for triangulation and analysis.

### 4.6.1 DATA SEGREGATION

Different narrative responces in the form of text (such as keywords and coded words etc.) from the case data were extracted as relevant to provide theoretical evidence and to compare with existing literature and elucidating the survey responces (Bandara, 2006). Inductive and deductive coding (Manual & Automatic and Vertical & Horizontal) is used to get the codes directly from the responses through automatic coding (using text analytics) so that all the codes are of the same level of specificity and importance. Nodes contain different categorical information and coding represent collecting the abstract of ideas, concepts, people, places, processes from the textual data. Nodes can be contained in any number of documents used for coding. We can rearrange, change the directory or grouping or coded words to generate ideas to form and merge within the nodes to get meaningful insights as sentences.

### 4.6.2 CODING, CLUSTERING AND VISUALIZATION

Clustering is the task of separating the responces or themes into groups in such a way that the responces from same groups are more comparable to other within the same group and which might be diverse with other groups. It is basically a gathering of items or themes on the basis of similarity and dissimilarity.

The items clustered by coding similarity (Fig 4.15) and word similarity (Fig 4.16) are generated with the word frequency results (minimum 2 to maximum 33-word count) identified by similarity count (Table 4.5). The most frequent words are automatically captured in the items coded under word similarity, expressed as proper sentences to capture the responces (Akylbayeva et al., 2018). The similarity metric is a arithmetical analysis tool for identifying correlation between the items and find common phrases or words to frame meaningful sentences using the hierarchical clustered approaches. This will narrate the typical responses which are similar in nature in a survey or a data set or simply a set of responses from interviews.

### 4.6.2.1 CLUSTURE ANALYSIS

Clusture analysis is a useful tool to interpret the data set with good judgment and in-depth knowledge of the raw data. When some samples in the same cluster have some missing data or similar narrative, we can gather the missing data from other cases or narratives in the same cluster or similar clusture within the group or study to conceptualize the views. These similarities can be measured between different instances by combining the cases or responces and the data is presented into a metric, called similarity measure in the clusture analysis algorithms. This way the clustering data can simplify large datasets into visual interpretations.

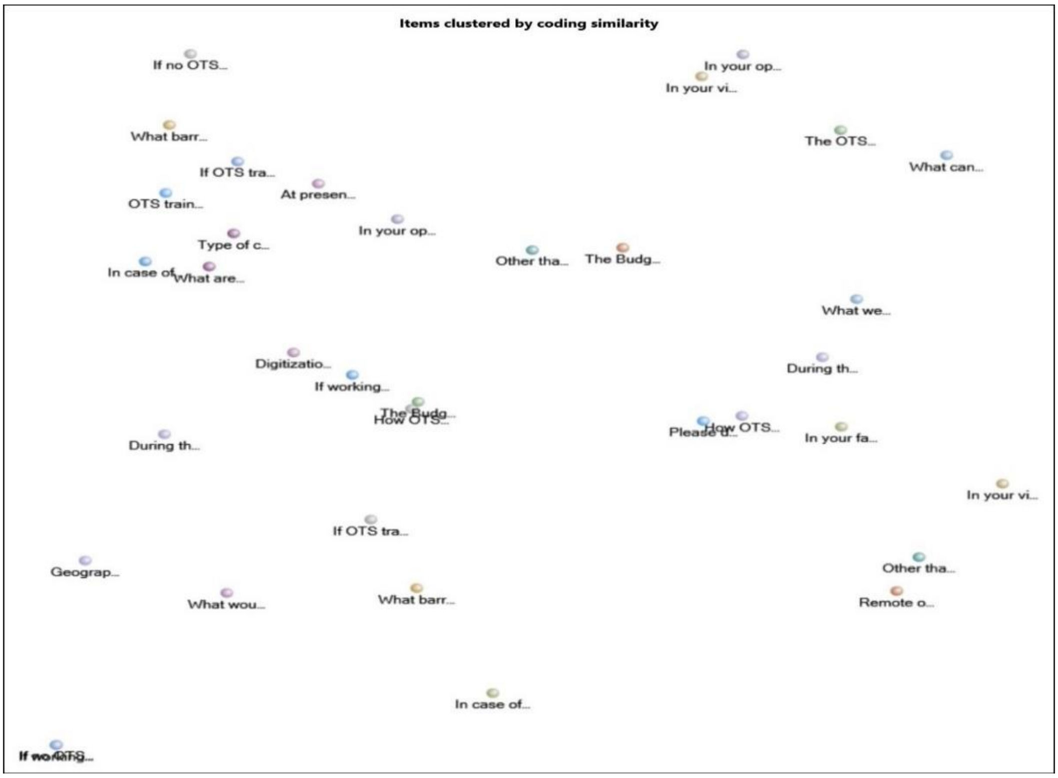


**Figure 4.17 Items clustered by coding similarity**

(Source: Author, compiled from NVivo data analysis)

When each situation or condition or statement is defined by one or two narratives, it is easier to measure their similarity. By using similarity of words used in the data bases or coding the words analysed thru word cloud and word frequency the qualitative data can be complemented to the impressions and provide explanatory evidence of association to generate meaningful insights of the study or research objectives (Akylbayeva et al., 2018).

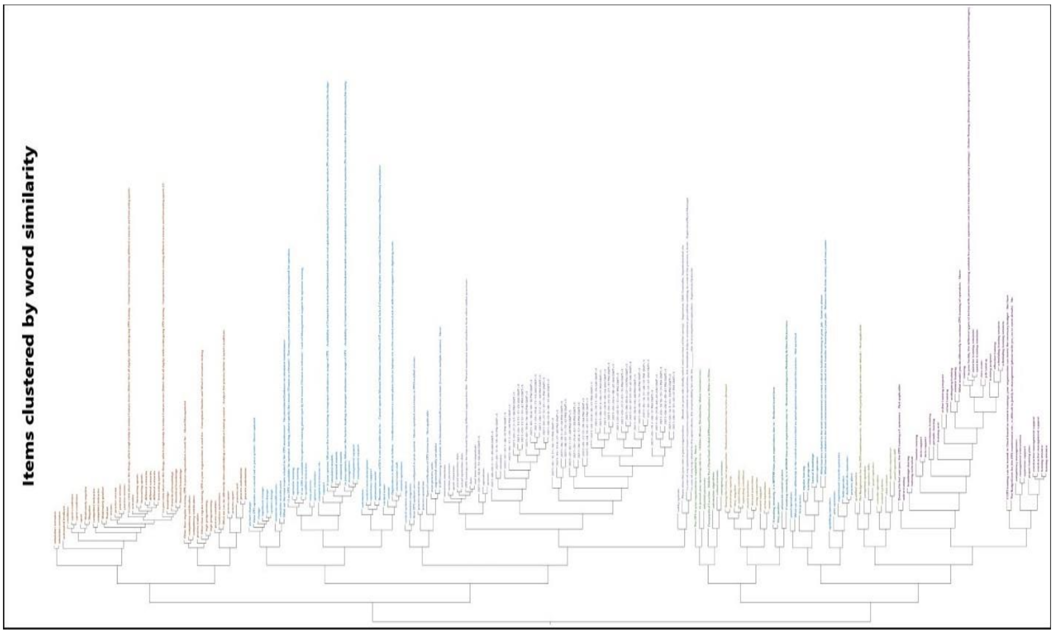


**Figure 4.18 Items clustered by word similarity**

(Source: Author, compiled from NVivo data analysis)

**Table 4.3 Word Frequency by Similarity (NVivo)**

| Word | Length | Count | Weighted % | Similar Words |
|---|---|---|---|---|
| Training | 8 | 33 | 1.83 | Conditions, Developed, Trained, Trainings |
| Simulation | 10 | 15 | 0.94 | Simulated, Simulator, Simulators |
| Performance | 11 | 16 | 0.72 | Operational, Operations, Performance |
| Better | 6 | 11 | 0.69 | Better, Improve, Improved, Improves |
| Part | 4 | 12 | 0.63 | Component, Contribution, Part, Role, Section |
| Effectiveness | 13 | 9 | 0.57 | Effective, Outcomes, Resulted, Results |
| Operators | 9 | 15 | 0.57 | Control, Operational, |

