THE IMPORTANCE AND FUTURE OF RELIABILITY IN A COMPLEX AND TURBULENT ENVIRONMENT.

Harry Roossien

ABSTRACT

Today, the world is very dynamic, turbulent and complex and developments are following each other at high speed. In the reliability and testing area there are many developments too, for example the management focus is shifting, new testing strategies occur and especially the playing field is changing continuously. Focus is on costs and time, and quality?

In this presentation firstly the importance of reliability testing will be reminded. Then an organizational roadmap will be presented with recent tendencies in companies' development related to reliability testing. Based on this, the complexity and the pressures on product development and testing will be approached from Porter's view. The second part is more technical, where the most common and future reliability philosophies, like simulation testing, robustness testing (ROSE, MEOST), highly accelerated testing (HALT, HASS), Life Cycle Analysis, Virtual Simulation/Testing will be put in context. This will be related to the context of financial crisis and costs and current developments in green environment policies. Finally your company position in the reliability playing field will be addressed by the Reliability Maturity Model, given you opportunities to compare and define your strategic development direction.

This presentation gives a broad overview of reliability test philosophies, their playing field and the future of reliability.

Introduction

The importance of reliability and environmental testing is rapidly growing over the past years. And this grow will continue in the coming years.

There are several reasons, from different perspectives, to explain this tendency. Firstly, the rapid development grow of electronics and especially today's nanotechnology leads to significant broader application areas. Due to this phenomena the public acceptance of electronics has grown, it has reached maturity. Especially new, reliable applications in automotive and consumer electronics market have driven occurrence and acceptance.

Another strong contributor to the rapid growth is the uncertainty in which we are living the past decennia. Key is to be in control, being pro-active, anticipate on events From technology point of view this means a higher demand on the reliability of products. We expect, actually demand, that our car starts in the early morning, that our computer runs fine. Not to speak from public facilities.

More and more we have relied on reliable products. Due to the emerge of nanotechnology and applications, the products became of sufficient quality, but new threats reduced the field performance. These threats come from the environment.

Today, the world is very dynamic, turbulent and complex and developments are following each other at high speed. In the reliability and testing area there are many developments too, for example the management focus is shifting, new testing strategies occur and especially the playing field is changing continuously. Focus is on costs and time, and quality?

There are no signs that the emphasis on Reliability will reduce. Quite contrary, the economic crisis has strengthen this position. Questions regarding lifetime, availability, total costs of ownership are 'hot' today. Investments are steadily more based on tailored quality, 'just enough' for the intended purpose.

Obviously there are reasons enough for the steady emerge of Reliability as specialism, but what is the importance, why this tendency?

Importance of Reliability

Reliability means '*the ability of an item to perform a required function, under given environmental and operational conditions and for a stated period of time*'. Keywords in this definition are:

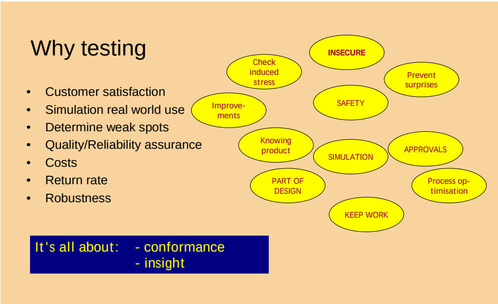
- required function, which refers to the product specification
- environmental conditions, should work under different conditions, and
- stated period of time, designed for a certain life time.

Reliability can quantify quality. Quality as such is difficult to describe, you have it or not, it's a perception, difficult to manage. In the contrary, reliability is clear. A product is designed for a lifetime of 5 years, need to pass a 1 meter drop test, for 10 times etcetera. Real world use can be easily simulated, just measure and play back, accelerated or aggravated, and anticipate on field use. This benefits to understanding of quality and reliability and provides us with a valuable design and control tool. From designer, architect to marketer and end user.

Translating back to the importance of reliability, we can state it as twofold between the different interests from customer and manufacturer. In both cases there are many reasons for applying reliability, but mostly they simply are not visible as such.

