Welding and Installation of Underground Pipes using Horizontal Directional Drilling (HDD)

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Abstract

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This paper studies the process undertaken in evaluating and enhancing the quality of a service relevant to a large-scale project. The paper scope covers the welding and installation of underground pipes using Horizontal Directional Drilling (HDD). The paper highlights the different quality control tools utilized in the relevant quality assessment; such as, the cause-and-effect diagram, the Pareto analysis, and the process flowchart. The analysis continues with a Statistical Process Control (SPC) study focusing on generating control charts and determining the process capability. After problem identification, both corrective and preventive actions are suggested and explained clearly as two main categories of continuous improvement. Finally, the paper is concluded with a quality cost analysis, occupational health and safety considerations, as well as brief summary including the proposed implementation plan.

Keywords: Horizontal Directional Drilling, Pareto, process flowchart, Statistical Process Control, process capability, continuous improvement.

1. Introduction:

The service project undertaken by Heliopolis Electric Co. subcontractor aims at welding and then installing underground High-density Polyethylene (HDPE) pipes of a length of 470m and an outer diameter of 280mm at a specific area beneath a water channel between Bahia and Saadiyat in Abu Dhabi. These underground pipes have physical and chemical properties to protect high voltage cables that will be pulled inside after pipes installation. The agreed-upon duration of the project is 72 days from the day of its commencement. However, the work has taken more than 200 days so far due to arising quality and safety considerations.

In order not to disturb the water channel crossing with excavation work for pipes installation, the latest advanced technology of Horizontal Directional Drilling (HDD) is used instead. HDD is a steerable trenchless method of installing underground pipes and cables in a shallow arc along a prescribed bore path by using a surface-launched drilling rig [1]. It eliminates the need to cut roads, reduces construction time and cost, and is environmentally friendly compared to the traditional trenching methods.

A well-planned HDD operation includes preliminary survey of the bore path area concerning other existing lines and the soil condition . The choice of the drilling unit depends upon the bore length, the diameter of the pipe to be installed, and the soil quality. Site operation starts with drilling of the pilot bore from the surface on one side of the obstacle to be crossed; the water channel in this project. Then, drilling continues along a designed profile below and beyond the obstacle to exit at the surface on the other side.

A pilot bore is launched from the surface at an angle between 6 and 15 degrees to the horizontal and transitions to horizontal as the required depth is reached. A bore path of very gradual curvature or near straight alignment is normally followed to minimize friction, which in turn minimizes the chance of getting the pipe string hung up in the soil or damaging the pipe string [1].

The next stage is the reaming of the pilot bore to a diameter sufficiently large enough to accept the pipeline. This is done by pulling back increasingly larger reamers, or reaming heads, from the pipe exit pit to the entry pit. It may be necessary to perform several reaming operations to achieve the appropriate bore path size.

Finally, the HDPE pipe is attached to the reamer using a swivel – a device that isolates the pipe string from the rotation of the HDD drill pipe. As in *Figure 1* below, the pipe is then pulled behind the final reamer back through the horizontal directional drill path (back reaming).

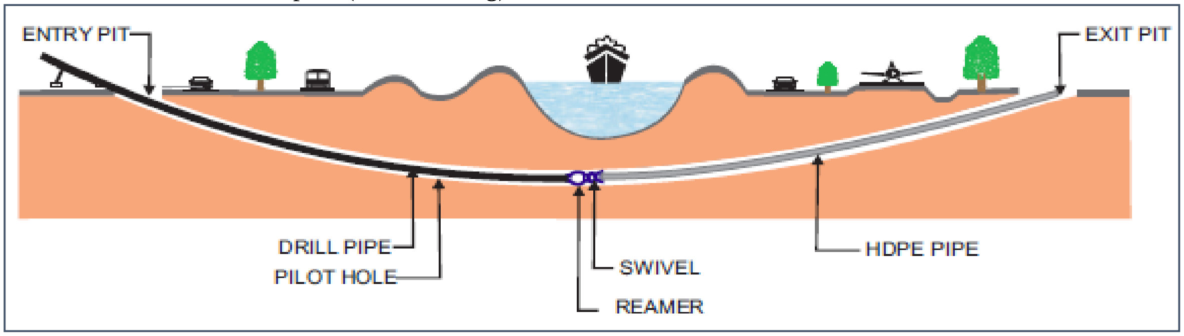

Figure (1): Pulling in the pipe [3]

Horizontal Directional Drilling is done with the help of a viscous fluid known as the drilling fluid. It is a mixture of water and usually bentonite continuously pumped to facilitate the removal of cuttings, stabilize the bore hole, cool the drill cutting head, and lubricate the passage of the product pipe [1]. Drilling fluids hold the cuttings in suspension to prevent them from clogging the bore. A clogged bore creates back pressure on the cutting head, slowing production.

A very important stage of work before pipes can be pulled through the drill path is the welding operation. Welding is done in several phases and by using several parameters. First of all, the welding zone must be protected from unsuitable weather conditions, and the surfaces to be joined must be undamaged and free from impurities or loose particles. The pipes must be aligned when they are clamped into the welder in such a way that the surfaces are parallel to each other.

Shaving of surfaces is the next phase of welding; the shaver is introduced, turned on, and adjusted to suitable speed. It can be stopped only after a continuous strip of HDPE is peeling off on both sides of the shaver; otherwise, it will create an end cut-mark and the shaving operation will have to be repeated [2]. After shaving is complete, the pipes must be realigned and all the chips scattered around must be cleaned.

