POLITECNICO DI TORINO

Department of Environment, Land and Infrastructure Engineering

Management of operator's performances for operational safety in manufacturing production

In partial fulfilment of the requirements for the degree of
MASTER OF SCIENCE DEGREE IN PETROLEUM ENGINEERING

Advisor:

PROFESSR DEMICHELA MICAELA
ENG. COMBERTI LORENZO

Submitted by:

AHMED MOHAMED IBRAHIM SULIMAN OMAR

Acknowledgment

I am grateful to GOD for the good health and wellbeing that were necessary to complete this project.

I wish to express my sincere thanks to Professor DEMICHELA MICAELA & ENG. COMBERTI LORENZO for their patience, motivation, immense knowledge. And for providing me with all the necessary facilities for the research.

Their guidance helped me in all the time of research and writing of this thesis.

I could not have imagined having a better advisor and mentor for my study.

ABSTRACT

Even the raise in the automation is in increasing trend and the developing of machine is in continues use by industrial engineering in manufacturing fields. Human Factor (HF) remains a very important factor that cannot be neglected by any field of engineering as it represents a main factor in the production process.

As an example, for this is the management system named World Class Manufacturing (WCM) which aims to reduce the negative potentials of manufacturing as reducing waste, reducing quality costs and other potential. All of this done by several concepts and philosophies that is dedicated as pillars of a temple called The World Class Manufacturing temple, beside the pillar of (safety and health) and (quality control),the Human Factor is dedicated one pillar that describe how important and essential the Human Factor is.

The Human Factor concept is about studying and understanding the Human Performance (HP) and assessing Human Capabilities (HC) through the production system, there are several methods used to assess and improve human performance.

These methods may differ from one field to another ,for example: field as Aviation , Training of the operators where used to develop the human performance also with respect to the safety standers , as the Aviation Engineering field is considered one of the main fields that requires high standers of safety as for this case Human Performance (HP) development was essential and very important in order to minimize the human error at the lowest level possible.

This work was focused on data analysis as an empirical approach to the assess the Human performance and The Human capabilities, the work begins by collecting data from a well-known automotive production plant.

The data gathered form the plant is about values obtained from four tests done by a committee from Politecnico Di Torino on around 250 operators working on four assembly lines, these four tests done represent four different tasks. The four tasks correspond to four different skills as: precision, memory, coordination and method skill which requires the operator to preform it in a correct and perfect way. Results of the data analysis is going to be used to asses and allocate operators based on their skills for example: one operator have a high memory skill but a poor coordination skill so it will recommend allocating that operator to the task that requires a good memory skill.

However, the applied method may be restructured to fit and to be applied in any other engineering discipline for example activities that requires maintenance or discontinues operations in oil and gas industry where the Human Factor (HF) is involved and considered to be a main factor in the production management system.

Keywords: World Class Manufacturing, Human Factor, Human Performance, Human Capabilities, Data Analysis, Industry 4.0.

Table of Contents

List of Figures:

List of tables:

1.Introduction:

Many companies rely on humans specially in manufacturing industries. In the latest years, the interest of human issues in operations had been increased humans are part of operations systems, both as decision-making managers and system operators. In order to increase the product quality, enhance the efficiency and the production process. The Human Factors (HF) are considered to be the most difficult area to manage due to its high variability, despite the relaying on the automation in the manufacturing, the human role remains an important factor to be considered and becoming more critical [1] [2].

In 1980, researches believed that modern technologies will lead the manufacturing industrial with the help of only limited work force consisting of operator, as they pushed their idea by the continuous development happening in technologies related to production such as: robotics workstation ,machine assembly and test systems and automated guided vehicle systems. But later, they realized that despite the modern technologies, there are no way to neglect the interference of human for reasons like: technical, cybernetic and economic [3].

Another reason describing the importance of human factor versus the automation is that automation could provide high level of complexity and it could handle tasks that require tough effort but in fact it has a low or a limited capabilities at the end where for example ,machines doesn't have the abilities in which they can(see , feel , touch and sense), chance to experience knowledge, ability to judge , ability to think and develop more flexible ideas and storing a very large amount of information that it can be recalled for a specific situation in a very short time [3].

Also, The Human Factor plays an important role in so many management system for example: in World Class manufacturing (WCM) in which the human factor had its own pillar in the Temple of the WCM beside the pillar of Safety and Health and the Quality Control pillar , this indicate how the Human Factor is an important aspect to achieve a world class manufacturing management system where it was globally trusted and worked by well-known automotive companies such as Jeep, FCA and Dodge [4].Not only this, when talking about the Industry 4.0 and its application of trying to automate systems at the end it is found that the most automated system is still semi-automated in manufacturing system contain of automated and manual tasks, this is very clearly observable ,maybe the reason is back to economics or tasks complexity, in which there are industrials where applying industry 4.0 won't be economic plus tasks could be very complex that could not be handled to automation only [5].

From this point in which we considered the human factor is a very important aspects ,we began to put knowledge on how to monitor and manage the human performances ,in general the assessment of the human performances firstly began due to safety aspects in nuclear, aviation and oil and gas field due to the strong influence human had in such fields [6].

The human operator having a task to do, is required to process and perform a considerable amount of information that to be sustained in a specific level of effort for the task time despite the complexity and the working environment and other factors that can affect the operator while performing the task [7].from this point of view the model developed by the committee from Politecnico Di Torino was mainly based on 5 main steps starts at the beginning with a

“Conceptual Model” in which it relays on understanding the variables having an influence on Workload and Human Capabilities. The second step comprised in portraying the conceptual model to suit the genuine experimental circumstance found in the case study. Data Field gathering as step number three was committed to exact estimations of all amounts characterized in the operative model: results were utilized for Human Performance Assessment including the evaluation of the workload (WL) at hand component together with worker’s abilities. Step four was about assessment of that data gathered from the field and last one was evaluation as it would permit an approval of the designed mode [6] [2].

However, this paper will introduce in chapter one the World Class Manufacturing (WCM) as the most important management system approved globally by man known companies and its relation to Human Factor then in chapter two the Human Factor is being discussed in details where the definition of the model is discussed and the explanation of the mental and physical workload is provided as a core of the method used to assess the human performance , then at the end the case study done in an Automotive company and the importance of data analysis relating it to industry 4.0.

2.World class manufacturing

The term World Class Manufacturing is related to how a lot of companies are trying to indorse this idea in their production process to try to be the best in the world at their field, by introducing a comprehensive performance value analysis on WCM and other advanced manufacturing system for example: computer integrated manufacturing (CIM),it was said that it is one of the best alternative for introducing and working and sustain a competitive advantages, in general it is known that there is no specific identification of World class manufacturing , as a different researches have different ideas and definitions on it [8] [9].

By introducing the WCM techniques, researches in the manufacturing sectors find that they must measure the performances to sustain and enhance the production, in this manner techniques, manufacturers had to modify their ways of measuring in this manner, three primary reasons are mentioned for this modification [7].

Firstly, traditional management accounting, which depend mainly on the financial indicators, but this technique is not very useful, and it does not depend on any scientific principle [7].

Secondly, by observing the output which is the customer, as the target of the customer are very common and know for example: delivery, cost, flexibility and quality [7].

So, therefore for sure these targets cannot be view by the financial indicator with the reference of point number one [7].

Thirdly, management techniques were highly developed the introduction of computer integrated manufacturing (CIM) had led to the operations to operate in more responsibility which at the end lead to developing new operating methods and techniques.

In 1980, Schonberger was the first to come up with the idea of "World Class Manufacturing", the term was viewed as to embrace the methodology as seen in figure1,it had been known that the idea will have a great development as it found that the manufacturing field or philosophy is in continues development, as shown in figure1 that the WCM techniques had evolved during the years, the evolution of the techniques was rapid, also as its observable that the techniques that started with WCM at the early time 1980 was very few comparing to that of 1996.

All of these elements shown in figure2 was also at the early beginning, Schonberger made his research and he came up with a new World class Manufacturing model that had a great effective to improve companies Quality and performances as shown in Figure3.

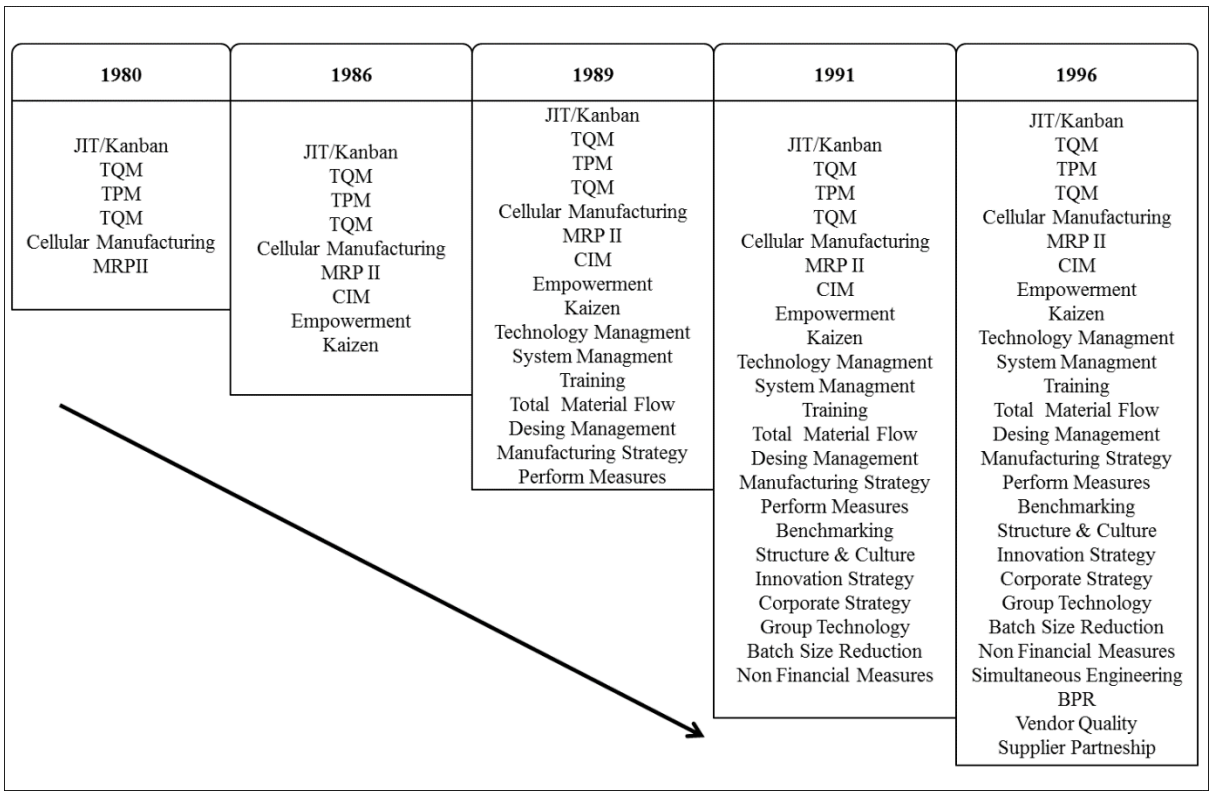


Figure 1 Development of WCM [8]

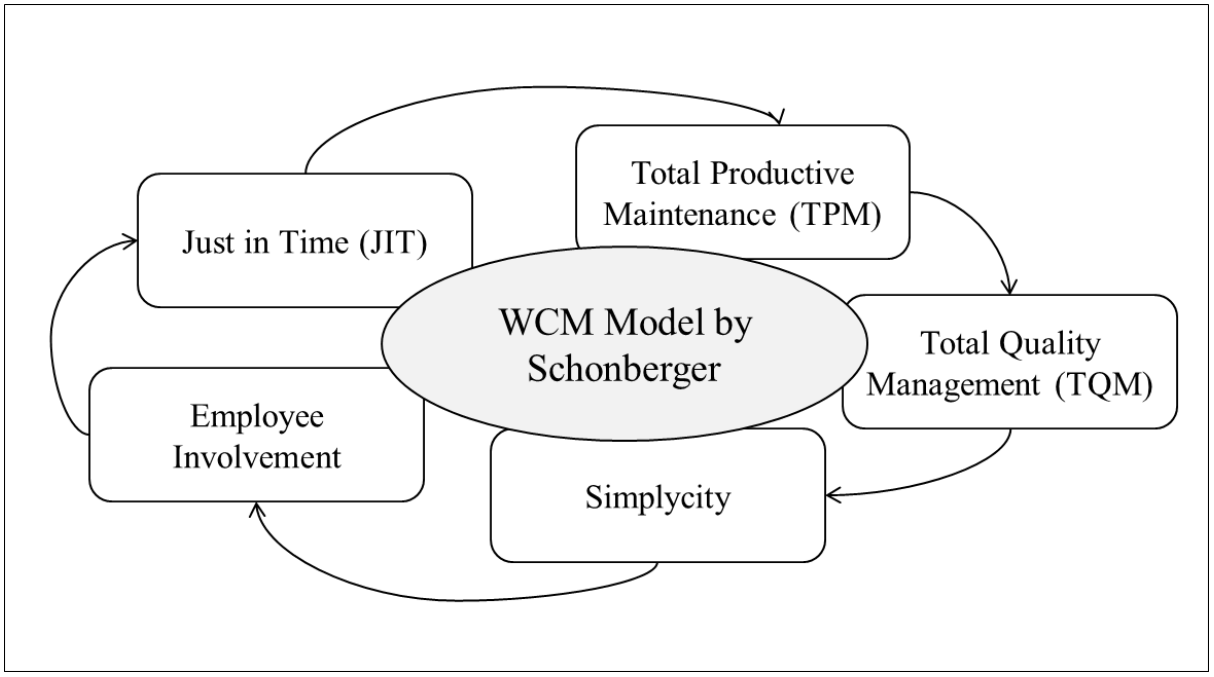


Figure 2 WCM Model by Schonberger identification [8]

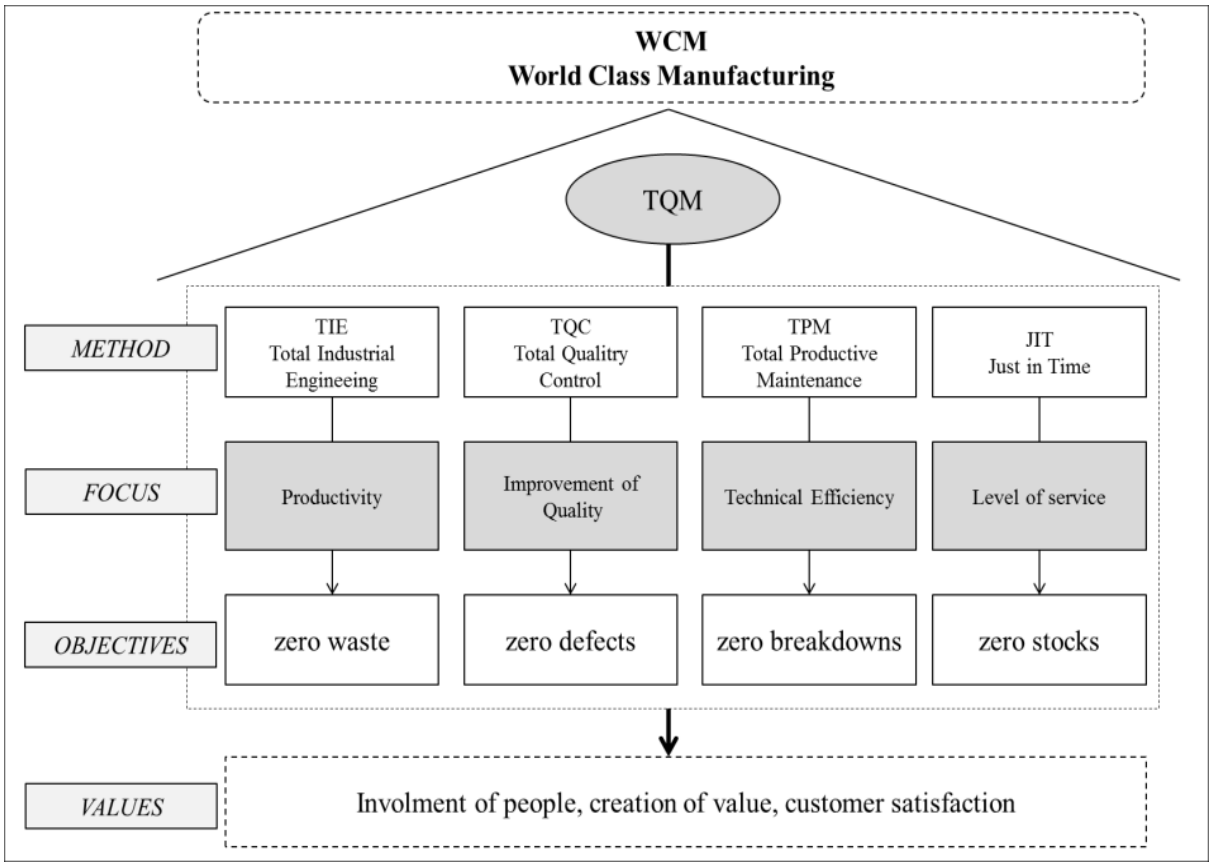


Figure 3 Methods, focuses and objectives of WCM [8]

In 2005, Professor Hajime Yamashina introduced a new integrated production system for

FCA group he said that:”WCM include many factor such as quality and logistics, processing of the plant, environment security, the target is always to enhance the performance of the production, elimination of the waste at all, for the insurance of customer satisfaction and flexibility and product quality, all this will be done by the people working in the palace environment as they are the main factor”. As shown in Figure3. Professor Hajime Yamashina’s program were illustrated. The procedure to accomplish "World Class Manufacturing" (WCM) has various theories , maybe it had the common theories in which what companies need in order to improve their performances but here it is characterised by view the customer satisfactory of the product quality and the client expectation and needs for future suggestion , this is very important aspects to be taken according to Professor Yamashina for his concept of the World Class manufacturing with the collaboration of Fiat group [10].

He added that workers involved in the working environment should feel like they are totally involved in the responsibility for achieving the targets and to move on the scheduled timetable, and the outcome should be characterized , the training program and operators satisfaction is essential factor for achieving a World Class Manufacturing for companies as its very important to understand the organization's vision and mission and considerable needs.

2.1 Principles of Wold Class Manufacturing

As mentioned before, the industry had viewed the world class manufacturing in different philosophies, these techniques are utilized to accomplish superb quality, it meant to eliminate and to totally get rid of the waste and losses in production, time, quality, customer satisfaction and to maintain the production and advancing the company targets [11].

WCM deals with some main major principles, such as:

- People (operators) is considered the main key of development.
- The visibility of the faults is essential.
- Applying the methodology of the scheduled work.
- Viewing it as a new developed way of working.
- The prevention of the accidents is non-criticized "Value".
- all departments and offices should respond to customer needs and targets they need.
- All the waste is not accepted.
- Standers are settled to all the operator and employee operating the working place even the leaders.
- Totally removing the causes but not to view the cause as something to be treated.