Some reasons can be

- Customer satisfaction
- Brand name marketing
- Conformance to specifications
- Control over quality and contracts
- Effective design process
- Early risk assessments
- Process optimization
- Reduce return rate
- Cost savings
- Etcetera

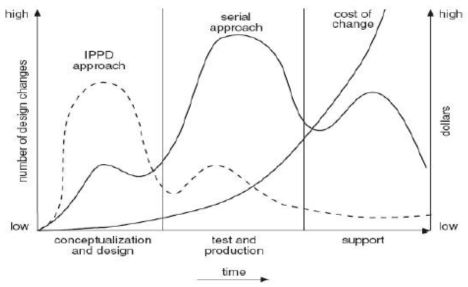


Picture 1: Reasons to Test

As customer, most likely you want get what you have paid for. (Best) Value for money, referring to quality and reliability as well. It is simply about a reliable product, meet the specifications, and especially in today's competitive world: exceed the expectations.

Reliability becomes a competitive element, an attribute to distinguish. Good reliable products, like some car brands, leads to customer trust and re-buying the product. It is no longer a technical term, but becomes a marketing tool in terms of brand loyalty and unique selling point.

Regarding to manufacturers, (1st and 2nd tier) suppliers and OEM, reliability leads to cost reductions. It starts in the development phase of components, products or systems. It is well know that the costs of changes are directly related to the phase in development process. Changes at the end of this process might lead to costs up to hundred, or even thousand fold higher than in the early design phase. Reliability analysis like FMECA (Failure Mode Effects and Criticality Analysis) or LCA (Life Cycle Analysis) enables you to do these early risk assessments in a integrated way. And in an early phase there are more opportunities to change then in latter development, manufacturing stages or in service. This curve is reverse to the costs of change curve.



Picture 2: Costs of Change

During production, interruptions due to failing, difficult to assemble components, or even worse, unreliable components leads to less efficient production lines or even production stops. Components used in the process, but as well components used in the machines. The demands on production machinery has increased significantly too. On one hand the machines should operate as much as possible, preferably 24 hours per day. But reality in the current economic situation, and with the smaller production series, is that the machine will stop and run. This can result in excessive wear-out and additional maintenance requirements. The maintenance interval can be calculated from reliability measures.

However, most important is understanding that your production is part of a *supply chain*. In today's economy, the network connections and subsequent relations are the preconditions for effective operation. Just-in-time, Kanban and other demand driven supply tools are making each supply chain step depending on another. When one step fails, the chain is broken. This will lead to production stops, reputation loss and high financial claims.

In the end it's all about expectations and costs. Expectations driven by requirements and specifications. Costs driven by effective design and efficient production and supply chains.

Complex playing field

The playing field of reliability is complex. This starts already with the definition of reliability where an integration of intended function, different environments and time is applied. These are more and more narrowly defined attributes than in the easier definition of quality.

The other complicating factor making reliability a complex concept, is the integration of mechanics, electronics and software. Often these three disciplines come together in a model or first prototype product, which is subjected to reliability testing. Anticipation can be done by system reliability and calculations, but the mutual influences remain a uncertain and complex factor in reliability estimations.

Experiences show that fail modes can be controlled at component or discipline level, but that unexpected fail modes occur after combination of these. Separate it is ok, but the end product is more than the sum of parts. On system level the product might fail then. Like the supply chain, the product is always part of a system and fail modes can come from different reasons, even culture relates, for example emerge of green environment, different use in different countries/cultures.

From a system perspective organizational influences will make product development and its reliability a complex force field. Studies from Porter, in value chain and 5 forces model can help to show the playing field in which reliability is subject.

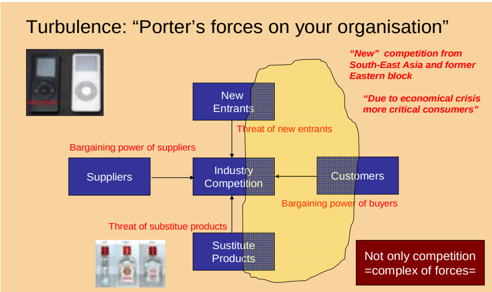
There is a dominant force from *branch internal competition*, which is the most common form of competition within the industry. Companies delivering the same proposition and competing on price, proposition and quality/reliability (Q/R).

This is not the only force working on the organization or Q/R. There is a risk that *new entrants* will enter the playing field. The amount of which depends on the entry barriers, but in time of economic pressure, price competition can lower this barrier. This makes it interesting for new entrants to enter the market with lower prices, accompanied with lower quality/reliability.