After that, the heat of the mirror (heating plate) is adjusted to reach the working temperature and the pipes are pushed together against it. The pressure is then raised to a certain limit then released down for a period of time after which the mirror is removed and the pipes are pressed together in a phase called fusion of surfaces. This operation has to be done quite fast since there is a time limit from the removal of the mirror until the two pipes are pressed together reaching the fusion pressure. Finally, the resulting joint has to be left undisturbed for a period called the cooling time during which the fusion pressure must be maintained. Fusion bonding occurs when the joint cools below the melt temperature of the material [2].

2. SERVICE QUALITY ASSESSMENT AND PROBLEM IDENTIFICATION

The problem in brief:

The main problem occurred after finishing the HDD Reaming, and during the Pipe Pulling operation in the reaming hole, before the pipes reached to the exit pit, the HDD Operator suddenly found a loss in the load (That mean there is a broken in the pipes or in the pulling accessories).to locate the broken pipes it required to excavate a pit of 7 meters deep, finally after the investigation been done we realized that the issue occurred in the pipes welded joints due to the non-conformance to the correct pipe welding procedures. This along with other issues also led to the project non-conformance to the contract.

2.1 Causes-and-Effect Diagram (Fishbone):

Time is a key factor in the delivery of almost all services and is considered one of the major dimensions of quality in service organizations. This service project of pipe welding and installation is supposed to take 72 days but the work has been ongoing for about 7 months, which raises a question mark with respect to the quality of the service that led to the project not conforming to contract.

To explore the reasons behind this delay problem, brainstorming of all the potential causes of poor quality is a necessity. This can be facilitated by the use of a cause-and-effect diagram, which is a graphical-tabular chart used to list and analyze the possible causes of a particular given problem. Owing to its characteristic appearance, this diagram is often called a fishbone diagram. Figure 2 below is the fishbone diagram of the pipe welding and installation project, where the head of the fish is the quality problem of project non-conformance to contract. Categories relevant to the identified quality problem are Materials, Machines, Mother Nature (environmental), Men, Methods, and Management (6 Ms).

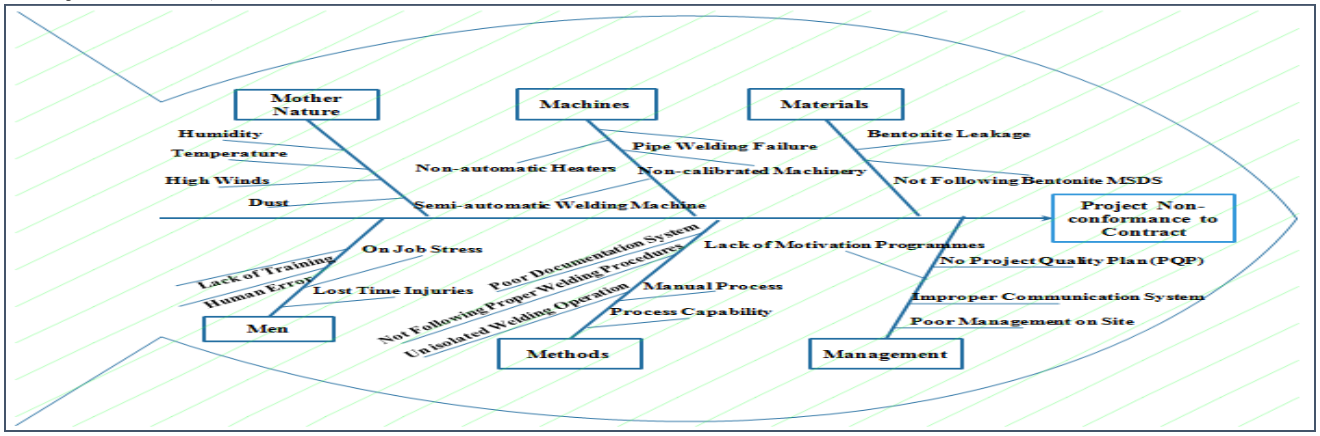

Figure 2: Fishbone diagram

2.2 Pareto Analysis:

Pareto analysis is a quality control technique used to identify problems based on their degree of importance. The logic behind Pareto analysis is that only a few quality problems are important, whereas many others are not critical. This concept has often been called the 80-20 rule stating that, for many events, roughly 80% of the effects come from 20% of the causes [3]. In quality management, this translates into the fact that most quality problems are a result of only a few causes. The trick is to identify these causes.

One way to use Pareto analysis is to develop a chart that ranks the causes of a certain quality problem in decreasing order based on their criticality. After exploring all the possible reasons behind the quality problem in the fishbone diagram, 7 issues are identified and claimed to have an effect on the project conformance to contract. One of the problems is the pipe welding failure that has occurred while pulling the pipes under the ground and which required to excavate a pit of 7 meters deep to locate the broken pipe, the broken pipe after being located and removed out of the pit. This has accounted for 50 days of delay. Two other issues are bentonite leakage and poor management both resulting in 12 days of delay. Provision of materials, transportation to alone island, safety issues, and human error are the remaining potential causes of project delay.