The world class manufacturing can be ranged in three areas [8] [11]:

1. Process:

Organization that characterizes the procedure as "a progression of individual activities performed in a particular grouping that make esteem." It is essential that forms must be institutionalized to provide sustainable output with respect of the time and maintenance of the equipment.

2. People:

Teams and operators in the company try to achieve work in a safe environment, developed companies is placed on health, safety, environmental thinking and behaviour. beside the essential points in this area are that researches considers the importance of education and training of operator as mentioned before also building customer thinking.

3. Production

Flow is the continuous transmission of the right material and accurate information within the manufacturing operations at the right specific time, in the correct quantity and in the perfect way. The goal of the flow production is to reduce human effort through a series of scheduled planed actions [8].

In general, WCM focus on the outcome direction and orientation by different ways such as the analysis of the of wastes and to enhance resources and reach the results in the shortest possible time. To do this performance, indicators of business performance are settled such that:

1. Maximize of profits by reducing parts that is defective as much as it’s possible.
2. By increasing the utilizing capacity.
3. Guarantee a suitable environment and a workplace for the operators.
4. Teaching the importance of the parts that had been assembled right.
5. Sustainable of the development of the process.
6. Monitor material Consumption and its efficiency.
7. Working on reducing the prices of the odd quality products.
8. Working on reducing the delivery time to the customer and the stratification of the products.
9. Working on assembling parts right and perfect from its first time.

2.2 Description of Pillars WCM

There are ten technical pillars and ten managerial that anticipate of WCM as shown in figure4 the pillars of WCM is described as a temple [8]:

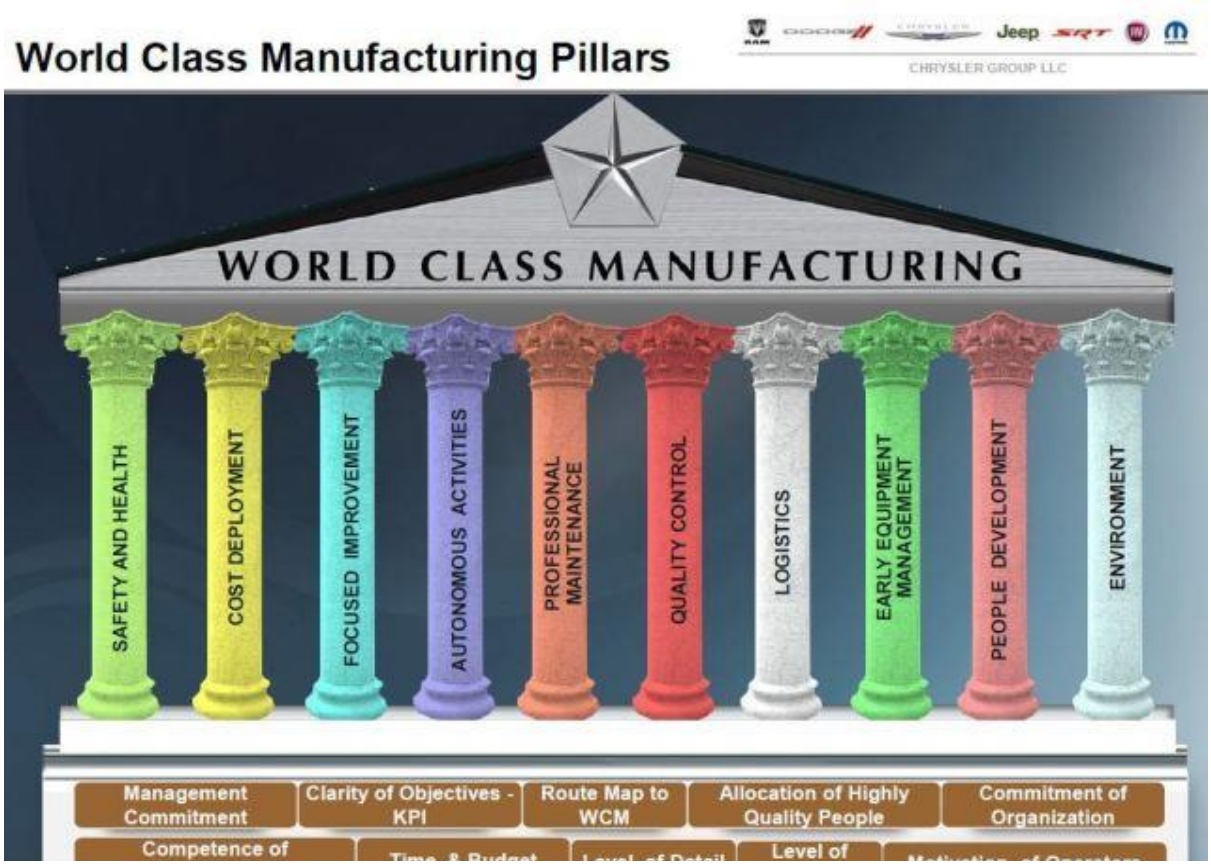


Figure 4 Word Class Manufacturing Temple [8]

The pillar structure showed the "Temple of WCM" which indicates that to achieve the slandered manufacturing class some aspects should be taken and done perfectly in a parallel way in order to achieve the desired development needed to the company, and this temple is what the leading companies are working with it such as Chrysler and Fiat group, as shown in the figure above each pillar concentrate on a specific sector to be identified as follows:

(a)

Pillar	Why	Purpose
FI Focused Improvement	Priorities of actions to management the loss identified by the cost deployment	To reduce drastically the most important losses present in the system manufacturing plant, eliminating inefficiencies. To eliminate non-value-added activities, in order to increase the competitiveness of the cost of the product. To develop specific professional skills of problem solving.
AA Autonomous Activities	Continuous improvement of plant and workplace	It is constituted by two pillars: *AM Autonomous Maintenance.* It is used to improve the overall efficiency of the production system through maintenance policies through the conductors (equipment specialists). WO Workplace Organization. It is develops to determine an improvement in the workplace, because often the materials and equipment are degrade; in particular because in the process there are many losses (MUDA)to remove.
PM Professional Maintenance	Continuous improvement of downtime and failures	To increase the efficiency of the machines using failure analysis techniques. To facilitate the cooperation between conductors (equipment specialists) and maintainers (maintenance people) to reach zero breakdowns.
QC	Continuous improvement of quality	To ensure quality products.
SAF Safety	Continuous improvement of safety	To reduce drastically the number of accidents. To develop a culture of prevention. To improve the ergonomics of the workplace. To develop specific professional skills.
CD Cost Deployment	Analysis of the losses and costs (losses within the costs)	To identify scientifically and systematically the main items of loss in the system production-logistics business. To quantify the potential economic benefits and expected. To address the resources and commitment to managerial tasks with greatest potential.

(b)

LOG Logistics & Customer Service	Optimization of stocks	To reduce significantly the levels of stocks. To minimize the material handling, even with direct deliveries from suppliers to the assembly line.
EEM Early Equipment Management EPM Early Product Management	Optimization of installation time and costs and optimization of features of new products	To put in place new plants as scheduled. To ensure a rapid start-up and stable. To reduce the Life Cycle Cost (LCC). To design systems easily maintained and inspected.
PD People Development	Continuous improvement of the skills of employees and workers	To ensure, through a structured system of training, correct skills and abilities for each workstation. To develop the roles of maintenance workers, technologists, specialists such as major staff training.
ENV Environment ENE Energy	Continuous improvement environmental management and reduce energy waste	To comply with the requirements and standards of environmental management. To develop an energy culture and to reduce the energy costs and losses.

Figure 5 Identifications of Each Pillar [8]

3.Human Factor:

Human factors are related to human beings and their relationship with, materials machines, information and environments used in performing tasks or living Human factors discovers and monitor information about human capabilities, behaviour and limitations, or any other characteristics related to the design of machines, products, tasks, jobs, systems and work-environments for comfortable and effective human use. Human Factors (HF) deals with scientific principles and knowledge also it can be from lessons learned from previous incidents and operational experience to enhance human wellbeing, in general system performance and reliability [12] [13].

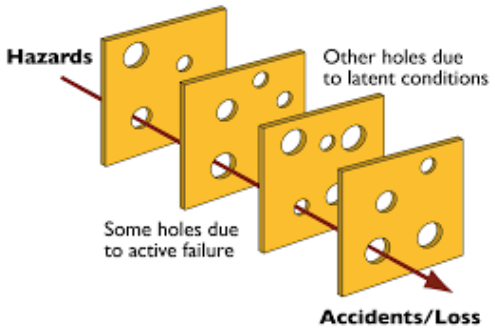
Human Factors engineering has two main concerns. The first is to optimise the effectiveness and efficiency with which tasks or work and other activities are held out. This is related to such issues for example the increase convenience of use, reduce errors and increase productivity efficiency. The second objective is to optimise certain human values, such as fatigue, safety, and stress, also how comfort the task is to the operator, user acceptance and job satisfaction and to minimize human errors ergonomics.

In manufacturing engineering fields, the dealing with productive control systems and the analysis design are very common and most reliable. By other meaning industrial engineering is about how to direct the human effort for a safely, efficiently operating systems. It's the mix of engineering concepts with human behaviour principles [5].

3.1 Human error

Poor human performances can cause errors, it is observable that the term "human error" is the cause of major accidents. In general, most of the accidents can be related to human errors for example: errors in design, operation, or maintenance.in general poor or less efficient human factor in a manufacturing field can cause several main points which should be pointed in order to evaluate or simulate in which sense should Human Factor be related to for example [14] [15]:

- increase of the cost such as raw materials.
- Increase in absenteeism.
- high risk to experience accidents.
- employee turnover will increase.
- very Low employee morale/acceptance.
- increase errors.
- Low and poor production output.
- increase the pause time, or time of production in general
- Increase in injury frequency and fatigue.



However, it's so rarely to refer human error for only single mistake action or attitude done by operator or controller as Reason's (1990) Swiss cheese model shows in Figure above.

Hence, it is useful to understand where the deficiencies exist.an indication of a poor human factor could be pointed as: wasting of high material and scraps, high frequency of mistakes done by operators, number of complaints from employee is high frequent, high turnovers, frequents gaps and breaks and time wasting is very high [16].

This design requires the study of the interaction between task complexity in term of mental workload and physical workload, and the evaluation of human capability to fit for it, to successfully implement ergonomics in Psychology Engineering and Ergonomics.

There are two types of Human Errors according to Baine.T in 2007 [17] as follows:

3.2 Types of human error:

1-where activities don't continue as arranged; **Slips** are related with defective activity. For this situation the individual knows precisely what they mean to do yet it had a deflection incidentally. even though he expected to enter the right number [17].

2-**Mix-ups** happen when the execution is flawless however the arrangement itself neglected to meet its objective, either since it was improper for the circumstance, or the circumstance was novel and in this way no arrangement was accessible.

3- Failure of the memory is dominated to **Lapses**, once more the intention to follow the right path is intended to be done but a failure occurred , its mostly may happen while performing the same (routine) task, as example for this is forgetting to press a switch which will lead to failure , hazard or risk.in conclusion this classifications is very useful in order to determine where the holes or the deflection lie in the classification of the swiss model that was dominated in figure1 [16].

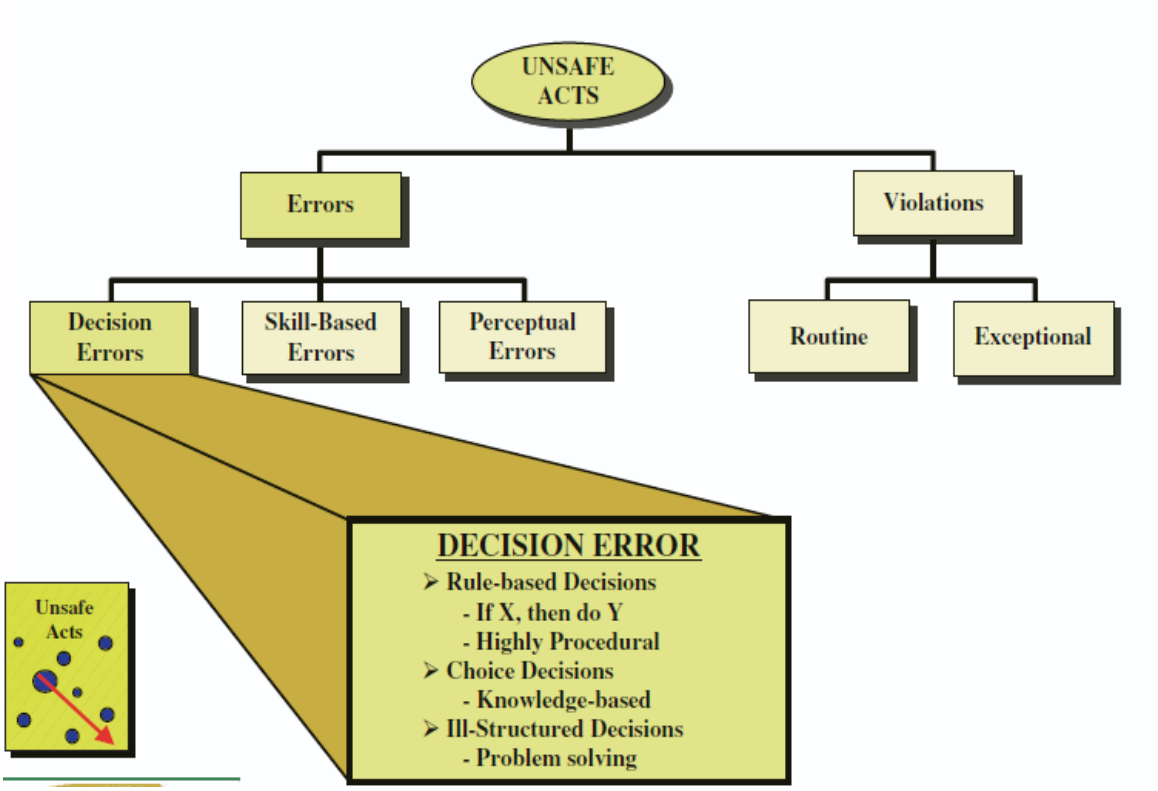


Figure 6 Human Decision Error identification in CHEESE MODEL [15].

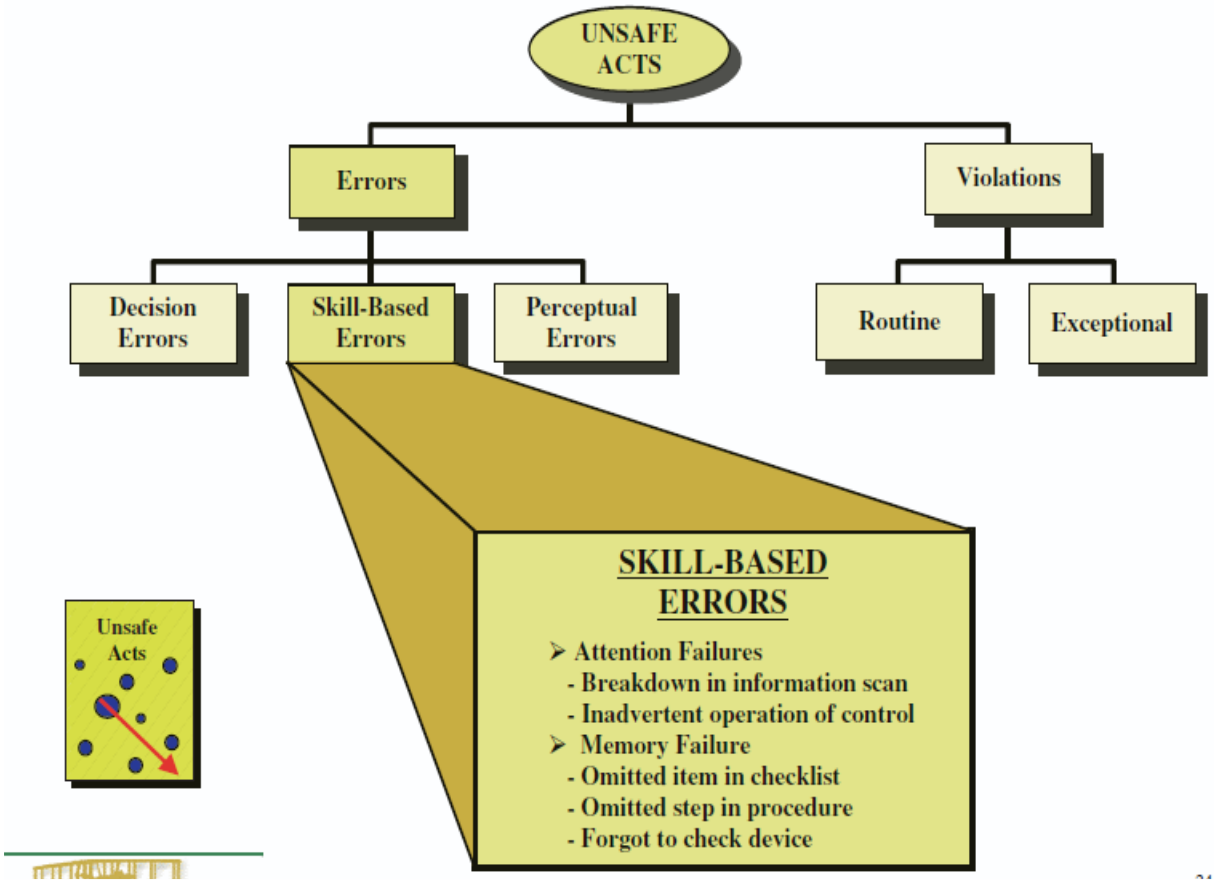


Figure 7 SKILLED BASE ERROR IDENTIFICATION IN CHEESE MODEL [16].

3.3 Human Performance (HP)

The model of human performances in general (figure10) is based on two main factors which are: [17]**Workload (WL):** indicating all factors effecting the mental and physical it represents all the factors contributing to the physical and mental demands to perform a given task, with the respect to the work environmental factors. **Human capability (HC):** it represents the resources of the human operators under the real working environments and includes the physical, mental and cognitive abilities of each worker.