Another force arises from *substitute products*. In prosperity societies and high developed cultures we are getting used to high value products with lot of functionality. In times of crisis or over-satisfaction, the market becomes open for alternatives, substitute products for existing products. This can be extremely simplified products, ‘back-to-basics’ or products changing the demand. For example, paper is substituted by electronics. This results in completely different reliability expectations and problems.

Another force, *supplier power* can be extremely powerful in situations of dependency. Prices and delivery are fixed in contracts, and quality is embedded in terms of yield and production quality. Not in terms of reliability. There is a risk that under pressure of prices and delivery time, reliability levels will decrease, despite remaining quality levels. Quality is just a end-of-manufacturing shot, an outgoing or incoming inspection, but never a relation to real world use. Reliability, principally as durability element, is affected imperceptible.

Finally the *power of buyer* is strong and complex. This paradox is difficult to address in longer development times, simply because buyer opinions and expectations will change over time. Needs will change, prices are constantly under pressure, brand loyalty is no guarantee anymore and there is choice on the market. It remains difficult to meet current customer requirements and especially their –changing- expectations.



Picture 3: Forces on Organisation and Reliability

In terms of reliability, there are two responses as mainstream reaction. First response is low quality/reliability in terms of cheap perception and short lifetime (1 year). The other extreme is high quality/reliability for longer lifetimes. Value for money, longer product use and quality feeling.

It is critical to clearly choose in this paradox in order to prevent a stuck-in-the-middle situation. Compliance or choice is the question. The first is safe, however real competitive advantage comes from choice, from doing something different. In today’s highly competitive environment, Reliability can be that ‘something’.

Although the experience is that most of the other drivers are covered in Porter's 5 forces model, other drivers might increase the complexity even further in this area. These attributes are derived from:

- Technological drivers
- Economic drivers
- Political drivers
- Regulatory drivers
- Socio- and cultural drivers
- Power structures
- Industry integration

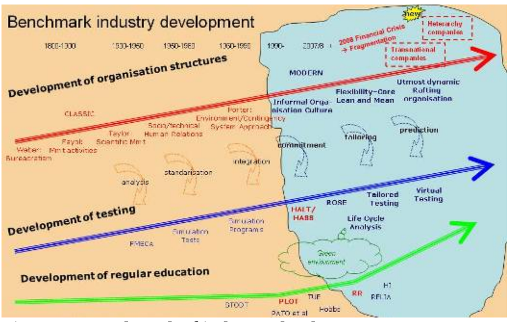
Turbulent environment

From internal complexity Porter refers to external turbulence too. As part of a contingency approach, developments in the external environment of companies need to be studied. Due to catastrophes, cultural changes, leadership styles, terrorism, wars, technological developments, new production methods etcetera, organizations and management models have changed over the past years.

Substantial changes have been influenced by different great, new thinkers on management philosophies. Names as Tailor, Fayol, Porter, Weber were founders of new era of management behavior. This management behavior was obviously the correct fit with formerly culture, social values, economic situation and expectations and became the 'rule'.

From reliability perspective it is interesting to relate these mainstream developments towards emphasized philosophies in reliability/testing.
With learning from the past, evaluating tendencies, evolutions and revolutions, it enables us after all to make an 'educated guess' on future developments.
Confidence on this guess can being increased by not only studying organizational developments from management point of view, but combining this with developments in reliability and environmental testing in the past decades.

Major developments in organizational atmosphere are presented in the picture below. On the horizontal axis the timeframes are plotted. The top line represents the '*development of organization structures*' over time. The line in the middle is referring to typical *'reliability philosophies'*. Regular '*education'* in the area of reliability and environmental testing is plotted on the lowest line.



Picture 4: Benchmark of industry developments

As marked in picture 4 we can make a difference between the *classical/ traditional* theories and the *modern* theories on the right part. In the classical theories it start around 1800 with bureaucratic thinking from *Weber*. The most remarkable phrase from Weber in this context was: "Domination is one of the most important elements of social activity". Formalization is key in a bureaucratic environment and –for so far applicable- we can see it back in Q/R by the extensive amount of (hand) written reports.

Slightly later the management principles of *Fayol* lead to awareness of control. Bureaucratic structures need strong control and this can be seen as reaction to Weber. The relation to Q/R from this perspective is the management layer around testing, control over testing, the first start towards management acceptance too.