| | | | | |
|---|---|---|---|---|
| | | | | Operators, Process |
| Supervisor | 10 | 9 | 0.57 | Supervisor |
| Take | 4 | 14 | 0.55 | Bring, Carrying, Involved, Learn, Learning, |
| Engineer | 8 | 10 | 0.53 | Engineer, Organization |
| Consultant | 10 | 8 | 0.50 | Advisable, Consultant |
| Allows | 6 | 5 | 0.31 | Agrees, Providing |
| Feedback | 8 | 5 | 0.31 | Response, Reaction |
| Manager | 7 | 5 | 0.31 | Management, Managing |
| Operator | 11 | 5 | 0.31 | Operator |
| Helped | 6 | 4 | 0.25 | Help, Helped |
| Session | 7 | 4 | 0.25 | Session, Sessions |
| Skills | 6 | 4 | 0.25 | Skills |
| Opinion | 7 | 4 | 0.22 | Feel, Opinion, Viewed |
| Actual | 6 | 3 | 0.19 | Definite, Real |
| Confident | 9 | 3 | 0.19 | Confidence, Confident |
| Critical | 8 | 3 | 0.19 | Critical, Critically, Decision |
| Meaning | 7 | 4 | 0.19 | Meaning, Significant, Think |
| Multi-Disciplinary | 17 | 3 | 0.19 | Many |
| Supervisor | 18 | 3 | 0.19 | Manager |

| | | | | |
|---|---|---|---|---|
| Safety | 6 | 3 | 0.19 | Safety |
| Team | 4 | 3 | 0.19 | Team |
| Conditions | 10 | 5 | 0.16 | Conditions, Learn, Learned, Learning |
| Understanding | 13 | 3 | 0.16 | Clear, Understanding |
| Preparation | 11 | 5 | 0.15 | Make, Making, Planning, Preparation |
| Organization | 12 | 5 | 0.14 | Organization, Preparation |
| Competencies | 12 | 2 | 0.13 | Competencies, Competency |
| Concept | 7 | 2 | 0.13 | Thought, Perceptions |
| Indicator | 9 | 2 | 0.13 | Indicator, Indicators |
| Interventions | 13 | 2 | 0.13 | Interventions |
| Process | 7 | 4 | 0.13 | Actions, Process |
| Regular | 7 | 2 | 0.13 | Regular |
| Manager | 14 | 2 | 0.13 | Supervisor |

The hierarchical clustered map captured in Fig. 4.17 is produced by using an iterative multidimensional scaling algorithm developed by hierarchical clustering technique of NVivo. By this visualization, we can verbalize phrases and articulate understandings by analysing the words as groups with reference to each question and corresponding responses. In the cluster analysis, groups are clustered together as per their similarity and is based on the sources or nodes frequency of occurrence.

Cluster analysis diagrams generated using the Cluster Analysis Wizard of NVivo, are based on Pearson correlation coefficient with -1 = least similar and 1 = most similar items. Sources or nodes having minor similarity, their existence and uniformity of words are exhibited farther. The group of words like ‘upset’, ‘conditions’ and ‘theoretical knowledge’ located next to each other in the dendrogram and form another small clusture with ‘forecasting’, ‘different scenarios’ joined by ‘competent instructor’ and ‘practice session’.

These pattern of words shows that they are closely related to each other and the far away clusture within the parent clusture shows that they can be combined to frame meaningful sentences by interpreting with the research question. This way cluster analysis provides an alternative tool to present data in a clearly defined two-dimensional place and interpretation through a swift and informal visual tool (Akylbayeva et al., 2018).

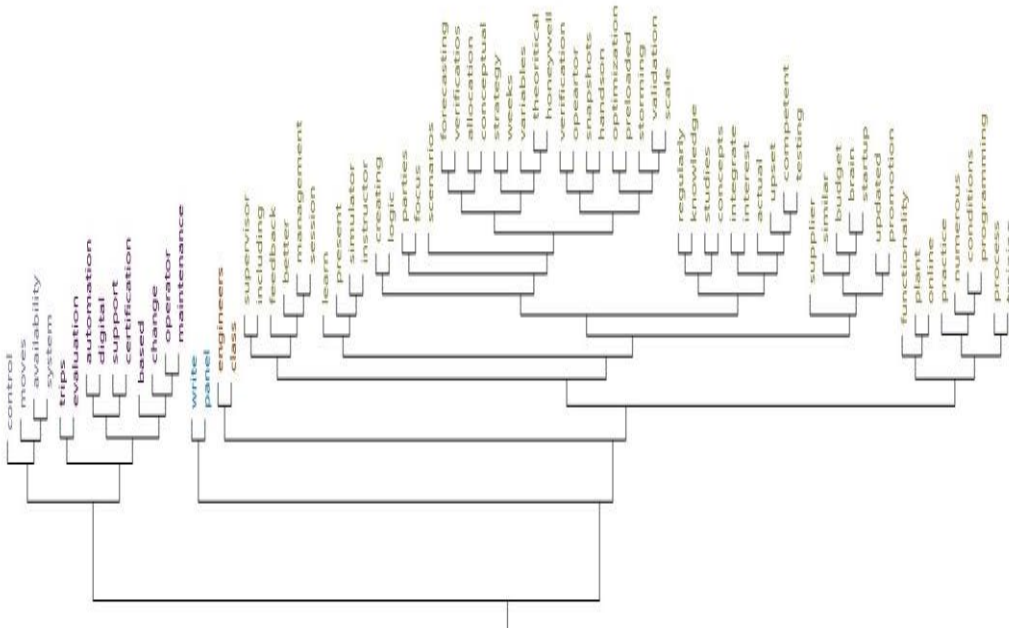


**Figure 4.19 Hierarchical Clusture**

(Source: Author, compiled from NVivo data)

### 4.6.3 EFFICACY OF OTS

The qualitative survey data is analysed using manual and automatic coding by extraction pattern learning technique to highlight subjective expressions that are linguistically richer than individual words or fixed phrase. This will help us to gather high precision phrases with minimal loss in precision and disguised between realistic and non- realistic information (Riloff and Janyce, 2003).

The study reiterates that the efficacy of the OTS is constructed on the capability of the learner to execute in the workplace. The assessment of training effectiveness must be a continuous process in the development of any training program based on feedback from the stakeholders. The efficacy of any training scheme is continuously depending on the overall design and its framework. Therefore, evaluating training effectiveness (and its economic benefits or utilization of simulator) should be blended with the work requirements, workplace tasks, skill attainment, organizational goals, and overall operational situation. If one cannot take care of these aspects, the training effectiveness calculations are impractical (Walker et al., 2009).

The effectiveness of a training program depends on how effectively the skills are transferred to the trainee (Reising and Bullemer, 2008). Effective training transfer is important to guarantee that all the planned knowledge outcomes are captured during the session and replicated in the workplace. This is often questioned as most of what is learnt in the program is not applied at the work. The perceptions from the stake holders (Table 4.4) in terms of OTS training and effectiveness are also analysed with reference to these responces are summarized in next section.

#### 4.6.3.1 PREVENTION OF HUMAN ERROR

The responces to the attributes which might help to reduce human errors in operations while undergoing OTS training are summarized in Fig 4.18. Over 90% of the stakeholders remarked that a competent instructor creating most common process upset scenarios with event reports taken from similar industries or lessons learnt exercises in training simulations along with theoretical inputs in a standard classroom helps to reduce operational errors.

Majority of the responders (77%), agree that theoretical knowledge updating thru classroom trainings to be supplemented along with updated simulator models (69%), which further enhances the training experience. Constructive criticism while analysing the outcome of the trainings during debriefing should be practiced and documented regularly was mentioned by more than 40% and supervisory support was mentioned by 60% respondents.

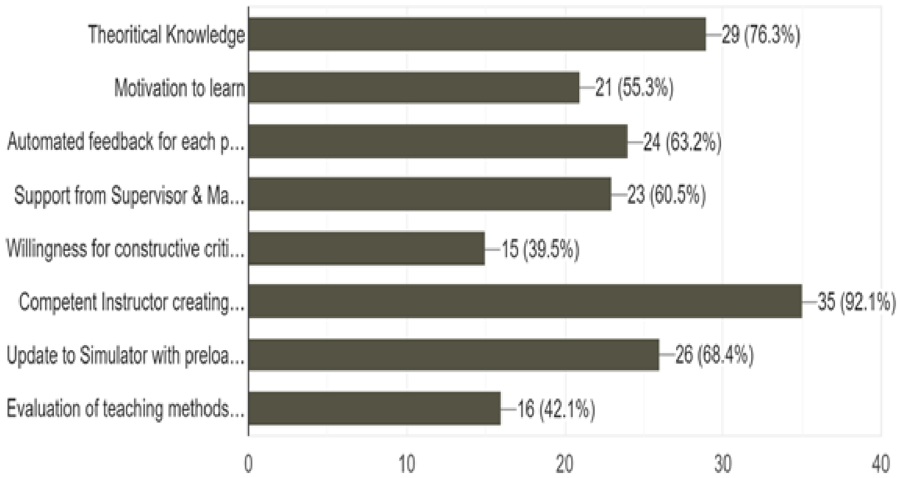


**Figure 4.20 Possible ways to prevent Human Error**

(Source: Author, compiled from qualitative survey data)

The responces to the question, by what extent the simulated scenarios in the simulator training reflecting actual actions or implementations at the workplace are summarized in Fig 4.19. More than 80% of the respondents agree that they are effectively utilizing the lessons learnt during the training are mostly replicated in the workplace.

