"Enhancement in NDT Inspection for Operational Effectiveness, Efficiency & Excellence"

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Abstract

In previous report, "End of the Paradigm of Quality Vs Production with NDT Inspections 4.0", there was an approach to show a way to help out to align all project stakeholders in the same direction to avoid disruptions & deviations that, nowadays, come from Project's Quality requirements.
It was exposed that *Quality* should become a management & financial tool that will boost or aid a project in alignment with company's strategies and immediate targets. To manage it, a small twist in actual Inspection Services shall be introduced.

However, it becomes evident that the potential client, although can see and understand the potential improvement, can believe that an added value carries cost increments and, therefore, under dynamic competitive business, performing the change can be, at short term, harmful.

In this document, we intend to show that any change shall be linked, not only to improvement, but also to immediate cost reduction so that all management structure can conceive quick implementation as part of its department strategy & enhancement in their budget cost.

For that, concepts such as *effectiveness*, *efficiency* and *excellence* must be approached. We will give *clear* saving cost ways which will follow the terminology.

In *Financial* terms and without a deep analysis, we can confirm cost savings above 30% from current prices are achieved.

1 Introduction

Many companies are moving into what is called *Industry 4.0*. Vast amount of capital resources are invested. We do not have any argument against this type of industry, certainly it is the future. It is evident.

However, we question whether or not this capital is rationally invested. Many companies, mainly management, have accommodated investments based on what the market is leading on rather than on what the company needs. In the near future, we will read news on companies that will bankrupt because their bet was reckless and they couldn't pass these investments on to the final consumer. And energy companies, even though they are strong, are not immune to these decisions.

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As a recent example, Abengoa used to have an average ROE above 20% just nine years ago, today has announced that is signing for bankruptcy. Since 2015, it has been surviving with governmental subsidies through banking alliances, but now the game is over.

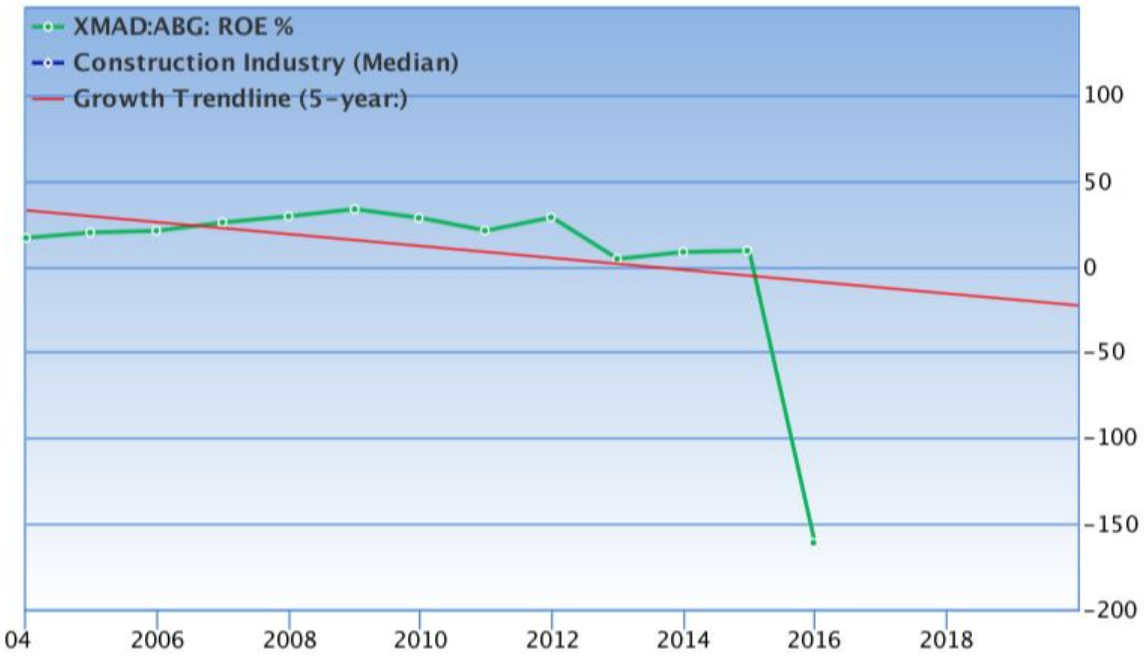

Figure 1: Abengoa ROE % time series

A company which had in 2014 over 25 billion in assets and, just now, at bankruptcy signing, only three billion in assets and 7.8 billion in liabilities. It seems that something went seriously wrong.

Why to start this document with this? Basically, no one would have bet money against this company five years ago. It is the idiosyncrasy of energy companies.

Just like transport & mining industries, these type of industries have got such magnitude that they tend to confuse people. Including their own employees. Economic history is full of companies that were big and, due to market disruptions, they die away or they barely survive because they were not able to overcome their inefficiencies created by those disruptions. Some of them were too naïve to believe in the disruption, others joined too late when the damage was done, and others joined without real acknowledgement of what, how and why they had to invest in the new disruption. They just simply did but they never really studied how the disruption had to fit in their structures.

A company's magnitude is determinant for disruptions. As per previous example[1], any company that is based on many employees, any change in rule's market is not reflected immediately. It can take years before the impact can be observed. And it is normally an abrupt change due to panicking.

Have companies learnt anything from others falling? We can say that not much. Years with great financial strength are used to premium shareholders with high dividends, or used the free cash flow to buy back shares, project acquisitions, etc. Basically, all wrong. They are more political movements rather than business. These operations should only be done after thorough studies in possible impacts which can come from disruptions. Some companies, such as automotive sector, understood this possible problem and they have got departments (many times under R&D acronyms) searching the market for possible trends that can impact them negatively if they do not take appropriate measures at that time. Thus, we can see in expositions how these type of companies show *futuristic* products. They are not. They are

[1]But other companies such as Kodak, Nokia, Blackberry can be used as example

presented to show investors that the company is ready to any small changes in market trends[2].

One may say that many big companies have got R&D departments but, and it needs to point out, these departments just focus on better performance or optimization of actual products and not new tendencies.

Energy companies, including their subsidiaries, can be financially strong. With a high Net Incomes but many times with high operational costs if they do not target these last ones, they will always have high dependency on market prices. When these prices are high, as their Net Incomes are positive and large and the market expectancy is positive, they tend to overlook them. Many factors, some of them more personal than business related, can be blamed on to act doing this overlooking.

However, it is precisely during positive economic cycles when a company should try to work out now for future downturns. Because, regardless company strength, those days will come. It is the work done ten years before downturn what will pay the dividends in terms of business durability in the long run.

Some skeptical people will tell that companies such as Coca-Cola, Microsoft, Exxon Mobile, Google, etc., are always growing. It is true but..., they keep surviving because they design their trajectory considering potential disruptions. The way Coca-Cola works today is way different that it was 30 years ago. If Microsoft survived to *Steve Balmer* CEO was due its huge market cap, but if he would have been kept on working on that position ten more years, Microsoft would have been old history.

What we mean is that uncertainty is a fact and no one is untouchable. Not pursuing on disruptive ways will always harm in the future. However, which disruption is the right one to follow? Here, it is the vision.

The way to find out which disruption is the right one, it is to follow a rational and logical reasoning. A successful disruption is always based on a *Win-Win* game. And then, all we need to do is to follow rationally the disruption. Invest irrationally, may work but, undoubtedly, at a huge expense for the company. Basically, three main points need to be followed:

- Operational Effectiveness
- Operational Efficiency
- Operational Excellence

If the actions answer correctly this three points, the company will gain moat and will reinforce its dominant position for future downturns.

Operational Effectiveness It is about doing the right things. It revolves around making sure that all the core work done by the organization creates value to their end customer; that the core Value Stream is correctly designed. Organizational effectiveness denotes the concept of how effectively an organization achieves the outcomes it intends to produce. It's about WHAT work is done.

