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Reliability Engineering: Value, Waste, and Costs

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Contents

Introduction

- Reliability of product depends to large extent on quality and integrity of processes used to design and to manufacture it.
- High field reliability is typically achieved through selection and execution of specific reliability engineering activities during product development.
- However, discipline of reliability engineering has not kept pace with modern technology.
- Some reliability engineering activities practised today are outdated, misleading, or even fundamentally flawed.

Introduction

- This may result in execution of activities which cannot contribute to primary objective of reliability engineering, which is prevention of failure.
- Furthermore, other useful reliability engineering activities are often omitted from product development processes, which may increase risk of releasing products with inferior reliability.

Introduction

- Lean Thinking (or lean) is well-known as management philosophy with primary objective of maximising value to customer by removal of waste from all activities.
- Fundamental concept in lean is creation of value through elimination of waste, which is defined as any non-value added activity or process.

Introduction

- It may therefore be appropriate to challenge value of reliability engineering, and to redefine role thereof in product development.
- Lean provides useful perspective with principles for meaningful and critical assessment of practice of reliability engineering.
- If development process or specific reliability engineering activity does not add value to design and production of failure-free products, it may be considered as waste.

Fundamentals of reliability engineering

- Reliability, according to conventional definition, is "probability that an item will perform a required function without failure under stated conditions for a stated period of time."
- This definition combines two distinct disciplines, namely statistics (e.g., probability) and engineering (e.g., required product or system functions, operating conditions and period of time).

Fundamentals of reliability engineering

- Unfortunately, focus on probability has over years resulted in major emphasis on various aspects of mathematics and statistics in reliability engineering.
- This emphasis is understandable given state of technology when reliability engineering activities were originally developed (i.e., vacuum tube).
- Many electrical and electronic parts at that time failed due to quality problems or due to wear-out, resulting in today's misleading beliefs that all parts have relevant failure rates, and that all system failures are caused by part failures.

Fundamentals of reliability engineering

- In 1965, Raymond Hollis wrote "Conventional statistical reliability techniques are a necessary condition of reliability. They are, however, insufficient and inadequate. Other reliability techniques are needed to turn a feasibly designed system into a completely successful one. The implementation of these techniques is lagging."
- It is interesting to note that Hollis expressed need for "reliability techniques which embody engineering principles" shortly after the birth of reliability engineering in 1957.

Fundamentals of reliability engineering

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- In 1995, Philip Crosby wrote that "All non-conformances are caused. Anything that is caused can be prevented."

- In 2011, Norman Pascoe wrote "All failures in electronic equipment can be attributed to a traceable and preventable cause and may not be satisfactorily explained as the manifestation of some statistical inevitability."

- These sentences suggest that product or system failures are caused, and that all these failures can be prevented.

Fundamentals of reliability engineering

- When product failure occurs and root cause analysis is performed, it becomes evident that failures are created, primarily due to errors made by people.
- These include design and production personnel, as well as operators and maintenance personnel.
- Based on these statements, and applying common sense to real life experience, reliability and reliability engineering may be defined as follows:

Fundamentals of reliability engineering

- Reliability is the absence of failures in products.
- Reliability engineering is the management and engineering discipline that prevents the creation of failures in products.

- These simple definitions imply that product is reliable if it does not fail (during its expected life under full range of conditions experienced in field), and that this failure-free state can only be achieved if failure is prevented from occurring.

Fundamentals of reliability engineering

- What is required to prevent failure?
- Firstly, engineering knowledge to understand applicable failure mechanisms, and secondly, management commitment to mitigate or eliminate them.
- Proactive prevention of failure should be primary focus of reliability engineering, and never reactive failure management or failure correction.
- Reliability engineering activities change from proactive during design and development to reactive during production and especially during operations.

Fundamentals of reliability engineering

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- Reliability is non-functional requirement during design and development, and that it becomes characteristic of product or system during operations.
- Product development is iterative process where design is followed by verification, with analysis and test as two primary verification methods used in engineering.
- Product reliability is the result of many management and technical decisions taken during all development stages (i.e., concept, definition, design and production).

Fundamentals of reliability engineering

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- Reliability engineering activities are often neglected during development, resulting in substantial increase in risk of project failure, or customer dissatisfaction due to inferior reliability.
- It is therefore recommended that reliability engineering activities be formally integrated with other systems engineering technical processes.
- Practical way to achieve integration is to develop reliability program plan at start of project.