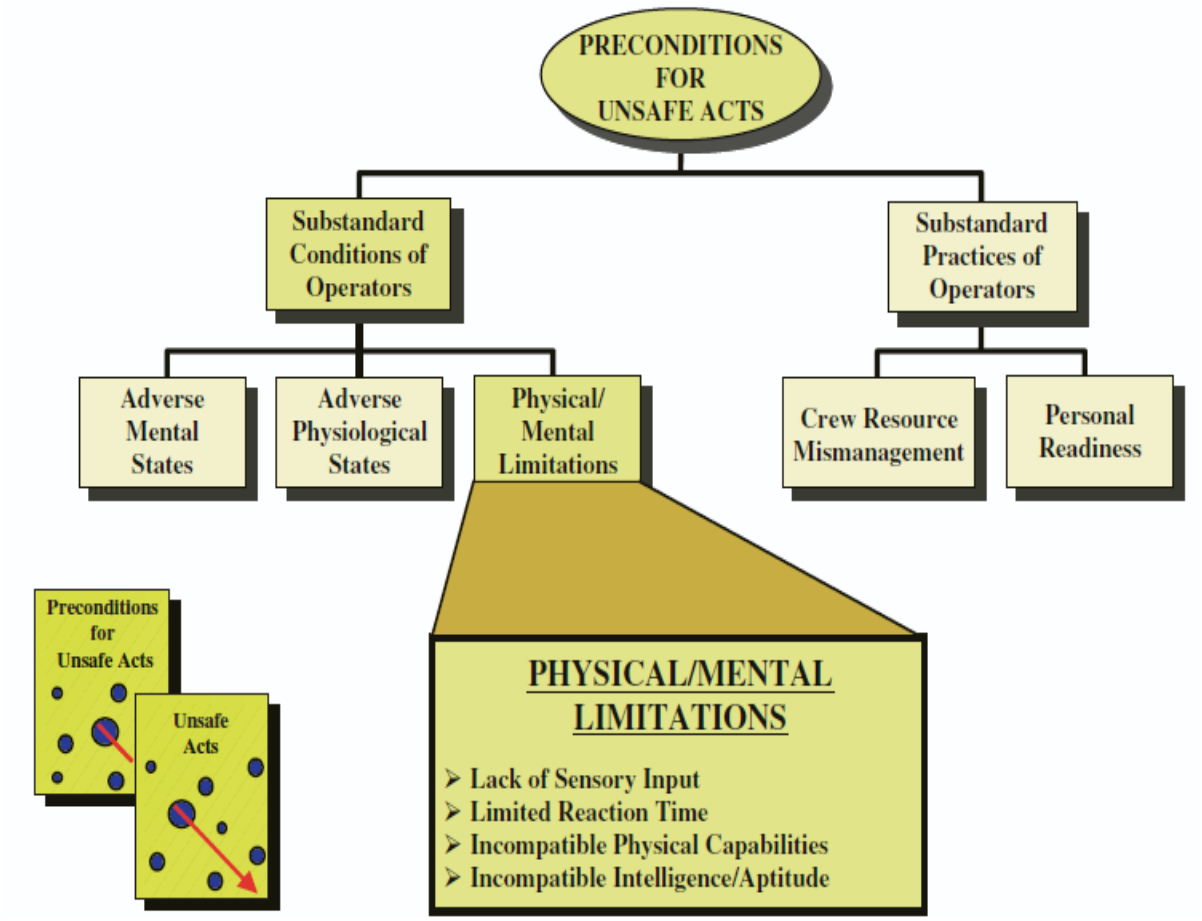


Figure 8 Physical/Mental Limitations in CHEESE MODEL [16].

3.4 Work load (WL):

Workload can be defined as a measurement that encompasses the amount of task an operator can performs with the respect of the amount of time available to complete it (Wickens et al., 2003). Also, workload overload happens when there are less resources available to allocate to the desired tasks, while workload underload occurs when there less tasks using available resources at this time. Both of these conditions can prevent overall performance (Nachreiner, 1995). Other factors that could affect the workload level and sustainability are related to human who must perform the task such as, how skilful he is, individual differences including training, or fatigue, also an external factor could have an effect on the work load such the environmental conditions [14].

Complex work environments require human worker to preform considerable amount of information and to sustain an adequate level of control performing a specific task. Both mental workload and stress associated with environmental and psychological factors affect cognitive functioning.

3.5 Human Capability (HC)

Human capital is a term discussing the "knowledge, skills and abilities" of operators. Human capability is about the total amount of resources that an operator can perform to do tasks in the respect of the condition or the environmental situations, some of the human skills were related to the workload associated to a specific task [1].

There are some human skills that were considered in order to develop the model of the human capability such as:

- Manual skill: skills like precision, manual handling, and coordination.
- Memory: remembering the sequence of operations and parts to be assembled together can differs considerably from one operation and another.
- Physical: the ability of maintaining a sustainable performance during the shift and performing with pace [2].

In 2005, A study was made in order to increase and improve the flexibility of their operators aiming to face the modern technologies and deal with it by understanding the concept of Human Capabilities. In this paper it had introduced that achieving this work is done by studying and learning the designed system manufacturing (evaluations, design, stage and decisions could avoid deflections from the right path) means that manufacturing systems design is a routine endeavour through industry and needs to be constantly monitored [10] [18].

The problem appeared after using a simulation program to simulate the system performance over time the data predicted was totally different from the predicted data is it showed a very optimistic data comparing to the real data gathered from the system as shown in figure11.

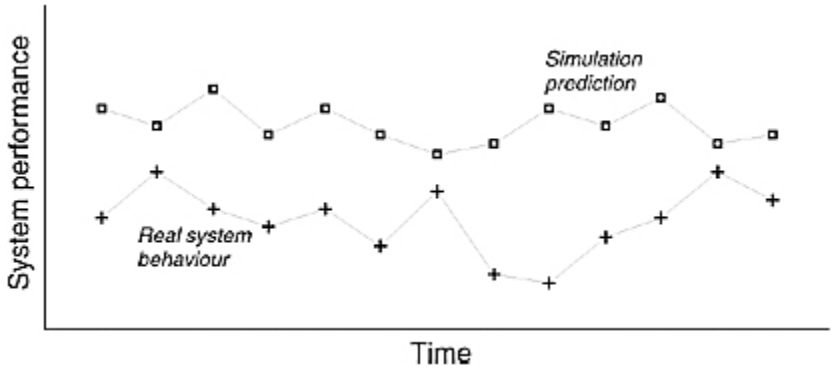


Figure 9showing the gap between real data and simulated data [10]

This event could occur in a wider extended if more human factors or elements applied as here in this model supervisor tend to observe people a bit simplistically, the attitude of the workers is identified as mentioned before as the type, number and skills of operators required for performing task, together with the environment surrounded in which an interruption could occur.in real life it is proven that humans does not act on a constant performance [19].

A lot of external factor might have effect on their performances also it might had been affected by the modern technologies over time.

In 2005 Brains introduced three sections regarding the performers of the operators as, (a)he introduced the personal characteristics effects, (b) working environment factor and (c) factors related to organizational plans. Figure 3. Shows a framework for human performance monitoring (Baines et al, 2005). As shown in figure the modelling defines six outcomes after the applying the transformation function are obtained for enough time required [20]:

a) absenteeism rate
b) accident rate
c) staff turnover rate
d) error rate
e) dependability
f) activity time

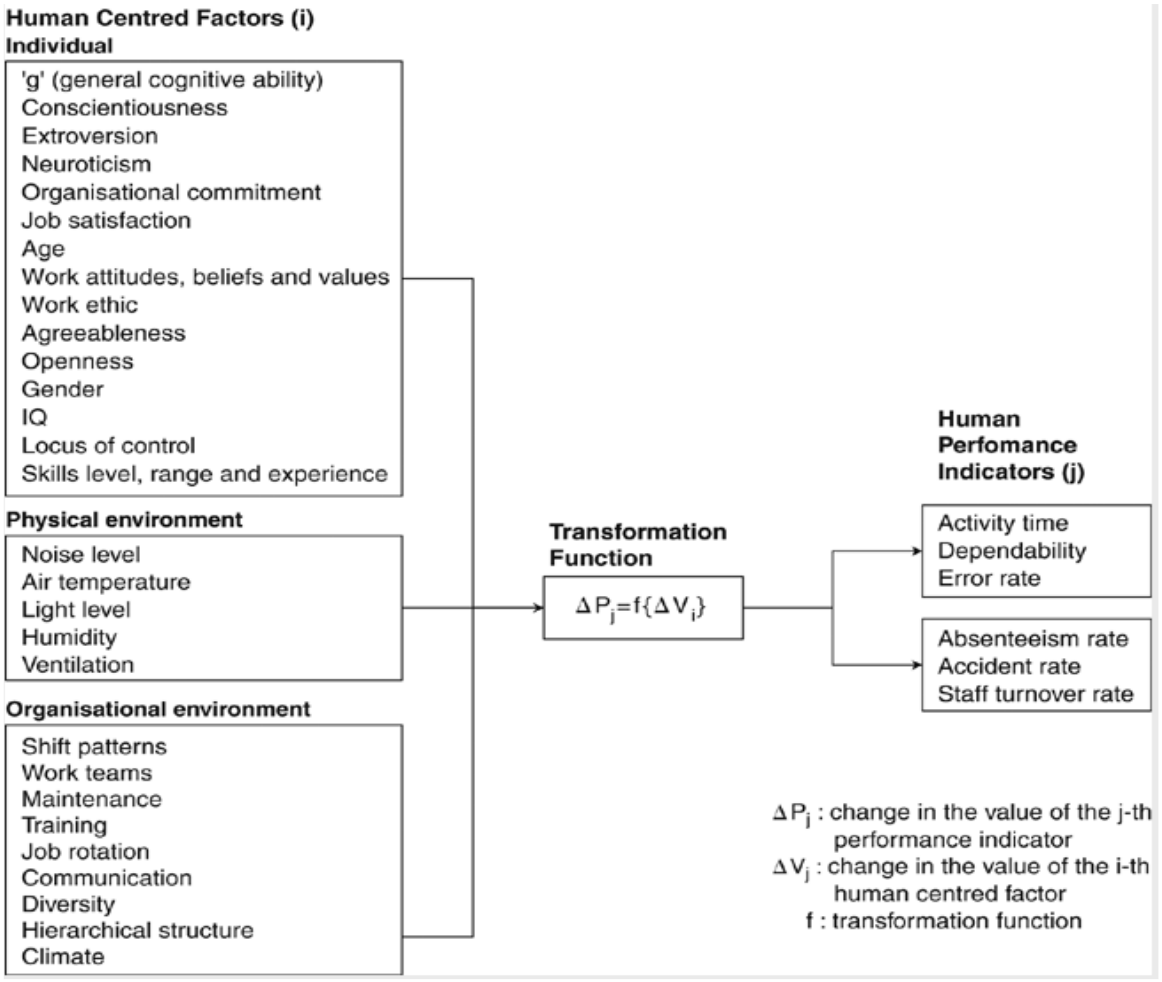


Figure 10 FRAMEWORK [10]

The research was up for an engine assembly line for engines done in UK for an automotive factory and it was divided into 10 main lines, Engine was travelled through the lines with parts which was automated in motion automated, each line had to operate different tasks containing from 6 to 12 operators [10].

3.6 Experimental design

The design concept was not to interfere the daily work routine, also not to affect the personal indeed and it's all done after the acceptance of the workers himself and for the assumption that no to gather data relaying on the supervisor of the assembly line.

Direct observation was also important for the test performers in order to observe operators for long periods of to gather data from the performances and direct impressions.

Hence, an automated device is installed in the work stations in order to monitor the activity times and movements by workers work stations were not necessarily aware of whether their

Attitude scale	Content	Author
Work involvement	*'The degree to which a person wants to be engaged in work'*	Warr *et al* (1979)
Intrinsic job motivation	*'The degree to which a person wants to work well in his or her job in order to achieve intrinsic satisfaction'*	Warr *et al* (1979)
Perceived intrinsic job characteristics	*'The person's reports about the degree to which features are present in his or her job which might give rise to intrinsic satisfaction'*	Warr *et al* (1979)
Job satisfaction	*'The degree to which a person reports satisfaction with intrinsic and extrinsic features of the job'*	
	• two subscales: intrinsic satisfaction, extrinsic satisfaction	Warr *et al* (1979)
	• three further subscales: satisfaction with working conditions, satisfaction with the job itself, satisfaction with employee relations	
Interpersonal trust at work	*'The extent to which one is willing to ascribe good intentions and to have confidence in the words and actions of other people'*	
	• two subscales: trust in fellow worker, trust in management	Cook and Wall (1980)
	• four further subscales: faith in fellow workers, confidence in fellow workers, confidence in management, faith in management	
Organizational commitment	*'A person's affective reactions to characteristics of his employing organization...feelings of attachment to the goals and values of the organization, one's role in reaction to this, and attachment to the organization for its own sake rather than for its strictly instrumental value'*	
	• three subscales: identification, involvement, loyalty	Cook and Wall (1980)

Figure 11 - Attitude scales applied in the survey (adapted from Fletcher, 2004). [10]

station was being monitored. This was conditioned on no direct linkage being made between activity time data and specific individuals [10].

3.6.1 Establishing the human-centred factors

Physical environment Factors were monitored during the study. it is identified as control variables.as mentioned before that the study aimed not to interfere the daily routine, so it was somehow limited by the factor of the shift change, for the individual effect such as worker behaviour attitude , values , goals job satisfaction , the study had considered these factors as a biographical data, the rest of data such as cognitive ability and conscientiousness were considered as psychological characteristics, and it was neglected as the tests was only available for psychological factors [10].

Researches who carried this research used attitude scales followed by an interview-based procedure, the table of attitude includes the agreement or disagreement level with the result obtained from the research, also the study was concerned about the biographical factors example: age, gender and skill (was mentioned as a length of the service of employment period) [10] .

3.6.2 Results and discussion of this survey:

At the end , the study was supported mainly by retaining activity time of the operators which will remain the basic factor that Human performance could be measured from it, however factors related to the physical environment wasn't relayed to the research study (as it affection was neglected due to its low value of variation) only shifts and team were considered due to the system of operation of the assembly lines that is consist of different shifts and assembly lines . so, in general the study aimed to provide a reasonably general evaluation when going from theoretical framework in practice frame work.
Finally, this research study suggested three main points [10] [20]:
Firstly, they suggested to perform this model with a lower number of investigations of relationship between the factors related to Human performance as they concluded the larger the number, the more difficulty the study is, therefore it should be concerned on the human performance measures only that got the main significant impacts. Also, for the reason to reduce the project time, possibility to do error and accuracy of the results.

Secondly, among all these factors they only proposed considering some input factors, the type of system involved by the company, the suitability records of the operator and Different task types that should be done, also they discovered that the flexibility of the worker relevant to the task should be identified on the research project.

Thirdly, the research project should have useful guidance in the development in the Framework of it While mentioning the input factors that have a direct effect on the human performance a function is needed to express model variability trends as what was mention that the human performance not constant under constant working [21].

3.7 Model Design asses Human Performances:

As mentioned before any project aimed to design an operational model to assess the Human Performance requires developing a five steps stations as shown in figure10.

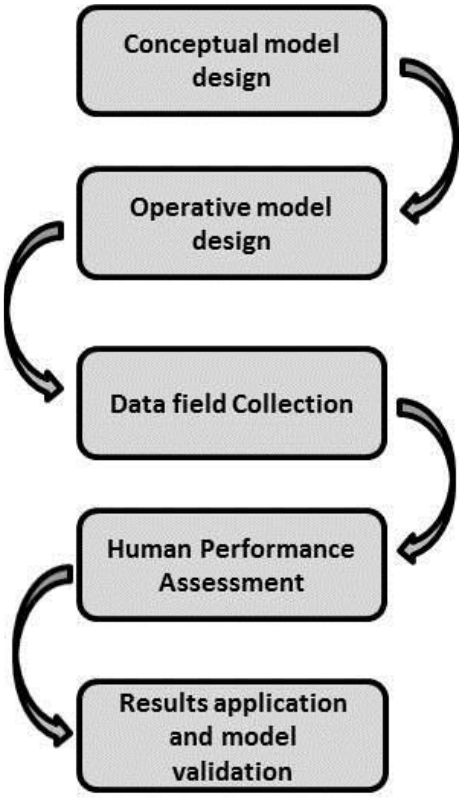


Figure 12 Project development steps to assess human performances [2]

As an overview of these steps, the development of this project starts at the beginning with a "Conceptual Model" in which it relays on understanding the variables having an influence on Workload and Human Capabilities. These variables were initially selected through a literature review, balanced by an assessment of the working conditions of the different workstations and a task analysis of the key workstations in the assembly line study [6] [20].

This progression started with understanding Those factors have been at first chosen through a writing audit adjusted by an evaluation of the working states of the diverse workstation and an errand examination of the key exercises of the workstations considered for the investigation in the sequential construction system.

The second step comprised in portraying the conceptual model to suit the genuine experimental circumstance found in the case study.it represent the actual empirical data sources and or proxies to assess the variables of the conceptual model gathered from the literature review, later to be connected to more observable and measurable quantities. This procedure prompts a disentanglement of the underlying theoretical model into a rendition relevant to the information accessibility and the necessities communicated for the case study.

Data Field gathering was committed to exact estimations of all amounts characterized in the operative model: results were utilized for Human Performance Assessment including the evaluation of the workload (WL) at hand component together with worker's abilities. The outcomes got from the Data-Field gathering effort prompt the Human Performance (HP) appraisal, and that is utilized to design interventions on the human resources administration of the sequential construction system. An approval period amid which results, communicated in term of efficiency, will be evaluated as it would permit an approval of the designed mode. [6].

3.7.1 Conceptual model

The conceptual model is based mainly to the Model developed by Rasch, In the Rasch show, the likelihood of a predetermined result (e.g. right/wrong outcomes) is demonstrated as a logistic function of the difference between the person and item difficulty parameter. Give Xni a chance to be a dichotomous irregular variable with parallel qualities where, for instance, Xni =1 means a right reaction and a Xni =0 a wrong reaction to a given appraisal thing. Hence the probability of the outcome is related to the equation1 [6]:

$$\Pr(Xni=1) = e\beta n-\delta i1+e\beta n-\delta i/ \quad (1)$$

where βn the ability of person n and δi the difficulty of item i.

This designed model needs to be radically enhanced to consider an assessment of the performance that related to the interaction between two macro factors as mentioned before:

Human Capability (HC): understanding the training, skills and experience of the operators performing tasks composition of their cognitive and physical skills to have an evaluation in which they match the requirements of this task or not.

Workload (WL) understanding the composition of two main factors" Mental Workload" (MW) and "Physical Workload" (PW), both are related to every activity identified and analysed in the industrial assembly line [6].

3.8 Physical workload (PW) & Mental workload (MW):

The Physical Workload (PW) factor is easily relatable to the physical, motion and postural efforts required to perform a specific task. Poor ergonomic state of the workstation, (for example, the need to support uneasy stances as well as burdens) were identified with an observable diminishing of execution for uneasiness of the specialist after some time, tedious movements and static undertaking were seen as extra reason for word related mishaps and lower execution. Physical workloads, for example due to unfavourable postures or heavy lifting and carrying, continue to present a health risk for workers while Mental workload is defined as in terms of two concepts (a) independent task requirements and the external factors. (B) or it can define the relationship between human factor in terms of capability and task required to be performed [6].

3.8.1 Mental workload:

1. As it was mentioned before that the Mental workload may have different definition, but it can be related to the human capability to perform a task correctly, now a days as more modern technologies are used and the beginning of the interventions of the semi-automated technologies , the monitoring of the mental workload become more and more important ,there is some conceptual characteristics of Mental-Workload (MWL): it could be described as the requirements needed for the task to be done by the operator which further on it could describe how the task would be like after that impact, it could be described as in terms of information processing with the respect of inspirational, emotional since it has an effect on the effort done.
2. MWL had several effects which could be related to health, and psycho-physiological in different words: alterations of blood pressure, fitness or illness.
3. From the point of view of task design, MWL should not be minimized that is because mental task requirements are specified for health issue and qualification as a result of what they produce the fitness and training options. Unqualified plans on the contrary could cause loss of physical fitness, deactivation, illness [6] [2].