Operational Efficiency It is about doing things right. In other words, it means ensuring that the work flows error-free, thus preventing delays and cost increases caused by delays and rework. Or, preventing below-specification products and services reaching the customer. Operational efficiency entails the capability of an organization to deliver products or services to its customers in the most efficient manner possible, while still ensuring the high quality of its products, service and support. It's not about cost cutting — it is about HOW work is done.

[2]Among many others. Also a way to influence possible new entrepeneurs.

Operational Excellence It is an organization's value proposition to its customers; in itself, it's a strategy. An operational excellence strategy aims to accomplish cost leadership, and it proves ideal for markets where customers value cost over choice, which is often the case for mature, commodities markets where cost leadership provides a vehicle for continued growth. Operational excellence is about WHY work is done.

Given the three definitions above, it becomes clear that effectiveness and efficiency are not an option for an organization that wants to compete in its chosen way within its market. The organization should never be discussing whether they need to be effective or efficient; rather, the only discussion should be about *how to be more effective and efficient.* This conversation must encompass what work takes place, and then how.

2 Increments in Productivity and Excellence in Quality Inspection through Enhancement in Effectiveness and Efficiency: *Real Cost Savings from Minute One*

Basically, in our previous document "End of the Paradigm of Quality Vs Production with NDT Inspections 4.0", we explained briefly Operational Effectiveness & Excellence (What and Why). In some sense, it can be thought that *Efficiency* was also targeted. It is true but, from a financial point of view, it was postponed to this document.

If "Efficiency" means to increase overall project/organization cost, then we have missed the definition.

Many ideas or disruptions are highly efficient but only in engineering sense. When they mean over-proportional cost unit increment, they just derail when they face board directors meeting. In economic terms, if the increment of one additional production of quality inspection means to increase its marginal cost, then it will be very difficult that it will go through. If *efficiency* is not aligned with some financial targets as reduction on Operational Costs, the change will be basically rejected.

A private company cannot allow inefficiencies. In a competitive market, the punishment is dear.

Hence, in order to make the change explained in previous document fully efficient, we need to tackle where actual Quality Inspection is hugely inefficient. And then, working out that specific point so we can meet where the disruption can be paid off.

We did mention that 50% of inspection time is based on unskillful activities. Time before introduction of advanced NDT technologies and massive use of internet, there was not much that we could do to improve such unskillful time. Changes were not justified considering the costs involved. Then, clients had to sacrifice excellency for productivity. Quality was compromised, but something was performed. To overcome this inefficiency, overengineering structures have been built all over the world. Examples of this can be found in shipping, Oil & Gas offshore structures and nuclear power stations which are consistently under life span extensions.

The implementation of state-of-art advanced NDT techniques without a doubt increases excellency and effectiveness, but it lacks in efficiency due to its high price compared to conventional NDT techniques. Hence, it is obvious why markets (including O&G) tend to use only advanced techniques when operational excellence is a must, otherwise they tend to select the cheapest NDT techniques. However, this happens because advanced NDT techniques are not really targeting client's financial saving costs, but only engineering efficiencies.

They keep same inefficiencies that burden conventional techniques, and enhancements that can produce these new technologies are not fully used or understood. Under this premise, will advanced NDT techniques fully substitute conventional techniques?

The answer is *NO*; basically because they only target Quality Engineering. They completely forgot one main premise: "A project is *Economy*". A Board Director, Project Manager, CFO, CEO, Financial Manager and so on, know that perfectly. There is a budget and a target.

But, what will happen if we target NDT inefficiencies? Can, then, advanced NDT techniques make up for their costs changing the Quality Inspection to become fully efficient?

The answer is a big *Yes*. Even more, the overall inspection campaign should cost less than using conventional techniques, as we will see.

There are several ways to achieve this statement.

Site NDT Inspections : Let's break down the daily activities of an NDT company:

- Toolbox and scope of work meeting
- **Equipment Calibration**
- Permit to work
- Data Collection
- Equipment post-calibration tests
- **Data analysis**
- **Reporting**

In bold, there are the only activities which are really skilled and, with current technologies, even two of them can be done by unskilled personnel.
Only data analysis is really skillful. The rest of activities, with proper arrangement, can be done by basically anyone.

With conventional techniques it is no possible to break down data collection from data analysis. Lack of *Digital Footprint* that can be analyzed after data collection forces the NDT inspector to carry out all unskilled activities as well.

Looking at the different daily tasks we can estimate that, at maximum, only during one third of daily working time the client is paying the right price. Two-thirds or 66,6% of the total workday is overpriced.

As an example, for a low-skilled worker, a client is expected to be charged per day around £200 or less. But for a high-skilled worker something above £500[3]

If we calculate the average daily cost based on the balance of skilled-unskilled work time:

$$\frac{2}{3} \times £200 + \frac{1}{3} \times £500 = £300$$

For a campaign of 300 days, we can estimate a saving of £60,000 minimum yearly per NDT inspector working onsite. But, if a manager wants to apply this in the market, he will face that skilled personnel will not join. The associated costs to become skilled are not aligned with expected salary. And, even more, this way *is not a cost reduction.*

[3]Both prices are an estimation, they are just based only on personnel cost without equipment, living costs, etc.

In many occasions, more than what we should be expecting, cost savings are misunderstood. Competitiveness [4] when not associated to an enhancement in productivity or in efficiency, only creates a conjectural price reduction, and the project costs derived from inefficiencies are only transferred to another stakeholder. It is only a transitional arrangement that never solves the problem. In fact, at short term it sharpens and creates new inefficiencies. Following this policy looking for improvement is to fool ourselves.

Keeping on with the example:

Let's say that the project have got 10,000 welds (assume one meter long each weld to simplify the model), that need to be inspected[5]. Actual NDT inspector production per day is, including reporting, four welds and the project last 300 days.

Total welds per day to be inspected:

$$\text{Welds per day} = \frac{10,000}{300} = 33,3$$

If one NDT inspector can test four per day, it implies that the number of inspectors needed would be:

$$\text{NDT inspectors} = \frac{33.3}{4} = 8,33$$

If each one costs £500 per day during 300 days, it means that project management should allocate £1,250,000 to cover NDT activities. Comparing with the goal price of £300 for the same work done, the price is almost double.

When the client's intention is to trade low the price, it is eminently flawed and defective when competitiveness is not based on overall efficiencies' improvement. As per above arguments, skilled personnel will flow to other areas where, in economic terms, their ROIC activities will be bigger than their WACC[6]. Plainly, it is to say that no inspector will invest to improve his education and skills if the return expected is equal or lower than the capital they have to spend. This argument is also connected with the cost of opportunity. Although this financial terminology is normally used only in business, everybody makes this analysis at some extent in many aspects of our lives.

What will be the purpose of anyone to invest a dear amount of money from his own pocket if it will not be reflected or barely in his future incomes? Or, better said, will anyone invest if the return is so far in the future than it is difficult to predict the returns due to many uncertainties?

The only reason people invest when the ROIC = WACC is to keep afloat their actual status quo, thus, they will trade to spend the minimum and only under the certainty that they will keep their status quo.

By trading low the most competent/skilled will leave the market looking for better opportunities elsewhere. Then, the market will only keep the unskilled who will be unable to perform the inspection activities, so NDT companies will try to invest to qualify these unskilled personnel but it will be limited. The ceiling price £300 will force them to invest the minimum to keep their operational margins at a safe level. This creates a mediocrity culture in the industry.

But the worst is that for the next project, as too many deviations occurred, the client will want to apply contingencies as lessons learned so they will try to trade even lower. That happens because they believe that by saving a little bit more in the next project, in case of another deviation, it will be compensated.