Fundamentals of reliability engineering

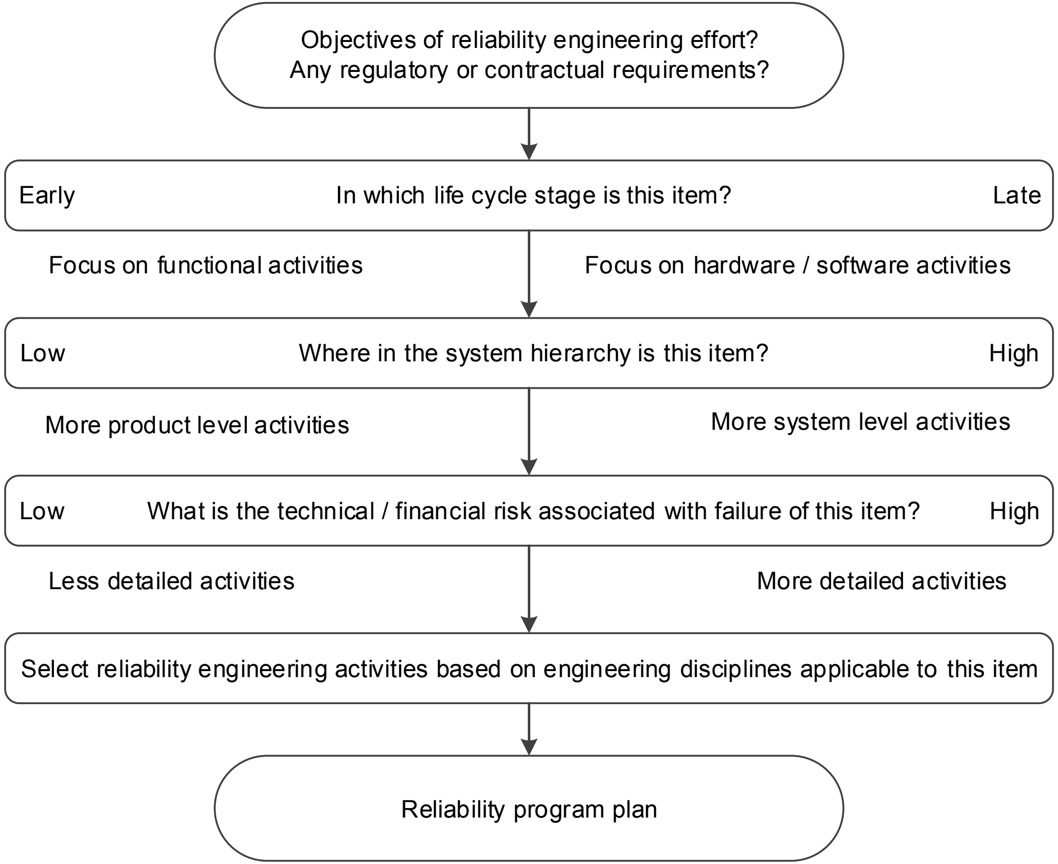
- ANSI/GEIA-STD-0009, Reliability Program Standard for Systems Design, Development, and Manufacturing, can be referenced for this purpose [ANSI/GEIA-STD-0009, 2008].
- This standard supports system life-cycle approach to reliability engineering, and consists of four parts with following objectives:
  - Understand Customer / User Requirements and Constraints.
  - Design and Redesign for Reliability.
  - Produce Reliable Systems / Products.
  - Monitor and Assess User Reliability.

Fundamentals of reliability engineering

- Reliability engineering activities can be divided into two groups, namely *engineering analyses and tests*, and *failure analyses*.
- Engineering analyses and tests refer to traditional design analyses and test methods.
- Failure analyses refer to traditional reliability analyses to improve understanding of cause-and-effect relationships.

Fundamentals of reliability engineering

- Due to multitude of reliability engineering activities available, inexperienced engineers may find it difficult to develop efficient and effective reliability program plan.
- Relevant aspects which may be used to guide development of reliability program plan for specific project.
- Aspects such as technology maturity, complexity, life cycle stage, and failure consequence should be considered during activity selection process.



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Fundamentals of lean

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- Lean is well-known as management philosophy with primary objective of maximising value to customer by removal of waste from all activities.
- Origins of lean can be found in Toyota Production System, which is seen as major contributor to Toyota's success in automotive market.
- This production system dramatically reduced vehicle production time and costs, and simultaneously increased product quality and reliability.