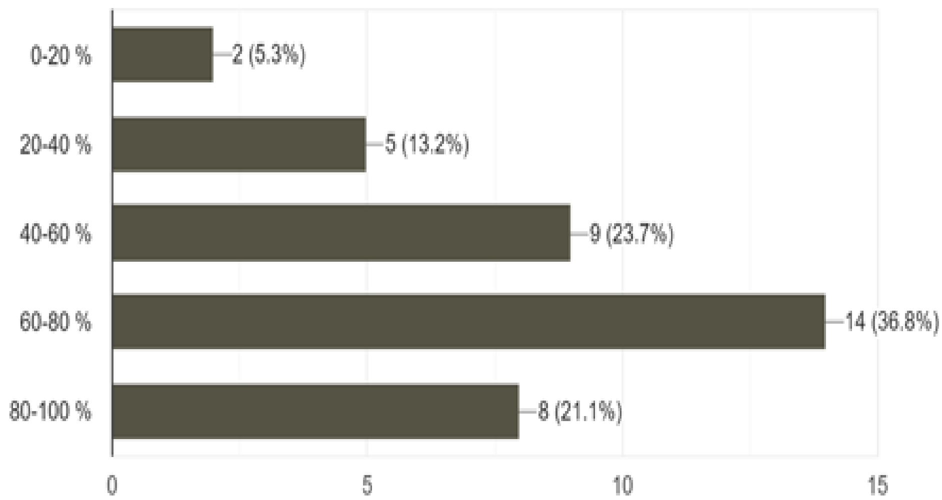


**Figure 4.21 Simulated scenarios Vs actual happenings**

(Source: Author, compiled from qualitative survey data)

To summarize that commitment from management to learning initiatives, budget and updating models along with regular training interventions contributes to less erroneous operations during process upsets and thereby preventing human errors. These are in conjunction with the previous findings that motivation to learn by management support and automatic feedback of participants thru gap analysis is very important to prevent human errors (Annette et al., 2014, Komulainen et al., 2018 and Ravikanth et al., 2018).

**Training Bias and Feedback**

Very few respondents (5%) mentioned that there some gaps of learning transfer during the training period to actual accomplishment during start up, shutdown etc. This might be due to limitation of the system functionality or lack of refresher training for the respondents. Instructor bias due to the fact that he himself may not be fully trained to transfer the knowledge and anticipating the scenarios himself due to lack of skills also might be a root cause. Almost 95% agree that the OTS system is the best tool/training to practice simulated scenarios than the theoretical trainings related to lessons learnt exercises etc.

### 4.6.4 BENEFITS OF OTS

The different benefits due to the well-defined, replicable OTS training system can be categorised as under Safety and Environmental compliance, Operational benefits (such as faster start-up, hot start-up after a brief shutdown etc.), operating under optimum production/quality levels, handling of process upsets without tripping or shutdown of all units, debugging of operating procedures and validation of the competencies of control room operators etc.

#### 4.6.4.1 IMPROVING OTS EFFECTIVENESS

The factors leading to proper utilization or most effective way of usage of OTS training in the organizational setup are as below.

a) Competent instructor with pedagogical certification (65%)
b) Instructional design embedded into the process models (60%)
c) Dedicated time slots for OTS training during the year (60%)
d) Classroom training followed by OTS training (35%)

e) Process models with up-to-date simulator (32%)
f) Well planned training sessions with qualified instructors (25%)
g) Support from management (25%)

All of these are in tandem with similar reviews in simulator development, usage and during the pilot study (Marcano et al.,2017, Kallakuri et al., 2017 and Manca et al., 2017).

**New approaches in the OTS development**

One of the central aspect of this study is to seek different approaches from stakeholders to improve OTS trainings in terms of improvements which are not readily available in the market and not taken up by neither suppliers nor organizations. These requirements can be taken up with the modelling engineers and OTS developers to undertake feasibility studies for possible inclusion in the latest models or existing model updates. These are summarized in Fig. 4.20, with more than 76% participants in favour integrating real plant data directly into the simulation models with a possible option of taking snapshots of upset conditions to practice/analyse in the training simulator, similarly 67% participants is interested to copy the actual operation data base on a continuous basis (with the process models and update continuously) to configure process upsets on their own to practice.

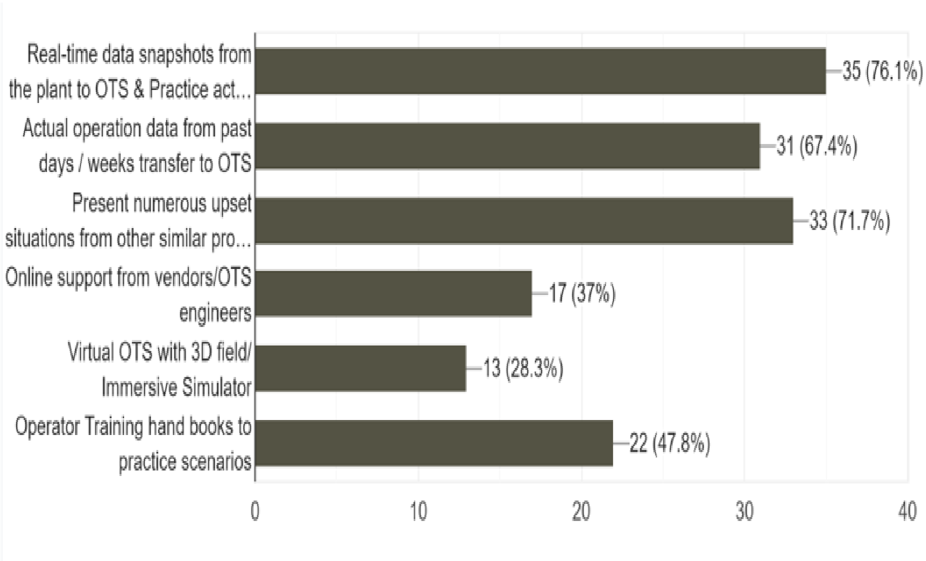


**Figure 4.22 Different approaches to OTS training**
(Source: Author, compiled from qualitative survey data)

Another interesting observation is the provision of training handbooks with real-world scenarios for practice (47%), followed by Virtual/3D process simulators with Immersive features (28%).

**OTS Utilization**

To improve the utilization of OTS the that one has to develop tools to take data directly from actual system in the form of snapshots feeding into the simulated environment. This capability of transferring the data and modified by the instructors as scenarios to practice an actual shutdown or retrieved operational data from the past transfer to OTS along with continuous online support from vendors OTS engineers.

Post training enhancements and methods to be implemented to the existing OTS training systems in the operations are captured in Fig. 4.21. Majority of the participants feel  that after a training session they can analyse the process better (89%) in upset conditions (but no one in the organization or the operator himself not being aware to record the event as a case to support OTS budget and auditing of the system itself).

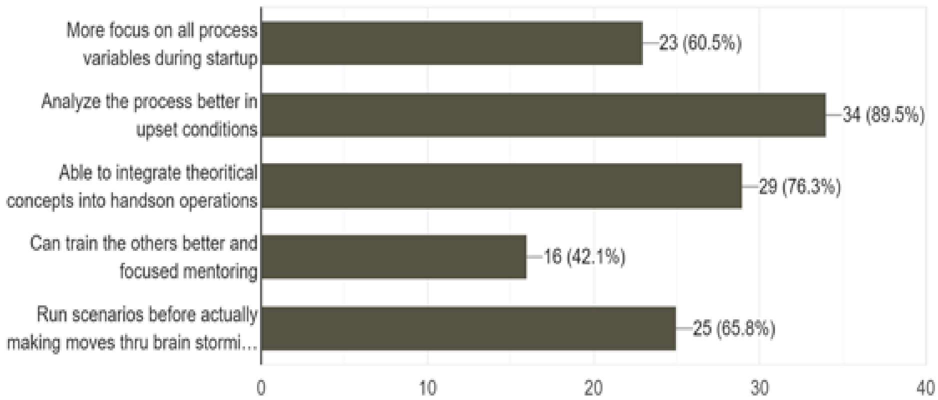


**Figure 4.23 Post OTS training improvements of operators**

(Source: Author, compiled from stakeholder responces)

They are able to integrate theoretical concepts into hands-on operations (76%), Run scenarios thru brainstorming as a group (65%) to support peer learning and sharing of knowledge, lessons learnt in another group etc. Around 42%

respondents are in a position to train others through focussed mentoring (most experienced operators and supervisors responded this way).