[4] Low product or services price comparing competitors

[5] Just as an example only

[6] Return on Invested Capital (ROIC) and Weighted Average Cost of Capital (WACC)

Surprinsingly, deviations become bigger.

Mainly, this *cost saving strategy* is built on a misinterpretation of productivity concept. This concept is normally defined as a ratio between the output and input volumes. In other words, it measures how efficiently production inputs, such as labour and capital, are being used in an economy to produce a given level of output. Productivity is considered a key source of economic & business growth and competitiveness. In labour terms, labour productivity can be measured as output per worker, or output per hour worked, where output is expressed as the 'monetary value' of the goods and services produced. It is a key economic indicator and shows how effectively labour is being used in an economy.

Productivity is normally confused with *Cost of Production*. In general, productivity is represented as follows,

$$Q = K \times L$$

Where Q is the amount of goods or services produced, K capital or fixed resources and L as labour, referring to the human resources a business uses to produce its good or service.

Labour can be variable, meaning it's a factor that can be changed by the business (by hiring more people). The actual formula used to calculate production could be any variety of the following:

$Q = KL$ (Output = Capital times Labor)

$Q = K + L$ (Output = Capital plus Labor)

Once the function is calculated, it can be graphed, and a company can see where inefficiencies are placed and how much the variables can or should be changed to maximize output in relation to the raw materials.

The main misconception is to apply that as a general rule. Also a great deficiency is that K is considered fixed or constant when an analysis of the business or project is done, and it should not.

Whereas Cost of production refers to the total cost incurred by a business/project to produce a specific quantity of a product or offer a service. Production costs may include things such as labour, raw materials, or consumable supplies.

When both concepts intermingle lead to misconception, then, the tendency is to try to trade low the cost by thinking that:

1. Output is always optimal.
2. Lowering all costs works to the benefit of project margins.
3. Understanding decisions under *Static* rather than *Dynamic* thinking.

Discussing this topic can be very lengthy and it is not the purpose of this article. However, it is essential to understand that, though related intimately, it is not the same. Surprisingly, people keep falling onto same mistake so, when looking how to reduce the cost of final output, they immediately believe that cost of inputs must be lower, when sometimes (most of them) by rearranging how the inputs are used the productivity can be enhanced, hence, lowering the unit cost. Mainly, it is achieved with a new use in technology.

And this last statement, yes, *it is cost savings!*

NDT inspection as part of modern industrial quality system, it really began at the end of 80s. Nowadays, it is fully implemented in the industry.

NDT equipment manufacturers have been investing large sums of money to develop better equipment that can improve a company's quality system. As an example, *conventional* ultrasonic from analog systems moved to digital and, then, they developed the technique to *Phased Array* Ultrasonic; from *Eddy Currents* to *ACFM & ECA*; from *Radiography* to *Digital Radiography* and so on. For every inspection need, NDT manufacturers have been developing new solutions. Nowadays PAUT systems can be even controlled remotely.

The added value of equipment has grown exponentially, the quality of their results are constantly evolving. The speed on data process is aligned with CPU processors' progression. Their current ceiling is based on the same restrictions than all computing systems are facing.

All industry is facing a constant change in processes to be competitive in a turbulent market. In offshore energy industry (known as the most reluctant to change), cost and productivity are becoming important factors. Number of energy actors have grown exponentially, same than different ways or sources to obtain energy. This has impacted energy price. Those days where energy cost was secondary due to huge margins are gone, nowadays to be competitive is aligned with production costs. So, it is normal to realize why they invest in new technologies to achieve the target.

Introduction of *Phased Array Ultrasonic* has changed NDT inspection but, *where has gone that added value for the industry?*. Looking at it, nowhere. And not because the technology is not advanced and revolutionary for quality systems, and not because it is more expensive (although nowadays cost of one advanced unit is very affordable);
If the industry is reticent to implement new technologies is because the NDT inspection organisational system *("The way they work")* is basically the same that they were using with conventional equipment. It did not develop at all. The opportunities, that new technologies are (or have been) offering, have been continuously overlooked.

With conventional techniques there were also inefficiencies, but the cost to tackle them were not justified as they were inherent to the technology that was used at that time. To implement labour division was not a solution in economic terms. Nowadays, the technology has surpassed those inefficiencies that were the ones to be blamed for. In fact, nowadays the highest inefficiency percentage in an inspection program comes from the human factor.

Technology is so advanced now that its inefficiencies are practically negligible.

The human factor in NDT structure as it is used nowadays is so inefficient that, no matter how much the price drops, inspection will always be considered *expensive*. In fact, these inefficiencies hide the full development in cost savings that new technology can achieve for an inspection program. A company that wants to be more competitive but it is not sorting out the inefficiencies from that area, has no chance but cutting salaries, cutting corners, hence, devaluing quality.

Unfortunately, it is because the NDT inspection did not adapt to new technology so they are not taking advantage of the huge added value that the advanced NDT techniques can accomplish when used appropriately.

It is frustrating to realize after all manufacturers efforts in development that its added value is constantly underused because NDT inspection services are so inefficient. We can witness many times how a

good manufacturer spends money in exhibitions, webinars, trainings, software, etc., showing the public that their system can achieve a new step on quality and speed and, however, it is being rejected because their system is more expensive than a previous and obsolete one, just because inspection inefficiencies are misplaced. £10,000, £30,000, £50,000 more are just peanuts for a project if the new technology allows to rearrange other production factors lowering the output cost. What means the cost increment in equipment if the overall inspection cost, due to rearrangement, is 40% less? If clients know that, they will undoubtedly enforce everyone to buy the latest technologies.

Unfortunately for manufacturers, their main clients are the ones who have got an inefficient system. So, their sales tactics cannot work properly.

We should move forward if we really want to improve at all levels. It is time to implement *Division of Labour* to NDT activities.

How can we achieve low cost, high inspection productivity and unbeatable quality? And, adding to all of that, auditable inspection at an insignificant cost?

Basically, removing inspectors from site. Essentially, it is to allocate them where they achieve their optimal performance, meaning by that, where their value is maximized.

Getting back to our initial example:

We contract unskilled personnel to collect all data on behalf of the NDT inspector, the new technology advancements make them too simple to do that. Hence, allocated time to collect data has just doubled. Although it is not exactly like that as data collection will easily be more than double as it is a non linear function. However, for our purpose, we are going to keep it as linear.

Hence,

$$\frac{33,3 \text{ Welds per day}}{8 \text{ per Data Collector}} = 4,16 \approx 5$$

So,

$$5 \times £200 \times 300 \text{ days} = £300,000$$

If initially one inspector could in one third of a total shift time analyze and report four welds, it is obvious that 12 joints will be affordable. So for 33.3 weldments per day we should contract three inspectors only.

So,

$$3 \times £500 \times 300 \text{ days} = £450,000$$

then,

$$\text{Total Inspection Cost} = £300,000 + £450,000 = £750,000$$

Cost savings are $£1,250,000 - £750,000 = £500,000$

The price per inspector is reduced to

$$\frac{£750,000}{8 \text{ Inspectors} \times 300 \text{ days}} = £312.5 \text{ per day}$$

where,

$$\text{Inspection cost per weld} = \frac{£750,000}{10,000 \text{ welds}} = £75$$

Given that the initial price per weld was £125, there is a saving cost of £50 per weld, representing a reduction of 40% in inspection price per weld.

So being conservative, as it can be worked around quite a lot, we can get an easy cost saving above 30% just by rearranging resources.

But this is just only the beginning.

We will deal with different ways to even decrease the overall cost, hence the price, without falling on a *zero-sum* business economy.

NDT inspectors at office *on-site* The activities in NDT can be summarized as,

1. New Fabrication Process
2. Shut downs
3. *In-service* inspection

For each one, the arrangement of inspectors can be more or less feasible. Though it isn't really about feasibility, or else about relationship between *Risk* versus time, experience, training, etc.