These problems are listed in Table 1 below on Excel along with their resulting amount of delay both in days and as a percentage. Cumulative values are listed too for the purpose of constructing a complete Pareto chart. Looking through the table, one can easily spot how critical the problem of pipe welding failure is to the quality of the project as more than 50% of the delay is due to this particular problem. Bentonite leakage and poor management come next with about 13% of the delay. However, a Pareto chart is needed to give a better visualization of how the values stated in the table are compatible with Pareto's principle or the 80-20 rule.

Table 1: Pareto table of problems affecting project conformance to contract

Why Did The Service Project Take 7 Months Instead Of 72 Days?				
Problem	**Amount of Delay (Days)**	**Percentage Amount of Delay (%)**	**Cumulative Amount of Delay (Days)**	**Cumulative Percentage of Delay (%)**
Pipe Welding Failure	50	53.76	50	53.76
Bentonite Leakage	12	12.90	62	66.67
Poor Management	12	12.90	74	79.57
Provision of Materials	8	8.60	82	88.17
Transportation to Alone Island	5	5.38	87	93.55
Safety Issues	4	4.30	91	97.85
Human Error	2	2.15	93	100.00
Total	93	100.00	539	100.00

Figure 3 below is the Pareto chart constructed based on the values listed in the Excel table. It illustrates that out of the 7 potential causes of delay, only the first 3 problems account for 79.57% of the delay – the thing that complies with the 80-20 logic behind Pareto analysis.

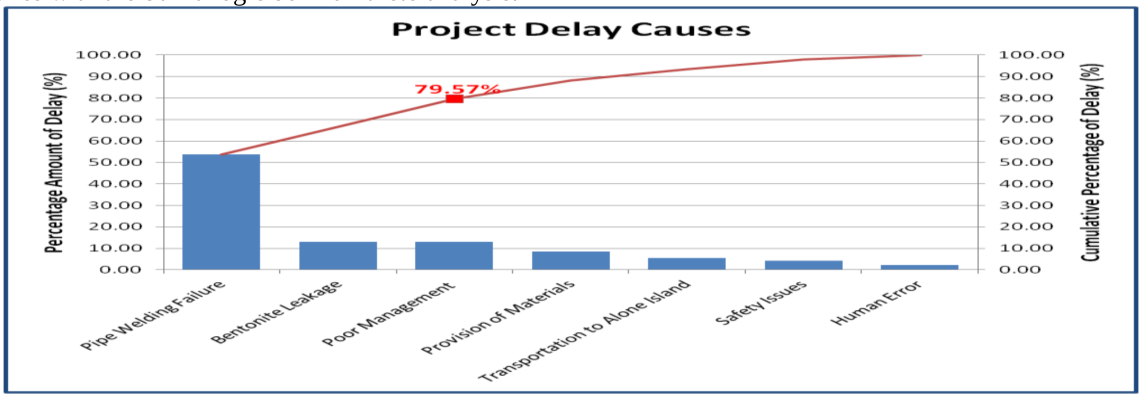

Figure 3: Pareto chart

2.3 Process Flowchart

As illustrated previously in the conducted Pareto analysis, the most critical cause of project non-conformance to contract is the pipe welding failure. Therefore, a considerable amount of attention should be given to this issue in particular. According to the concepts of Total Quality Management (TQM), a quality product or service comes from a quality process. This means that quality issues should be sought in the process, and quality solutions should be built into the process – a concept usually referred to as Quality at the Source. It is the belief that it is far better to uncover the source of a quality problem and correct it than to try to figure out a solution for the problem after it occurs.

The current process of pipe welding starts with alignment of the pipes to be welded and shaving of the parallel pipe surfaces. The current shaving operation is not isolated from dust and other environmental contaminants, so the setting is not totally free from loose particles even after cleaning. After that, the mirror is introduced for the purpose of heating the pipe surfaces and its heat is manually adjusted, which requires the welder to be very cautious until the working temperature is reached. Then, the pipes are pushed together against the mirror also manually – the thing that may introduce dust or dirt from the hands of the welder onto the pipes. This is followed by the fusion of surfaces phase after removing the mirror, which should be done by the welder very fast. Finally, the welded joint is left to cool down and the current operation is also not isolated in a tent or a container, so cooling time may be an issue due to the surrounding weather.

In visualizing the sequence of steps involved in an operation or a process, a flowchart is a useful quality control tool that is easy to use and understand. Figure 4 below is the flowchart of the current pipe welding process. The oval shapes mark the start and end steps in the process while the rectangular shapes with red borders signals an identified issue that needs to be looked at and corrected.

