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Certified Reliability Professional Sample Material

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1. STRATEGIC MANAGEMENT

Reliability engineering is engineering that emphasizes dependability in the lifecycle management of a product. Dependability, or reliability, describes the ability of a system or component to function under stated conditions for a specified period of time. Reliability engineering represents a sub-discipline within systems engineering. Reliability is theoretically defined as the probability of success (Reliability=1-Probability of Failure), as the frequency of failures, or in terms of availability, as a probability derived from reliability and maintainability. Maintainability and maintenance is often defined as a part of "reliability engineering" in Reliability Programs. Reliability plays a key role in the cost-effectiveness of systems.

Reliability engineering deals with the estimation and management of high levels of "lifetime" engineering uncertainty and risks of failure. Although stochastic parameters define and affect reliability, according to some expert authors on Reliability Engineering, e.g. P. O'Conner, J. Moubray and A. Barnard, reliability is not (solely) achieved by mathematics and statistics. "Nearly all teaching and literature on the subject emphasize these aspects, and ignore the reality that the ranges of uncertainty involved largely invalidate quantitative methods for prediction and measurement"

Reliability engineering relates closely to safety engineering and to system safety, in that they use common methods for their analysis and may require input from each other. Reliability engineering focuses on costs of failure caused by system downtime, cost of spares, repair equipment, personnel and cost of warranty claims. Safety engineering normally emphasizes not cost, but preserving life and nature, and therefore deals only with particular dangerous system-failure modes. High reliability (safety factor) levels also result from good engineering, from attention to detail and almost never from only re-active failure management (reliability accounting / statistics).

1.1. Reliability Benefits

Reliability engineering or the work to minimize failures, improve maintenance effectiveness, shorten repair times, and meet customer & organization expectations has many benefits. Here is a list of benefits to consider when wondering if your work as a reliability professional is worth the effort.

- ✓ Expectation - Products work under environmental and use conditions imposed by the customer. Creating a product the matches the expectations imposed by the customer permit the product to work as expected. Understanding the conditions allow the design to meet without over designing thus optimizing product cost and customer satisfaction.
- ✓ Time - Unanticipated failures cost time for customers and for the organization to resolve the failures. Using reliability and availability concepts we can minimize failures and avoid wasting time.
- ✓ Throughput - Downtime for any reason reduces the system's throughput, downtime can be minimized by applying predictive and preventative maintenance programs. A well maintained system minimizes operating expenses and maximizes throughput.
- ✓ Production - Some products require a run-in or burn-in to identify and eliminate early life failures or to refine and optimize system operation. Using reliability engineering techniques we can minimize the time and resource impact of run-in or burn-in operations. Eliminating or

minimizing the time we reduce inventory carrying costs, tooling costs, and energy requirements.

- ✓ Distribution - Fewer failures and optimized maintenance implies fewer spare parts in the logistics system. This minimizes the distribution system costs for transportation, logistics, and storage for spare parts. This also minimizes service labor costs.
- ✓ Warranty - Products that operate as expected without failure avoid being returned or serviced under warranty. Calls to service support, trouble shooting, product returns, failure analysis, and reengineering all part of the cost of unreliability. Warranty provides customers insurance in case of failure and with reliability engineering techniques the costs are minimized.
- ✓ Safety - Some product failure cause unintended or unsafe conditions leading to loss of life or injury. Reliability engineering tools assist in identifying and minimizing safety risks.
- ✓ Liability - Product failures can cause the loss of property. Minimizing failures and mitigating the damage caused by any failure minimizes the exposure to liability for the property loss.
- ✓ Design - Enhancing the design team's reliability engineering capabilities through training and staffing of reliability professionals enables the entire team to make decisions fully considering the impact on product reliability. This reduces the need for expensive redesign or rework costs to address reliability related design errors.

There are more ways reliability engineering is of value, yet this list provides a few ways to consider the benefits of reliability engineering. Optimizing reliability has plenty of benefits, therefore enjoy the difference you are making.

1.2. Quality and Reliability

Reliability is "quality changing over time." The everyday usage term "quality of a product" is loosely taken to mean its inherent degree of excellence. In industry, this is made more precise by defining quality to be "conformance to requirements at the start of use". Assuming the product specifications adequately capture customer requirements, the quality level can now be precisely measured by the fraction of units shipped that meet specifications.