3.8.2 Physical workload:

Physical workload is related to musculoskeletal ,it's very important to monitor and recorded the physical work of the body to assess it and there is many ways to perform this tasks, hazard happened due to physical are countable and observable , related to risk factor for work-related musculoskeletal disorders (MSDs) that could be very important due to its high frequency causes of work-related faults . a study was made for The estimated economic production loss it was due to MSDs was very high [2].

In Risk management process, to minimize MSDs are considered an important part

It consists of different approaches in order to improve the workplace environment, enhancing productivity and improving safety, identified by main 5 steps to be taken for this order

I. Determining different hazards and those at risk
II. evaluating risks that could be faced
III. action to be taken in order to avoids.
IV. Actions to be executed.
V. Measuring, reviewing and monitoring.

4.Further Work (Case Study):
Data Analysis of data gathered from (an Automotive Company)

Introduction:

This case study is done with the collaboration of a well-known automotive company where there are about 300 operators working on 4 assembly lines in two shifts as a morning shift and a night shift. For understanding how important is to monitor the performance of human and to assess the human capability, four tests are performed which are (precision, method, coordination and memory test), for each test of these it corresponds to a specific task done by the operator. These tests aim to assess the human performance simulated by these tests with the recording of the time and error of the operators in the two shifts.

4.1 Four tests identification &Methodology

As mentioned before that the tests were mainly depending upon four tests done ,the four tests correspond to the task that human operator preform in his daily routine ,these test aimed to monitor the human performance by performing each test of four and recording the time and error done by the operator after this a formula applied in which we have the value correspond to each worker .The four tests are precision ,method, coordination and memory test.

Precision test:

A precision test is done by holding a tool in which the operator can path the tool through a wire as quickly as possible with touching the wire, hence touching the wire means an error, time and error are recorded for every worker such as shown in table.1.

Precision test:	Time	Error	Tot.
Worker 1	22	6	40
Worker 2	58.666667	16.666667	108.66667
Worker 3	22	5.6666667	39

Table 1 shows the precision test monitoring column

As shown in table1 that time is recorded against the error made by each worker, then a total value is computed in which the equation of precision test is: $(\text{Time}_{\text{Measured}})+(3\times\text{Error})$,to provide more reasonable values a constant of 3 is multiplied by error for all the workers.

Method test:

A method test is done as simulating mainly what the worker does in his/her daily routine working day, as putting small parts together in its right order way, table.2 shows the Method test

Method test			
	Time	Error	Tot.
Worker 1	67	0	67
Worker 2	90	0	90
Worker 3	59	0	59

Table 2 Shows Method test monitoring column

As observed in the table that time is recorded against the error made by each worker, then a total value is computed in which the equation of precision test is: $((\text{Time}_{\text{Measured}})+(3\times\text{Error})$, to provide more reasonable values a constant of 3 is multiplied by error for all the workers.

Coordination test:

The coordination test is done by setting up two computers in front to each other but closer enough to the worker in order to use his two hands on the computer touch screen as the test consist of two windows full of symbols in random spread, the operator has to choose the same symbol on both screens as soon as possible because as well as the other test time is considered but this time there is no error, but there are a score points, so no constant is needed to provide a reasonable values as shown in table3 that time is recorded against the error ,then a total value is computed and the equation is: $(\text{Time}_{\text{Measured}})+(5\times\text{Error})$.

Coordination		
Time	Error	Total
147.6667	9.3	194.3333
165	8.333333	206.6667
78.33333	1.666667	86.66667

Table 3 Shows Coordination test monitoring column

Memory test:

The memory test is a test done by an application on the computer where there are pictures that the operator can have a look on it for several seconds that it disappears to let the operator choose the similar pictures after random spreading of these pictures, hence the equation of Memorial test is: (score points/Time) .

Memorial		
Time	**points**	**Total**
153.3333	20750	135.3261
162	17166.67	105.9671
151.3333	24283.33	160.4626

Table 4 Memorial test monitoring column

Results and Discussions:

By completing recording all the data needed to start the analysis of it, we begin to do data analysis to the information we had.
Firstly, we begin to make analysis to each test for all workers who got involved in the test even from different lines.

4.2 Precision test:

As mentioned before, after recording the performance of all operators , we start to calculate the total value, each test had its own equation as mentioned before ,afterwards, we make a criteria of the values scored by the operators then by inserting counting formulas in Excel, we are able to count how many operators scored a value between bigger or equal to zero and smaller or equal to 19 then ,We do the same for the ranges we have, after this to get the percentages we divided the quantity of the criteria over the total number which we have here 254 operators.
As shown in figure14., by finding its characterisation through excel we are able to get the characterisation of this distribution as shown in table6:

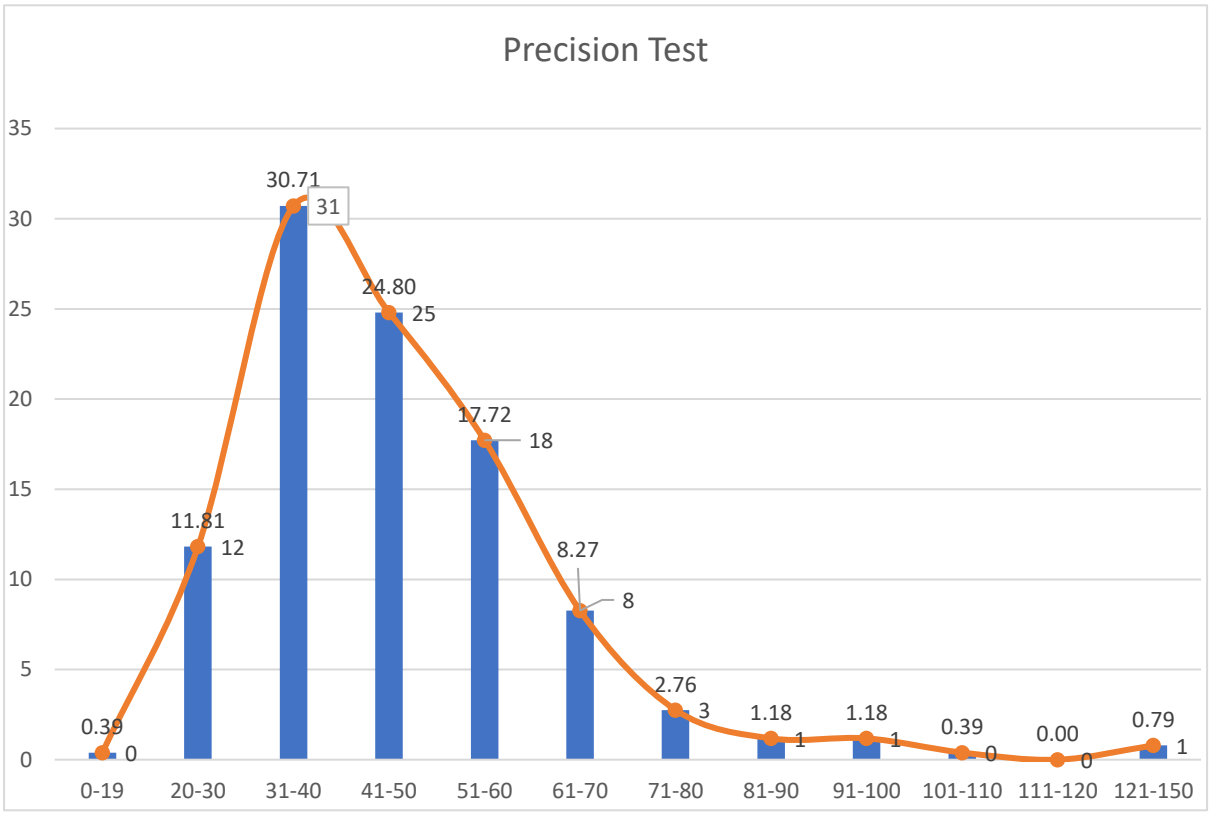


Figure 13 shows distribution of precision test

Criteria	Quantity	%
0-19	1	0.393701
20-30	30	11.81102
31-40	78	30.70866
41-50	63	24.80315
51-60	45	17.71654
61-70	21	8.267717
71-80	7	2.755906
81-90	3	1.181102
91-100	3	1.181102
101-110	1	0.393701
111-120	0	0
121-150	2	0.787402
SUM	254	

Table 5 shows Precision test analysis

Mean	**8.333333**
Standard Error	3.087034
Median	1.968504
Mode	0.393701
Standard Deviation	10.6938
Sample Variance	114.3573
Kurtosis	0.23629
Skewness	1.215288
Range	30.70866
Minimum	0
Maximum	30.70866
Sum	100
Count	12

Table 6 characterisation of Precision Distribution

By obtaining this information of the Mean, Mode, Median, slandered deviation, kurtosis and skewness, we can identify and understand the type of the distribution of the curve.

Description and Discussion:

As shown in figure14. Containing the distribution curve of the Precision test that the curve is skewed to the right this situation is called positive skewness, which is observable that mean exceed mode as the value of the mean is 8.3 while the value of the mode is 0.39. Therefore, from this point we can conclude even not from the graph that since the mean and mode had a significant different value, so the distribution cannot be normal distribution. This is because normal distribution had a specific characterisation in which mean, mode and median are all equal. Since the graph is skewed and the number of trials is fixed. hence, we can conclude that this distribution is considered to be Bernoulli type distribution. Bernoulli distribution has 2 type of distributions: Binomial and negative Binomial.

Binomial means when number of trials is fixed while number of success is a random variable, while Negative Binomial is when number of success is fixed and number of trials is a random variable. So, in our test here the number of trials is fixed, and the outcome is random variable that is independent.

4.3 Method Test:

The same procedures were done for precision test is done for method test. Also, by considering the same criteria ranges, we have an outcome as shown in Table7 Once obtaining the quantity of each range we can sketch the criteria vs the percentages. We get the distribution as shown in figure15 by finding its characterisation through excel we are able to get the characterisation of this distribution as shown in table8.

Table 7 shows Method test analysis

criteria	numbers	%
0-20	0	0
20-40	0	0
40-60	17	6.692913
60-80	65	25.59055
80-100	62	24.40945
100-120	46	18.11024
120-140	29	11.41732
140-160	15	5.905512
160-180	9	3.543307
180-200	1	0.393701
200-220	2	0.787402
220-240	6	2.362205
240-260	1	0.393701
260-280	0	0
280-300	0	0
300-320	0	0
321-340	1	0.393701
SUM	254	

	%
Mean	5.882352941
Standard Error	2.117580752
Median	0.787401575
Mode	0
Standard Deviation	8.731009112
Sample Variance	76.23052011
Kurtosis	1.068741078
Skewness	1.522988058
Range	25.59055118
Minimum	0
Maximum	25.59055118
Sum	100
Count	17

Table 8 characterisation of Method Distribution

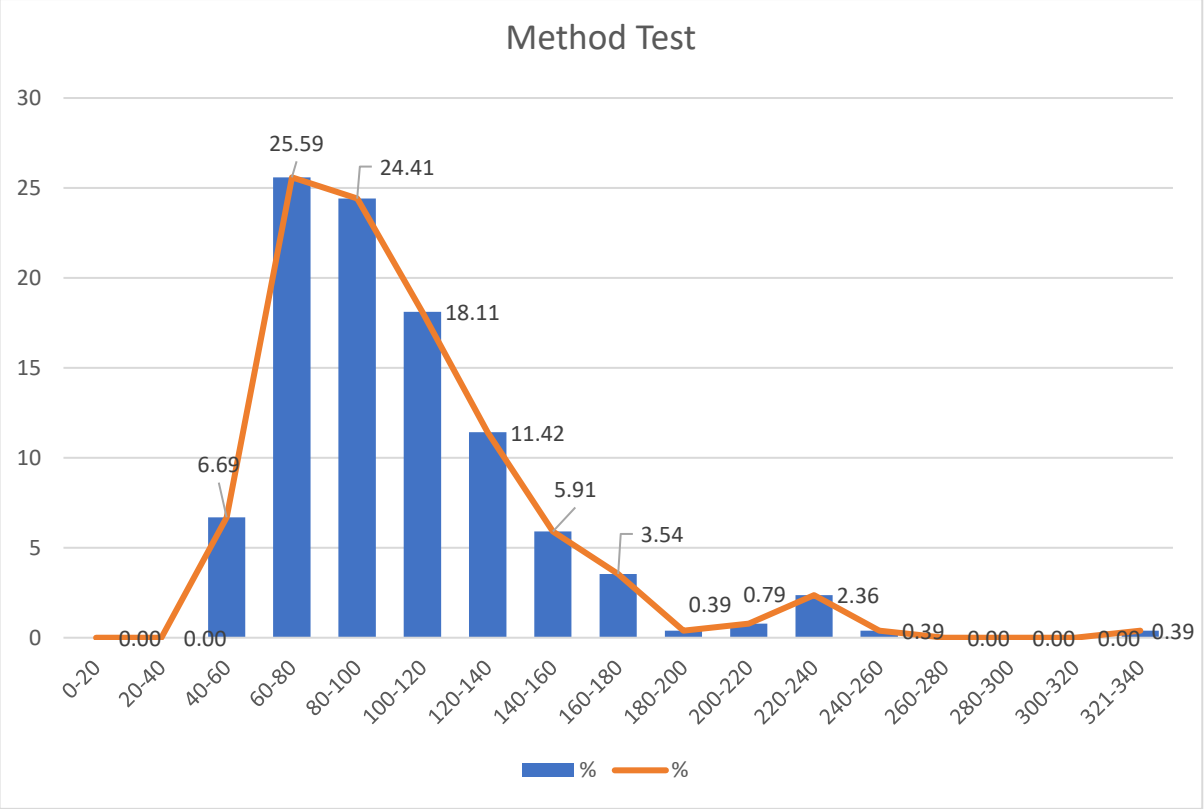


Figure 14 Distribution of Method Test

Description and Discussion:

As shown in figure15 containing the distribution curve of the Method test that the curve is skewed to the right this situation is called positive skewness, which its observable that mean exceed mode as the value of the mean is 5.8 while the value of the mode is 0. Therefore, from this point we can conclude even not from the graph that since the mean and mode had a significant different value, so the distribution cannot be normal distribution, because normal distribution had a specific characterisation in which mean, mode and median are all equal. Since the graph is skewed and the number of trials is fixed, hence we can conclude that this distribution is Bernoulli type distribution.

4.4 Coordination test

Coordination test is done to measure the stability and physical status of the performance that can coordinate the tool through the wire without causing an error as soon as the worker can, the same procedures are done and data is recorded time versus the error, then grouping and creating number of ranges as shown in table10.

By sketching the criteria vs the percentages, we get the distribution as shown in figure16. By finding its characterisation through excel we are able to get the characterisation of this distribution as shown in table9.

Prectentages %	
Mean	4
Standard Error	1.339292694
Median	0.787401575
Mode	0
Standard Deviatio	6.696463471
Sample Variance	44.84262302
Kurtosis	3.275586154
Skewness	2.021532851
Range	23.22834646
Minimum	0
Maximum	23.22834646
Sum	100
Count	25

Table 9 characterisation of Coordination Distribution

Criteria	Quantity	Percentages %
0-20	0	0
21-40	0	0
41-60	0	0
61-80	7	2.755905512
81-100	36	14.17322835
101-120	59	23.22834646
121-140	55	21.65354331
141-160	30	11.81102362
161-180	18	7.086614173
181-200	17	6.692913386
201-220	7	2.755905512
221-240	8	3.149606299
241-260	3	1.181102362
261-280	3	1.181102362
281-300	4	1.57480315
301-320	0	0
321-340	2	0.787401575
341-360	2	0.787401575
361-380	2	0.787401575
381-400	0	0
401-420	0	0
421-440	0	0
441-460	0	0
461-480	0	0
481-500	1	0.393700787
SUM	254	

Table 10 shows Coordination test analysis

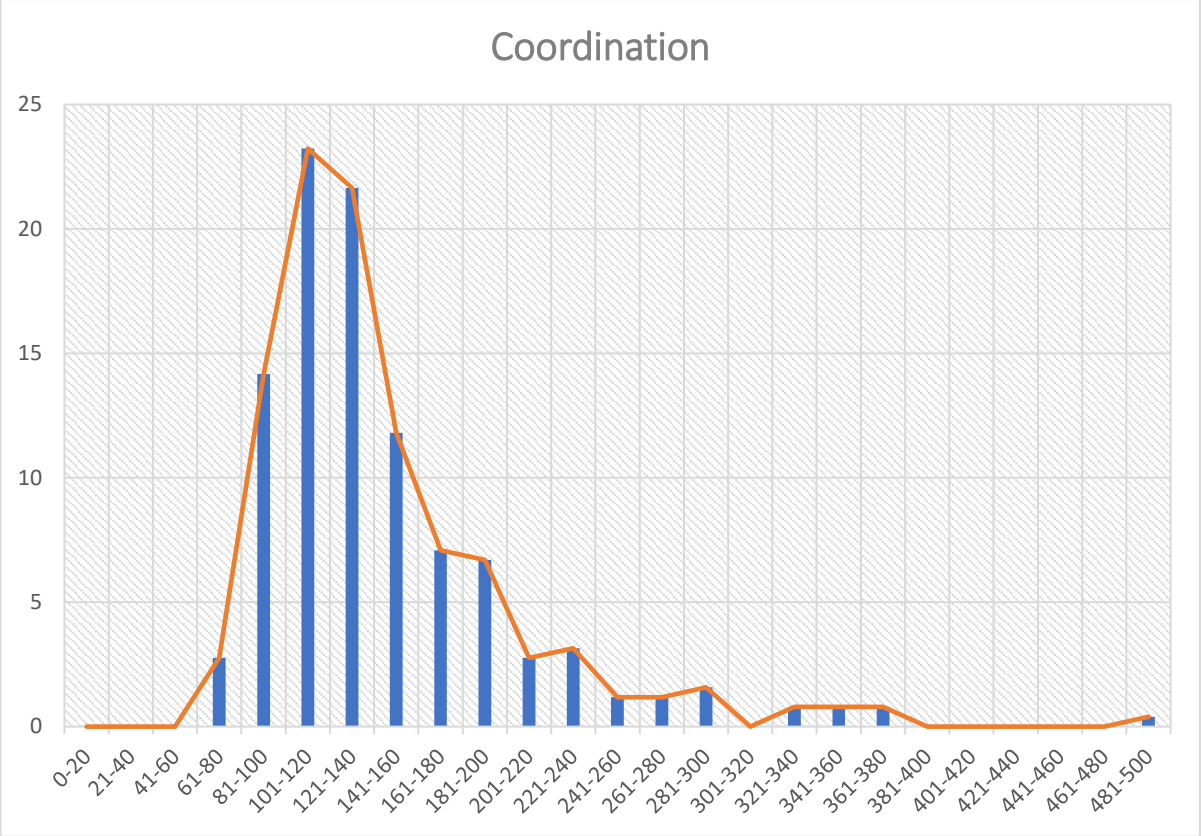


Figure 15 Distribution of Coordination Test

Description and Discussion

As shown in figure16, Containing the distribution curve of the Coordination test that the curve is skewed to the right this situation is called positive skewness, which its observable that mean exceed mode as the value of the mean is 4 while the value of the mode is 0. therefore, from this point we can conclude even not from the graph that since the mean and mode had a significant different value, so the distribution cannot be normal distribution, because normal distribution had a specific characterisation in which mean, mode and median are all equal. Since the graph is skewed and the number of trials is fixed, hence we can conclude that this distribution is Bernoulli type distribution.