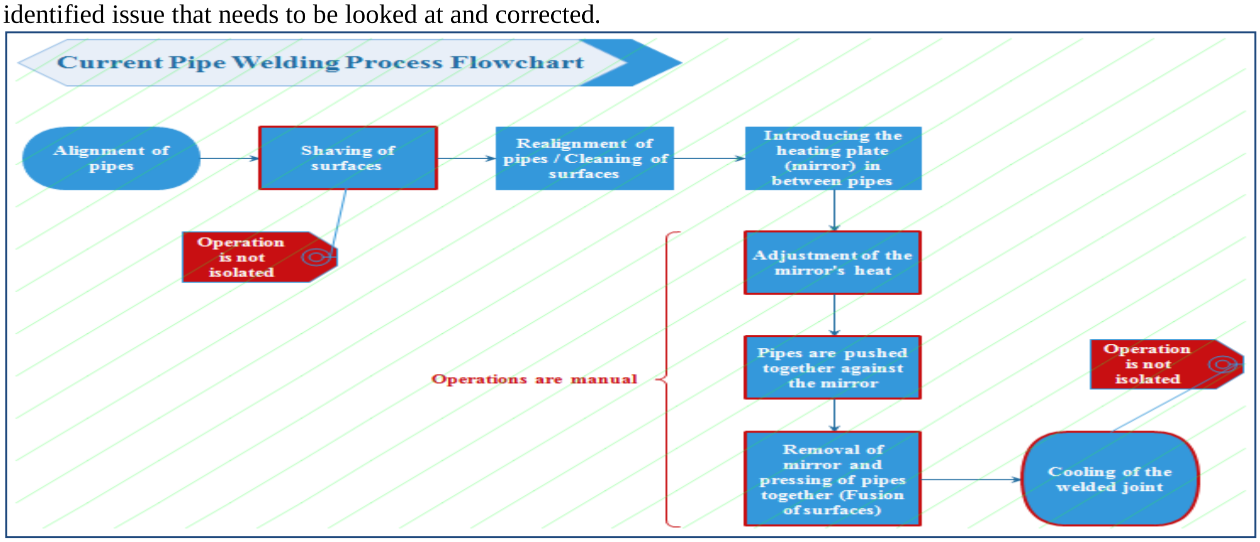

Figure 4: Flowchart of the current pipe welding process

2.4 Quality Characteristics and Statistical Process Control (SPC):

Statistical Process Control (SPC) is a statistical tool that involves inspecting a random sample of the output from a process and deciding whether the process is producing with characteristics that fall within a predetermined range. It answers the question of whether the process is functioning properly or not. SPC tools are used most frequently because they identify quality problems during the production process matching TQM's concept of Quality at the Source.

Every product or service has a number of quality characteristics that can be measured statistically in order to arrive to a conclusion regarding the process functionality. These characteristics can be divided into two groups: variables, and attributes. A variable is a characteristic that can be measured and has a continuum of values, whereas an attribute is a characteristic that has a discrete value and can be counted. The monitoring of attributes usually takes less time than that of variables because a variable needs to be measured while an attribute requires only a single decision. In this project, 4 variables and 1 attribute are picked to be analyzed statistically. The variables are related to the pipe welding process and they include thickness of joints, width of joints, the maximum load capacity of joints, and the joints' tensile strength. The attribute is the number of weekly client complaints over 7 months. Table 2 below shows these 5 quality characteristics along with their upper and lower specification limits. It is worth to mention here that joint specifications are taken from ISO 4427:2007 polyethylene pipes requirements in part 2 of the standard.

Table 2: Project quality characteristics [7]

Quality Characteristic	Type	Unit of Measurement	LSL	Target	USL
Thickness of Joints	Variable	mm	24.00	26.00	28.00
Width of Joints	Variable	mm	24.80	25.00	25.20
Maximum Load Capacity of Joints	Variable	N	16000	16500	17000
Tensile Strength of Joints	Variable	MPa	24.00	25.00	26.00
Number of Pipe Failure	Attribute	No. / Week	/	0	/

Using statistical process control, the amount and type of variation in the process is determined so that it can stay within the normal range. Variation in the process can be due to two types of causes: common or random causes of variation, and assignable causes of variation. Random causes of variation are those that cannot be identified as they are unavoidable and are due to slight differences in processing. The second type involves variations where the causes can be precisely identified and eliminated, such that we can assign the variation to a particular cause then we can correct the problem.

The most commonly used tool for monitoring a process is the control chart, which is a graph that shows whether a sample of data falls within the common or normal range of variation. Control charts usually monitor the process stability, which refers to the consistency of the process with respect to important process characteristics like the average value of a key dimension or the variation in that key dimension. If the process behaves consistently over time, then we say that the process is stable or in control. A control chart has upper and lower control limits that separate common from assignable causes of variation. A process is said to be out of control when a plot of data points reveals that one or more points fall outside the control limits, and then it is attempted to identify the cause of the variation and correct it. Different types of control charts are used to monitor different aspects of the process. For instance, the mean (x-bar) chart measures the central tendency of the process while the range (R) chart measures the dispersion or variance of the process figure 5.