There is lack of consensus on the usage of virtualized OTS with 3D field models and Immersive Simulators among the participants as they feel that they are not suitable for larger sized/integrated units as the piping/process arrangement is too complex to navigate. They are more suitable for offshore and unmanned installations and isolated units located in remote places where physical presence is minimal, and where On the Job Training (OJT) cannot be imparted in the location.

The stakeholders are not sure (49%) of cloud-based storage, virtual setup and configuration of the training simulation systems, which are deployed in large numbers during the pandemic as an alternative to the traditional on the site-based systems summarized in Fig 4.22.

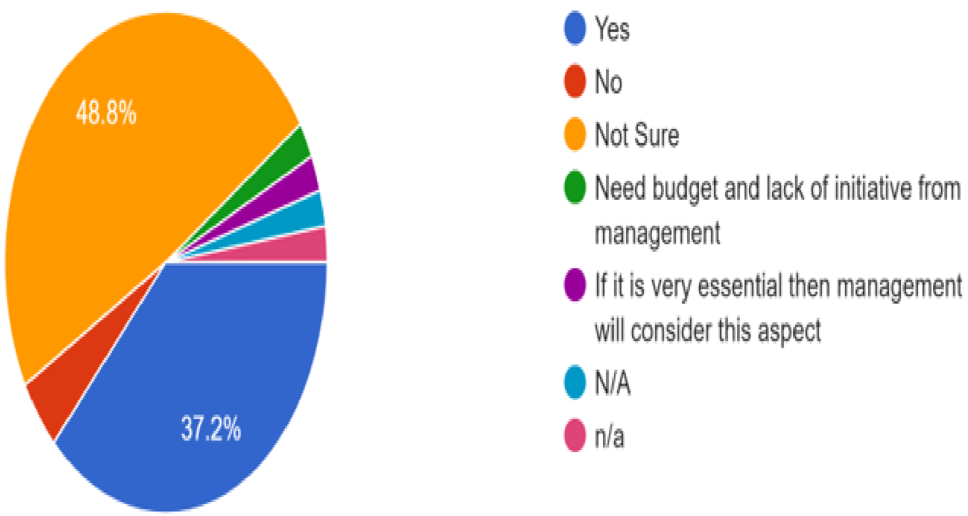


**Figure 4.24 Budgetary support for Cloud based OTS setup**

(Source: Author, compiled from stakeholder responces)

More than 37% does provide the necessary support (mostly from Europe and Middle East) to upgrade the facilities to cloud based setup and some managers did agree to provide the management support. The other areas are not ready to deploy additional capital for cloud-based systems due to uncertainty in the oil prices and lack of budget due to prioritization. The ownership of hardware & software is with the supplier/vendor and the organization simply needs to have the necessary arrangements to remotely connect and using the system.

## 4.7 EPILOGUE

The findings of the study establishes a direct relationship between the OTS instructor and the training effectiveness from the operator training simulators. Demographics and survey method, stakeholder sampling design is discussed with reference to the survey questionnaire and ADDIE model. UNISIM training simulators supplied by Honeywell found to be market leader in the OTS industry.

Different hypothesis formulated to test the role and industry as cases, normality of the data, interrelationship between ADDIE components as Independent and Dependent variables and all are found to be in tandem with similar studies and present research method. ADDIE model is analysed with its constructing variables as dependent and independent using ANOVA and Linear Regression.

Qualitative data is segregated by coding, clustering and visualization using NVivo data tools. Clusture analysis carried out to summarize key words as phrases and to interpret results. OTS functionality and its usage, efficacy to prevent human error and benefits are summarised. Key points related to improving operator competency in process operations is described as per stakeholder responces across the organizations.

Due to the present situation in the industry pertaining to COVID, many organizations are reluctant to invest in the traditional training systems and prioritization is towards process automation and migrating to cloud-based training systems from third party providers.

# CHAPTER 5

## 5. CONCLUSIONS AND RECOMMENDATIONS

### 5.1 INTRODUCTION

The inferences and commendations pertaining to this research are presented in this chapter. The main contributary views of this study are categorized in three broad subsections, namely i) Effectiveness of OTS training, ii) OTS training phases and its usage and iii) Role of stakeholders. This is to ensure that the relevant topics are grouped and discussed in alignment with the research objectives in contribution to the existing theory and practice.

### 5.2 EFFECTIVENESS OF OTS TRAINING

The usefulness of the training program or the training process itself depends on number of aspects like the actual time spent on the training, inspiration to learn, efficacy of the overall training system and intellectual ability of the learner. Human errors can be addressed by integrating the current simulators with assessments embedded with the model itself so that the dependency on the instructor to evaluate the operators is eliminated so that same rules and criteria is applied to all the staff using the same simulator. The training simulator does not guarantee an effective training without a structured training program based on instructional design and systematic approach to training. The positive results from these methods may not guarantee that the simulator training is effective unless one is addressing the needs of the operators in a more tangible way such as reduction of human errors, procedural modifications proposed and implemented after OTS training, validating start up time reduction from earlier start up and data collection for future comparative analysis and validation. Training assessment should be considered as a continual process, rather carried out only after the training. There are number of blockages in the present setup from appraising operators at different stages across many organizations.

The main driving points to appraise OTS trainings are i) to measure the progress of the training, ii) utilization of learning and realising operator performance and iii) to validate the worth of training or simply the effectiveness. Along with tangible improvements, there will be intangible enhancements and the main aim is to successfully recognise these points and present them with statistics to prove the business case to the management.

### 5.3 OTS TRAINING PHASES AND ITS USAGE

Although OTS are widely used across the industry for operator training, mostly the benefits are seen in the commissioning phase of training. This is due to fact the operators are new to the process and OTS is the only visual and hands on tool to view operating conditions along with the graphics, which represent the actual process flow conditions. The immediate benefits to the management and supervisors include less time to start up, optimizing operating conditions to reach product quality and quantities as per the design.

OTS is also widely used to check control loop configuration and tuning during this phase. Once operators are accustomed to the process conditions and able to achieve start-up of the units in a more proactive way as they already know the different conditions in the OTS and actual plant. Sometimes modifications carried out in the actual process on the basis of operating conditions cannot be captured. The operators are also reluctant to go back to the OTS and practice, as they do not have more to learn and easily demotivated to use their time for OTS refresher training.

There are three primary concerns in the initial development of training simulator. They are, Fidelity (imitation to real life), Interactivity (level of user interaction) and Immersion (extent to which a user is really occupied in the simulation) (Philips,2003). The straight association between the fidelity, interactivity and immersion in the simulator configuration increases the cost of developing the simulator in-tandem with them. The management has to spend resources in the initial phases without thinking of immediate return of investment as the benefits are long-term and not directly measurable in dollar terms. The opportunity of having modelled and computer-generated process, architecture of the logics and algorithmic diagrams of control systems is useful in a simulating environment to test (tests such as loop tuning, acceptance of advanced control configurations etc.) and validate before being used in the actual distributed control systems during start up and revamp of existing facilities (Tverskoy et al., 2011).

One has to verify the actual budget to the simulator weighing in contradiction to the cost of obtaining real systems to practice and the charge to physical testing on actual processes similar to the factual conditions. One can also calculate the recurrent cost of sending required number of operators to another site or similar processes for training and initial investment needed for a training simulator with the number of operators to be trained. One of the major discernments among the management is that having an operating simulator cannot be justified economically in the operating budget. A simulator does not train automatically, it has to be used by manual intervention of the instructor to extract the benefit, yields the advantage and the desired results for the management.

One of the most productive way of configuring the simulator is to incorporate intelligence in the initial design and rules-based functionality using technical information available at that time (Arango and Herrera, 2020). Rather than emphasizing on the simulator technology, it is very significant to show how educational methodologies are applied in the simulator and how these are contributing to training effectiveness. This has some issues as often the simulator trainer is not properly trained to use pedagogical tools and updated learning methodologies as he is often selected internally without any external recruitment and most of the time, he is senior most among the many control room operators present in the organization. Even though some companies have the most modern and upscale simulator with full scale simulation of the units along with safety shutdown systems, using it for training and maintaining them over a period of time is a continuous effort of both the instructor, operations and automation teams. The operations team, being the end user also have to follow up for OTS maintenance, tracking its usage and provide necessary resources for OTS maintenance and upkeeping.

## 5.4 ROLE OF STAKEHOLDERS

One of the significant parameter to determine the performance or competency of the operators is not to carryout technical steps very fast rather judge him by watching how they are going to make the overall process more stable without escalating the situation. We have to nudge supervisors by saying this as not impairment of the operator performance, but without proper practice they can carry out procedural mistakes in the need of immediate execution but in some cases immediate action is needed to protect the facilities. These difficult actions should be prudently measured by accompanying human reliable analysis and going through case studies across the industries for best practices. This is due to the fact that the complex procedures not only weaken the operator’s performance but also seen as root cause for unrecoverable errors if they are not trained properly and confident in the execution.