I guess it's been simple to show that, by a simple resources rearrangement, an immediate financial impact is visible. Basically the example is based on keeping the inspectors at office maximizing their valuable activity whereas the ones without value are performed at more affordable prices without a negative impact on salaries, which is highly counterproductive as previously explained.

Keeping NDT inspectors at office but *on-site* have got some pros and cons and it may be either or not recommended depending on time availability for implementing new activities. There are some advantages to place them onsite (at office) looking for low risk, if training time on unskilled personnel is limited, and the NDT activities need to begin almost straightforward. Then, indeed, keeping inspectors reachable is advisable. There is a learning curve for unskilled personnel to know how to set up the equipment and collect the data correctly.

Having NDT inspection personnel on-site will have associated costs that are unavoidable such as accommodation, travelling, meals, etc. In both cases, we use the same amount of personnel. In the first case 8 people all skilled, and in the second case also eight people but five unskilled and three skilled. But, *inspection price* can be reduced even more by a small twist using more efficiently the current technology.

Just by rotating inspectors on-site as follows, the inspection program cost will be reduced even more without any impact on risk. For example:

- Three working full time onsite during all project length (actual example)
- Three working full time onsite during the first half of the project, and during the second half:
    1. Two inspectors working onsite and one remotely (rotating with the other two)
    2. Gradually, start rotating them with one onsite only and two working remotely
- Two inspectors working onsite full time and one remotely during the whole project
- Other combinations...

Using specific servers and internet connection, it is all what is needed. Implementing this way, it is easy to believe that £500 can be easily renegotiated. For example, time onsite at £500and time working remotely at £375. If one third of the whole project is based working remotely, it means that:

$$\text{Inspector daily price} = 66.6\% \times £500 + 33.4\% \times £375 = £458.25$$

$$\text{Total cost} = £458.25 \times 3 \times 300 \text{ days} = £412,425$$

It is a small reduction but it is an extra 8%.

Regardless of the final percentage in cost reduction, what is clear is that this one is achievable. The risk is not increased and it allows other areas like production to mitigate their deviations.

NDT inspectors working remotely If learning curve for unskilled personnel has been achieved previously, then it can be considered keeping them remotely 100%. However, for the purpose of this document and estimating that we want to keep the risk contained, we are going to estimate that one NDT inspector is kept onsite at all times, and the other two are working remotely. Then the cost reduction follows the previous calculation:

$$\text{Inspector daily price} = 66.6\% \times £375 + 33.4\% \times £500 = £416.75$$

$$\text{Total cost} = £416.75 \times 3 \times 300 \text{ days} = £375,075$$

$$\text{Total Inspection Cost} = £300,000 + £375,075 = £675,075$$

So, the price per inspector is reduced to

$$\frac{£675,075}{8 \text{ Inspectors} \times 300 \text{ days}} = \textbf{£281.28 per day}$$

where,

$$\text{Inspection cost per weld} = \frac{£675,075}{10,000 \text{ welds}} = \textbf{£67.5}$$

So, our initial price ceiling £300 has been reached. In fact, NDT operators gain a 6% increment in margin if they invoice at £300.

Implementing this method allows the main client to control several sites at low price, high productivity and quality. We need to understand that unskilled people can be contracted locally.

Adapt Components Fabrication to Quality Inspection

Certainly, we must reckon that changes in the inspection system must be studied for each case, because every place and project has got their own idiosyncrasy and specific needs. Nevertheless, some previous clients came with some problems, as per fabrication as per in-service, regarding inspection *availability*.

In any industry where fabrication is the leading department and every aspect of the company works around their schedule, quality inspection tends to become problematic as it is difficult to fit them in a smooth flow. Sometimes, inspectors are needed but, other times, a standby period can become frequent. In some industries, such as automotive, where a constant manufacturing flow is designed, contracting an

amount of inspectors as permanent staff can be the most adequate formula. However, there are many industries where manufacturing prediction is subject to many variables very difficult to be controlled, hence, inspection resources can become redundant in many situations and, in others, availability can become a conflict.

As any other market, NDT companies needs to be supplied with enough workload to keep their own personnel and equipment working constantly so that their prices are stable and competitively low. The current structure does not favour them and it is very frequent to see these companies to hire eventual staff (a.k.a *freelancers*). Their permanent staff are just a few of them who are unable to cope with different production stages. Due to subcontracted staff, the unreliability of the inspection increases and, sadly, it is frequent.

Inspection traceability is lost because in many occasions it is not possible for the company to contact with the inspector who performed a specific inspection task as he is not part of the NDT company anymore. Then, the main client is facing a problem as, when they question the NDT company regarding a particular job, responsibilities are derived to the inspector whose whereabouts are unknown, or the answer is delayed because they need to investigate internally the work previously done by him, and so on. At the end, a new inspection is requested and an extra budget needs to be allocated.

The dilemma of which formula would be the best to optimize inspection resources, leads actually to minimize the inspection to the essential. This is because the main company needs to compete for inspection resources, so they will need to pay higher prices to ensure the availability. Any company is willing to inspect as much as possible in order to increase their competitive moat but, obviously, as long as this expense is not increasing the price at a marginal point where they cannot compete. Under current *inspection structures*, there is not much margin to act and only financial strong companies can really secure resources. The rest are just battling among themselves and crossing fingers.

A low cost and effective way to keep reliable NDT resources engaged with main company should be to contract by productivity in analyzing and reporting. Invoicing will be linked to productivity rather than on time. Obviously, price will be higher but efficient and, overall, cheaper.

Remote Auditing One point which can support to have inspectors working remotely is that they can be easily audited.

When using NDT techniques with digital footprint, it will be recommended to place some safeguards to keep high inspection reliability and avoid a possible negligence. If only one inspector is used, that will be very risky. Ideally workload shall be split, using two or three different inspectors. To make sure that their attention is kept on, same weldments, chosen randomly, shall be asked to be analyzed and reported by two or three inspectors without their acknowledgment. Once results are submitted, reports shall be compared to check out that they have reached same conclusions. Obvious tolerances shall be allowed but, with selected inspectors with similar experience and reliability, no significant discrepancies shall be noted.

As it will be completely random, the inspectors will never know when it is going to happen, hence, the probability of negligence will be minimum or negligible. These countermeasures will act as crosschecks as well which, then, the company will save money to allocate resources to reinspect areas. The data collectors will not have influence in crosschecks if they applied the techniques correctly. The main company shall have the responsibility to observe that the personnel collecting data are doing the job properly.

Using this type of auditing adds quality as it will allow to discriminate the reliability of the inspectors.

At the same time, if a discrepancy is found, it will allow decisions to be managed more efficiently as the discussion will be performed at a higher level based on same tools.

Could be this considered an extra expense? Well, not really, if we take into account that we avoid to contract a new team for crosschecks. There is no reason to develop this topic any longer. It is crystal clear that the use of *Advanced NDT Techniques* will always offer more flexibility than conventional techniques in economic and quality terms. At any time, at any request, a re-analysis can be asked for with negligible economic impact for a project, whereas when using conventional techniques a minimum divergence skyrockets prices and costs.

"Conventional NDT techniques will ***ALWAYS*** *be more restrictive than the implementation and use of Advanced NDT techniques. Hence,* ***more expensive***" .

The fact that industry is paying high prices for these techniques has got no real arguments but lack of interest by some companies which are still using fallacious reasoning. Encouragement of zero-sum economies/businesses are the only reason that burden quality to reach its highest peak.

3 Economic Impact on NDT companies

It is inevitable to believe, based on initial explanation of ROIC versus WACC, that companies opposing to the progress will end up by being substituted in the market because of their own inefficiency. All advanced technologies, in any business area, have been developed and spread their sales at such level that equipment prices are continuously more and more affordable to everyone. A laptop at the end of last century was afforded by a minority while, nowadays, it is a normal tool as it is a stapler in an office.