Fundamentals of lean

- Concepts of value and waste are fundamental in lean.
- Overall objective is to minimise waste in order to maximise value.
- Waste is simply anything which does not create value.
- There is inverse relationship between value and waste; more waste means less value (and vice versa).
- "In short, lean thinking is *lean* because it provides a way to do more and more with less and less."
- Lean has increasing efficiencies as central aim.

Fundamentals of lean

- Lean has been widely applied in many manufacturing industries, and in other sectors.
- More recently, lean has been introduced to new product development and systems engineering.
- Lean product development is "customer focused and knowledge based approach to eliminate waste of design reiteration in new product development."
- Lean systems engineering is defined as "application of lean wisdom, principles, practices and tools to systems engineering in order to enhance the delivery of value to system's stakeholders."

Fundamentals of lean

- Overemphasis on waste removal should be challenged when applied to industries other than manufacturing.
- Approach of identifying wasteful activities and then to eliminate them, has caused lean to be thought of (and even incorrectly defined) in terms of removing waste.
- Focus should in first place be on value creation, and not on waste removal.
- Lean can become disabling if it privileges short term efficiency gain over design integrity, robustness and system reliability. Disabling effect is especially relevant in non-repetitive activities such as product development.

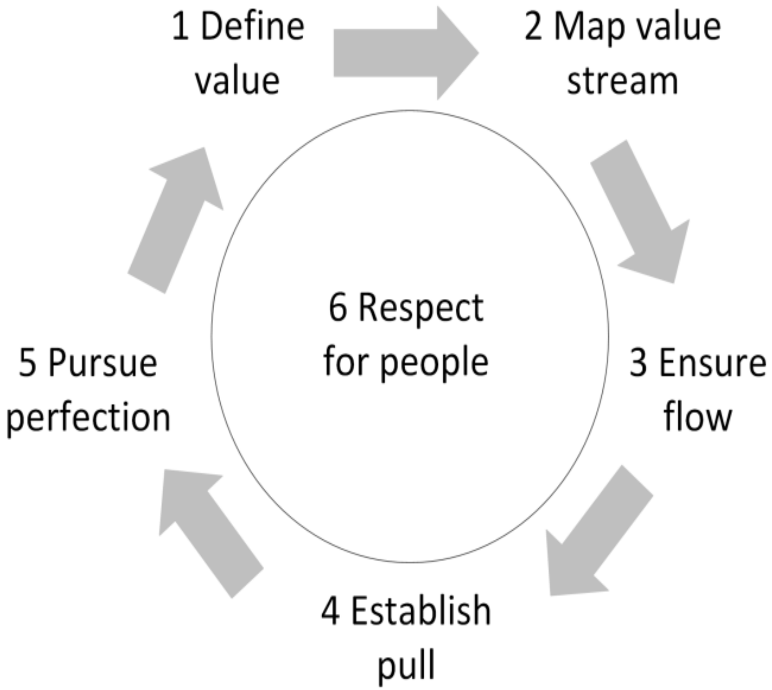
Lean principles

- Practice of lean is often described by so-called lean principles, originally described as definition of value, mapping of value stream, flow, pull and perfection.
- Sixth principle was later added to ensure adequate consideration for respect for people in any lean implementation.
- Implementation of lean techniques therefore consists of following:

Lean principles

1) Define value from viewpoint of customer (either external or internal).
2) Identify and map all steps in value stream (eliminating waste whenever possible).
3) Ensure that work flows through these steps without delays or rework.
4) Establish pull from next upstream activity.
5) Pursue perfection of all activities and processes.
6) Introduce respect for people in all work activities.

Lean principles



Value

- Value of product or system to customer depends on customer perceptions and preferences.
- Value is concerned with importance, worth, or usefulness of something.
- Value of product or system is always determined by customer, and not by developer or producer.
- It is important to note that customer is not necessarily end user; it can be anybody receiving product or service in supply chain.

Value

- Value essentially as ratio of benefits to costs:

$$Product\ value \propto Benefits/Costs$$

$$Product\ value \propto Product\ performance/(Price)(Lead\ time)$$

Waste

- Lean classifies all work activities into three categories:
- Value added activities, which have to satisfy three conditions:
  - Transform information or material, or reduce uncertainty.
  - Customer is willing to pay for (that is, if customer understood details, he would approve of this activity).
  - It is done right the first time.