### 5.4.1 OTS INSTRUCTOR AND OPERATORS

The OTS instructor perform a variety of roles like planning, tutoring, managing trainings along with sustaining the system ready for training all the time. They further facilitate in preparing required training materials, carryout lectures and role-plays the scenarios. The OTS instructor can be in a position to generate a collaborating atmosphere to actively participate the OTS training sessions while applying instructional design, learning theory to the real-world scenarios. The Instructor is responsible in the design, development and management of simulation training sessions. During the course, the instructor creates multiple learning experiences such as pre-briefing, session groundwork, conducting the training, learner assessment, keeping the records and session debriefing. Training instructors by virtue of their expertise and scientific reasoning skills bring maturity to the training environment. In the debriefing, it has to be stressed that the real time situations have their own complexity and professional intervention is needed to control the process/operations so that the process remains operational without any untoward incident or loss of production (Marcano et al., 2017). The OTS Instructor can change the process parameters (variables) and simulate conditions for unit operations as required to train the operators. The instructor should have both content acquaintance and instructional qualifications to teach in the simulated atmosphere. Common standards or industrial guidelines with clearly defined instructor credentials are needed to safeguard instructional efficacy of simulators.

The availability of fully competent instructors is limited in the industry and similarly effects the training of operators. They are anticipated to have constant touch with actual plant operations staff, so that they can preserve their operations know-how and acquaintance to latest operational procedures (Meshkati, 2006). The simulators also allow trainees to make actions and review the impact of their actions with the instructor. This is a critical part of learning that is not possible using OJT activities and thereby OTS provides a clear advantage over the other type of operator trainings. The benefits to the staff come from repetitive training on infrequent operator actions and once in a lifetime process upsets, validating new measures, which in turn rises self-confidence, augments efficacy and possibly reduce cognitive stress.

Another approach to improve the effectiveness is by using triangulation of multiple facts and approaches to collect data from stakeholders and then mix the qualitative data with quantitative data like controlled study of situations, process type, with or without safety systems etc. (Crabtree and Miller, 1999).

OTS instructor and operators are also mainly responsible for validating the simulated model. Operational validation is to determine whether the simulated model output behaviour is having same accuracy as envisioned in the design stage or during the upgrade, where most of the authentication and appraisal can be done (Sargent, 2013). Once the simulation model is validated by instructor, any problems in the encountered in the earlier simulation model including modelling theorems can be easily corrected and then it can be finally used for training as the authenticated model.

### 5.4.2 MANAGEMENT

Transfer of training is an ongoing issue and across the sectors many scholars have been converging on diverse issues affecting it so that they can provide significant feedback to organizations. As per the survey and from the literature, supervisory care and co-workers support is imperative for effective learning. We can envisage that supervisory support definitely affects training transfer, impetus and motivation indirectly affects the training transfer. This is in tandem with similar studies carried out in social sciences (Muhammed et al., 2013).

The root causes of many industrial accidents and their corrective action reports in the industrial literature are linked to the human performance and suitable training to improve the competency and performance. Site managers are suggested to safeguard that instructor training replicates the administrative and technical skills along with other instructional competencies. This is to ensure that the instructors are able to cater the increasing capabilities and able to create their trustworthiness to trainees on a continuous basis (excerpts from IAEA TECDOC Series 2018).

The operations, automation, process and engineering sections have to facilitate the maintenance of OTS in tandem with instructor. The management have to make sure this approach is similar to the actual plant control system if both are supplied by same vendor, if not they need to work along with both suppliers in arranging continuous support either offline or online. The supporting staff should be accessible to the instructor and needs to be trained first before site installation. This way we can close the gaps between the actual systems and simulator models, even carryout modifications first in the OTS, test and validate the results before being implemented in the actual process.

### 5.4.3 OTS DEVELOPMENT & AUTOMATION TEAM

The operations management in coordination with automation, process and engineering sections have to facilitate the maintenance of OTS along with the instructor. Some companies deployed a separate position called OTS engineer to carry out the maintenance tasks, modification related to the system & models or contract out the same to OTS supplier or vendor. This is also challenging as the supplier’s team always focus on the new customers rather than delivered projects unless they have long term service agreements and annual contracts to keep up the system with predefined methodology.

The management have to make sure this approach is similar to the actual plant control system if both are supplied by same vendor, if not they need to work along with both suppliers in arranging continuous support either offline or online. The supporting staff should be accessible to the instructor and OTS engineer, who needs to be trained first at the commencement of contracts or site installation. This way we can close the gaps between the actual systems and simulator models, even carryout modifications first in the OTS, test and validate the results before being implemented in the actual process to create organizational value.

## 5.5 DIGITIZATION OF OTS SYSTEMS

Digitalization refers to empowering the processes by using digital technologies. Digitalization increases efficiency and productivity with a possible reduction of budgets. It was to improve the prevailing organizational processes without changing the overall nature and intended to transform them to the latest offerings (ARCWEB).

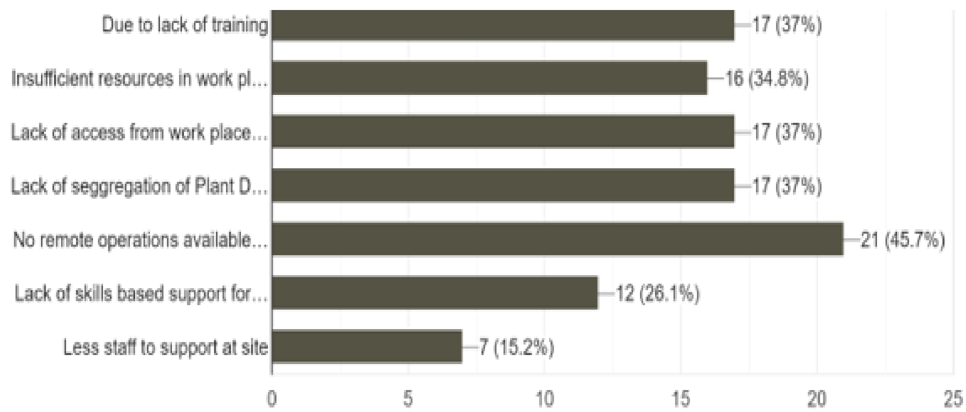


**Figure 5.1 Digitalization and Usage**

(Source: Author, compiled from Qualitative data analysis)

Contemporary challenges from the digitalisation of specialised employment, training and teaching have recently been intensified by the transfer to remote work, caused by the need to follow pandemic induced rules and statutory regulations. It is important to measure the organizations readiness to deploy cloud based OTS and digitalization of existing facilities in terms of upgradation and willingness to implement by providing resources, budget and manpower etc. Majority of the participants are of the opinion (Fig 4.23) that there is lack of access from workplace to use the digital products (37%), lack of training to use digital products (37%) and lack of segregation between the industrial network and internet access (37%) to use from workplace. 45% don't have remote access available in their organizations due to lack of budget and 15% cannot be able to use them, although there is an option due to less staff in the site to support the digital operations using cloud etc.

Amalgamation of trained instructors, modern simulator with pedagogical tools, cloud storage integrated with latest high-fidelity simulators are vital to ensure best conceivable training to new and experienced operators. Organizations are facing many challenges in the advancement of skilled personnel to manage their industries. Staggered manufacturing progress, geo-political uncertainties and crude price oscillations, retiring and elderly workforce forcing the establishments to train the new hires very quickly and make them competent in the current environment. Training by simulation continued to be one of the best and most cost-effective tools in the operator training process, due to its customization to specific requirements and continually updated components.

**Workplace Competency and Digitization**

Demand for "Big Data" skills in the workplace competency management is growing sharply across all the domains in the operations as shown in Fig 23. Bulk of the data is available to organizations each day, but workers are lacking analytical skills to analyse this complex data. Cost-effective alternatives to hard-wired systems continue to emerge, helping to address staffing pressures and the increasing speed of development, operations and production required in the commercial world. Varying market environments escalating the need for justifiable operations and foster excellence culture. The key constituent that has facilitated companies achieve technical progression is skill development through automation. This is at the heart of all processes and industries are also embracing the digital culture and industrial data analytics integrated with automated data tools and applications.