4.5 Memory test

Memory test is designed to measure how good the worker can memorize doing the same procedures in a task with the minimum value of error. The same procedures are done, and data is recorded time versus the error, then grouping and creating number of ranges as shown in table11.

Prectentages %	
Mean	7.142857143
Standard Error	2.541391487
Median	1.771653543
Mode	0
Standard Deviat	9.509016229
Sample Variance	90.42138963
Kurtosis	-0.441051229
Skewness	1.049095323
Range	26.37795276
Minimum	0
Maximum	26.37795276
Sum	100
Count	14

Table 11 characterisations of Memory Distribution

Criteria	Quantity	Prectentages %
0-20	1	0.393700787
21-40	0	0
41-60	0	0
61-80	8	3.149606299
81-100	30	11.81102362
101-120	49	19.29133858
121-140	67	26.37795276
141-160	56	22.04724409
161-180	34	13.38582677
181-200	6	2.362204724
201-220	3	1.181102362
221-240	0	0
241-260	0	0
261-280	0	0
Sum	254	

Table 12 Shows Memory test analysis

By sketching the criteria vs, the percentages on y-axis, we get the distribution as shown in figure17,by finding its characterisation through excel we are able to get the characterisation of this distribution as shown in table 11.

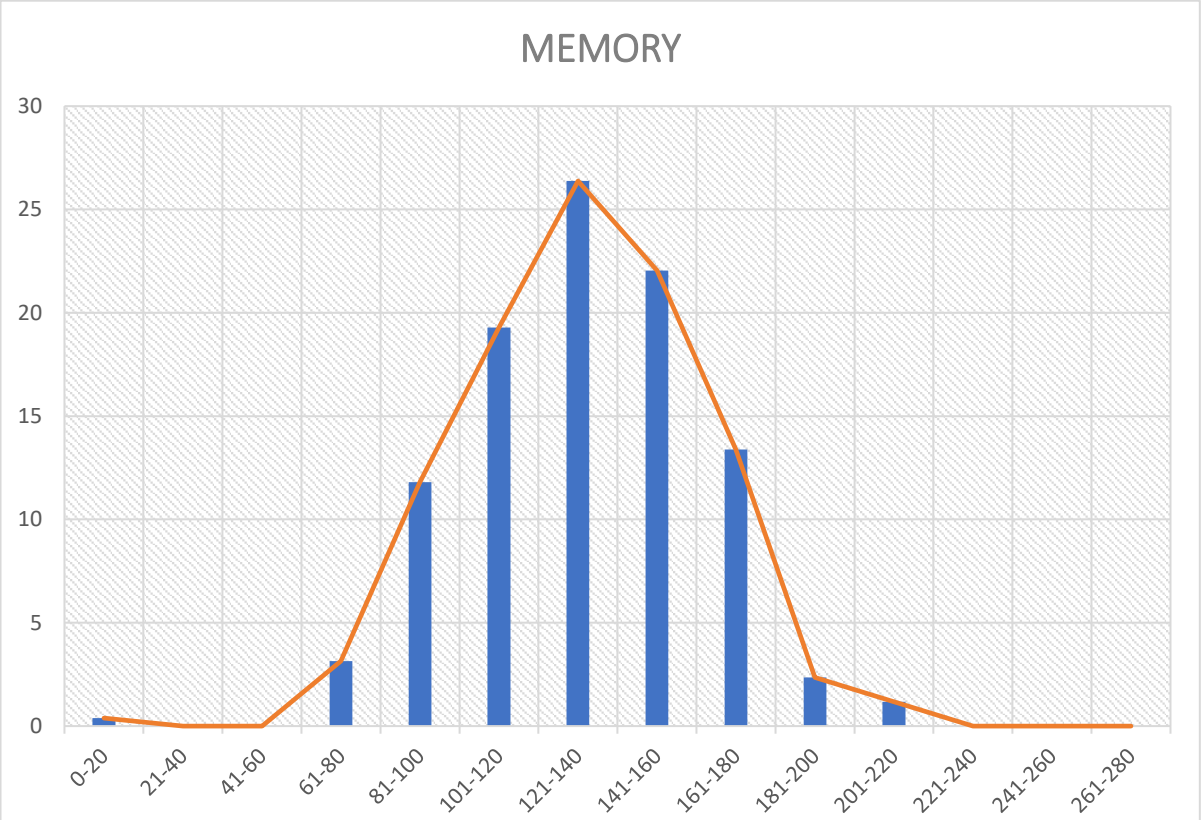


Figure 16Distribution of Memory test

Description and Discussion

As shown in figure17. Containing the distribution curve of the Memory test that the curve is not skewed in any direction, but it tends to be symmetrical. And it is observable that mean 7 while the value of the mode is 0. Also as long as the shape of the cure looks like its normal symmetrical but we cannot conclude this from only the shape because, for example in the characteristics of the curve the mean is not equal to the mode, also we can observe that the variation is not very high but it can be considered as a moderate variation with a slightly skewness of a value of 1 which is also considered a binomial Bernoulli distribution.

4.6 Mentoring the performances of Male vs Female in each test:

In this section, the performances of test are going to be compared based on the gender of the operators, this will lead to understand more and to have a good evaluation between workers among the four tests, the data of the workers are collected and classified according to gender: male versus female.

4.7 Precision test Male Vs Female

As mentioned before, starting with precision test, values of male and female are sketched in one same graph and compared together, as shown in figure18.

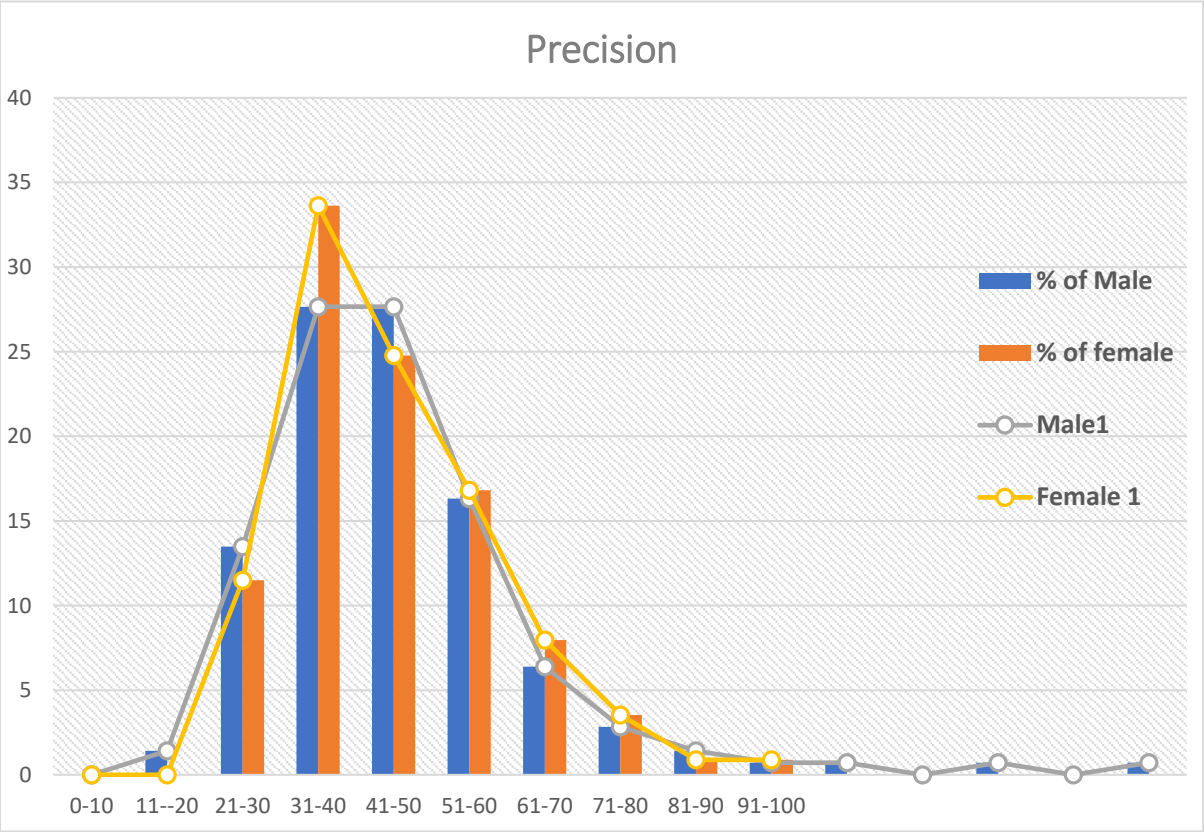


Figure 17 Distribution curves between Male Vs Female

% Male	
Mean	6.666667
Standard Error	2.550376
Median	1.41844
Mode	0.70922
Standard Deviation	9.877562
Sample Variance	97.56623
Kurtosis	0.986214
Skewness	1.508262
Range	27.65957
Minimum	0
Maximum	27.65957
Sum	100
Count	15

Table 14 characterization of Male Dist.

% Female	
Mean	10
Standard Error	3.708024443
Median	5.752212389
Mode	0
Standard Deviation	11.72580286
Sample Variance	137.4944527
Kurtosis	0.245507337
Skewness	1.115311446
Range	33.62831858
Minimum	0
Maximum	33.62831858
Sum	100
Count	10

Table 13 characterization of Female Dist.

After sketching the graph, we get two table of characterization, one for the distribution of male and the other is for the female, as shown in table14 and table13.

Result and disscusion:

As shown in the graph above that the two graphs are skewed but with very low values of 1.5 and 1.1 for male and females, by comparing the mean and median. We can conclude that, the variation of male results is higher that the variation of the female results, as observed that there are two females ranges that is comparing to other values is out of the range, the reason behind this could be caused by several causes such that maybe the age had an effect on their results, the contract type in which permanent and temporary contract can have an effect on the operator.

4.8 Method Male Vs Female:

The same procedures are done to compare the two performances between male and females and the outcome was as shown figure19. then we can get the characteristics tables as shown in table15 and table16.

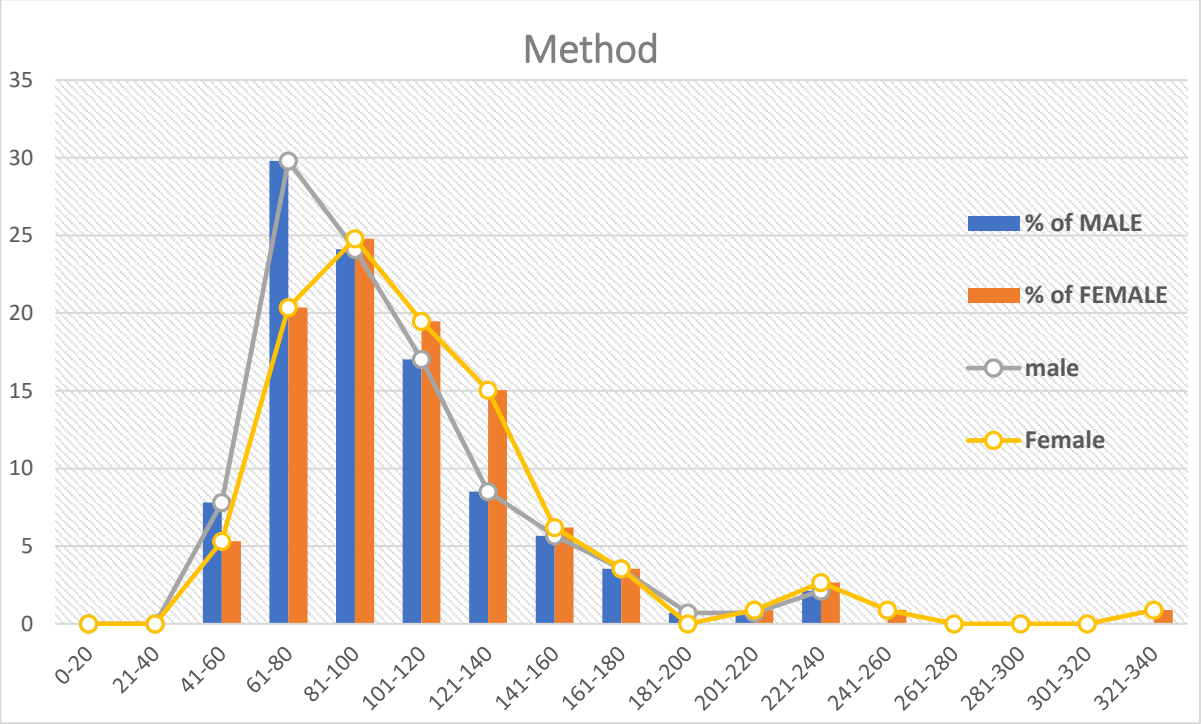


Figure 18 Dis between Male and Female in Method test

% MALE	
Mean	8.333333
Standard Error	2.898173
Median	4.609929
Mode	0
Standard Deviat	10.03957
Sample Variance	100.7929
Kurtosis	0.589052
Skewness	1.298894
Range	29.78723
Minimum	0
Maximum	29.78723
Sum	100
Count	12

Table 15 characterisation of Male Dis.

% FEMALE	
Mean	5.882352941
Standard Error	2.041755537
Median	0.884955752
Mode	0
Standard Deviati	8.418373739
Sample Variance	70.86901641
Kurtosis	0.36254256
Skewness	1.355043717
Range	24.77876106
Minimum	0
Maximum	24.77876106
Sum	100
Count	17

Table 16 characterization of Female Curve

Result and disscusion:

As shown in the graph figure19 obtained that both graphs show positive skewness, and the type of it is Bernoulli binomial. It's clear from the graph that in Method test Male scored the lowest values as about 7.8 % of males had a score between 41-60 comparing to Females that their range was 5.3%, and for the maximum values the female is slightly higher as the values is 2.11 for males and 2.65 for females but they tends to be the same quantity of people how scored a very high values, also from the graph we can discover that the males values had less variation compared to that of females.

4.9 Coordination Male vs Female

The same procedures are done for the coordination test and Male results is compared to female results then sketching both on the same graph as shown in figure20 and by analysing the two graph we get two characterisation table as shown in table19 and table18.

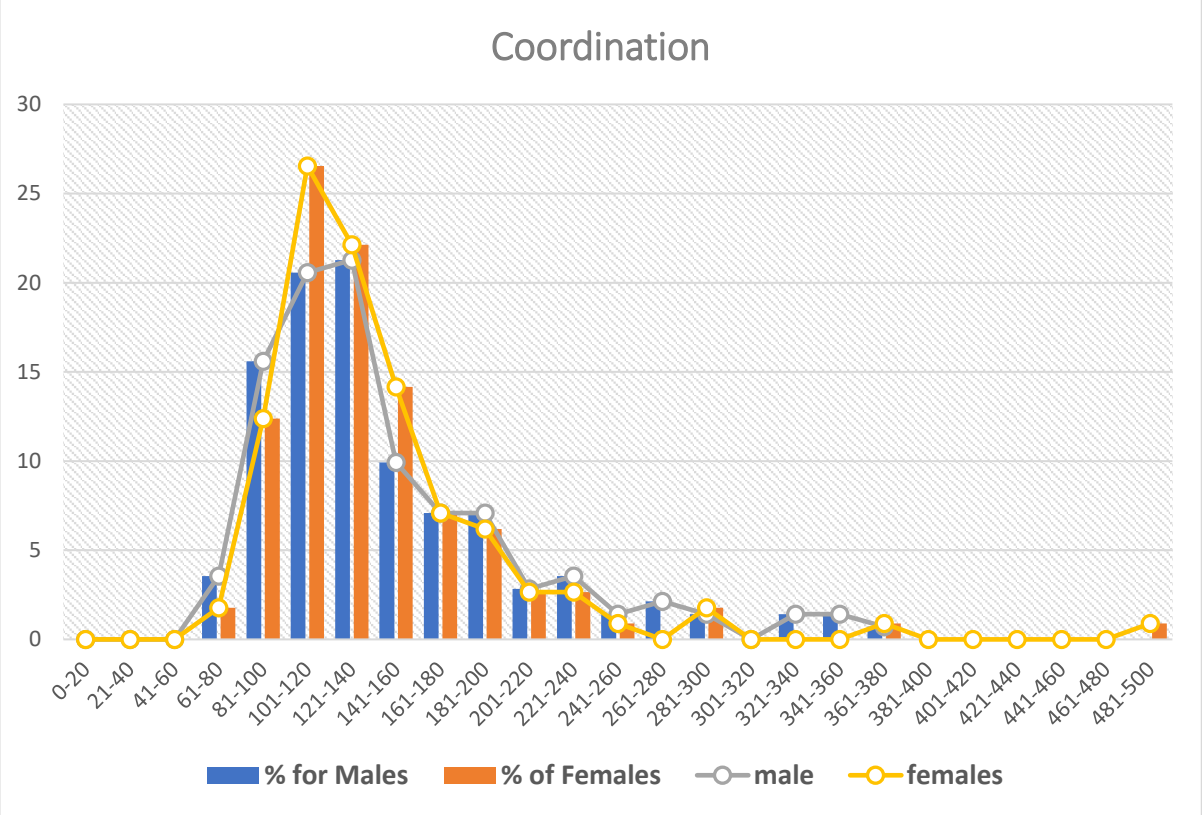


Figure 19 Male Vs female Dis in coordination test

% Male	
Mean	5.26
Standard Error	1.57
Median	2.13
Mode	0.00
Standard Deviation	6.82
Sample Variance	46.57
Kurtosis	1.33
Skewness	1.55
Range	21.28
Minimum	0.00
Maximum	21.28
Sum	100
Count	19

Table 19 Male characterisation in coordination test

% female	
Mean	4
Standard Error	1.45
Median	0.88
Mode	0.00
Standard Deviation	7.24
Sample Variance	52.48
Kurtosis	4.08
Skewness	2.17
Range	26.55
Minimum	0.00
Maximum	26.55
Sum	100
Count	25

Table 18 Female characterisation in coordination test

Results and Discussion:

As shown in the graph in figure20,both are graph are being shifted or the had positive skewness and its type of distribution is Bernoulli binomial distribution , also from the graph we can conclude that Females results are better than males results as there skewness value are higher than that of male in which Female value of skewness is 2.17 while male value is 1.55 so that means quantity of females who scored low values which is better is higher than those of males in the coordination test, also we can observe that the gender which scored values outside the range or values that they are very odd are male.