But how many of these units still meet specifications after a week of operation? Or after a month, or at the end of a one year warranty period? That is where "reliability" comes in. Quality is a snapshot at the start of life and reliability is a motion picture of the day-by-day operation. Time zero defects are manufacturing mistakes that escaped final test. The additional defects that appear over time are "reliability defects" or reliability fallout.

The quality level might be described by a single fraction defective. To describe reliability fallout a probability model that describes the fraction fallout over time is needed. This is known as the life distribution model.

Difference

The person who uses a product often uses the terms quality and reliability interchangeably, but they mean very different things.

Quality is the standard of something as measured against other things. It is the measure of excellence or state of being free from defects or deficiencies. From this definition, you assess the quality of something relative to something else, and what you measure is the result of its manufacture.

Reliability has two related definitions. One is the state of being dependable. The other is consistency – that is, the degree to which something yields the same or compatible result time after time. These definitions are related in that one is dependable based on his or her ability to do, act, say or behave in a consistent manner.

So where do quality and reliability come from? Reliability is a function of the design; quality is a result of the manufacturing. When a product is designed and handed over to manufacturing to produce, it is accompanied by a "specification." The specification, or "spec," describes the product completely and is the basis for determining quality, and becomes the standard against which it is measured.

If developing a new product is difficult, specifying it so manufacturing makes it as designed is just as difficult. When someone returns a product with a complaint and it is taken to manufacturing to inspect, manufacturing takes out the specifications they were given and compares the product to the specs. If the product conforms to the specifications, manufacturing will correctly say, "The quality is perfect." So, the definition of quality is simply whether or not the product meets the specification.

Reliability is what engineers build into the product as part of the design and specification. The creative concept behind the design plays a huge role in determining the overall reliability of the design.

Reliability is built into a product as part of the design and selection of materials. In the end, it is a combination of great design, materials selection, specification and manufacturing that creates products that have both reliability and quality you can trust.

1.3. Customer Needs Assessment

Customers expect products to not only meet the specified parameters upon delivery but to function throughout what they perceive as a reasonable lifetime.

The study of reliability engineering is usually undertaken primarily to determine and improve the useful lifetime of products. Data are collected on the failure rates of components and products, including those produced by suppliers. Competitor's products may also be subjected to reliability testing and analysis.

A needs assessment is a systematic process for determining and addressing needs, or "gaps" between current conditions and desired conditions or "wants". The discrepancy between the current condition and wanted condition must be measured to appropriately identify the need. The need can be a desire to improve current performance or to correct a deficiency.

A needs assessment is a part of planning processes, often used for improvement in individuals, education/training, organizations, or communities. It can refine and improve a product such as a training or service a client receives. It can be an effective tool to clarify problems and identify appropriate interventions or solutions. By clearly identifying the problem, finite resources can be directed towards developing and implementing a feasible and applicable solution. Gathering appropriate and sufficient data informs the process of developing an effective product that will address the groups needs and wants. Needs assessments are only effective when they are ends-focused and provide concrete evidence that can be used to determine which of the possible means-to-the-ends are most effective and efficient for achieving the desired results.

There are three perspectives on need in a needs assessment; perceived need, expressed need and relative need.

- ✓ Perceived needs are defined by what people think about their needs, each standard changes with each respondent.
- ✓ Expressed needs are defined by the number of people who have sought help and focuses on circumstances where feelings are translated into action. A major weakness of expressed needs assumes that all people with needs seek help.
- ✓ Relative needs are concerned with equity and must consider differences in population and social pathology.

Reliability Engineering Tools

Reliability engineering tools help the design engineer work more efficiently and effectively in various ways, as various terms used are

- ✓ Mean Time Between Critical Failure (MTBCF) – The mean time between failures of mission-essential functions, calculated as the ratio of active hours (those excluding scheduled maintenance) and the number of critical failures.
- ✓ Mean Time Between Downing Events (MTBDE) – A measure calculated as the total uptime over the number of downing events.
- ✓ Mean Time Between Failure (MTBF) – The mean equipment operating time between failures of any type, calculated by dividing uptime by the total number of failures.
- ✓ Mean Time To Failure (MTTF) – A system, subsystem or device's mean time to failure, as calculated at a specific point in time. This differs from MTBF in that it changes over time as the system is maintained.
- ✓ Mean Time To First Failure (MTTFF) – The Mean Time to Failure starting from when the system is first made to be Mission Capable.
- ✓ Mean Time to Repair (MTTR) – The total amount of time spent performing all corrective maintenance repairs divided by the total number of those repairs.