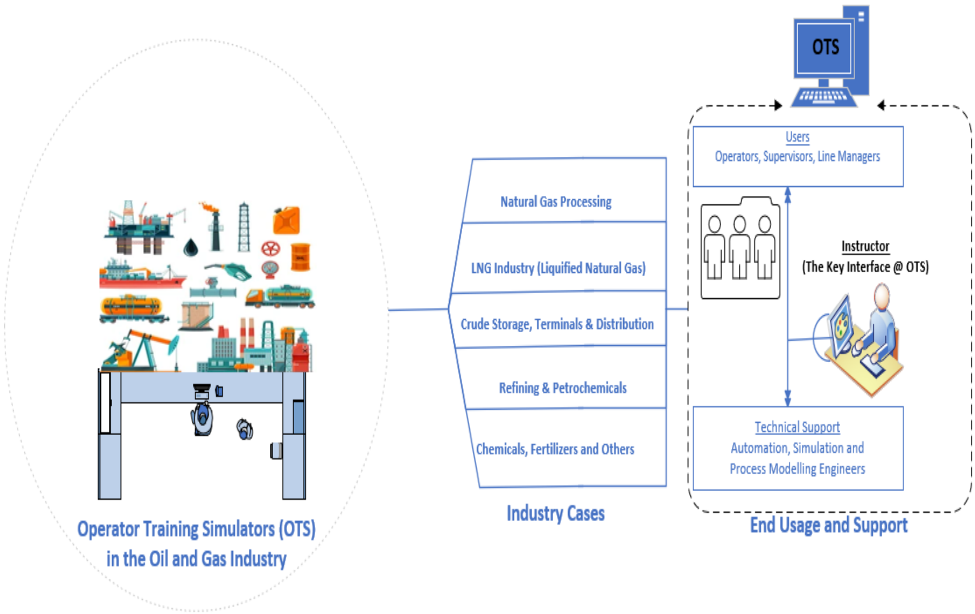


**Figure 5.02 Workplace Competency and Research Overview**

(Source: Author, compiled from research)

### Effect of COVID-19

Further due to the present crisis enforced by COVID19, almost all the companies continue reducing workforce, cut training budgetary allocations etc., and remote working of training professionals with further creating difficulties for hands of operators using traditional training methods like simulator training etc. (Patrick, 2021). Across the industry everyone tried to keep the operations running with minimal operational staff, mobilization of new crew to replace lost or retired workforce and organizational approaches to keep the operations without operational mistakes to avoid production losses etc. Operational models are reorganized to overcome new challenges arises from different variants of COVID19.

## 5.6 LIMITATIONS AND CONCLUSION

Organizations across the world are meeting with extraordinary challenges to improve return of investment while continuing operations on schedule and within their budgets. To meet increasing demand, the industry needs to access continuous supply of appositely and technically qualified professionals to help them by taking advantage of the new technologies and navigating the landscape. Mainstream learning culture across the organizations is confronted with several crucial challenges in the dynamic markets conditions and geo-political influences.

More research and analytical tools are required on the current talent management methodologies where in the interface designs of the OTS and existing systems (DCS) are remarkably changed due to the advent of digitization across the industrial world and enhanced cybersecurity requirements. The current training evaluations and methods are not suitable to evaluate virtual and augmented training systems. The next sections summarise these points under limitations and conclusion.

### 5.6.1 LIMITATIONS

The limitations of the survey include validating the proposed model in operating companies along with process units modelled with instructional design tools. The sample size for each case of individuals and industry is small compared to large number of operating companies and vast population size. Transfer as a behaviour is highly complex subject to the framework in which we are deliberating it and we have to define a general measure. This way we can eliminate misrepresenting the training transfer and leading to precise information related to that context. Due to the above the present study does not address the categorical statement of many distinguished things related to exact training instruments other than OTS.

The duration of the course (like short courses covering lesser topics or smaller units versus courses spreading over no of days, similar to initial start-up of multiple processes etc) have longitudinal effect on learning and transfer and this needs to be studied in multiple groups. The efficacy of different groups of the training populace also need to be studied and compared with human errors and process upsets data analysis across each organization to validate the effectiveness of these trainings. Measuring training transfer is not a straightforward process and prone to methodological flaws, inexplicable factors due to lack of data within the industry and needs to be studied more with reference to similar proven cases from aviation, health care etc.

### 5.6.2 CONCLUSION

The findings validate that the four key features of effective simulator training with reference to the research questions. They are

1. Precise process modelling of simulators
2. Accurate feedback instrument incorporating in the model design
3. Analysis of training data in combination with operational/human errors
4. Continuous learning assessment of operators by the instructor

This study reinforce the fact that the “OTS Instructor” is pivotal to coordinate the developmental aspects of the system for effective customization, maintaining or upkeeping the system and records keeping of the individual and overall training data. The instructor can proactively involve operators in the development and management of change processes and administering the trainings as per individual and organizational requirements. This will further enhance the site staff being more proactive to attend the training, being involved from the system development and motivate learning culture across the organization. The reduced incidences of accidents and resultant downtime, in the case of both personnel and equipment, means an increase in productivity, which justifies the investment on the simulators.

The training effectiveness also reduce the cost to the company when the participants able to understand the process effectively and maintain their competence at workplace for fast/efficient start-up and limited downtime during unwanted shutdowns. Operator training simulator offerings across the industry are likely to have increasing demand in the next few years due to increasing employment opportunities for the national workforce across the Middle East and Asia Pacific regions. Companies plan to invest due to higher-than-expected profits from high rude prices and demand for fossil fuels. Due to regulatory requirements and sustainability goals, there is increased focus on operator competencies and to ensure safe, consistent, and profit-driven process operations. Across several sectors in the industry, these factors are likely to drive the demand for operator training simulator solutions.

Field challenges such as extreme weather, irregular terrain etc for offshore locations and high turnaround time for these facilities necessitate that field operators are efficiently trained to face these situations physically as well as mentally by using augmented simulators. The important challenges to consider are a) instantaneous learning transfer, b) managing talent aligning with business goals, c) transforming to drive organizational culture and d) influence strategy all the way down across the organization.

## 5.7 SCOPE FOR FURTHER RESEARCH

Additional research is needed to address the simulators used today are following the instructional design practices and learning theories, institutional processes, excellence in process control, training to prevent human errors and a broad research program to focus on future experimental work on operator training simulators. The research possibilities to include developing domain specific training tools, design and implementation of pedagogical learning strategies.

Future research can be on summative assessments using behavioural indicators explicitly recognising the main factors associated with ineffective training interventions and automatic data collection mechanisms. The disadvantage lies in the resulting uncertainty of data capturing concerning the effectiveness of that training in the operational situation.

Research on the optimal sequencing of training simulators from practitioners and researchers alike is needed. We also need more case study reports of simulator training applications through public domain as many companies are not willing to share the data openly and also not allowing access for outsiders to use the data for educational purposes showing robust data confidentiality policies.

## 5.8 EPILOGUE

This chapter provides the comprehensive inference with references to the main stakeholders along with the boundaries of this study. Scope for additional research is discussed with conclusions of the research gap and responces to the research questions are deliberated sequentially. Digitization of the operator training systems and effect of COVID-19 on the operator training processes is summarized.

The overall training program should be effective and not just one component alone. Although the program is well designed, repeated training is needed to maintain the skill level and sustain competencies. Structured evaluation of trainee performance post training is essential at the workplace to monitor training effectiveness.

The study accentuates that ADDIE model is one of the effective instructional design basis in the preparation and assessment of training sessions. The key stakeholders emphasized their individual limitations and alternative options available to improve the overall training process.

Simulators should be selected to replicate the actual process and simulation models are configured to meet desired training objectives and not vice versa. Performance of operators must be measured using agreed evaluation criteria, in-tandem with the management. The training should be a continuous affair till the identified level of competency is reached. This way we can optimize the OTS functionality and derive maximum benefits.

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# APPENDICES

## APPENDIX- 1. SURVEY QUESTIONNAIRE

| |
|---|
| **Section:1.**<br><br>**Demographic Data ↓** |
| Stakeholder Name (Optional):<br>Email (Mandatory):<br>*Note: For sharing research feedback and proving authenticity of responces* |
| Age group (Select as Suitable)<br>o Below 30 Years<br>o 30-40 Years<br>o 40-50 Years<br>o Above 50 Years |
| Total Work Experience in Years (Select as Suitable)<br>o Below 10 Years<br>o 10-20 Years<br>o 20-30 Years<br>o Above 30 Years |
| Geographical Location (Select as Suitable or Write in Others)<br>◌ Middle East<br>◌ India<br>◌ Europe<br>◌ Americas<br>◌ Asia Pacific<br>◌ China & Hongkong<br>◌ Others________________ |
| At present your role is based in (Select as Suitable or Write in Others)<br><br>o Onshore |

| |
|---|
| ○ Offshore<br>○ Terminal (Crude and Hydrocarbon Storage, LNG etc)<br>○ Others________________ (Please write) |
| At present your operating role is in which industry<br>(Select as Suitable or Write in Others)<br>◌ Refinery & Petrochemicals<br>◌ Natural Gas Processing Storage (LNG/Crude Oil etc)<br>◌ Chemical Industry (Fertilizer, Chemicals etc)<br>◌ Utilities (Power, Desalination, Water treatment etc)<br>◌ Others_____________________________ |
| Please describe your role in your organization<br>(Select as Suitable or Write in Others)<br>◌ Panel, Console or DCS Operator<br>◌ Supervisor, Shift Controller, Superintendent etc Manager Production/0perations etc<br>◌ OTS Trainer, OTS Instructor, Training Specialist etc OTS consultant, Engineer, Developer etc<br>◌ Automation/Instrumentation/Maintenance Engineer etc<br>◌ Other______________________________________ |
| **Section:2.**<br>**Questions with Likert Scale measurements and mapped to ADDIE Model ↓**<br>[All questions are having option to select one response and some questions the order is reversed to ensure proper marking of responces] |