4.10 Memory test Male vs Female

The same procedures are done to compare the two performances between male and females and the outcome was as shown figure21. then we can get the characteristics tables as shown in table20 and table21.

% of MALE	
Mean	9.09
Standard Error	2.97
Median	4.96
Mode	0.00
Standard Deviatic	9.84
Sample Variance	96.86
Kurtosis	-0.95
Skewness	0.72
Range	26.95
Minimum	0.00
Maximum	26.95
Sum	100.00
Count	11.00

Table 20 Male characterisation Memory test

% of FEMALE	
Mean	9.09
Standard Error	3.04
Median	1.77
Mode	0.88
Standard Devia	10.07
Sample Varian	101.35
Kurtosis	-1.50
Skewness	0.59
Range	25.66
Minimum	0.00
Maximum	25.66
Sum	100
Count	11

Table 21 Female characterisation in Memory test

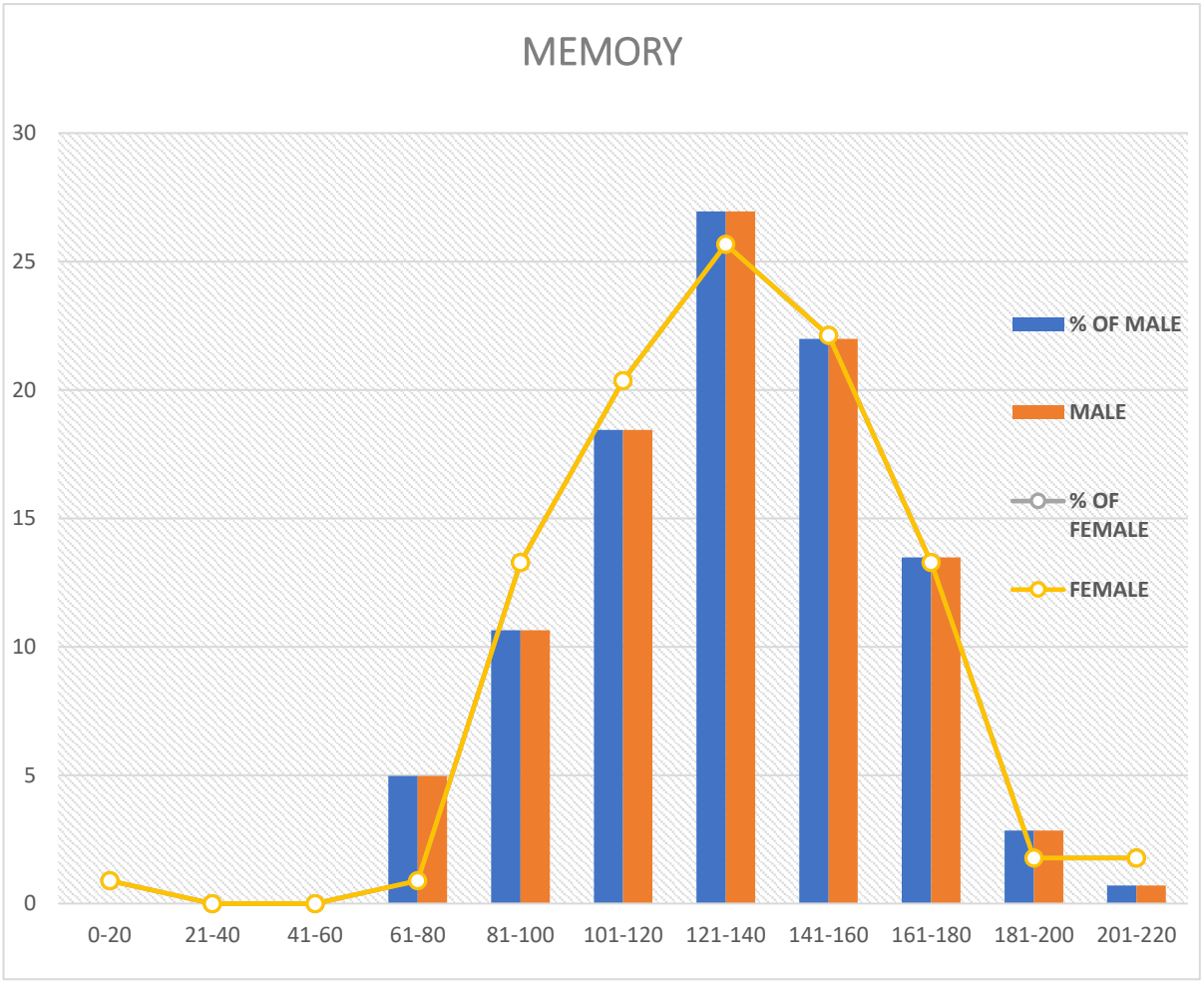


Figure 20 Dis. between Male vs Female in Memory test

Description and conclusions:

As shown in figure21,the two graphs are almost the same for that specific test for Male and Female , also from the characterisation curve its observable that the Mean had the same value of 9.09, also the slandered deviation and skewness tend to be the same ,this means that for the test male and females values are almost the same, performing with the same quality and almost having the same error.

5.Analysis of data between Age and Gender:

5.1 Precision test Gender and Age

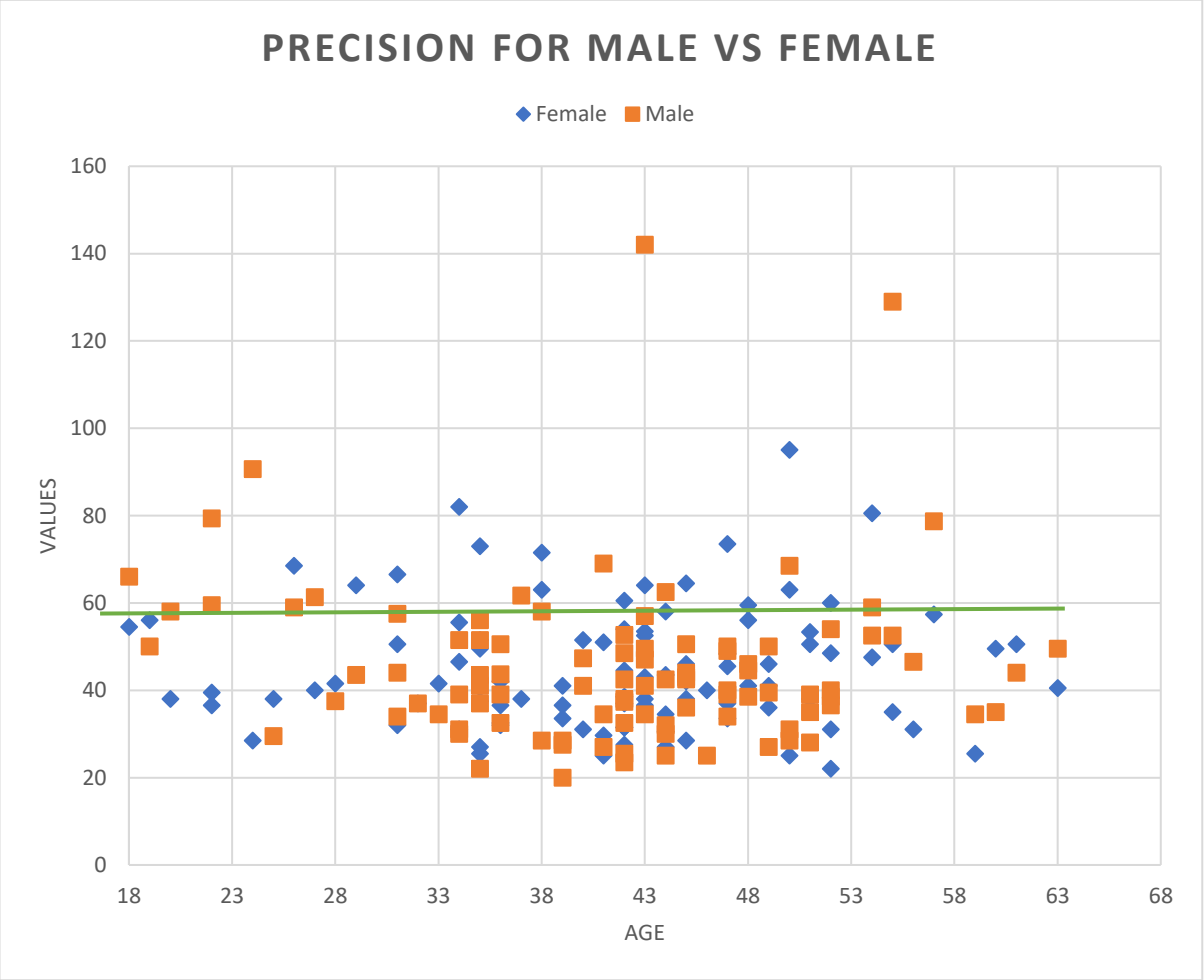


Figure 21 Precision Test Gender & Age

Result and Description:

As shown in figure22,the age of operators are being compared based on the gender in which the Age is described on X-axis and the Values of test is described on the Y-axis , also the Blue dots represent the Female gender and the Orange dots describe the Male Gender , as it's observable that the Female values **at the youngest age** between 18 and 30 had the lowest values that's mean a better values compared to that of Males , for example if we had two people with the same age which is 18 as shown in the figure above , we will find that the Female value is 54.5 while the male value is 66.

At the middle range of the age from around the age of 33 to 53, the values are a little bit scattered but there is a tiny difference that could be observed, in which at the beginning of

the age 33 to around the age of 48 the male values were better than that of female values for example at the same age of 39. A male had a score of 20 while a female had a score of 36.5.

While **at the older age** between 53 to 63, we can find that Female values are better than the male values for example at the age of 55 a male value is 52.5 while a female is 35 which is very observable difference and it mean to be considered when locating operators based on their age and for a task that's require a good skill of precision, also we can conclude that the female values at the older age is more or less the same values of the female values at the younger age. Also, it's observable that there are two male values that their score is way out of the range of a values (142 and 129) as the average values is around compared to the value of the average 39.

What we can conclude from the values that is out of the range is that they require consideration in order to be assessed and to be located in a new task that they can perform with effectiveness because as shown from the graph they effectivity for that precision task is very low , and as mentioned before that the human factor is very essential for the improvement of the Quality and they act like a chain.

5.2 Method test Gender and Age:

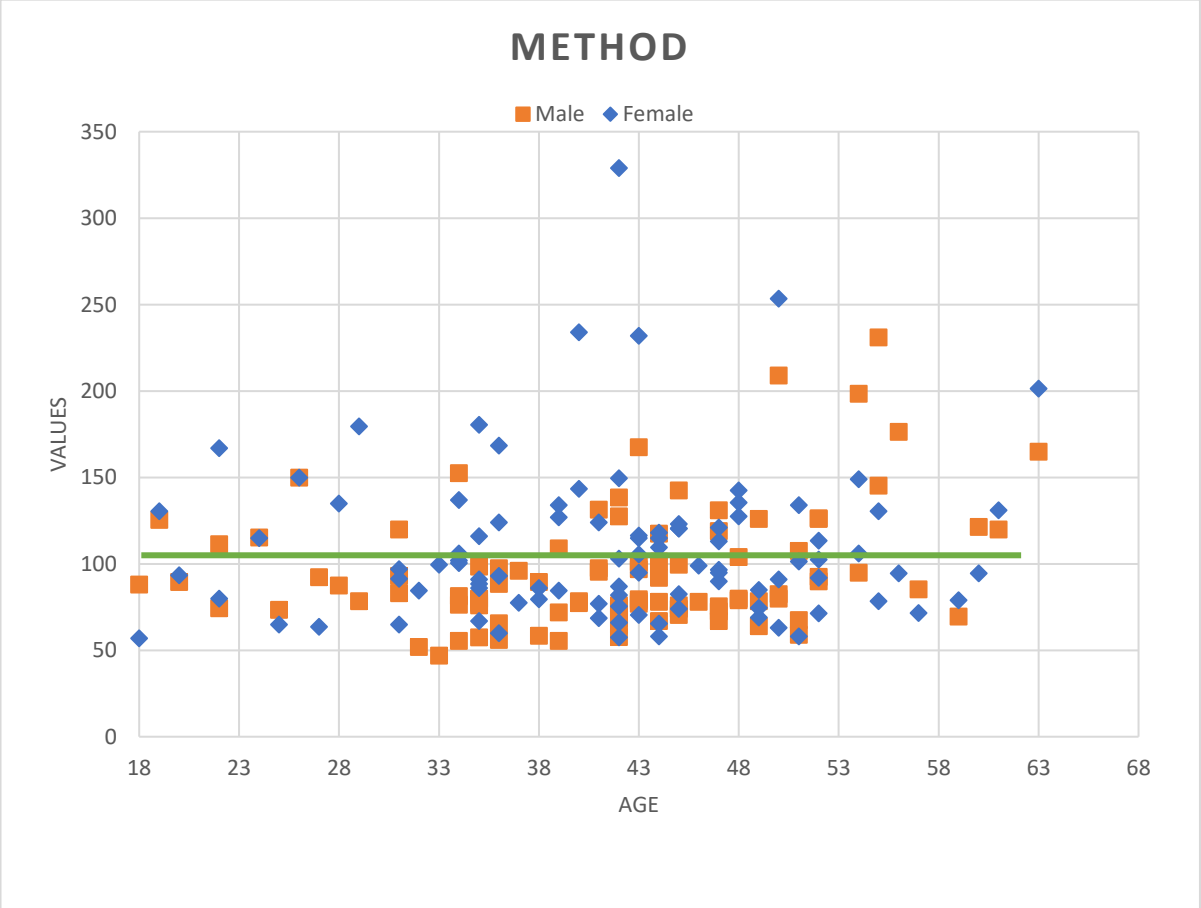


Figure 22 Method Test Gender & Age

Result and Description:

As shown in figure23,the age of operators are being compared based on the gender in which the Age is described on X-axis and the Values of test is described on the Y-axis , also the Blue dots represent the Female gender and the Orange dots describe the Male Gender , as it's observable that the Female values **at the youngest age** between 18 and 31 had the lowest values that's mean a better values compared to that of Males at the same range of the age , for example if we had two people with the same age as 18 as shown in the figure above , we will find that the Female value is 57 while the male value is 88.

At the middle range of the age from around the age of 33 to 53, the values are scattered but there is a difference that could be observed, in which at the beginning of the age 33 to around the age of 40 the male values were better than that of female values for example at the same age of 39. A male had a score of 55.5 while a female had a score of 84.5.

While **at the older age** between 53 to 63 , we can find that Female values are better than the Male values for example at the age of 55 a male value is 145.3 while a female is 78.5 which is very observable difference and it mean to be considered when locating operators based on their age and for a task that's require a good skill of Method procedures, also we can conclude that the female values at the older age got different values of the female values at the younger age while for male they values tends to be the same despite the difference of the Age's considering the average value we can observe that the there's about 4 Female values that they're out of the range.

5.3 Coordination Test Gender and Age:

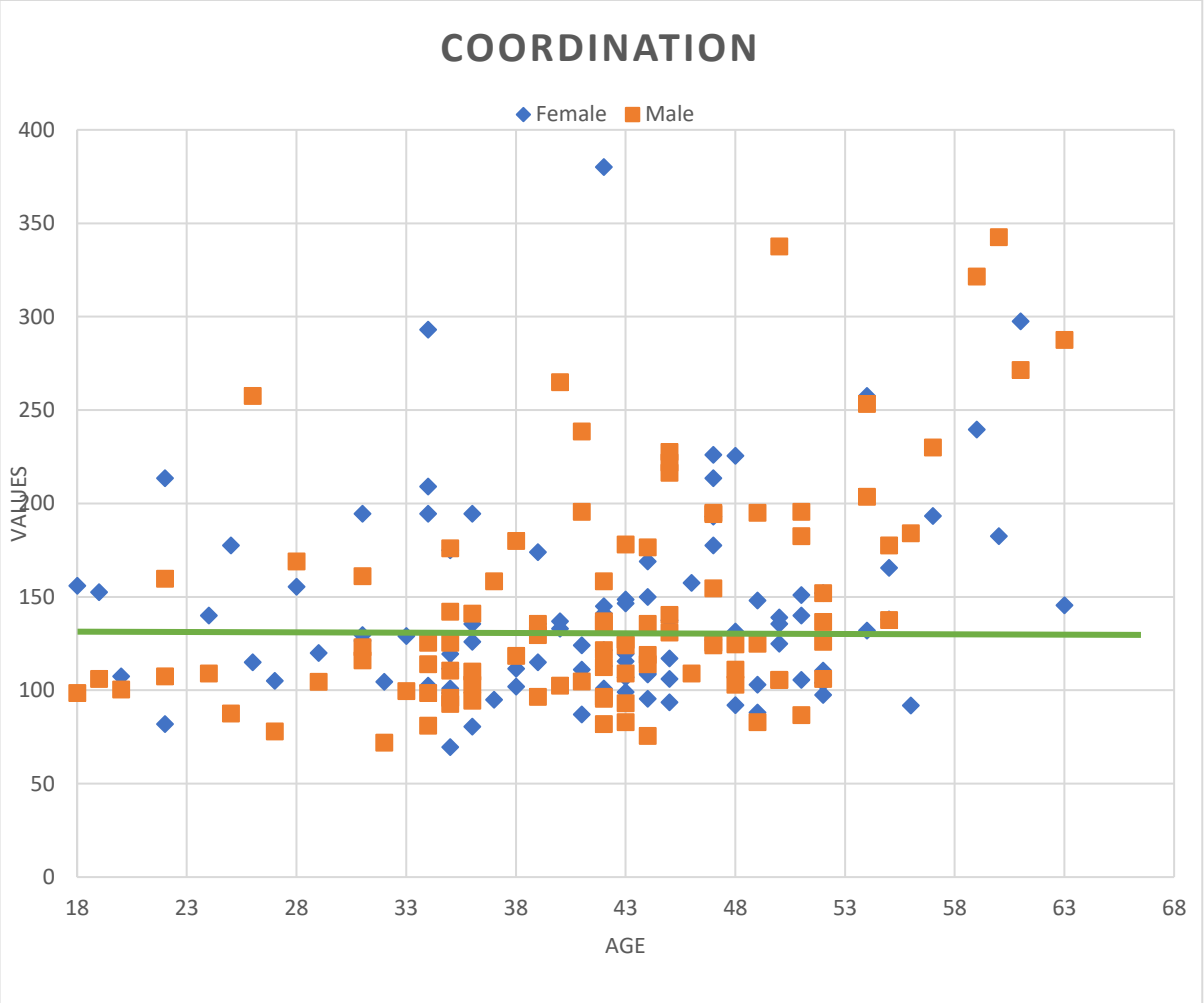


Figure 23 Coordination Test Gender & Age

Result and Description:

As shown in figure 24 the age of operators are being compared based on the gender in which the Age is described on X-axis and the Values of test is described on the Y-axis , also the Blue dots represent the Female gender and the Orange dots describe the Male Gender , as it's observable that the Male values **at the youngest age** between 18 and 33 had the lowest values that's mean a better values compared to that of Females at the same range of the age , for example if we had two people with the same age as 18 as shown in the figure above , we will find that the Male value is 98.5 while the Female value is 156.