Advanced NDT equipment has gone and still going through the same process. In 2009, an Olympus Phased Array MX unit 16:64 (with limited capabilities) cost over £70,000. Nowadays, one unit with same capabilities is around £15,000 or less. And a second hand with its current certificate can be found by £6,000. The cheapest brand new conventional ultrasonic flaw detector device in the current market is around £5,000. As we can see, advanced NDT devices are closing the financial gaps with conventional equipment more and more. If the use of these advanced equipment is dealt with efficiency, the initial investment which is initially higher, pays out very quickly.

With the actual business structure were margins are forced to be tighter, the NDT companies look at the business by cutting cost, trying to invest the minimum in new equipment because every detail around implementation of advanced techniques is seen as a cost rather than as opportunity. However, it has been proved in previous section that *Advanced NDT techniques* allow to improve in efficiencies and, therefore, increase in margins.

There is no doubt that some amendments need to be done and it will not be easy at the beginning, but if NDT companies keep waiting for implementation of Advanced Technologies, then, they will risk to be expelled from the business game by other more efficient companies.

More and more, we are being bombarded with news that *business game* is changing. And it is true. When we assert that the companies who don't adapt quickly to the change are doomed to be bankrupted, it is not a simple saying. Competent personnel who will be capable of coping with new market requirements are still very few. In the near future, to be only NDT technician will not be enough. In fact, new technologies are allowing the NDT industry to substitute them easily. New NDT professionals are going to be asked to be also academically qualified with an engineering degree as their tasks are going to be beyond mere analysis of data collection. In the current market, these professionals are scarce. One

of the reasons behind has been based on the current market structure. NDT jobs have been focused on vocational premises rather than academic. Given that it has been a profession where the manual or human factor has been always high for many years since the technology was not developed, there was no pressure by the market to have these skilled professionals educated beyond simple and practical trainings. However, the scientific characteristics of the profession, the advanced in technology (among many other factors) and the more stringent quality requirements, are forcing these professionals to amplify their skills beyond typical features to specialize in other areas as well.

It is incipient but irreversible. The amount of time required to collect data, analyse, file or storage and report is closing to minimum due to the exponential advance in technology. To design and make calculations for current engineers with the new computing capabilities is allowing them to expand their horizons. What in the past used to take weeks to be performed, nowadays is taking minutes if not seconds. It should not surprise anyone that engineers, who also compete in the labour market, are starting to see opportunities by extending their skills to other areas. NDT profession as such is over. It needs to move forward.

For over ten years, BINDT has joined with University of Northampton offering NDT professionals engineering degrees at bachelor and master degree levels. Every year, more NDT professionals are joining and it will not cease. This investment, initially seen as fruitless is changing course because technology is now up to it now. A mechanical engineering degree with an NDT level 3 in advanced ultrasonics is seen highly desirable by companies now.

With the new opportunities that current technologies are offering in *efficiency*, NDT professionals as currently known are doomed to become less demanded. However, graduated engineers with an NDT profile are going to be in high demand. It is simple to understand, basically, they are more versatile. In economic terms, we obtain marginally more for one extra unit. NDT companies denying the change will see how the doors will start to close in front of them. By the time they will want to join the new market course, it can be very late. Getting the right professionals as part of their staff will be also hard if not improbable. They need to understand that a business moat would have been formed. To convert an NDT professional in a qualified engineer takes time.

A sudden change only based on purchasing new Advanced NDT technologies will not be enough if it is not followed by a highly qualified personnel behind it. This is a mistake that has been used to lure main contractors for many years and it has shadowed the inefficiencies. BP, Shell, Chevron, Aramco and many others have been paying millions of pounds for not much. They still pay. Technology brightness has blinded them in many occasions. NDT companies have been using the new technology to sell them (overpriced) characteristics such as speed, productivity, accuracy, etc., *Which are REAL!!*, but they forgot to mention that they should restructure their own staff to avoid that their inefficiencies will burden and sink those characteristics.

Many engineers from these large corporations who bet for these technologies have been constantly disappointed when they realized that the promised advantages were not economically justified. Then, they make the mistake to blame the technology. But they are wrong. The technology was not the problem, but the inefficient structure on which the quality companies are based on.

Investing in a laptop was useless if the personnel using it did not understand the immense capabilities and they adapted to them.

The economic impact on NDT companies moving to the new business paradigm will be very low in the medium term. However, if they wait too long to shift, it may be highly probable that they will not be able to overcome the huge moat. Although prices will tend to drop by implementing efficiencies, in

reality, net margins will raise significantly. The fierce competition among NDT manufacturers will keep pushing down equipment prices. Many manufacturers are already moving into new digital tools such as cloud storage, software rental, machine learning, etc., to gain competitive advantage, so it is not expected that inefficiencies will come from them.

Main contractors *MUST* look at the teams using the new technology to know whether or not the enhancement in technology is using efficiently and the inherent human wear is not impacting negatively in economic terms.

Undoubtedly, many NDT companies will raise a fair question: *"What will be the future for them?"*.

We can estimate that they will split in two complementary companies. The ones betting for new technologies and highly qualified personnel will be the main actors but their structure will be with minimum staff, and the others will become their suppliers of data collectors. Basically, the companies with advanced technology and qualified personnel will see inefficient economically to hire permanently unskilled personnel in the new paradigm. But the need of data collectors will be still demanded. In fact, due to price dropping, it is expected that main contractors will increase the amount of inspection, so both company types should expect high demand. NDT companies will need to decide which way they will follow. Both of them will be profitable as they will be specialized. The company intending to be in between will be doomed to be pushed away from the market.

In any project, the main contractor will need to look at it carefully if they do not want to face sudden surprises which can damage dearly their finance plans.

And, *"what about NDT technicians?"*. Well, as in all technologies disruptions or crisis, they will need to adapt. Some will not see adequate to invest in their education, many fair reasons such as age, social circumstances, personal capabilities, etc.; some will not do it by *no so fair reasons*, justifying their posture on more ideological or political aspects than in honest causes. These people will become data collectors. Initially, ideal candidates for it but not essential, hence, easy to be substituted. Certainly, their salary will have the tendency to drop, not necessarily happening immediately, but undoubtedly in the long term. Promotions will come from their own savings invested on their own education. The companies will not invest on them because it will be no need. It will be more profitable to invest on a newly graduated mechanical engineer to specialize him.
The NDT technicians who will aspire to higher ambitions will need to invest their own time and money to reach a position in the High-Tech NDT companies which, obviously, will pay higher rates. Will it be worthy to invest?

Always

.

The expected demand on high qualified and specialized engineers is going to be really high. Their high salaries will be justified for high productivity and efficiency.

4 Advanced NDT Techniques to Implement in a Project

To decide which technique shall be selected for its implementation in a new project, we should consider some factors such as:

1. Inspection Characteristics such as volumetric, visual, surface breaking methods, etc.

2. Length & Type of Project
3. Learning Curve for data collectors and time availability

These items can be extended and evaluated specifically for each project. Our case is going to be based on offshore wind jackets fabrication but, once again, each project needs to be studied previously as techniques can differ depending on several other factors.

Academically, there are already numerous references showing what is the next path NDT industry is going[7]. In fact, it is obvious by looking at manufacturers; they all are developing their products around *Digital Footprint* data that can be stored for further analysis using new techniques such as *Big Data, IoT* [8]*, Machine Learning*, etc. Perhaps, it is too early to affirm that NDT analysis can be automatized by using Artificial Intelligence (AI). There are some companies that are developing and investing in AI such as neural networks analysis, fuzzy logic, etc., but it is still in very early stages and, in my personal opinion, we won't see reliable results in the next five years, and its implementation will take at least a decade.