Waste

- Required (also called necessary) non-value added activities, which cannot be eliminated because they are required by law, contract, company mandate, current technology, or other such reason.
- Non-value added activities, which consume resources and create no value (also called pure waste).

Waste

- Overproduction (e.g., producing more than next process or activity needs).
- Waiting (e.g., waiting for information).
- Transportation (e.g., moving information around).
- Processing (e.g., doing unnecessary processing on task, or unnecessary task).
- Inventory (e.g., build-up of information that is not being used).
- Motion (e.g., excessive motion or activity during task execution).
- Defects (e.g., inspection or correction of errors made).

Lean applied to reliability engineering

- Any process can be viewed as group of related activities that collectively produce required output.
- While efficiency of all processes may be improved by removal of wasteful activities, process can in totality be considered as waste, and specifically if it does not produce required output.
- It may therefore be useful to distinguish between waste associated with process failing to support primary objective of that process, and waste associated with individual activity of otherwise valuable process.

Lean applied to reliability engineering

- Accurate definition of value and subsequent identification of waste are essential steps for successful lean implementation.
- Value and waste may be relatively easy to define for manufacturing process, but it may be much more difficult for product development.
- Lean in manufacturing process is activity (or task) based, with strong focus on identification and elimination of wasteful activities.
- Focus is on waste removal (i.e., activity based).

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Lean applied to reliability engineering

- However, lean in product development is knowledge based, with strong focus on development process itself.
- Major source of waste in product development is caused by reiteration of design stage due to late identification of design deficiencies, including inferior product reliability.
- Overall objective is thus to increase learning and capturing of knowledge early during development stages to make correct design decisions to prevent repeating design stage.
- In lean product development, it is therefore often beneficial to perform more (and not less) activities to become leaner.
- Focus is on value creation (i.e., knowledge based).

Value

- Application of lean to reliability engineering implies that reliability engineering activities should focus on creation of value to customer.
- Alternatively, it means that execution of reliability engineering activities should not be considered as waste.
- We therefore need definition on value of reliability activity.

Value

- Closer look at execution of typical reliability engineering activities reveals that specific activity can:
  - Identify design or process improvement opportunity (i.e., creates value), or
  - Confirm absence of design or process improvement opportunity (i.e., creates value), or
  - Provide no useful information (i.e., creates no value).

Value

- Value in reliability engineering is therefore created by:
  - Performing an activity which, through any design or process improvement, results in elimination (or reduction in probability) of product failure, or
  - Performing an activity which, through confirmation of absence (or low probability) of potential failure modes, results in reduction in uncertainty.

Value

- $Reliability\ engineering\ activity\ value \propto Activity\ performance/(Price)(Lead\ time)$
- Activity performance should always be viewed in terms of its ability to contribute to overall objective of reliability engineering, namely prevention of failure.
- This definition is useful when different reliability activities are evaluated in terms of their performance, price and lead time.
- For example, identification of design or production weakness using efficient and inexpensive accelerated life test conducted over a short time period is clearly more valuable than inefficient

Value

- Diagram which is proposed to facilitate development of reliability program plan, does not refer to value of reliability engineering activities.
- From lean viewpoint, we have to include question "What value can be added by this specific activity?" to diagram.
- If specific activity does not contribute to objective of designing and producing failure-free products and systems, it should simply not be performed.

Waste

- Any product development process involves numerous engineering and management decisions.
- Execution of specific reliability engineering activities may provide knowledge required to make right technical decisions at right time.
- Techniques such as QFD (Quality Function Deployment), set-based development, extended exploration stage, and execution of reliability engineering activities (e.g., design of experiments, accelerated testing, FMEA and FTA) can be used for this purpose.

Waste

- If reliability engineering activity is not selected and executed where required, it may increase risk of making inferior decisions.
- For example, worst case analysis performed during product development may prevent several problems in later life cycle stages (such as integration difficulties during production, and inferior product reliability during operations).
- All analyses and tests performed to understand applicable failure mechanisms prior to finalising design configuration are thus extremely valuable.