At the middle range of the age from around the age of 33 to 53, the values are scattered but there is a difference that could be observed , in which at the beginning of the age 33 to around

the age of 40 the Female values were better than that of Male values for example at the same age of 38 ,A male had a score of 118.5 while a female had a score of 102.

While **at the older age** between 53 to 63, we can find that Female values are better than the Male values for example at the age of 56 there are only one female which had the value of 92 and it is located below the average, while all the rest at the same age are located above the average line which had a value around 141 in the coordination test. This means that as long there is young operator performing tasks that require coordination skills, it is recommended to assign young operators to preform it with the reference on the graph above.

5.4 Memory test Gender and Age:

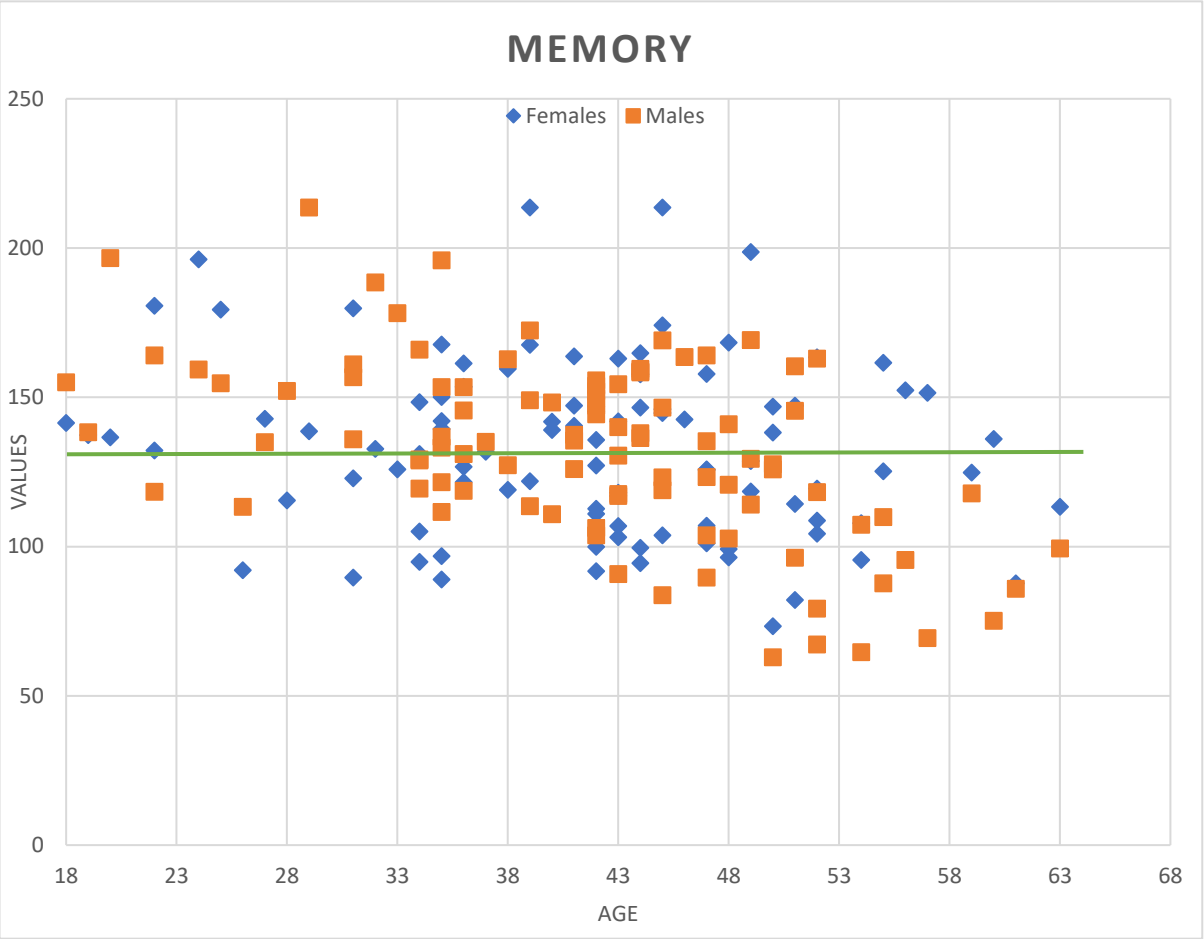


Figure 24 Memory Test Gender & Age

Result and Description:

As shown in figure25,the age of operators are being compared based on the gender in which the Age is described on X-axis and the Values of test is described on the Y-axis , also the Blue dots represent the Female gender and the Orange dots describe the Male Gender also as mentioned before that the memory test depend on the score in which the highest score represent a good value , as it's observable that the Female values **at the youngest age** between 18 and 33 had the lowest values that's mean a better values compared to that of Males at the same range of the age , for example if we had two people with the same age as 18 as shown in the figure above , we will find that the Female value is 141.5 while the male value is 155.

At the middle range of the age from around the age of 33 to 53, the values are scattered but there is a difference that could be observed, in which at the beginning of the age 33 to around the age of 43 the female values were better than that of males values for example at the same age of 35, A male had a score of 111 while a female had a score of 89.5.

While **at the older range of the age** between 53 to 63, we can find that Male values were out of the range and there is a significant difference in the values between the average value and their values this can be related of course to the age, so it is recommended for tasks that requires memory skills to be advised to people aged below than 50 years old by referring to the figure25.

6.The importance of data analysis in Engineering industry

6.1 Background:

Gathering data is a very important activity we understood nowadays, hence its Leeds for the Artificial intelligence at the Dartmouth Conference in 1956, it was the first time to talk about it. the conference aimed to show that computer can do many things especial is to prove mathematical theorem, which was thought to be an intellectual feat that only human beings could perform therefore expectations of the growth of artificial intelligence was great [22].

In 1980, the idea began to work, and it started focusing on imitating the decision making by experts and from the knowledge a deduction was performed, at the point human were able to build a data base, referencing form knowledge experienced and predicate logic however, later people understood the variation effect on the data base. For example, the more the variation and characteristics the data have the more data base it needs to cover or monitor it and resulting of high accuracy.

When manufacturers have experienced the acquisition of big (range from a few dozen terabytes to many petabytes of data) in a single data set. For example, the personal care products that GE company produces requires generating over 5000 data samples will require generating of forecasting manufacturing performances and operator's quality performances for so many reasons example: maintenance proposes, production, and business proposals [4].

In general, nowadays big data analytics had experienced very intention for research interest from both sides of academic and industrial. A report is published from McKinsey institute that data analysis had a strong influence for supporting the growth of economics and maintaining or enhancing the increase of the productive growth to its maximum level. Resulting now a days of a competition for today's enterprises, and for employee's attraction.

In 2015, industrial big data analysis came for manufacturing maintenance and service innovation, which discusses automate data processing, health assessment and prognostics in industrial big data environment [22].

- DEVELOPMENT OF INDUSTRIAL BIG DATA ANALYTICS:

Data production out could be in a lot of forms such as design maintenance and manufacturing, sale and testing, all this kind of data are monitored and recorded then transmitted turning it to be useful material or product for a whole life cycle management.

- Enterprise operation data:

Data in the form of marketing , production, procurement, goals, plans, inventory ,e-commerce , quality control and other data form, it is considered as the development of production processing ,improving productivity and innovation research in management style like what is going to be introduced in Chapter 4 , about this paper , the research done and what it reached ,the optimum use of this data could be the main reason to enhance the production and helping in improving the quality of the products hence , time will be reduced which is considered the most important factor requiring for the good productivity and for the customer reviews ,second is the cost , minimizing the cost of productivity is the most

important aspect , hence the cost is related to chain for example , if there is a default in a product this may require stopping the production line in order to start the discovering process where did the default happen , and what was the cause , then quality , production and safety departments may get involved for this issue [22].

6.2 INVESTIGATION METHODS FOR HUMAN PERFORMANCE

Introduction:

This part is investigated by U.S. Nuclear Regulatory Commission Office of Nuclear Regulatory Research Washington ,March 2002, the introduced the reason to investigate human performance problems is to collect the information needed to help them to study their causes and introduce effective actions that could be corrective ,they introduced that the study of human performance should be constructed on how , who, what, when and where? [23].

The impact of a human error is investigated and analysed upon (economic impact, safety, potential), also they added that a fault that was the root cause of an event will have more consideration more attention than a fault that only contributed to the event. The investigation should be way systematic to procced the many challenges to developing human performance [23].

6.3 LINES OF INQUIRY

The priority of the investigation was to discover and identify the basic facts surrounding the human performance problem, the investigation started to expand and then until it reaches to investigate possible causes for the human performance problem and the scope of any problems that are identified [23].

The initial lines of inquiry in an investigation help characterize the human performance problem. Questions to be answered may include: • What were the specific actions (or failures to act) that occurred in the event or that comprise the human performance trend? • What were the conditions under which the actions occurred? • What work activities, if any, were going on at the time of the error [23].

6.4 Industry 4.0

Throughout the 20thcentury, a lot of effort had been involved in order to develop and sustain a higher productivity of industrial product, not only concerning on tasks done but on other materials such as , storage , transport and handling materials),however the most automated system is still semi-automated in manufacturing system contain of automated and manual tasks, this is very Cleary observable within assembly lines which became not sufficiently economic to bring in automation to it [24].

However ,the demand to customize products and the increase of complexity of the products had led to increase of the complex ability of the manufacturing system , however the level of automation requirements did not affected to achieve the flexibility in tasks, but in fact the excessive level will be a result of low quality or poor system productivity, due to vulnerable in general it may be a result of degradation of the equipment efficiency , in parallel of the degradation or the loss of the sustainability of the operator performance with the increase of

the level of the automation exceeding the limit ,also it may lead to degradation of the cognitive workload . As a matter of facts, a state of the art review of Industry 4.0 based on research and practice can be found in Weyer, Schmitt, Ohmer, and Gorecky (2015) and Stock and Seliger (2016) but, as highlighted in Qin, Liu, and Grosvenor(2016), applying the technology of Industry 4.0 to get benefit from it is still not clear or there is still a long way to be taken in order to find relationship between current systems and Industry 4.0 requirements.

However, moving to the future require the development of the structure found nowadays till reaching what is called the smart product, as it mentioned the human operators in the industry will face task complex ability when going further with the Industry 4.0 as they will have to be qualified with some characteristics such as: working with high flexibility and demonstrating high capability with a dynamic environment [20].

6.5 So, what is automation?

“Automation is defined as Automatic control of products through number of stages and the definition lays in the use of mechanical and electrical power to replace the human labour”, this definition was from oxfords English Dictionary (2006) [25] [22].

However ,in general the meaning of it is to introduce the mechanism techniques in the in the industry , as the increase of information technology and data bases all over the world it is leading the way to the rapid growth of the interference of the automation in the Engineering industry (Stachell 1998),because of the use of the computer in the industry to collect data gather a lot of information by sensors , recording , monitoring and evaluation , it become the trend in the last few years ,the automation also tended to replace the human operating the tasks in some as mentioned before, this situation is very common in industrial with high and very specific safety aspects such as (aerospace and nuclear industry) ,So, the question remains how to balance between automation in general and machines in which we can optimize the allocation of tasks and increase the productivity [25].

6.6 Task allocation

The first one to introduce task allocation was Fitts in 1951, he introduced a list which presented in table22 illustrating tasks in general between human and machinery.

HUMAN EXCEED MACHINE AT	MACHIENE EXCEED HUMAN AT
• Detecting the small values of acoustic / visual energy	• Due to data base, ability to respond quickly to control signals smoothly is very high
• Ability to receive light and sound patterns	• Performing in repetitive way
• Chance to experience judgment	• Storing information in a brief way and control it by which it can be removed completely
• Reasoning inductively	• Reasoning deductively
• Ability to think and invent more flexible procedures	• Handling high complex tasks
• Storing very large amount of information for whatever period needed and recalling specific facts for specific time	• Performing in routine and reparative way

Table 22 HUMAN VS MACHIENE CAPABAILITIES [25]

However, since that time a range of concepts behaviour had raised for example, in 1963. Jordan introduced a concept that comparing machine to human abilities is not valid or cannot be done because of machine is designed for a specific task to do and it was pre identified ,so he concluded an idea of when making a system design for human and machinery system , the concept should be built on what human do best and what machine can do best which was complimentary when identifying system design, following up the ideas of Jordan [25].

In 1985 Price introduced the allocation of task between human and machinery in a graph in which x-axis is for how good or bad human performance on how good or bad machine will perform in figure 26 it represents Price concept graph.

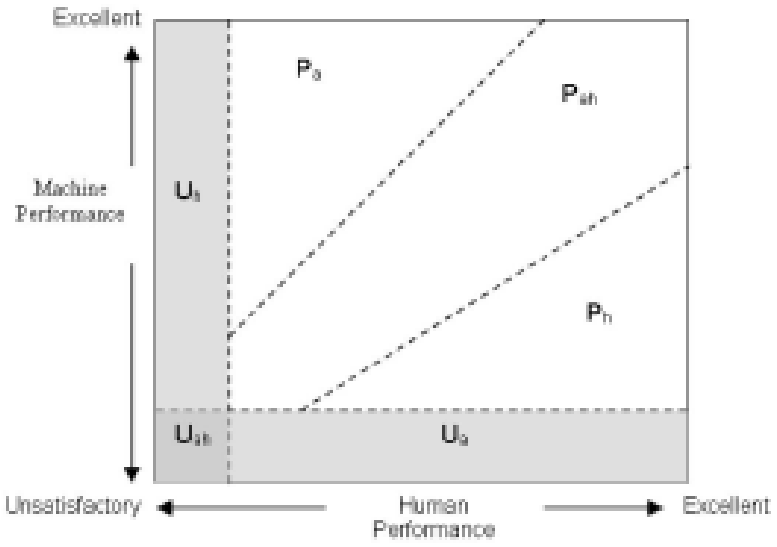


Figure 25 represent Price concept of the goodness between human and machinery in 1985 [25]

Figure26 represent the goodness of human and machinery according to Price 1985. In the figure as shown he introduced two lines Uh and Ua, the Uh line is the task can be related to machines only and Ua line are the task that Human can do it only he added the reason for this is physical strength or ability to solve problems [26].

The range of (Pa,Pah,Ph) is the ranges that both human and machinery can perform the task, while the Uah range is those tasks that handled to both human and machinery because these tasks cannot be done by only one of them but it require the support for both of them [25].

An example of the relationship between the level of automation and human is introduced in the following part as an example in oil and gas industry [27]:

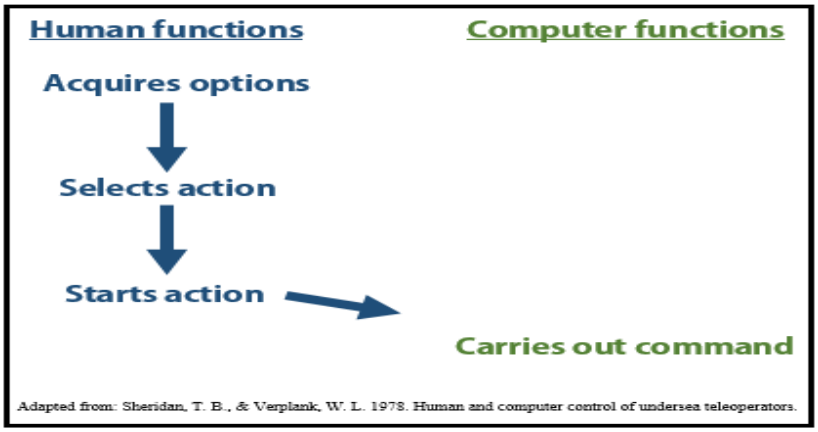
6.7 Level of automation in oil and gas industry

The oil and gas industry is considered one of the most field that require high standers of safety and quality ,the development in oil and gas industry is becoming very rapid as more technologies is becoming advanced every day, for the example the interference of the artificial intelligence (AI) and robotics to follow up the increase of automation in oil and gas industry , from this point the definition of Levels Of Automation (LOA) comes by W. L. Verplank and Thomas B. Sheridan as it mentioned before that degree of automation could be related to only human control or completely to machine control or tasks that require the support of both of them to be performed completely [25].