There is no doubt that in the energy market companies that stick to conventional NDT technologies in their Quality Development, are destined to reduce their operating margins more and more, becoming noncompetitive and therefore, under *free market and competitive* rules, they will be relegated to become residual energy actors.

It is very simple to demonstrate this statement. Looking at previous section where we have easily reached a 40% cost reduction and with a tendency to become bigger, if one company invests in this direction and another company doesn't, the margin between them can only become bigger between them. One will be able to allocate new economic resources to increase its market cap and the another will need to start to work out its financials by two very common ways: *1. selling assets and 2. increasing its debt.* There are more but they are not based on *free market rules*[9].

Nevertheless, this is a very long topic and it should be treated in another article more dedicated to investments rather than to operational management. Going back to our case, there are three main NDT techniques that should be immediately implemented in an offshore wind jacket fabrication:

- Phased Array Ultrasonic Technique (PAUT) for Volumetric Inspection
- ACFM or Eddy Current Array Testing (ECA) for Surface Breaking Inspection
- 3D Scanning technique for Visual Inspection

Among the three techniques, the one that has got a deeper learning curve to be used by data collectors is PAUT. The other two are very simple to be implemented. Depending on *Data Collectors'* background, PAUT will take more or less time. Meaning by that, when qualified NDT inspectors can only work remotely.
ACFM and 3D scanning can be taught in two, maybe three, sessions. PAUT can take longer but in one week, if the scope of work is fully defined, it should be sufficient.

[7]Saucedo-Martínez, J.A., Pérez-Lara, M., Marmolejo-Saucedo, J.A., Salais-Fierro, T.E. and Vasant, P., 2018. Industry 4.0 framework for management and operations: a review. Journal of ambient intelligence and humanized computing, 9(3), pp.789-801.

[8]Internet of Things

[9]Abengoa has been rescued from bankruptcy with Taxpayers money in Spain

In terms of production[10], the three techniques can be operated by one unique operator but, to optimize inspection production, I will suggest to use two (maximum three) data collectors per Qualified NDT inspector analysing and reporting. The decision between using two or three data collectors will depend on the production capacity and production needs for quality analysis and reporting.

It has been tested that, combining the three techniques appropriately, one team (one-two plus one) can easily inspect daily two nodes (around 32 weld metres) using the three techniques (24 reports submitted daily in total). Data collectors can double this production without problem but it will not be feasible for one inspector to analyse so much data daily to cope. Optimum will be two data collectors per two NDT inspectors. The team will be able to perform daily four full nodes. Currently a company will need to deploy around 10-12 conventional NDT inspectors to cope with such production. Some people will argue that it can be done with less people, and it is true but not with the same quality. To be able to give the same quality, they will need between 10 to 12 people. Quality standards where inspection will give us data such as following,

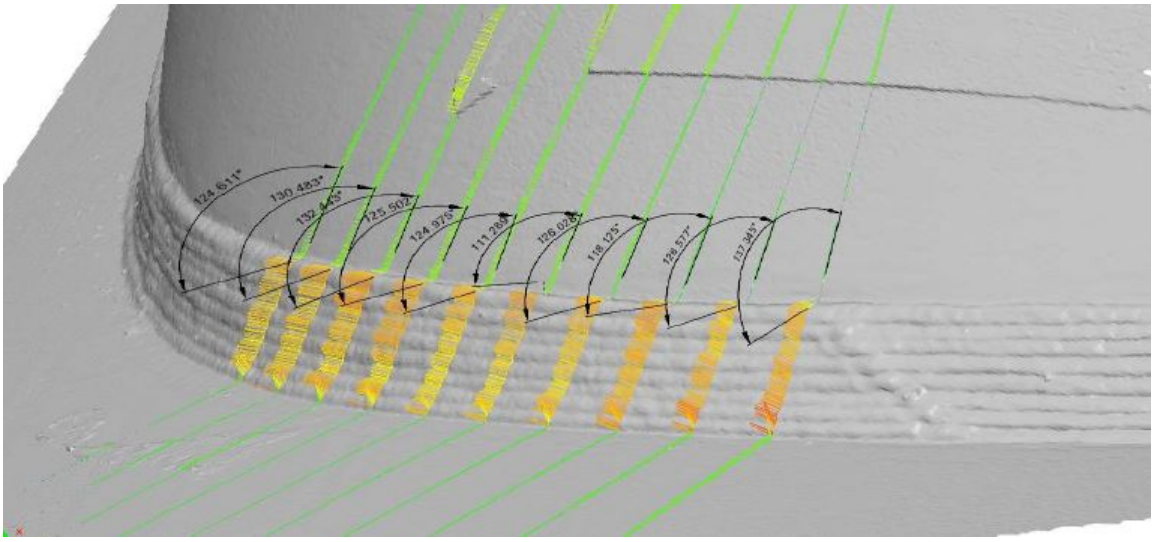

Figure 2: Toe weld angle

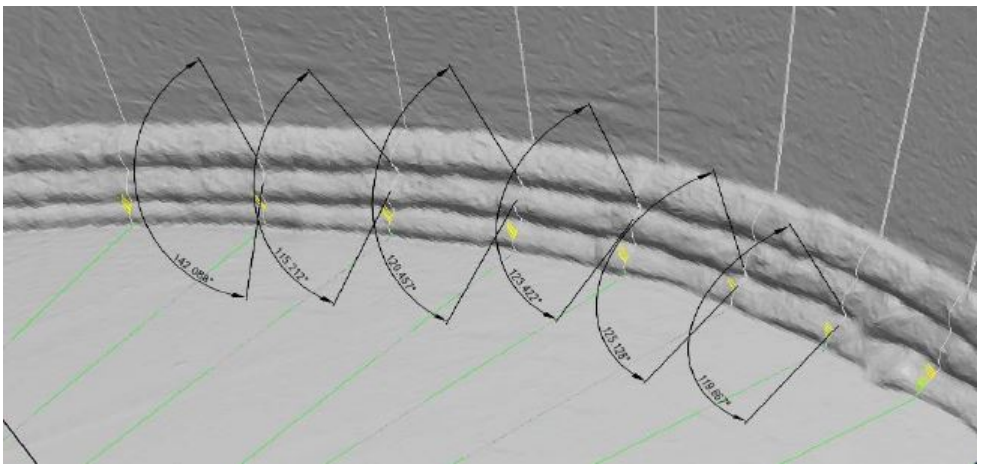

Figure 3: Weld angle between Cap Weld run to check possible Stress Concentration Factors (SCF)

As per Figures 4-6 for an accepted weld, the amount of data given is not comparable with current Visual NDT reports where, in most cases, there is only a line with the weld ID and an excel cell with