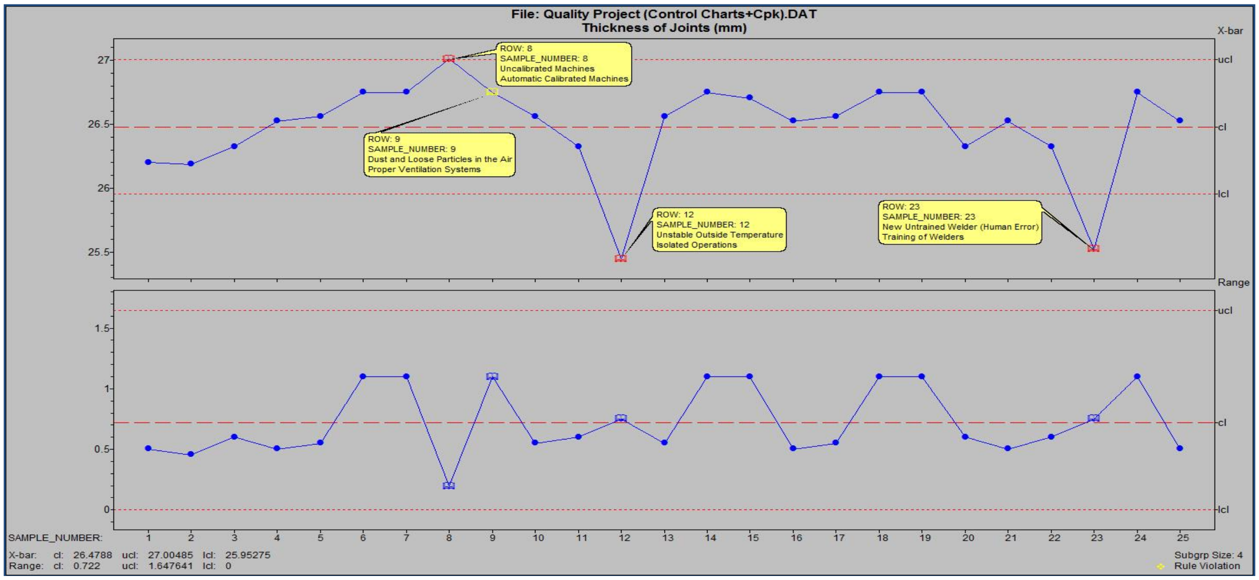

Figure 5: X-bar chart and R chart for the thickness of joints variable

3. SERVICE QUALITY IMPROVEMENT PLAN:

This chapter discusses the team's proposed solutions to the project quality issues stated in advance based on the quality assessment conducted earlier. The suggested continuous improvement plan is divided into two main parts: Corrective Action, and Preventive Action (CAPA) which are improvements to an organization's processes taken to eliminate causes of non-conformities or other undesirable situations.

3.1. Corrective Action

Corrective actions focus on the systematic investigation of the root causes of identified problems in an attempt to prevent their recurrence. They are implemented in response to customer complaints, unacceptable levels of non-conformance, or unstable trends in process monitoring that could be identified by Statistical Process Control (SPC) [4]. In this service project, SPC has shown that variation in a number of quality characteristics is due to assignable causes that have been identified. Some corrective actions have also been mentioned briefly in the previous chapter, but they are explained in details below.

3.1.1 The Application of the USA Principle of Automation

According to the Quality-at-the-Source concept mentioned before, the very first efforts of quality improvement should be focused on the process of interest. The current process of pipe welding, which is found to be affecting the project progress the most, has some critical steps carried out manually and this is anticipated to impact the process negatively. For example, the mirror's heat is adjusted manually and the current machine is not calibrated to reach the target working temperature, which is not compatible with ISO 9001:2008 calibration and maintenance requirements in section 7.6 of the standard stating that *"Un-calibrated equipment should be pulled from product or engineering and kept in a controlled area until it can be calibrated."*. Also, the pushing and pressing of pipes at later stages needs to be done both fast and in a timely manner for having properly-welded joints, and this is done manually too indicating a high likelihood of experiencing human error.

The analysis of these operations has led to the feeling that an automated process is needed to replace manual work, so the USA principle is suggested to be applied. The ***USA*** principle is a commonsense approach to automation projects. It stands for three steps in the analysis and design processes [5]:

1. ***U****nderstand* the existing process.
2. ***S****implify* the process.
3. ***A****utomate* the process.

The purpose of the first step in the USA principle is to understand the current process in all of its details and search for weaknesses and opportunities for improvement. Once the existing process is understood, then the search begins for ways to simplify it. This includes the possibility of removing unnecessary steps in the process or combining several steps together [5]. Simplifying the process may lead to the conclusion that automation is not necessary, thus saving the significant investment cost that would be entailed. Finally, when the process has been reduced to its simplest form, automation can be considered following a number of available strategies that provide a road map to search for improvement [5].

In this particular project, the welding process has been understood, simplified, and found ready to be automated. Therefore, a proposed solution to the aforementioned critical issues is to hire new full-automatic welding machine with a calibration certificate from the pipe manufacturer. It is expected that the human error would be reduced, if not eliminated, and the process would result in joints whose characteristics would be within specification limits and would match ISO 4427:2007 polyethylene pipes requirements in part 2 of the standard.

3.1.2 Isolated Pipe Welding Operations

The current process of pipe welding is carried out outdoors, which means that the welding machine, the pipe joints, and the hands of the welders are all exposed to dusts and other loose particles in the air. This has a negative impact on the process itself and, as a result, on the reliability of the welded joints. Besides, a couple of critical welding phases require certain levels of stable temperature, which cannot be guaranteed in a process directly influenced by the outside environment. Therefore, it is recommended to perform the welding process indoors in an isolated area with a proper ventilation system. It is expected the process would result in joints whose characteristics would be within specification limits, and would match ISO 4427:2007 polyethylene pipes requirements in part 2 of the standard.

3.1.3 Training of Welders

Lack of training, human error, lost-time injuries, and other safety issues are listed previously in the fishbone diagram as factors contributing to the project nonconformance to contract. Actually, poor technical competence among many welders could be identified as one of the major assignable causes of variation in the process that need to be promptly eliminated. Consequently, it is highly urged to abide by ISO 9001:2008 training requirements in section 6.2 [8] of the standard encouraging *to "Deliver training or other learning activities to develop the required knowledge and skill."*

3.1.4 Waste Management of Bentonite

After pipe welding failure, bentonite leakage is the second problem identified by the Pareto analysis to be affecting the progress of the undertaken project. During the reaming process before pipeline installation, bentonite is continuously pumped to stabilize the bore hole, cool the drill cutting head, and lubricate the passage of the product pipe. Huge amounts of bentonite are being used (1000 packages, 50kg each) and then dumped as waste at the end of the reaming process after being dried to 20% moisture content. A permit needs to be taken from Tadweer Waste Treatment L.L.C. to hire an approved truck to dump the waste. This is all costly and requires a lot of paperwork. In addition, leakage of bentonite to the sea has been experienced throughout the period of work causing legal consequences from Abu Dhabi Environmental Agency and the risk of having the work stopped immediately. On such occasions, disposal of used materials is the least favorable option according to ISO 14001:2004 waste management requirements [9].