One of the most crucial reliability function is the anticipation of possible failures and the establishment of reliability acceptance goals that will limit their occurrence and consequent costs. Once component, product, and system reliability goals have been set, a testing protocol should be implemented to provide validation that these goals will impact the failure rates and the associated consequences as planned.

Reliability engineers take the long-term view and develop cost-effective ways to reduce lifecycle costs. These may range from design techniques such as redundancy and adhering to specification of manufacturing parameters such as burn-in-time. Increased reliability sometimes means increased manufacturing cost and selling price. Properly implemented, however, the result will be a decrease in lifecycle cost.

Prototyping

A prototype is an early sample, model, or release of a product built to test a concept or process or to act as a thing to be replicated or learned from. It is a term used in a variety of contexts, including semantics, design, electronics, and software programming. A prototype is designed to test and try a new design to enhance precision by system analysts and users. Prototyping serves to provide specifications for a real, working system rather than a theoretical one. In some workflow models, creating a prototype (a process sometimes called materialization) is the step between the formalization and the evaluation of an idea.

There is no general agreement on what constitutes a "prototype" and the word is often used interchangeably with the word "model" which can cause confusion. In general, "prototypes" fall into two basic categories:

- ✓ Proof-of-Principle Prototype (Model) (in electronics sometimes built on a breadboard). A Proof of concept prototype is used to test some aspect(s) of the intended design without attempting to exactly simulate the visual appearance, choice of materials or intended manufacturing process. Such prototypes can be used to "prove" out a potential design approach, such as range of motion, mechanics, sensors, architecture, etc. These types of models are often used to identify which design options will not work, or where further development and testing is necessary.
- ✓ Form Study Prototype (Model). This type of prototype will allow designers to explore the basic size, look and feel of a product without simulating the actual function or exact visual appearance of the product. They can help assess ergonomic factors and provide insight into visual aspects of the product's final form.

Quality Function Deployment (QFD)

Quality Function Deployment is a method for prioritizing and translating customer inputs into designs and specifications for a product, service, and/or process. While the detail of the work involved in QFD can be both complex and exhaustive, the essentials of the QFD method are based on common-sense ideas and tools. QFD is a planning tool that relates a list of delights, wants, and needs of customers to design technical functional requirements.

With the application of QFD, possible relationships are explored between quality characteristics as expressed by customers and substitute quality requirements expressed in engineering terms. In the context of DFSS, these requirements critical-to characteristics, which include subsets such as critical-to-quality (CTQ) and critical-to-delivery (CTD). In the QFD methodology, customers define the product using their own expressions, which rarely carry any significant technical terminology. The voice of the customer can be discounted into a list of needs used later as input to a relationship diagram, which is called QFD's house of quality.

One major advantage of a QFD is the attainment of shortest development cycle, which is gained by companies with the ability and desire to satisfy customer expectation. The other significant advantage is improvement gained in the design family of the company, resulting in increased customer satisfaction. QFD is a robust method having many variations in applications, as

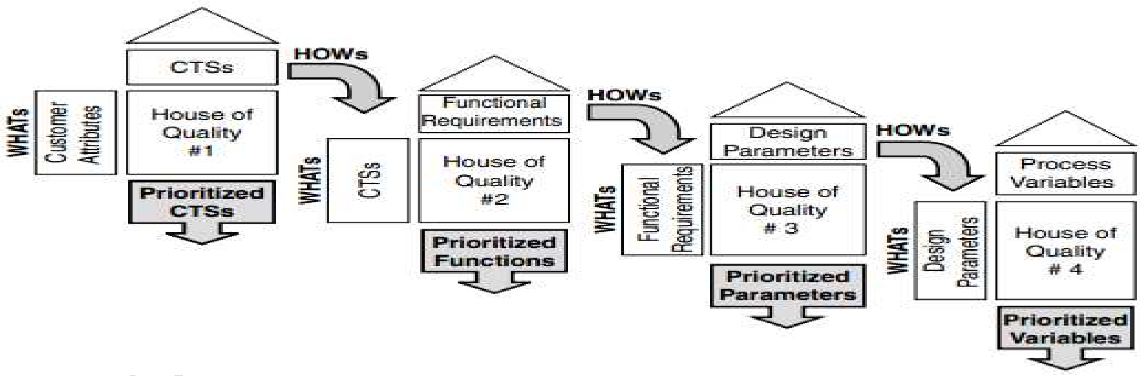
- ✓ Prioritize and select improvement projects based on customer needs and current performance
- ✓ Assess a process's or product's performance versus competitors
- ✓ Translate customer requirements into performance measures
- ✓ Design, test, and refine new processes, products, and services