[10]We have already developed analysis in economic terms

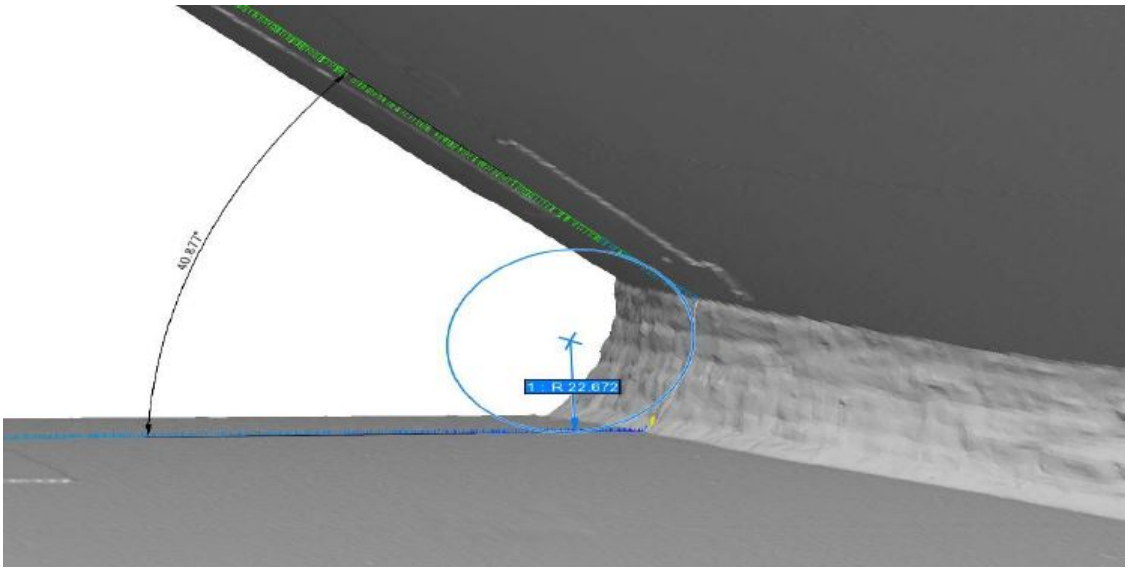

Figure 4: Weld Radius Profile at Acute Node Area to Comply with Standard

an isolated *Accept* term. The Structural and Weld Engineer cannot have a real input. For example, in Figure 5, although the weld is accepted, we can notice that the weld filler with nickel (Ni) based component at weld temperature preparation tends to sag which can provoke overlap defects, SCFs, interrun lack of fusion, etc. To avoid them, the welder needs to increment times, skills, etc., which can work economically against project. The design engineer may need to look for another approach to optimize jacket production. A change in weld filler may avoid future delays due to repairs, welder performance, etc.

As we can see, per conventional reporting this data will never be seen by weld, design or structural engineer. The chances to optimize and save millions of pounds are eluded. So, next project will have the same (or similar) design and this minuscule and overseen detail that leads to delays in production cannot be remedied. In fact, a current project is showing that PAUT is detecting 40% more defects (all rejected) that by conventional UT. Many of them very small and most likely not critical but, under current standards, they all are rejectable.

Phased Array Ultrasonic scans as per Figure 7-8, with defects which are not rejected by MUT, may be used by engineers to think over about current design. Looking at project data, it looks like there are abundant planar defects overseen by MUT and probably not critical. There should be two considerations to point out. First: *Why these defects are so recurrent?*. Is it because weld design? Materials selection? Welder performance? And so on. Second: *These overseen defects will be permanently in the jacket.* How will they affect structurally in offshore jacket's life span? Knowing that 50% of weldments are not defect free but, after pertinent calculations, assuming they do not affect structural life span: "A development in NDT quality performance and a change in design, how will it impact economically? Among many other questions".

And Third: *If these defects are real, how do they really affect our life span?* Can we estimate the cost of future maintenance inspection? Can we, at commissioning stage time, plan ahead where & when offshore jackets should be inspected? Definitely, yes.

ACFM NDT technique Figure 9-10, as any Eddy Current based technique, can give some extra data apart from surface breaking defects, such as change in permeability, hardness, conductivity, type of material, paint thickness, etc. These changes can be checked out in the ACFM/ECA scan. In fact, NDT inspector eyes must be able to locate and discriminate them so that he is not submitting false calls.

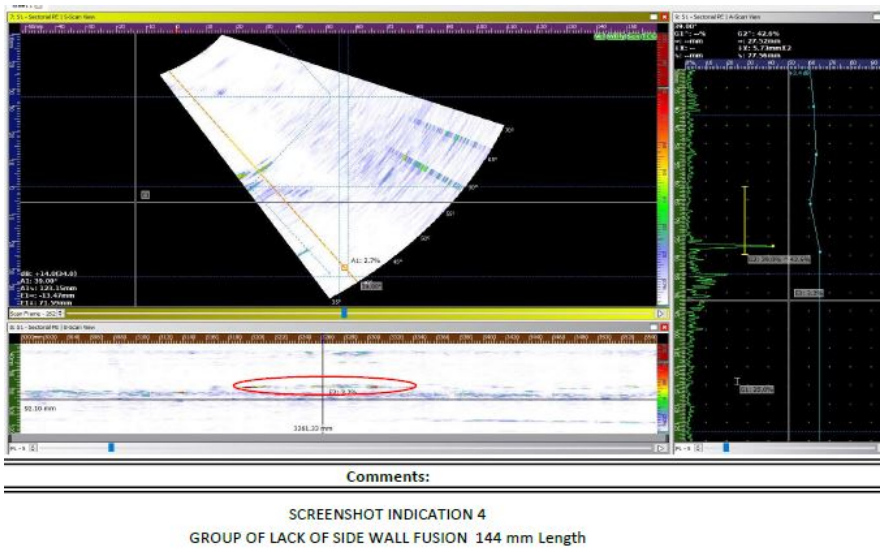

Figure 5: Weld Lack of Fusion PAUT defects

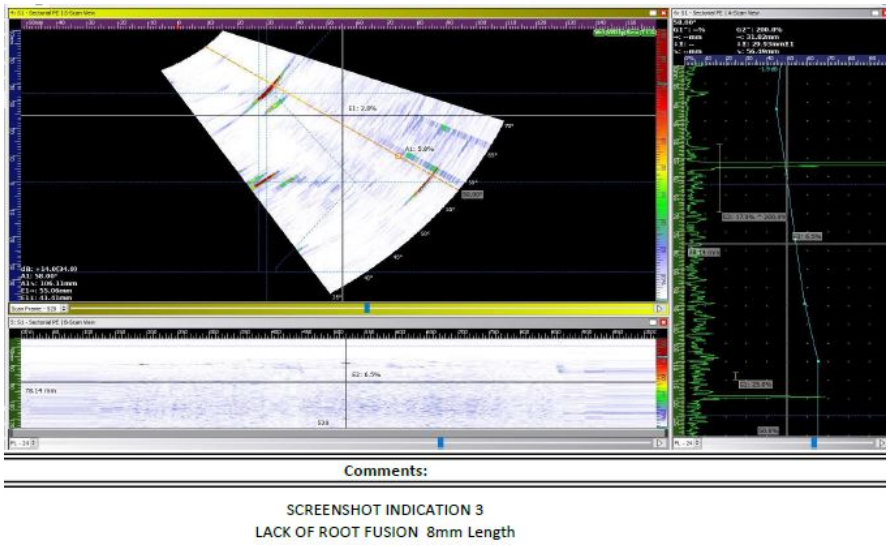

Figure 6: Weld Lack of Fusion PAUT defects

Will it be useful for Mechanical/Design Engineer to know about hardening? Well, to know relevant changes in hardening can tell us where the weak points are, which areas will be more likely to be corroded than others. And, under structural stress calculations, how these brittle areas will be affected.

The point is that, with only three *Advanced NDT* techniques, we are able to perform a deeper analysis. Actual inspection does not feed the future company's performance. Only if the item produced complies or not with a specific standard. Hence, it has been interpreted as a form of taxation on production department. Understandable when all the data is only based on *Accept/Reject*. Plainly, it happens because the NDT inspection is only focusing on the item, a broader perspective cannot be achieved under conventional NDT structures. By integrating advanced NDT techniques with simulation techniques as commented in our previous article[11], it can be achieved a better quality performance and, definitely, higher financial operative margins, thus, greater market caps and huge business moats.