Waste

- Apart from the general sources of waste as defined by lean (i.e., overproduction, waiting, transportation, processing, inventory, motion and defects), there are specific sources of waste in reliability engineering.
- These can be grouped into categories relating to *selection* and *execution* of reliability engineering activities.
  - Selection of fundamentally flawed activities
  - Selection of incorrect activities
  - Execution of activities at incorrect time
  - Incorrect execution of activities

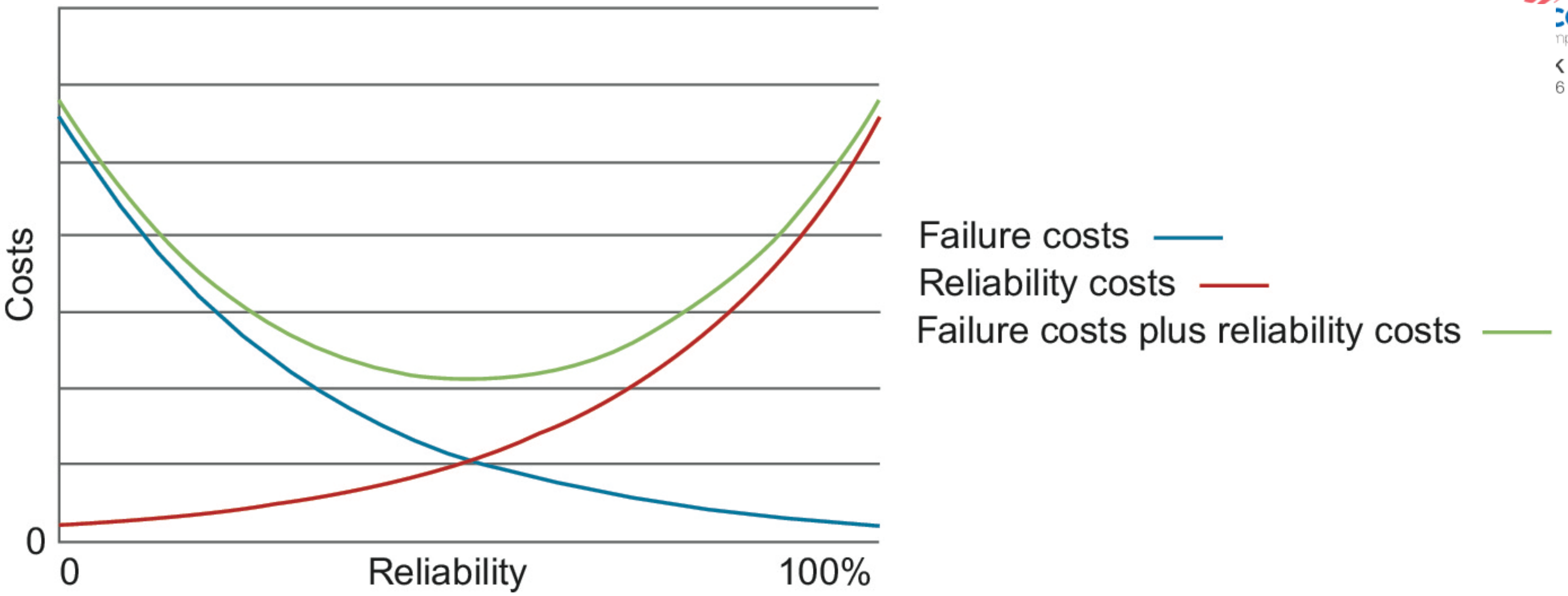
Reliability costs

- Value of reliability engineering activity is related to costs associated with that activity (i.e., price and lead time).
- Execution of activities described in reliability program plan can be expensive, depending on specific product and its reliability requirements.
- This is due to costs involved with design improvements, reliability personnel, reliability analyses, reliability tests, test equipment, and test units.

Reliability costs

- Conventional viewpoint on reliability costs suggests that for higher reliability, reliability costs will increase and failure costs will obviously decrease, resulting in an optimum reliability value where total costs are minimised.
- Reliability costs include all costs associated with achieving reliability, while failure costs refer to all costs related to unreliability (e.g., rework, repair and warranty claims).