QFD uses various other methods like Voice of the Customer input to Design of Experiments, to work well. A special multidimensional matrix, also called as the "House of Quality," is the best-known element of the QFD method. A full QFD product design project will involve a series of these matrices, translating from customer and competitive needs to detailed process specifications. QFD concept involves two core concepts, which are

<u>The QFD Cycle</u> - An iterative effort to develop operational designs and plans in four phases of

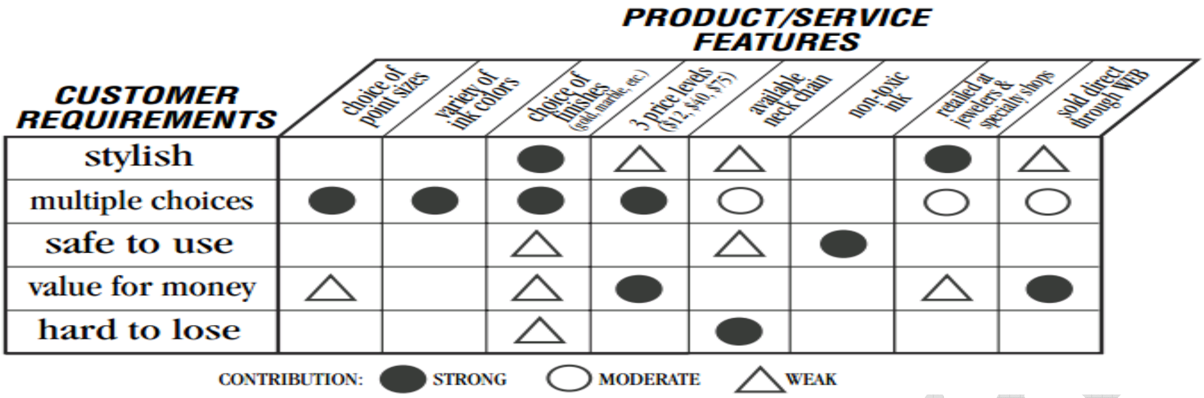
- ✓ Translate customer input and competitor analysis into product or service features.
- ✓ Translate product/service features into product/service specifications and measures.
- ✓ Translate product/service specifications and measures into process design features.
- ✓ Translate process design features into process performance specifications and measures.

QFD is accomplished by multidisciplinary DFSS teams using a series of charts to deploy critical customer attributes throughout the phases of design development. QFD is usually deployed over four phases. The four phases are phase 1—CTS planning, phase 2—functional requirements, phase 3—design parameters planning, and phase 4—process variables planning, as shown in the figure below.



<u>Prioritization and Correlation</u> - Detailed analysis of the relationships among specific needs, features, requirements, and measures. Matrices like the House of Quality or the simple L-Matrix keep this analysis organized and document the rationale behind the design effort.

The QFD Cycle develops the links from downstream Ys (Customer Requirements and Product Specifications) back to upstream Xs (Process Specifications) in the design process itself. With an existing process or product, it can be used to clarify and document those relationships if they've never been investigated before. Another benefit of the House of Quality is a "diagonal" relationship test afforded by the matrix, testing combinations that may not have been considered by our standard human "linear" thought processes. An example is shown below



QFD analysis is conducted in six steps as

- ✓ It starts with the articulation of customer requirements. Techniques used could be interviewing, observation, prototyping, conceptual modeling, etc. The data from marketing research are also used. These requirements are also known as the "What's".
- ✓ In the second step, the company's current product is ranked against the competitors.
- ✓ Next, the team looks at Product/Process Characteristics, in other words, the "How's" of meeting the customer requirements. Candidate CCR's are listed across the top and for each their relevance is considered and ranked as to which will address customer needs.
- ✓ Then, the team relates customer and technical requirements with ratings such as "high", "moderate", "low", and "no" correlation. The team evaluates the degree to which customer wants and needs are addressed by the product or process characteristics.
- ✓ In the fifth step, the roof of the "House" focuses on relationships among product/process characteristics. It shows whether the "How's" reinforce or conflict with one another.
- ✓ In last, the team summarizes the key conclusions. It ranks the relevance of product or process characteristics to the attainment of customers' wants or needs.