6.8 Automation levels:

Level 1

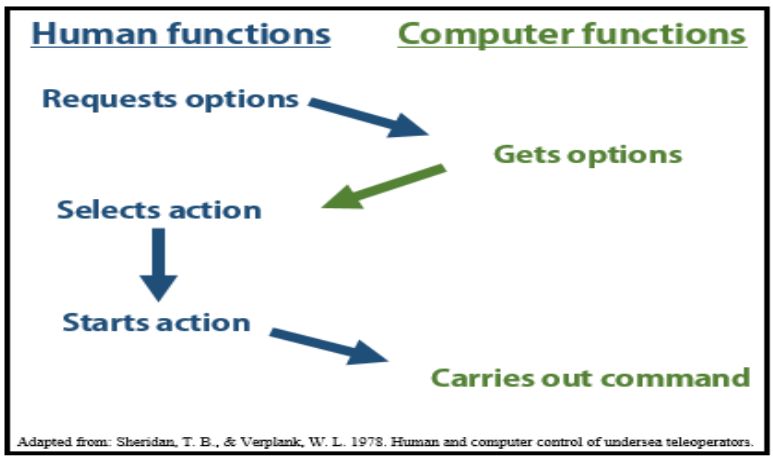
The human worker performs a task and pass it to the computer to carry out and proceed



level1 of Automation [27]

Level 2

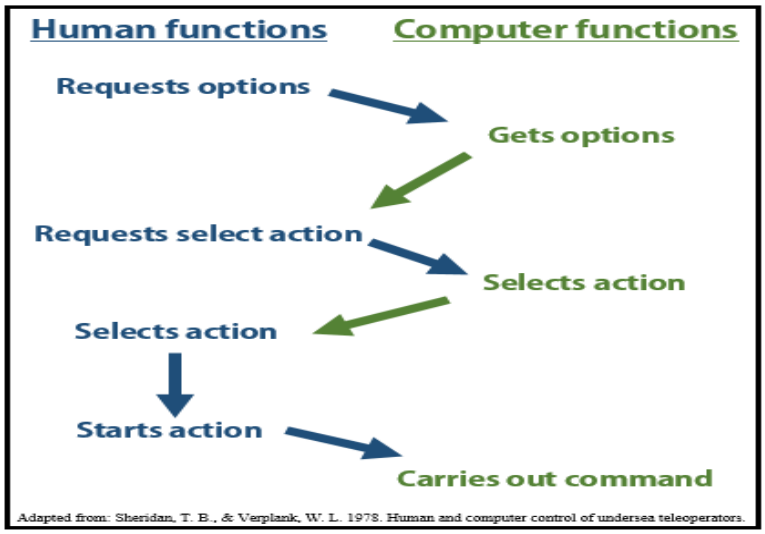
The computer provides several options.



level2 of automation [27]

Level 3

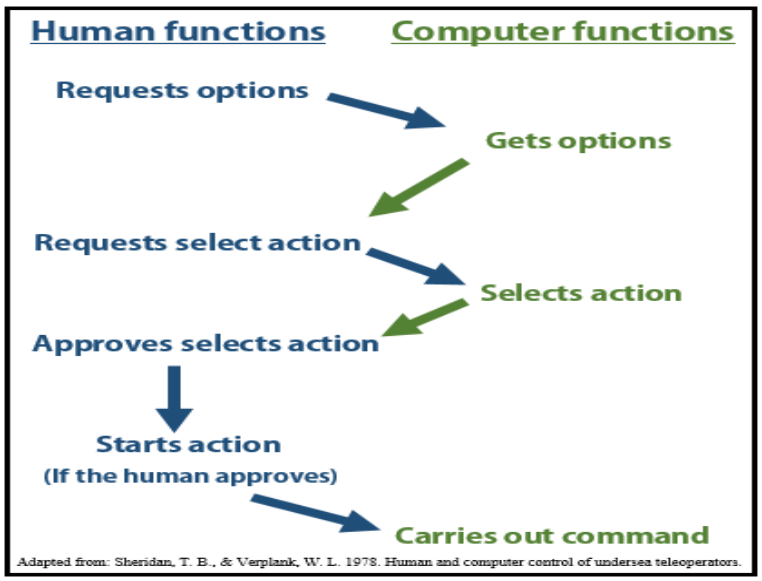
The computer helps to provide options. The human operator had the option to choose from several recommendations provided by computers.



level3 of Automation [27]

Level 4

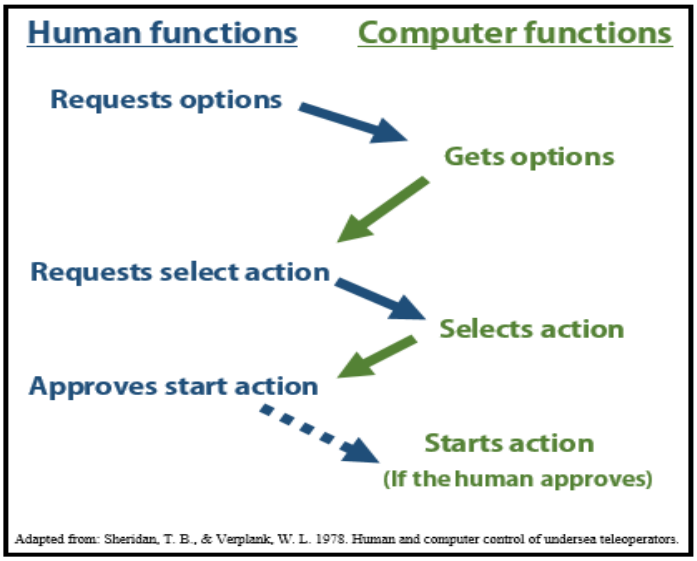
The computer provides an action and the human operator take decisions to take this action or not.



level4 of Automation [27]

Level 5

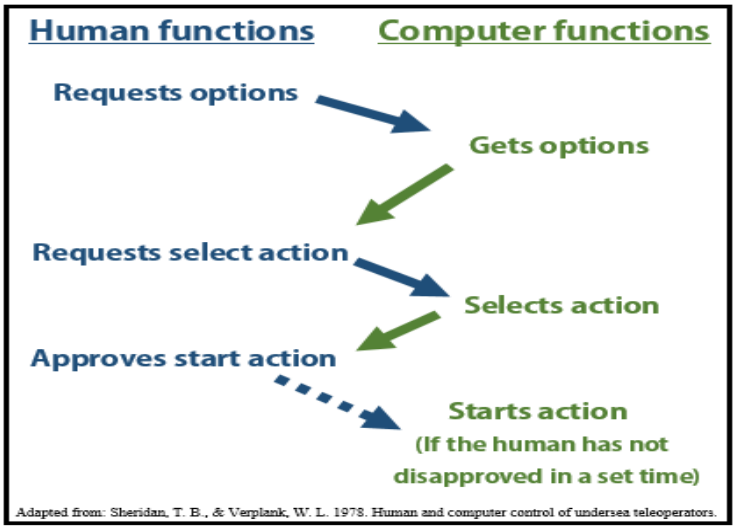
When human operator selects the action, the computer approves it and start to implement it.



level5 of Automation [27]

Level 6

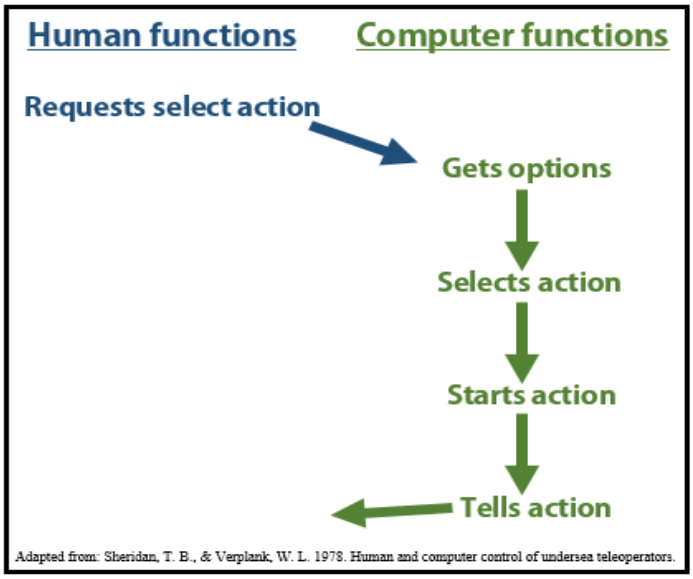
The computer provides the choice of the action and provide the human operator if the human worker wants to deactivate the action.



level6 of Automation [27]

Level 7

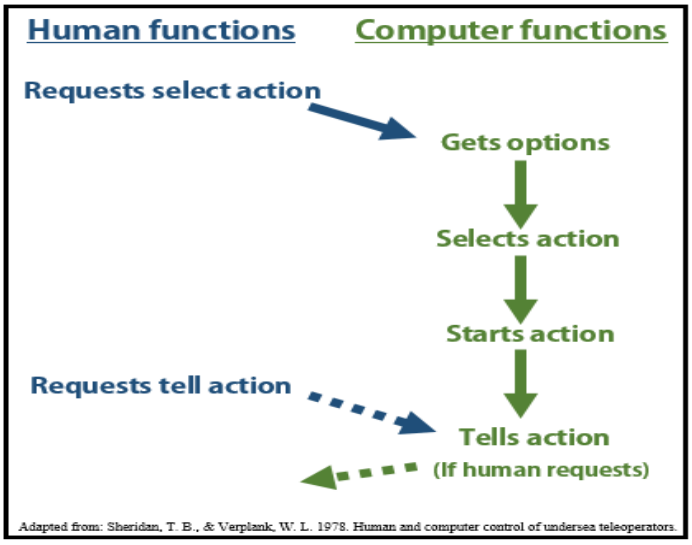
The computer preforms the action and provide the human operator what happened.



level7 of Automation [27]

Level 8

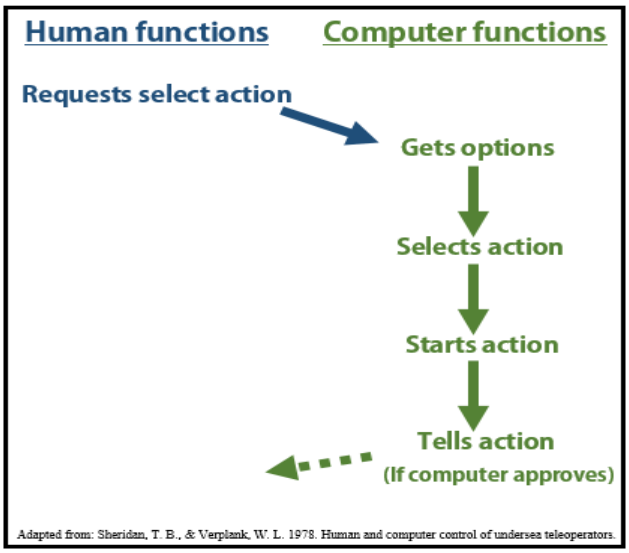
The computer performs the action and provides the human operator only in case if the human operator needs.



level.8 of Automation [27]

Level 9

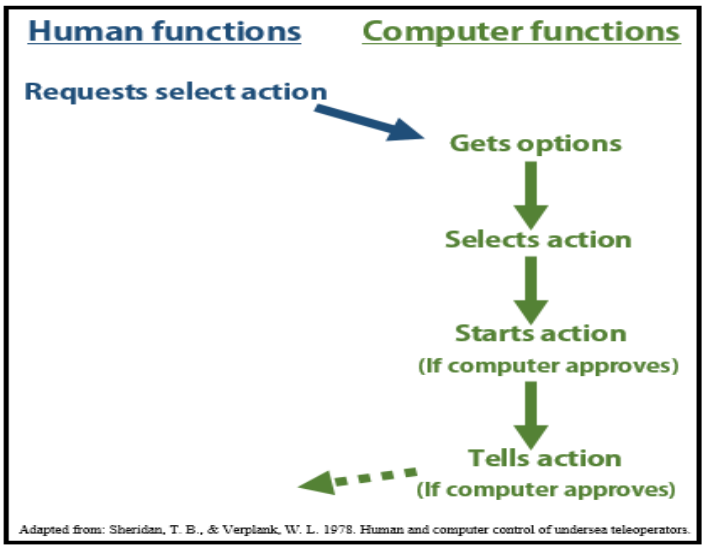
The computer performs the action when asked for it and provides the human only if the computer decides the operator should be known.



level.9 of Automation [27]

Level 10

The computer performs actions if it is certain that it should be done. The computer provides the human operator only if it decides the operator should know.



level.10 of Automation [27]

6.9 Four-stage model of human information processing:

Parasuraman, Sheridan, and Wickens introduced the concept of associating levels of automation to several functions [17] [25].

The four-stage model of human information processing includes:

i. Processing of sensory

ii. Memory working and Perception

iii. Taking decision

iv. Selection of response

Processing of sensory

Means in the ability to acquire and register so many information from deferent sources, this stage contains processing of sensory, orienting and positioning, inference, integration and attention in selection.

Memory working and Perception

Contains manipulation perception of several information from the working memory that had been reviewed and processed it contains operations that happened in the priority of decision

Taking decision

Continuous cognitive processing will lead at the end to take suitable decision.

Selection of response

Contains the implementation of a response or action consistent with the decision choice. Four-steps model of processing information that can be converted into system functions:

- Gathering information
- Analysis of information
- Decision selection
- Action implementation

Humans in the automated systems:

According to Groover (2005) During the production cycle, human will remain the most flexible and the most important factor in which it can be enrolled to solve planned and unplanned problems [25].

When speaking about the relationship between man and machinery and advantages and disadvantages in manufacturing system several factor should be identified, as there is several cases or tasks that manual work is preferred over the automated work:

- Performing tasks that it too complex for technologically, hence is difficult to be automated, that case mainly due to economic reasons the system couldn't be operated by automation.

- a short life cycle production will not be provided by a complicated automation system, also it won't be economically inappropriate.

- Sometimes tasks require customization of the product, cases of uniqueness in which automation cannot deal with it.

- There are constant changes in the production, this is not common to happen in modern advanced production systems, but still some cases are too complex, also when the capacity system of the automation is very small to handle the production, for that issue human factor is essential for the system.

- Introducing brand new product to the market also will require the advantage of the human manual hence the product could be successful and not successful, the life of the product is of course considered, for short time projects the investment to input machinery would not be economic so it's more essential to depend on human operators.

7.Conclusions:

This paper focused on the importance of human performance beside the automation and machine development throughout the entire industry , there are many methods and approaches to assess human performances done by researches ,from this point , data analysis is one of these methods In 1980,the idea began to work and it started focusing on imitating the decision making by experts and from the knowledge a deduction was performed , at the point human were able to build a data base ,referencing form knowledge experienced. During performing data analysis, it is discovered that time required to perform is short once data is acquired, also it is very reliable.

Case study done in this project was on a limited number of operators (around 250 operators) between male and females with the variation of age between (18 and 63 years old) ,the 250 operators were distributed in 4 different assembly line in two shifts, they were preforming four different tasks that requires four different skills as follows: Precision , Method , coordination and memory skill .

By performing data analysis on the four test at the beginning we observed that precision, Method and coordination test result were having a positive skewness where the curve is skewed to the right where its value ranged for those three tests between (1.2 and 2) , also those three tests showed a positive kurtosis , that means a peak is occurred due to the phenomena of the positive sign kurtosis except for memory test which showed a negative sign with a value of (-0.44) but this value is considered a very low value so it tends to take the shape between normal and flat kurtosis. From this point we concluded even not from the graph that since the mean and mode had a significant different value, so the distribution cannot be normal distribution, because normal distribution had a specific characterisation in which mean, mode and median are all equal. Since the graph is skewed and the number of trials is fixed. hence, we can conclude that this distribution is Bernoulli type distribution, Bernoulli type has two types of distribution Binomial and negative Binomial. Binomial means when number of trials is fixed while number of success is a random variable, while Negative Binomial is when number of success is fixed and number of trials is a random variable. so, in our tests here the number of trials is fixed, and the outcome is random variable that is independent.

Then, after this we began to preform data analysis based on the Gender in which we concluded number of percentages of Males and Females who scored low, medium , high values among each test , we concluded that by using this method we can compare between Male and Females in each test, after this we began to compare Age factor among the females and males results for also the four test.in which it was found that the age factor had played an important role to observe more different approaches for the tests for example in the memory tests where that results that were out of the range were belong to people aged between 50 to 63.

At the end , those results and conclusions obtained from data analysis performed is then used to better management of the operators such as an operator could be to memorize the procedures when performing the task very well but he have a poor Precision skill in this matter it is recommended to allocate the operators based on their capabilities , a period range of time is required which is approximately three months relevant to observe the changes done in Quality trends , also some other factors should be taken in consideration such as , the type of contract of the operator , physical and mental world load ,ergonomics , all of these factors could play a role to have an effect on operator's performance. Also, observing the safety measures will be concluded in the monitoring process. In addition, observing the safety measures will be concluded in the monitoring process, in fact the primary results of the test were satisfying, the quality trends were positive as the human error decreased as a confirmation of the last procedure of the Human Performance (HP) model.

This empirical approach could be restructured in order to fit and to be applied in any other engineering discipline for example activities that requires maintenance or discontinues operations in oil and gas industry.

References

[1] T. A. R. H. L. M. J. F. Baines, “Towards a theoretical framework for human performance monitring,” vol. 13(6), p. 451–524, 2005.

[2] M. C. L. D. S. D. ,. G. B. a. F. M. Lorenzo Comberti, “ An empirical approach to workload and human capability assessment in manufacturing plant,” TORINO, 2016.

[3] M. Govindaraju, “utminers,” University of Cincinnati, Cincinnati, Ohio, USA, [Online]. Available: http://utminers.utep.edu/apennathur/papers/ergoinmanufac/qualityhumanperfor.pdf. [Accessed 7 4 2019].

[4] M. C. B. B. J. B. R. D. C. R. A. H. B. J. Manyika, “Big data: The Next Frontier for Innovation, Competition, and Productivity.,” McKinsey Global Institute,, 2012.

[5] S. C. BOMMER, “A Theoretical Framework for Evaluating Mental Workload Resources in Human Systems Design for Manufacturing Operations,” Wright State University, USA, 2016.

[6] M. C. L. Micaela Demichela & Lorenzo Comberti, “A multi-discipline method to assess the human performance in manufacturing industry for safety and quality optimization,” Safety and Reliability – Safe Societies in a Changing World, 2018.

[7] P. A. S. De Felice F., “Multi-criteria risk analysis to improve safety in Manufacturing systems,” *International Journal of Production Research,* Vols. 50,17, pp. 4806-4822, 2012.

[8] A. P. a. S. M. Fabio De Felice, “Improving Operations Performance with world class manufacturing techniques,” IntechOpen, Cassino, 2015.

[9] P. A. De Felice F., “Methodological Approach for Performing Human Reliability and Error Analysis in Railway Transportation System,” *International Journal of Engineering,* vol. Vol.3 (5), pp. 341-353, 2011.

[10] T. S. B. a. O. Benedettini, “Modelling human performance within manufacturing systems design: from a theoretical towards a practical framework”.

[11] P. A. De Felice F., “Hierarchical model to optimize performance in logistics policies:,” in *The 8th International Strategic Management Conference.*, 2012.

[12] P. B. C. D. F. G. H. D. I. P. J. Dennis Attwood, “HUMAN FACTORS METHODS FOR IMPROVING PERFORMANCES IN PROCESS INDUSTRIAL,” American Institute of Chemical Engineers, New Jersey, 2007.

[13] “International Symposium on Hazard Identification and Risk Analysis, Human Factors and Human Reliability in Process Safety,” Center for Chemical Process Center, 1992.

[14] J. Reason, Human error, CAMBRIDGE: CAMBRIDGE , UK, 1990.

[15] M. S. (. Bogner, Human error in medicine, Hillsdale,NJ: Lawrence Erlbaum Associates., 1994.

[16] “Importance of Human Factors in Quality Improvment,” Wright State University, 2006.

[17] B. Baine T.S., “Modelling human performance,” *Journal of SImulation volume 1,* vol. 1, p. 121–1306., 2007.

[18] B. R. a. E. P. (2000), “Tinkering with technology: Human factors, work redesign, and professionals in workplace innovation.,” 2000.

[19] A. L. H. L. M. J. F. S. a. K. J. (. Baines TS, “Towards a theoretical framework for human performance modelling within manufacturing systems design,” 2005.

[20] B. Baine T.S., “Modelling human performance within manufacturing systems design: from a theoretical towards a practical framework,” SW, 2007.

[21] C. A. (. J. W. &. Sons, “Simulation of Manufacturing Systems,” New York, 1998.

[22] W. Z. JunPing Wang, “Industrial Big Data Analytics: Challenges,Methodologies, and Applications,” IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING, 2018.

[23] B. A. a. A. Hobbs, “Design, Development, Testing, and Evaluation:Human Factors Engineering,” NASA, USA, DEC 2006.

[24] kilbo, “Industrial Research and development corporation,” Sweden, 2001.

[25] G. Mishev, “Analysis of the Automation and the Human Worker Connection between the Levels of Automation and Different Automation Concepts,” Department of Industrial Engineering and Management, Jönköping, Sweden, 2001.

[26] M. W. Jörgen Frohm, “Levels of automation in manufacturing,” ResearchGate, 2008.

[27] “PetroWiki,” 2015. [Online]. Available: https://petrowiki.org/Levels_of_automation.

[28] M. Rouse, “what is,” DEC 2012. [Online]. Available: https://whatis.techtarget.com/definition/skewness. [Accessed DEC 2012].

[29] N. R. P. I. M. D. Hong K., “Human Factor and Ergonomics in Manufacturing,17,” 2007.