The big change came with *Taylor's* scientific management (1900). Analysis of work processes, efficiency focus and ‘the best way’ to do things are some key elements from that time. In the industrial revolution(s) there was high focus on work organization and efficiency. It became quite common to analyze work processes and that penetrated into Q/R tasks. From typical production histograms and Pareto analysis towards root cause analysis and later on risk analysis. When these analysis became more structured, typical production FMEA’s developed, later on combined with Criticality Analysis (CA).

As reaction on the machine and efficiency driven approach of Taylor, the *socio-technical human relations* approach emerged. In stead of rationalism and formalization, focus became on human being and well-being in the organization. To centralize individuals, was a new way of thinking, and has lead to more involvement and customer focus in testing. Reliability thinking started and FMECA’s from earlier approaches were linked to effects for end-users. Combined with standardization -clear tasks in working process-, this ended up in today’s simulation tests. Simulate use.

The years 1950-1960 were dominated by lot of economic and social developments, like the economic crisis we face anno 2009. It became clear that we are under influence of a turbulent environment, rapidly changing, unpredictable and uncontrollable. In general, *Porter* has entered into the system approach.

But within the system approach, two major models found birth an developed as main response to the dynamic environments. Firstly the contingency approach from *Lawrence and Lorch*, addressing the direct environment in which the system operates. Secondary the information processing model from *Galbraith*, looking strongly into the effects of information technology and processing.

In all cases the accent and purpose was to adapt to the dynamic and turbulent environments. In steady of resistance it became acceptance and integration. Related to Q/R this enabled a further development of simulation testing under different circumstances. Simulation programs were the answer to handle different environments. This got support, especially because of making the uncontrolled more structured and controlled. There is a good response to mutual influences of the environment towards testing.

In modern theories there is more balance between formalization and informal structures. We can talk about *‘organization cultures’*, where culture stand for an uniform set of attitudes, beliefs and behavior. From Q/R perspective this leads to commitment. Q/R is accepted and raised to the level of core competencies and competitive advantage. It becomes possible to introduce new test philosophies, for example ROSE or HALT and HASS testing.

Adaptation to environments requires flexibility in organizations, which is one of the most recent developments. In order to make flexible organizations, there should be as less as possible overkill in the organization. Lean and mean production, rapid development and flexible organizations. Focus is on core activities and outsourcing of non-core activities.

Related development, catalyzed by 2009 economical crises, is *fragmentation*. Small companies arise, activities are scattered over different companies, in- and outside Europe and people leave, change jobs or drift. For Q/R this means an extremely dualistic situation. Small companies can specialize on reliability, but on other hand, the system approach (integration between departments) is fully scattered. The glue between in terms op people is reduced. The answer is found in clear targets and testing towards those targets. Element that fit in this new and turbulent environment are based on *tailoring*. This is typical in philosophies like Life Cycle Analysis and Tailored Testing, and already today we can see this growing interest in LCA.

Growing interest is not only from evolutionary point of view. Financial considerations and costs awareness of tests due to the increased outsourcing, are stimulated the need for 'just enough testing'.

These developments will continue and might result in utmost dynamic organizations, called *'rafting organizations'*. This means even more flexible Q/R approaches, where time becomes most crucial. Testing, however takes time and we need to find faster way to control the uncontrolled.

Predictions are required, already in an early design stage. Predictions on lifetime, on risks, on design flaws, on costs. Although relationships between virtual simulation testing are still weak, this area will be the future topic.

Green environment

One remarkable tendency, steadily growing and interfering with reliability is the emerge of green environment requirements. From reliability perspective it brings new challenges in terms of keeping the current Q/R levels with green products. Green products are lacking long experiences, like the lead free emerge in 2005, and intensifies reliability testing in this area. New competence on products and especially new materials have to been build and proven.

Many reliability testing is based on comparisons between the old and new materials. This required typical Q/R values, not longer a pass/fail criterion, but a solid quantification of reliability, and has accelerated the testing philosophies based on levels. ***Robustness levels*** are easy to compare and good risk assessment leads to less tests to be performed.

However, new materials have lead to new fail modes. Not only from material, but as well from construction point of view. An identical construction with new, green materials is no guarantee for good reliability.