1.4. Project Management

Project Management refers to the process of getting the project completion within the available resources and designated timeframe effectively and efficiently. It includes various crucial entities which are

Project Charter and Plan – Project charter is a statement of objectives of a project which also sets out detailed project goals, roles and responsibilities. It also identifies the main stakeholders. Project charter henceforth consists of the problem statement for which the project is initiated, the purpose outlining the goals to be achieved by the project, the scope of the project on enlisting the resource requirement and the results to achieve in quantifiable terms. Project charter also contains the likely benefits to the stakeholders for taking up the project and justifies the feasibility for same.

Project plan development involves setting up timelines and milestones to achieve as the project processes. It acts as the basis on which resource requirements are computed. Various project planning tools are used for the purpose like Gantt charts, CPM/PERT charts, project schedules, etc.

Project Risk Analysis is conducted during project planning to work out feasibility of the project as well develop counter-measures to mitigate risks involved and their impact. Usually aspects of project which are analyzed are safety, reliability, serviceability, etc. Risk analysis involves identification and mitigation of risks. Various analysis tools are used like

- ✓ SWOT (Strengths, Weaknesses, Opportunities and Threats) Matrix - It involves a scan of the internal and external environment to classify internal as strengths (S) or weaknesses (W), and those external to the firm can be classified as opportunities (O) or threats (T).
- ✓ Risk Priority Number - Risk Priority Number (RPN) is a measure risk by assigning the RPN values range from 1 (absolute best) to 1000 (absolute worst) to identify critical failure modes with project.
- ✓ Failure modes and effects analysis (FMEA) - It identifies failures in a project by studying the impact of all possible failures which are prioritized according to severity, frequency and identification.

Risk mitigation involves continuous review of risk identification and mitigation plans as during project progress environmental changes and new risk are identified if any step changes mid way thus, a risk management system is embedded during project planning.

Project Scope – After defining the project charter and planning, the project scope is finalized thus, defining the resource requirement and listing the affected departments during the project execution. Project managers utilize various tools during this step like SIPOC, Pareto charts, brainstorming, etc to defining and documenting the project scope.

Project Metrics – They are the essential component of project management which shows the status of the project. Their selection and updation is necessary for proper monitoring of the project's progress. Project metrics are tactical and used by project manager to adapt project work flow and technical activities i.e. guide adjustments to work schedule to avoid delays and assess product quality on an ongoing basis. Project metrics usually applied measure consumption of time, budget, other resources and quality of output.

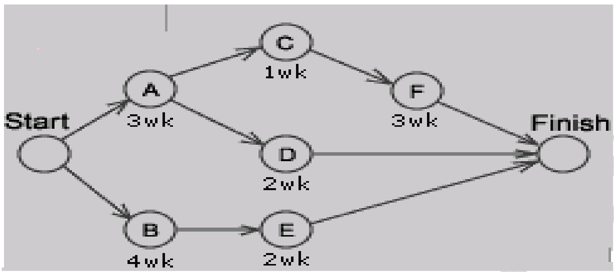
Project Documentation – It involves documenting all objectives, milestones, activities, process and blueprints of the project or in short all documents from project being conceived to implementation so as to provide accurate measure of project success. Large projects need more detailed documentation to cover all aspects of the project. Various graphical tools and techniques are used like state mapping, storyboard and six sigma projects implement DMAIC methodology thus documentation is done accordingly with figures and charts showing activity at that stage.

Project Closure – It is the last phase of project which confirms achievement of laid objectives for the project with completion of required documentation. It also involves discussion with project sponsors for project completion agreement which involves comparison with the project charter.

CPM/PERT Chart

CPM or "Critical Path Method" - It is a tool to analyze project and determine duration, based on identification of "critical path" through an activity network. The knowledge of the critical path can permit project managers to change duration. It is a project modeling technique developed in 1950s and is used with all forms of projects. It displays activities as nodes or circles with known activity times.