| |
|---|
| ☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| Completing the OTS trainings helped in understanding the classroom training information in a better way<br><br>☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| While using the OTS, one is expected to learn new concepts that will help during their job<br><br>☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| OTS training challenged my decision-making skills during emergency conditions and process upsets<br><br>☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| OTS training helped us to be more assured in carrying out operational changes to supplement process safety and reduction of Human Errors |

| |
|---|
| ☐ Agree<br>☐ Strongly Agree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Disagree<br>☐ Strongly Disagree |
| There is noteworthy variation in the process control and self-confidence levels before and after OTS training<br><br>☐ Strongly Agree<br>☐ Agree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Disagree<br>☐ Strongly Disagree |
| The skills learned from simulator training reflected the actual happenings in your job<br><br>☐ Strongly Agree<br>☐ Agree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Disagree<br>☐ Strongly Disagree |
| Simulator based training is viewed as a Strategic component or Key Performance Indicator (KPI) for operations by the management<br><br>☐ True<br>☐ False |
| Debriefing, Feedback and Group discussion during training are valuable to sustain learning |

| |
|---|
| - ☐ Strongly Agree<br>- ☐ Agree<br>- ☐ Neither Agree nor Disagree {Neutral}<br>- ☐ Disagree<br>- ☐ Strongly Disagree |
| One need to upgrade the OTS continuously along with the real plant like Digital Twins<br><br>- ☐ Strongly Agree<br>- ☐ Agree<br>- ☐ Neither Agree nor Disagree {Neutral}<br>- ☐ Disagree<br>- ☐ Strongly Disagree |
| During the training, Automatic feedback of training allows trainees to be more independent<br><br>- ☐ Strongly Agree<br>- ☐ Agree<br>- ☐ Neither Agree nor Disagree {Neutral}<br>- ☐ Disagree<br>- ☐ Strongly Disagree |
| Simulation training assessment can be effectively used as a skill verification tool for job progressions and job ladder<br><br>- ☐ Strongly Disagree<br>- ☐ Disagree<br>- ☐ Neither Agree nor Disagree {Neutral}<br>- ☐ Agree<br>- ☐ Strongly Agree |
| Simulation is the only effective tool that is needed for console operator training |

| |
|---|
| ☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| It is advisable to take part in OTS training as part of a multidisciplinary team<br><br>☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| Automatic feedback communication modelled with performance indicators to enhance efficiency of training<br><br>☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| In your opinion, operator's groundwork and self-study of exercises during training helps them to be accurate and have meaning full sessions<br><br>☐ Strongly Agree<br>☐ Agree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Disagree<br>☐ Strongly Disagree |
| Operators are generally familiar with the concept of simulation and its limitations |

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neither Agree nor Disagree {Neutral}
- ☐ Disagree
- ☐ Strongly Disagree

It is better to take part in simulation training as part of team within the same shift, operational group

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neither Agree nor Disagree {Neutral}
- ☐ Disagree
- ☐ Strongly Disagree

The instructor helped me to think critically and bring a refresh change for actual operations

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neither Agree nor Disagree {Neutral}
- ☐ Disagree
- ☐ Strongly Disagree

I learned as much from observing my peers actively involved in the simulated environment

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neither Agree nor Disagree {Neutral}
- ☐ Disagree
- ☐ Strongly Disagree

In the OTS Training, the results are derived on the process outcomes without a clear relationship to specific competencies

| |
|---|
| ☐ Strongly Agree<br>☐ Agree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Disagree<br>☐ Strongly Disagree |
| Providing regular feedback Improves performance and there by simulator training effectiveness<br>☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| We feel more confident to recognize changes in the actual plant process conditions after OTS training<br>☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| Simulator training can improve the performance of operators in managing control room emergencies<br>☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| OTS empowered to make critical interventions and developed a better understanding of control loops and safety logics |

| |
|---|
| ☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| Having the opportunity to introspect myself on the simulator, It improve my skills and performance<br><br>☐ Strongly Disagree<br>☐ Disagree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Agree<br>☐ Strongly Agree |
| The contribution of the employees trained on simulators resulted in better performance across organization<br><br>☐ Agree<br>☐ Strongly Agree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Disagree<br>☐ Strongly Disagree |
| After the OTS training, the operator's actions have improved safety of control room operations<br><br>☐ Strongly Agree<br>☐ Agree<br>☐ Neither Agree nor Disagree {Neutral}<br>☐ Disagree<br>☐ Strongly Disagree |
| We are more confident in the ability to report information more accurately to superiors and there by contributing to process efficiency |

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neither Agree nor Disagree {Neutral}
- ☐ Disagree
- ☐ Strongly Disagree

**Section:3.**

**Qualitative Study Questionnaire with Responces ↓**

In your facility, the different types of technical & process training available for process operators are (other than mandatory safety trainings)

- o Classroom based training
- o Operator Training Simulator (OTS)
- o Online Training (Outside company provided thru third parties using Cloud technologies)
- o Virtual Training (using 3D models of the facilities, including Augmented Reality)
- o No training Provided

If OTS training is available, the Simulated Units/Processes include (Can select multiple answers or write in others)

- Full Scale OTS without ESD systems
- Full scale OTS including the ESD (Digital Twin to DCS)
- Virtual/Augmented Reality Simulator coupled with DCS & ESD
- Operators sent to other companies with OTS for training
- Only Main Process Units modelled in the OTS
- Other_________________

The OTS in your organization is supplied by (Tick that apply or write the name in others)

- Aspen Dynamics & HYSYS, Aspen Technology (www.aspentech.com)
- AZprocede, Azprocede (www.azprocede.fr)
- ChemCad Dynamics, Chemstations (www chemstations com)
- DYNSIM, Schneider Electric Software (schneider-electric.com)
- K-Spice, Kongsberg Oil&Gas Technologies (www kongsberg com)
- Petro-SIM, KBC owned by Yokogawa (www kbcat com)
- TSC Sim, TSC Simulation (www.tscsimulation.co.uk)
- UniSim, Honeywell (www.honeywell.com)
- Other____________________

If no OTS is available for operator training, please specify the reason (Check all that apply or write in other).

- Lack of Budget during the EPC phase and not aware of OTS
- Lack of Management support for operator training Lack of qualified instructors for managing the OTS
- Too easy process to operate and no training required
- Operators are trained in generic simulators by third party
- Lack of initiative/coordination between Automation and Operations for OTS
- Other____________________

Approximately, How many days of OTS training per year is allocated as training days per operator (Mark only one oval).

- 0-5 days
- 6-10 days

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| ○ 10-15 days<br>○ More than 15 days |
| What barriers related to the work environment are most critical to the transfer of learning in your job (Please write few details) |
| Does your OTS have a Maintenance Plan (For new updates, debugging, modifications etc.). If so please describe briefly in few words. |
| In your opinion, What are the factors leading to improper utilization or usage of OTS. Check all that apply or write in other for detailed description<br>- Availability of Competent instructor<br>- Simulated models are not updated regularly<br>- Lack of Interest from operators<br>- No budget allocation due to lack of management support<br>- Other___________________: |
| The Budget/costs for the OTS maintenance etc., is difficult to justify (please write some details). |
| In case of any operational issues or process upset related to operations, the immediate help or assistance you will be seeking to control the process is from _____________________. (Check all that apply)<br>- OTS Trainer<br>- Supervisor<br>- Panel Operator from other area Plant Manager<br>- Manage Myself<br>- Allow the safety systems to take over or Trip the process Other: |

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| To what extent the skills learned from simulator training reflected the actual happenings in your job<br><br>Check all that apply.<br><br>- 0-20 %<br>- 20-40 %<br>- 40-60 %<br>- 60-80 %<br>- 80-100 % |
| In your view what are the things, which might help to reduce human errors while undergoing OTS training (Select that all Apply).<br><br>- Theoretical Knowledge<br>- Motivation to learn<br>- Automated feedback for each practice session<br>- Support from Supervisor & Management Willingness for constructive criticism<br>- Evaluation of teaching methods by external parties and validate<br>- Competent Instructor creating different scenarios and forecasting upsets<br>- Update to Simulator with preloaded upset conditions for practice<br>- Others______________________ (Please write) |
| As an approximation, how many days can be saved on commissioning or start-up or after major modifications due to undergoing OTS training<br><br>- 1<br>- 2<br>- 3 |