New NDT Personnel Profile It has been proved that lack of efficiencies comes, actually, from personnel rather from technology. This fact brings one question regarding personnel for our purpose:

[11] "End of the Paradigm of Quality Vs Production with NDT Inspections 4.0"

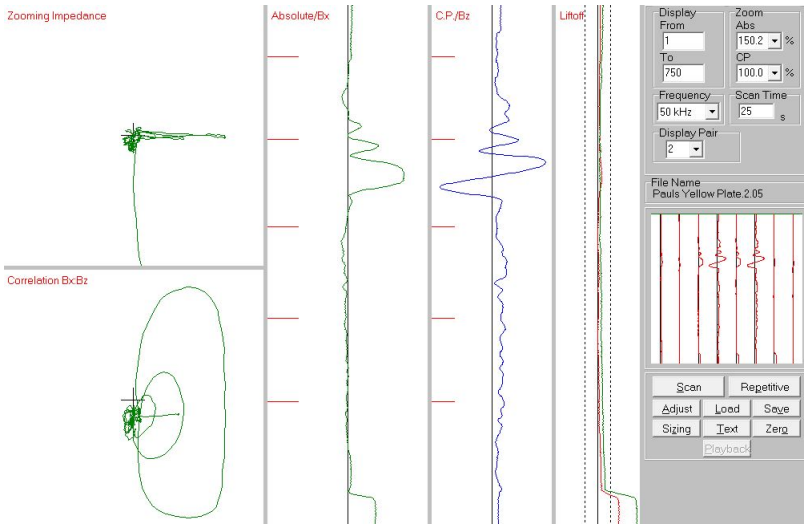

Figure 7: ACFM Crack Indication and Location

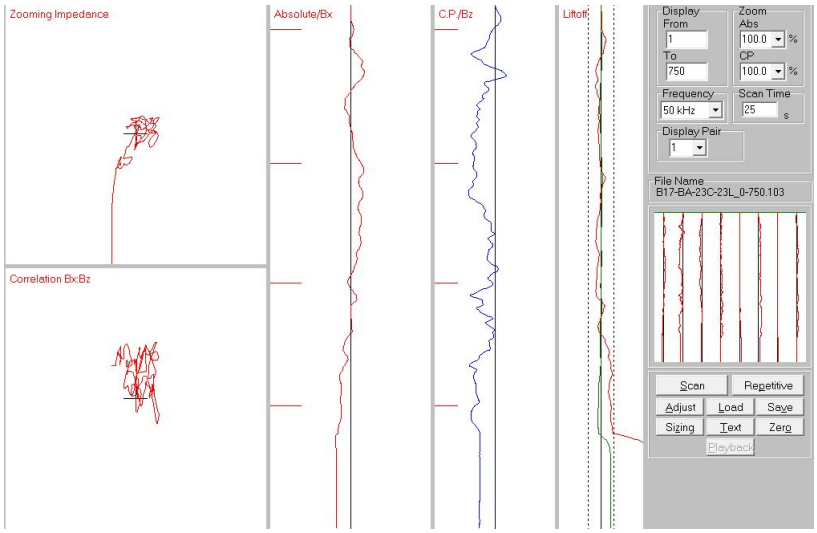

Figure 8: ACFM Change in Permeability/Hardness

What will be the ideal profile for "Qualified NDT personnel"? Will it be sufficient for them to be qualified in advanced NDT techniques only?

In a previous section, we have already highlighted that graduated engineers are moving into NDT areas. Hence, it is clear that a person with just only NDT *vocational* qualifications will not be sufficient, even more when we are looking for simulation analysis as per *"End of the Paradigm of Quality Vs Production with NDT Inspections 4.0" article.* The new quality inspector should be knowledgeable or qualified in areas such as:

- Mechanical and Structural engineering
- Welding Engineering
- Advanced NDT methods at Level III (onsite experienced)
- Structural Analysis using Finite Element Analysis (FEA)

Other areas should be expected such as statistics, project management, economics, etc. Nowadays, to find these kind of personnel is very rare but, no doubt, the future will ask for this. To be just qualified in NDT with qualifications such as PCN or CSWIP will not satisfy future project expectations. Perhaps in some industries will be possible but the salaries expected will be low in comparison. As previously

explained, vocational qualifications will become part of engineer's specialization.

Reporting will need to change to adapt to new technology. Analysis will need to focus beyond product and being integrated as part of company's strategy.

None of what has been said in this article can be implemented immediately. It is a long journey but it is unstoppable. Many people have already started to walk this path. Companies will test in the very near future a new group of professionals who will demand higher salaries. The companies that can foresee the advantages will be the future winners in the market. The ones that underestimate the possibilities that these people can offer, will suffer in the market.

5 So, What Now: "New NDT Project Management"

For over five years, personally, I have been requested to assist many companies around the world to correct a quality problem at last fabrication stages. In places such as Latin America, Kuwait, Egypt, Morocco, Spain, Kazakhstan, Japan, Holland, Australia etc. Regardless of specific complications, they all were rooted on the same problem: *Wrong NDT management.*

Before proceeding further, it must be pointed out that this problem occurs mainly in new constructions. It doesn't normally happen in-service inspection programs.

When a project is awarded for construction of a new refinery, offshore substation, jackets, and so on, engineering procurement and manufacturer are two different companies sharing the project at 50% each. The first one, basically, controls the second one (manufacturer). Up to this point, everything goes all right but, suddenly, the whole system breaks down due to a small factor. The NDT services are hired under production/manufacturer umbrella. And then, all the problems begin. When the project stages start to stress production, there is always a conflict arisen: Quality drops. Resources are allocated mainly in production to comply with deadlines (hence, payments) and quality/NDT testing can only work against production target. At these stages, quality is facing a conflict with production department work schedule. Any rejection is becoming a problem due to intrinsic delays, and given the tight production schedule at the end of the project, any delay is seen as project *"sabotage"*.

As NDT services are contracted by the manufacturer, it is not unlikely to see inspectors under certain pressures which brings concerns about quality inspection. Then, NDT management folds under this pressure and is forced to, sometimes, cut corners with its inspections. Facing with the possibility to lose future contracts, NDT company supports their arguments in favour of production rather than quality parameters. Endless discussions are formed between engineering procurement company and manufacturer.

Under new NDT program as exposed in this article, NDT advanced services should always fall under engineering procurement company. All high qualified NDT personnel shall be contracted by engineering services. Manufacturers shall provide the data collectors. This way, the quality costs are shared but NDT integrity cannot be jeopardized.

Doing that, the positions do not overlap. It is not rare to witness two or three different NDT companies working in the same project. All of them disposing administrative, consultants, managers, etc., multiplying those resources in detriment of NDT investments. Unifying the head of inspection allows control and, when deploying advanced technologies techniques, comparative costs will always be lower.

6 Conclusions

Implementing Advanced NDT techniques is NOT more expensive or else cheaper if they are used properly. What brings cost increments is to keep old structures.

Nobody nowadays discusses that the *iphone* has been a huge disruption that have changed the way we communicate and interact with each other and the market. However, it was just a phone. Very advanced, but only a phone. When it was introduced in the market, *who was forced to change?*. If people would have been stubborn and they would have used the *iphone* just like any other mobile phone, this disruption would have died immediately. Instead, we observed the huge possibilities by performing small changes in our behaviour. And now, we can see a new market worth billions of pounds. Was the *iphone* cheap? Is it now? Can we find, nowadays, similar phones with same capabilities at very affordable prices?

Summarizing, it is unfair and very simplistic to value technology according only to its market price. It is necessary to evaluate possible advantages in economic terms. Not only in engineering terms.

We have proved with a very simple example how we can reach cost savings above 40% over current market prices by small changes in our relationship with the new advanced NDT technology. Just by dealing with it under a *Win-Win* economy game.

In all disruptions, all stakeholders, big and small must embrace the change to improve their intrinsic inefficiencies which are highlighted because of the disruption. Otherwise, the market will punish dearly their subsistence in the future.

As a final comment, the wheel was a disruption, the car was a disruption, transistor was a disruption and so many cases. In all of them, we found cases of companies and people who refused and denigrated them. Our world is much better today because the right disruption *always* wins. Advanced NDT techniques, after a decade in the market and growing in sales, is a right disruption. To reject its presence is, basically, to fight against our future.