It is therefore suggested for the company to purchase a recycling machine to reuse the bentonite instead of dumping it as waste. It is true that this machine is costly, but the cost of dumping the whole bentonite waste after usage is much higher. Besides, this solution would result in a very small amount of residual bentonite waste, which would make the process environmentally friendly. It is actually not advisable for any company to ignore the business risks resulting from the poor environmental performance because this would not only cost money but also the loss of reputation and credibility.

3.2. Preventive Action

Preventive actions focus on the systematic investigation of the root causes of identified risks in an attempt to prevent their occurrence. They are implemented in response to the identification of potential sources of non-conformity [4]. For future contracts of similar projects, two preventive actions are suggested for immediate adoption: the application of Quality Function Deployment (QFD), and the initiation of a Project Quality Plan (PQP).

3.2.1 The Application of Quality Function Deployment (QFD)

A critical aspect of building quality into a process is to ensure that the design meets customer expectations. A useful tool for translating the voice of the customer into specific technical requirements is Quality Function Deployment (QFD). QFD allows for a preventive proactive action rather than a corrective reactive action to customer requirements as it discloses aspects, problems, and issues in the design of a product or a service before they even occur – the thing that helps in performing a considerable amount of changes at early stages reducing cost, time, and resources utilized in the lifecycle of the process from the beginning until the arrival at the market.

QFD begins by identifying important customer requirements, which typically come from the marketing department. These requirements are numerically scored based on their importance, and scores are translated into specific product or service characteristics. Evaluations are then made of the how the product compares with its main competitors relative to the identified characteristics. Finally, specific goals are set to address the identified problems. The resulting matrix looks like a picture of a house and is often called the house of quality. *Figure 6* below is the house of quality generated for this project.