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| ◌ 4<br>◌ Cannot Say |
| As an approximation, how many unplanned shutdowns of critical equipment or units per year can be avoided (or a near miss shutdown) due to OTS training<br>◌ 1<br>◌ 2<br>◌ 3<br>◌ 4<br>◌ Cannot Say |
| What we can do differently after undertaking a simulation training course.<br>(Check all that apply)<br>◌ More focus on all process variables during start-up<br>◌ Analyse the process better in upset conditions<br>◌ Able to integrate theoretical concepts into hands-on operations<br>◌ Can train the others better and focused mentoring<br>◌ Run scenarios before actually making moves thru brain storming |
| OTS training can be improved by using different approaches like _______________ (Check all that apply)<br>◌ Real-time data snapshots from the plant to OTS & Practice actual trips<br>◌ Actual operation data from past days / weeks transfer to OTS<br>◌ Present numerous upset situations from other similar processes<br>◌ Online support from vendors/OTS engineers<br>◌ Virtual OTS with 3D field/immersive Simulator<br>◌ Operator Training handbooks to practice scenarios |

| |
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| ⁘ Others________________________ (Please write) |
| Other than regular training, OTS in your organization is used for<br><br>Check all that apply.<br><br>o Procedural verification and validation<br>o New logic programming, verifications and functionality<br>o Conceptual Studies and What if scenarios testing<br>o Control strategy development and Process studies<br>o Testing of Operators for Promotion and Competency Certification |
| How OTS updates are carried out in your system?<br><br>⁘ The simulator is updated before the changes in the actual DCS<br>⁘ The simulator is updated after each smaller change (field device / instruments /piping / DCS system/ DCS picture change)<br>⁘ The simulator is updated after each significant change (process equipment / DCS system change)<br>⁘ Never updated<br>⁘ Updated as per Obsolesce policy of OTS supplier |
| How OTS updates are configured in your system?<br><br>Check all that apply.<br><br>⁘ Maintenance is done based on an annual evaluation/audit of OTS<br>⁘ Online thru a secured connection with the licensor<br>⁘ Changes done by inhouse OTS /Automation engineers<br>⁘ Part of control systems Migration to new hardware or software<br>⁘ Never updated and remain first installed version |
| What are the main issues related to the OTS maintenance? |

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| Check all that apply.<br>- Non-availability of competent personal<br>- Working with simulator modifications is not required Least priority of OTS compared to DCS<br>- Lack of budget and Cost optimization<br>- No procedures/Guidance on simulator maintenance |
| The Budget/Costs for the OTS maintenance etc., is difficult to justify to management (please write yes, no or some details) |
| If no OTS is available for operator training, please specify the reason (Choose as relevant or write in other)<br>- Lack of Budget during the EPC phase and not aware of OTS<br>- Lack of Management support for operator training Lack of qualified instructors for managing the OTS<br>- Too easy process to operate and no training required for operators<br>- Operators are trained in generic simulators by third party or Other (Pls write)<br>- Lack of initiative/coordination between Automation and Operations for OTS<br>Other: ________________________ |
| Across the organization, Critical DCS upgrades and other projects are_______due to COVID19 (Mark only one oval)<br>○ Cancelled<br>○ On Hold<br>○ Going as Usual<br>○ Extended time to complete |

Digitization is difficult to follow (Check all that apply)

- Due to lack of training
- Insufficient resources in workplace (such as laptops etc in the control room)
- Lack of access from workplace due to network limitations etc
- Lack of segregation of Plant DCS and Office networks accessible from same consoles
- No remote operations available for control room staff
- Lack of skills-based support for digitizing assets
- Less staff to support at site

During the Crisis, our organization (Check all that apply)

- Increased production to meet demand
- Reduced operations due to less demand
- Closed operations due to risk to staff
- NO change in production/processing capacity
- Change operating conditions for minimizing production loss Update technology to sustain production
- Accommodate staff onsite itself to continue operations
- Replaced manual operations to remote operations using automation

During the last one year, the OTS training of operators

- Continued to take place as usual
- Stopped due to social distance measures
- Replaced with online training without practice
- Moved to cloud based OTS
- Other________________ (Please write)

What would you do differently to continue OTS training of operators?

| |
|---|
| |
| What can be done differently in the control room to limit no panel operators to operate the process (Please write) |
| You are well supported by the organization and management doing everything without any staff being laid off<br>◌ Yes<br>◌ No<br>◌ I don't know |
| Given the choice and technology, you are ready to operate the DCS/Plant Remotely with minimum site personnel (Mark only one oval).<br>◌ Yes<br>◌ No<br>◌ Not sure |
| Autonomous systems making own decision based on predefined algorithms and safety features can replace operators in future (Mark only one oval).<br>◌ Yes<br>◌ No<br>◌ Not Sure |
| Remote operation of DCS is not possible due to ____________<br>Check all that apply or Write in the space provided.<br>○ Cannot operate Manual Shutdown systems<br>○ Fear of IT issues and lack of Connectivity |

- Cyber security and Network Communication issues
- Lack of guidance and policy across the automation world for remote DCS

# APPENDIX- 2. <u>CURRICULUM VITAE AND PUBLICATIONS</u>

## CURRICULUM VITAE:

### Career Summary

- ❖ Over 25 years of experience in Oil & Gas, Petrochemical and Downstream industries.
- ❖ Presently working as Training specialist, with Dolphin Energy Limited, Ras Laffan, Qatar, looking after Training, Assessment and Competency of the expatriate and national staff.
- ❖ Subject Matter Expert (SME) for operations in training and assessment, competency assurance.
- ❖ Worked in Petrochemical, Ammonia, Gas Processing and LNG terminal in various roles.

### Experience

- ✓ Natural Gas Extraction (Onshore and Offshore)
- ✓ Natural Gas Treatment
- ✓ Petrochemicals and Ammonia
- ✓ LNG Storage & Re-gasification
- ✓ Competency Management and Assurance Systems (CAMS)
- ✓ Learning and Knowledge Management Systems (LMS/KMS)
- ✓ Plant Emergency Response and Management

### Education

- Bachelor's degree in Applied Chemistry (BSc) from Andhra University. Vishakhapatnam, India.
- PG Diploma in Environmental Studies (PGDES) from Andhra University, Visakhapatnam, India.
- MBA (Oil & Gas Management) from University of Petroleum and Energy Studies, Dehradun, India.

**Professional Certifications**

- Certificate- IV in Training and Assessment (TAFE) from MRWEB, Australia.
- Level-3 Award in coaching skills from Institute of Leadership and Management (ILM)- U.K.
- Taproot Member & Investigation leader.
- ILM-UK certification in Learning and Development.
- Competency Assurance Systems (OPERCAP-TOTAL Energies).

**RESEARCH INTEREST:**

❖ Process Simulation, Operator Training Simulators (OTS), Human Factors Studies, Human Errors with reference to process control, Process Simulation Modelling, Learning Management Systems (LMS) and Competency Management.

**PUBLICATIONS:**

**2022**

Manuscript titled "Efficacy of Operator Training Simulators in the Oil and Gas Industry and Impact of COVID19" was published in the Journal, Korea Review Of International Studies, Processual Approaches In Management & Technology, Vol-15, Issue 31, Korea University, 145, Anam-ro, Seongbuk-gu, Seoul- 02841, Republic of Korea. Vol. 15., Issue 02 | Special Issue - Korea Review of International Studies (kristudies.org)

**2021**

1. Manuscript titled "Role of Operator Training Simulators in Hydrocarbon Industry – a Review" was published in the International Journal of Simulation Modelling (IJSIMM), Vol-20, No.4, December-2021, published by DAAM International, Vienna, Austria. http://www.ijsimm.com/Volume20/Contents20-4.pdf

2. Review paper titled "Operator Training Simulators (OTS) in the Oil and Gas Industry: A Review" is presented in the conference, 'Advances in

Management and Technological Innovations Impacting Industries'- ICAMT III, 20-22 April 2021, School of Management Studies, Motilal Nehru National Institute of Technology Allahabad (MNNITA), Prayagraj, U.P., India.

**2018**

A paper titled "Evaluating the Effectiveness of Operator Training Simulators in the Oil and Gas Industry" is presented in the 59th Scandinavian Conference on Simulation and Modelling (SIMS 59), 26-28 September 2018, Oslo Metropolitan University, Norway. https://doi.org/10.3384/ecp181531

**2017**

A review paper titled "Riding the Oil Tides- Strategies for the Oil & Gas Companies" is presented in 5th International Conference on Management of Infrastructure-2017 (ICMI-2017) under the theme, Internal Business Environment, 9-10 Feb 2017, University of Petroleum and Energy Studies (UPES), Dehradun, India. ISBN: 978-1-63535-614-4.