Reliability means quality over time and degradation patterns are one major attribute to this. In the green materials, new degradation mechanism are identified and can occur unintended, but it can be the purpose too. For example the biodegradable plastics. Future topic will to estimate these degradation patterns.

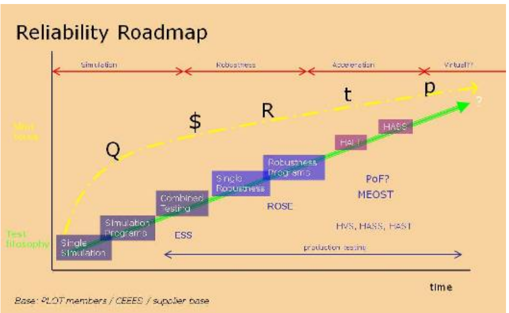
Maturity

Reliability can be proven in different ways. Firstly by analysis, in most simple format a FMEA combined with CA. Or in today's world with LCA. Secondly it can be calculated by means of RAM, MTBF and related calculations. This fits in future trends. Finally it can be established by means of testing, this is the most common, traditional and proven way.

Testing philosophies are derived from developments as stated in the earlier chapters and have lead to a separate roadmap (picture 5). In this picture the solid line with blocks is representing the test philosophies, whilst the dotted line with characters is representing the development of management focus.

Management focus towards Q/R has shifted over time. It starts with quality focus (Q), evaluating towards costs focus ($). Simulation testing is an appropriate way to match reliability with this management focus. Single tests, like a drop test or high temperature tests are giving control over the reliability of the product. Evolution of simulation testing lead to sequential testing (vibration test after temperature test) in order to check mutual dependency and have more relation to field returns. New fail modes and upcoming demands to reduce development and testing times results in further development of sequential testing in terms of combined testing, like high temperature vibration test.

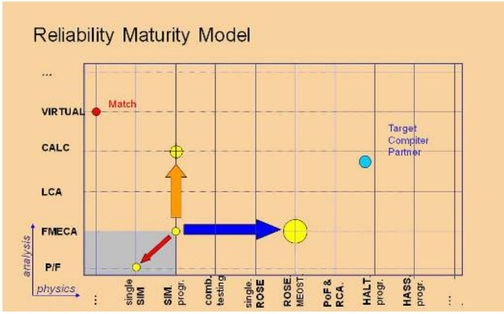
Even more pressure on reducing costs, decrease development times and faster testing the need for a more specific design related reliability focus arises (R). Robustness testing programs, where the number of tests are reduced, and the information from test increase, have become the standard. In stead of pass/fail, the robustness level is important. This is input for design and customer experience and baseline for calculations and contracts.



Picture 5: Reliability Philosophies

Today the focus will be more and more linked to time (t), where extremely fast techniques like HALT are appropriate. Although this are extremely fast testing techniques, still the preparation time need to be incorporated. It looks like the ultimate shortening of test times is reached.

Therefore the need for predictions pops up as logical response to time effects. Management focus will continue towards shortening time, combined with prediction and control (p). This is the working field of virtual simulation, modeling, linked directly to CAD systems.
In order to plasticize these reliability developments the Reliability Maturity Model is made. The 'soft' reliability, like the reliability analysis and calculations are plotted against developments in 'hard' reliability testing, the physical test philosophies (figure 6).



Picture 6: Reliability Maturity Model

The already explained physical developments are put on the horizontal axis and on the vertical axis the reliability analysis approaches are plotted. It starts with pass/fail approach. Perform a test with given specifications and check if it has met the specification or not, it can be a *pass or fail*. The next step in maturity is to work from risk assessments (*FMECA*). Firstly start with doing an analysis and then check on those critical points, for example by design evaluation or testing. Higher up in the matrix *Life Cycle Analysis* leads to more customer focus and relates the risks to usage. In more contractual form and control of usage, reliability calculations and *assurance* comes into account. Reliability measured in terms of 90% availability, 95% confidence etcetera are typical for this maturity level. Finally *virtual simulation*, virtual testing, predictions brings control over the design. Reliance on models and load/stress relationships is a significant part of this philosophy.