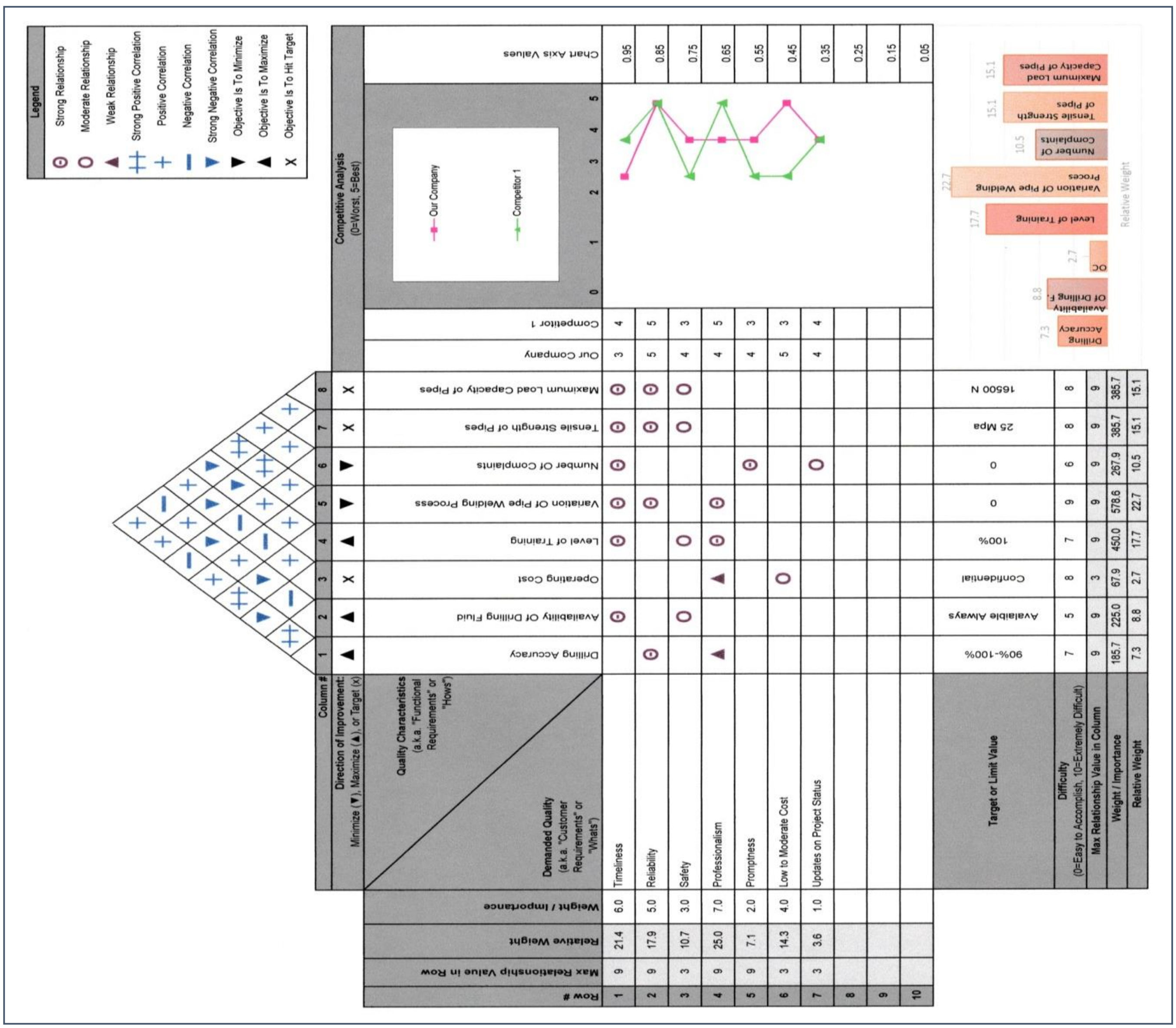

Figure 6: QFD house of quality of the service project

3.2.2 The Initiation of a Project Quality Plan (PQP)

A Project Quality Plan (PQP) is a project-specific quality plan that describes the activities, standards, tools, and processes necessary to achieve quality in the delivery of a project. It aims at establishing quality assurance and quality control procedures in line with the project's contractor scope of work. PQP is a suggested important action because it demonstrates how the organization's Quality Management System (QMS) applies to a specific project, and how quality requirements will be met. It actually increases confidence that customer requirements will be fulfilled, and provides insights into future opportunities of improvement.

As per the requirements of ISO 9001:2008, the structure of a PQP consists of 7 major sections; project scope, quality objectives, management responsibilities, control of documents, resource management, communication, and design and development. Some projects may also add purchasing, control of design change, identification and traceability, control of non-conforming products, monitoring and measurement, and audits.

4: CONCLUSION

This chapter concludes the report with a quality cost analysis of the studied service project as well as some beneficial health and safety considerations. A brief summary including the team's proposed implementation plan is provided too.

4.1 Quality Cost Analysis

Quality affects all aspects of the organization and has dramatic cost implications. The most obvious consequence occurs when poor quality creates dissatisfied customers and eventually leads to loss of business. However, quality has many other costs that can be divided into two categories. The first category consists of costs necessary for achieving high quality called quality control costs, which are prevention costs and appraisal costs. The second category consists of the cost consequences of poor quality called quality failure costs, which are internal failure costs and external failure costs.

Prevention costs are all costs incurred in preventing poor quality from occurring. They include quality planning costs, the costs of product and process design, employee training costs, and the costs of maintaining records of information and data related to quality. Appraisal costs are incurred in the process of uncovering defects. They include the costs of quality inspections, product testing and performing audits to make sure that quality standards are being met, as well as the costs of worker time spent measuring quality and the costs of equipment used for quality appraisal.

Internal failure costs are associated with discovering poor product quality before the product reaches the customer site. They include rework, scrap, the costs of machine downtime due to failures in the process, and the costs of discounting defective items for salvage value. External failure costs are associated with quality problems that occur at the customer site. They include everything from customer complaints, product returns, and repairs, to warranty claims, recalls, and litigation costs resulting from product liability issues. A final component of this cost is lost sales and lost customers. Figure 7 below shows these 4 types of cost as incurred throughout the period of the project.

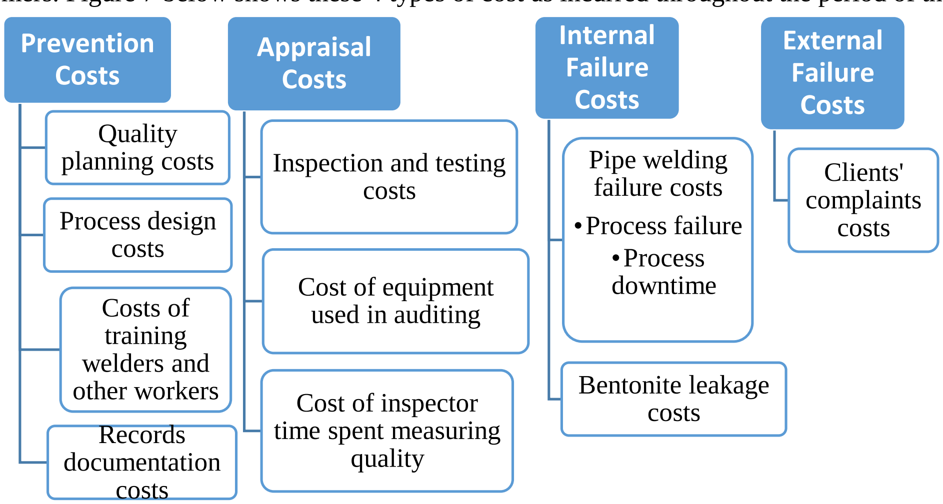

Figure 7: The 4 types of cost incurred throughout the period of the project

4.2 Occupational Health and Safety Considerations

Quality of almost all products and services cannot be completely addressed without paying attention to issues related to health, safety, and environmental aspects of the relevant processes. Actually, occupational health and safety is a very broad field, and organizations may have viewed it in the past as being too complex or difficult to do anything about. However, many attempts have arisen to overcome such fears especially with the widely-spread ideas of quality management.

Lost-time injuries, human error, and other safety issues have been previously listed in both the fishbone diagram and the Pareto chart as factors affecting the project conformance to contract. This raises a flag with regard to the need of careful consideration and prompted actions in order to promote a positive health and safety culture. OHSAS 18001 is an internationally-applied British standard for occupational health and safety management systems that all organizations should comply with in order to control and improve their health and safety conditions.