CPM is a diagram showing every step of the project, as letters with lines to each letter representing the sequence in which the project steps take place. A list of activities is required to complete the project and the time (duration) that each activity will take to complete, along with the sequence and dependencies between activities. CPM lays out the longest path of planned activities to the end of the project as well as the earliest and latest that each activity can start and finish without delaying other steps in the project. The project manager can then, determine which activities in the project need to be completed before others and how long those activities can take before they delay other parts of the project. They also get to know which set of activities is likely to take the longest, also called as the critical path which is also the shortest possible time period in which the project can be completed.



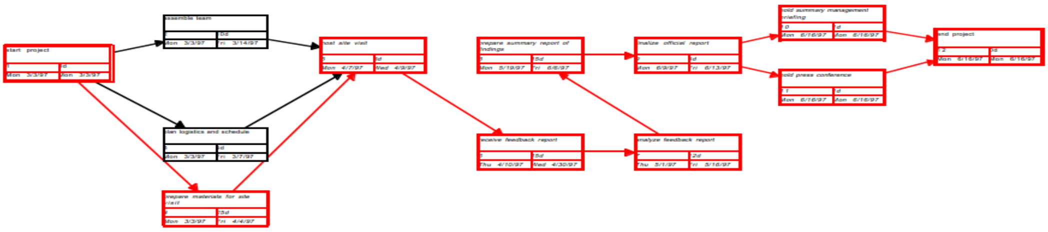
PERT Chart - A PERT chart (program evaluation review technique) is a form of diagram for CPM that shows activity on an arrow diagram. PERT charts are more simplistic than CPM charts because they simply show the timing of each step of the project and the sequence of the activities. In PERT, estimates are uncertain and ranges of duration and the probability that activity duration will fall into that range is taken whereas CPM is deterministic.

A PERT chart is a graphic representation of a project's schedule, showing the sequence of tasks, which tasks can be performed simultaneously, and the critical path of tasks that must be completed on time in order for the project to meet its completion deadline. The chart can be constructed with a variety of attributes, such as earliest and latest start dates for each task, earliest and latest finish dates for each task, and slack time between tasks. A PERT chart can document an entire project or a key phase of a project. The chart allows a team to avoid unrealistic timetables and schedule expectations, to help identify and shorten tasks that are bottlenecks, and to focus attention on most critical tasks. It is most useful for planning and tracking entire projects or for scheduling and tracking the implementation phase of a planning or improvement effort.

Developing PERT Chart

- ✓ Identify all tasks or project components - Ensure the team has knowledge of the project so that during the brainstorming session all component tasks needed to complete the project are captured. Document the tasks on small note cards.
- ✓ Identify the first task that must be completed - Place the appropriate card at the extreme left of the working surface.
- ✓ Identify any other tasks that can be started simultaneously with task #1 - Align these tasks either above or below task #1 on the working surface.
- ✓ Identify the next task that must be completed - Select a task that must wait to begin until task #1(or a task that starts simultaneously with task #1) is completed. Place the appropriate card to the right of the card showing the preceding task.

- ✓ Identify any other tasks that can be started simultaneously with task #2 - Align these tasks either above or below task #2 on the working surface.
- ✓ Continue this process until all component tasks are sequenced.
- ✓ Identify task durations - Reach a consensus on the most likely amount of time each task will require for completion. Duration time is usually considered to be elapsed time for the task, rather than actual number of hours/days spent doing the work. Document this duration time on the appropriate task cards.
- ✓ Construct the PERT chart - Number each task, draw connecting arrows, and add task characteristics such as duration, anticipated start date, and anticipated end date.
- ✓ Determine critical path - The project's critical path includes those tasks that must start or finish on time to avoid delays to the total project. Critical paths are typically displayed in red.



Activity Network Diagram

It charts the flow of activity between separate tasks and graphically displays interdependent relationships between groups, steps, and tasks as they all impact a project. Bubbles, boxes, and arrows are used to depict these activities and the links between them. It shows the sequential relationships of activities using arrows and nodes to identify a project's critical path. It is similar to the CPM/ PERT and also called as arrow diagram.

Developing Activity Network Diagram - Development starts with compiling a list of tasks essential for completion of the project. These tasks are then arranged in a chronological order, depending on the project considering inter-task dependency. All tasks are placed in a progressing line with tasks that can be done simultaneously, is placed on parallel paths, whereas jobs that are dependent should be placed in a chronological line. Apply realistic estimate to each task then, enlist the critical path.