In the matrix you can plot your position and compare it with others. It enables you to look into the synergy you have with you supplier, to check if you are on the same thinking level, talking from the same background. But as well your competition can be plotted. Are you following the same approach, how is your competitors maturity i.c. investment in reliability. It provides an instrument for further strategic development. Is grow in your turbulent environment desired in testing direction –the horizontal axis- or in more analysis direction –the vertical axis-. Where are you and where do you want to go.

This answers the question how to cope with today's complex and turbulent situation. Start to get insight in your current position. Benchmark your position with suppliers and competitors (see the organizational forces from Porter). And finally find the appropriate philosophies in order to do correct strategy development in reliability terms.

Reliability is no longer voluntary, it's a must. But we can make it a great opportunity and create new competitive advantage by this.

The future of reliability

In past text we have seen organizational developments translated into developments in reliability. We have defined the complex and turbulent environment. For the future, it will be a time with even more social, financial and cultural influences. Trend watchers are predicting savings by big companies on innovation and start ups will take over this gap, like the internet in the 80's. Industry will change, work will be more human centralized and becoming an event, where satisfaction is key. Transnational companies and heterarchic companies will occur.

Although unclear, scattering, flexibility, development time and cost focus will result in new approaches on Q/R. Virtual simulation, modeling and prediction will be baseline for future developments. It will start with a link between physical testing and virtual simulation in order to build trust on the new techniques.

The new era requires reliability in different ways, from starting your car to controlling avionics, from coffee machine to medical equipment. Availability, and especially the contractual assurance of availability, becomes the rule.

Green environment will lead to other approaches of reliability. New materials and new fail modes will occur. Especially degradation curves will be the challenge on stable and biodegradable materials. Testing will increase.

So, it is no longer a question if we need reliability, it is that much incorporated already that we cannot do without it. Perhaps it is better to speak in terms of non-reliability. The integration of reliability in today's operation will end up in new forms of competition. Challenges will be to control costs and competence.

CONCLUSION

The *importance* of reliability in a complex and turbulent environment is rapidly and steadily growing. The importance is strongly influenced by cost awareness, shorter development times and the emerge of reliability as competitive tool.
The *complex environment* is clarified by means of Porter's 5 forces model, where not only internal competition rules. Buyer's and supplier's power, as well as threats from substitute products and new entrants are applicable for quality and reliability too.
The *turbulent environment* is defined in terms of organizational developments, where these are related to dominant approaches in reliability philosophies. This allows a look into the *future*, where this approach is combined with developments in test laboratories and ideas from trend watchers. Future companies will focus on core

competences and reduces innovation, leading to an even more fragmented reliability playfield.
Green environment will increase and put specific demands on reliability testing.
Tailoring in terms of modelling, virtual simulation, life cycle analysis and tailored testing will be the buzzwords in the new era. It's no longer a question if we need reliability, it a challenge to utilize it in timely, predictive processes and as competitive advantage.

Abbreviations

CA:	Criticality Analysis
ESS:	Environmental Stress Screening
FMEA:	Failure Mode Effect Analysis
FMECA:	Failure Mode Effect and Criticality Analysis
ROSE:	Robustness Specification for Environmental testing
HALT:	Highly Accelerated Life Testing
HASS:	Highly Accelerated Stress Screening
LCA:	Life Cycle Analysis
MEOST:	Multiple Environment Overstress Testing
PoF:	Physics of Failure
Q/R:	Quality and Reliability
RAM:	Reliability, Availability and Maintainability

References

[1] System reliability theory; Models, Statistical Methods, and Application. M. Rausand and A. Hoyland, 2004, Wiley
[2] Michael Porter, Competitive Advantage, New York, 1985
[3] Strategy systhesis, Bob de Wit, Maastricht, 2005
[4] Designing organizations, Jay R. Galbraith, Colorado, 2001
[5] Handboek Managmentvaardigheden, Robert E. Quinn et al., New york, 2003
[6] Organization Life Cycles, Robert E. Quinn et al. Management Science, 1983
[7] A contingency approach to strategy implementation, V. Govindarajan, Academy of Management Journal, 1988
[8] Theories of bounded rationality, H.A. Simon, Amsterdam, 1972
[9] SEES Environmental Engineering Handbook, Stockholm, 1997
[10] World Class Reliability, Keki R. Bhote, New York, 2004
[11] Adjieh Bakas, The future of work, 8 Megatrends, Amsterdam, 2009