In fact, human error can be considered the major factor influencing both the lost-time injuries and the other safety issues. Human factors revolve around job and organization factors as well as human and individual characteristics which influence behavior at work in a way that can have a considerable impact on people's health and safety. As illustrated in Figure 8, the realization of these three aspects (job, individual, and organization) invokes thinking of the job task and its characteristics, the individual and his/her competence, as well as the organization and its attributes. It also involves addressing such factors in risk assessment, during accident investigation, in design and procurement, and in daily operations.

Careful consideration of human factors at work can reduce the number of accidents occurring through people's involvement with their work. People are involved throughout the lifecycle of an organization from design through to operation, maintenance, management, and demolition. As technical systems have become more reliable, the focus has turned to human causes of accidents. This is one of the reasons why human factors are important aspects to pay attention to at the workplace.

Not only does work have an impact on people's safety but also on their health. Physical health problems can result from lost-time injuries like slips and falls, and from manual handling problems. Mental well-being can be affected if someone suffers bullying or violence, or experiences stress at work. Therefore, taking care of human factors can reduce the cases of occupational ill-health. A positive work experience contributes to physical and mental well-being. Well-designed tasks and working environments can help too.

After an accident involving human error, there will often be an investigation into the causes and contributing factors. Finding out both the immediate and the underlying causes of an accident is the key to prevent similar occurrences in the future through the design of effective control measures. Examples of causes and factors of human error are given in Figure 8 below.

Job	• Missing or unclear instructions • Poorly-maintained equipment • High workload
Individual	• Low skills and competence levels • Tired or bored staff • Individual medical problems
Organisation and Management	• Lack of safety systems • Poor health and safety culture • Inadequate responses to previous incidents • One-way communications

Figure 8: Causes and factors of human error

4.3 Summary and Proposed Improvement Implementation Plan

This report provides a detailed quality assessment of the undertaken service project that covers the welding and installation of underground pipes using Horizontal Directional Drilling (HDD). The project is supposed to take 72 days but the work has been ongoing for about 7 months. The cause-and-effect diagram has listed all the possible causes of project non-conformance to contract classified into categories of Materials, Machines, Mother Nature (environmental), Men, Methods, and Management (6 Ms). Pareto analysis of this quality problem has shown that out of 7 potential causes of delay, only 3 problems (pipe welding failure, bentonite leakage, and poor management) account for about 80% of the delay. The pipe welding process has been investigated via a process flowchart signaling the areas of weakness that need to be looked at; these include manual operations, and un-isolated work setting. Then, quality characteristics of the service project have been identified, and statistical process control has been applied monitoring both the stability and the capability of the studied processes.

One suggested corrective action lies in the application of the USA principle of automation through hiring new full-automatic welding machine with a calibration certificate from the pipe manufacturer. Other corrective actions are to perform the welding process indoors in an isolated area with a proper ventilation system, and to equip welders with the necessary training. Last but not least, a proper waste management of bentonite is recommended by purchasing a recycling machine to reuse the bentonite instead of dumping it as waste. Preventive actions revolve about the application of Quality Function Deployment (QFD) and the initiation of a Project Quality Plan (PQP).

Cost analysis at the end of the report describes 4 types of cost as incurred throughout the period of the project. These are prevention costs, appraisal costs, internal failure costs, and external failure costs. The analysis suggests that a considerable amount of money could have been saved if preventive actions had been carried out at early stages of the project. Finally, the report sheds light on human error as a major factor influencing occupational health and safety especially that is has been listed in the Pareto analysis as one of the problems affecting project conformance to contract.

As for the proposed implementation plan, it is highly recommended to combine the conducted analysis with the suggested corrective and preventive actions into a Quality Management System (QMS) to be adopted by the company and built on when necessary. A quality management system is a collection of business processes focused on achieving quality policy and quality objectives to meet customer requirements. It is expressed as the organizational structure, policies, procedures, processes and resources needed to implement quality management. Elements of a QMS usually include quality policy, quality objectives, quality manual, organizational structure and responsibilities, data management, processes including purchasing, product quality leading to customer satisfaction, and continuous improvement including corrective and preventive actions. Top management should be involved and committed to the correct implementation and following of this proposed QMS. As continuous improvement requires that the company continually strive to be better through learning and problem solving, one beneficial tool that can assist in that is the Plan-Do-Check-Act (PDCA).

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Biography

Dr. Basel Alsayyed is an assistant professor at the department of mechanical engineering in the United Arab Emirates University. With over 16 years of experience in academia in many colleges and universities, and over 12 years of industrial experience, most of which are in the American automotive industry, Dr. Alsayyed has a passion for education in general and teaching in particular. Teaching is an art, a trust, a valuable transformation of students using certain methods and tools, and it is holy, are all part of his belief. He practices it in all aspects of his life, and to Dr. Alsayyed, students are the most valuable element in the education process; their needs have to be addressed in any continuous improvement discussion of the education process. Integration of academia and industry goals and activities are paramount. Sensing the industry needs and prepare future engineers to meet the challenges is an important dimension of Dr. Alsayyed’s activities. Dr. Alsayyed research interests are in the areas of advanced manufacturing, quality & reliability, renewable energy, engineering education and knowledge management.