Reliability costs



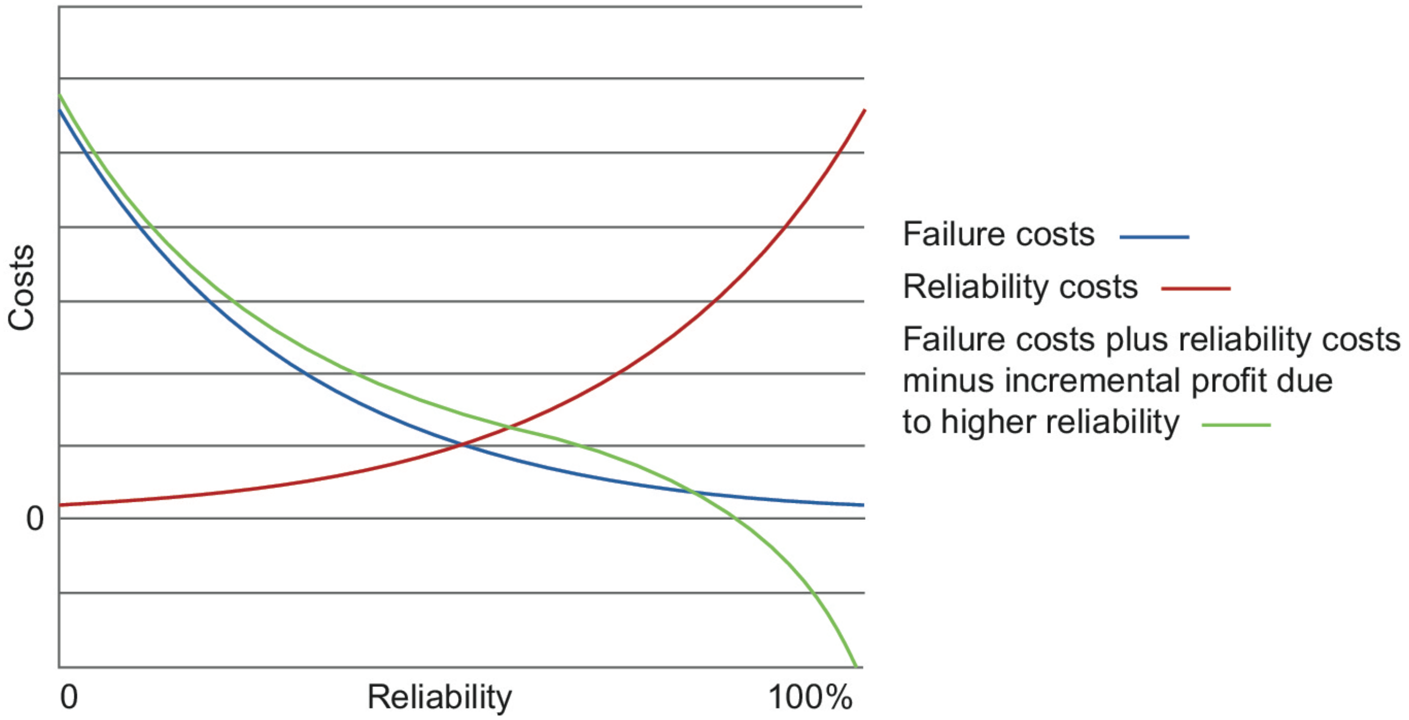
Reliability costs

- However, since less than 100% reliability is result of failures, all of which have preventable causes, this viewpoint may be misleading.
- All efforts to improve reliability by identifying and removing potential causes of failures should result in cost savings later in the product life cycle.

Reliability costs

- Conventional viewpoint ignores other important ‘bigger picture’ or system aspects such as enhanced brand reputation, increased market share, and more focus of engineers on new product development (and not repairing failed units).
- At higher levels of reliability, return on investment becomes progressively larger than cost of achieving that higher reliability (i.e., incremental profit).

Reliability costs



Conclusions

- Several reliability engineering activities practised today cannot contribute to primary objective of reliability engineering.
- It may therefore be appropriate to challenge value of reliability engineering, and to redefine role thereof in product development and systems engineering.
- Lean as management philosophy provides useful perspective with principles for meaningful and critical assessment of practice of reliability engineering.

Conclusions

- Reduction (or preferably elimination) of waste is key principle of lean.
- Major source of waste in product development is caused by reiteration of design cycle due to design deficiencies (e.g., inferior product reliability).
- Risk associated with this type of waste may be reduced by *correct selection* and *correct execution* of specific reliability engineering activities, especially early during product development.

Conclusions

- Any reliability engineering activity which does not contribute to objective of designing and producing failure-free products and systems may be considered as waste, and should not be performed.
- On other hand, execution of more reliability engineering activities (and not less) can be extremely valuable in product development.

Conclusions

- Lean is thus applicable to reliability engineering, and definition of value and identification of waste should be considered during any product development process.
- Focus on value plays important role in establishment of specific development process, while focus on waste applies more to individual activities of that development process.