**Supply Chain Management: (Lean)**

**Quality Management**

|  |  |  |
| --- | --- | --- |
| Producer’s View | Meeting and exceeding the specifications of a product or service. | Six-Sigma (Product Design, Manage, Control) |
| Consumer’s View | Meeting and exceeding the expectations of customer satisfaction. | Customer Relationship Management |
| Internal Cultural View | Maintaining total commitment to quality and continual improvement. | TBL |

**Quality Tools**

|  |
| --- |
| W. Edward Deming’s PDCA Cycle and 14 Points |
| Kaoru Ishikawa’s 7 Basic Tools |
| Walter A. Shewhart’s Statistical Process Control Charts (SPC) |

**Lean Supply Chain Management. Lean = Eliminate Waste (Work, Time, Cost)**

|  |  |  |
| --- | --- | --- |
| PMS  Production  Management  Systems | Production Control | PDCA  7 Basic Tools  Kanban |
| WMS  Warehouse  Management  System | Inventory Control. | Stochastic Inventory Models,  ABC Inventory Classification |
| TMS  Transportation  Management  System | Network Configuration and Strategy | Transportation,  Cross-Docking,  Standardization,  Postponement |

**Deming’s PDCA Cycle**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |
|  | **Plan**  Establish objectives  and processes and metrics | | 🡪 | **Do**  Implement “Plan” | |  |
|  | 🡪 | | **PDCA**  **Cycle** | 🡪 | |  |
|  | **Act**  Improve “Plan”  using “Check” results | | 🡨 | **Check**  Communicate results  from “Do” | |  |
|  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Plan** | **-** | **Do** | **-** | **Check** | **-** | **Act** |
| **🡪** |  |  |  | **🡪** |  |  |

**7 Management Tools 7 Basic Tools**

|  |  |  |
| --- | --- | --- |
| 1. Affinity (Creativity)  2. Relationship (Logic)  3. Tree  4. Matrix  5. Data Matrix  6. CPM/PERT  7. PDPC  “Process Decision  Program Chart” |  | 1. Check Sheet  2. Pareto Analysis  3. Stratification  4. Cause and Effect Diagrams  5. Histograms  6. Scatter Diagrams  7. Control Charts |

**7 Management Tools**

1. **Affinity Diagram**. (Creativity). Organizes brainstormed ideas into affinity groups.

2. **Relationship Diagram**. (Logic). Identifies cause-and-effect relationships between affinity groups.

3. **Tree Diagram**. Decomposes broad categories of information into more detailed information where examination proceeds from generalities to specifics.

4. **Matrix Diagram**. Shows relationships between groups of information.

5. **Data Matrix Analysis**. Mathematical and statistical analyses.

6. **CPM/PERT Diagram**. Creates schedule with complex relationships.

7. **PDPC, Process Decision Program Chart**. Monitors processes and risks.

**PERT: Program Evaluation and Review Technique**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **A** | **PA** | **T** |  |  |  |  |  |  |  |  |  |
| 1 | -- | 5 |  | 1 |  | 3 |  | 6 |  |  |  |
| 2 | -- | 2 |  |  |  |  |  |  |  |  |  |
| 3 | 1 | 2 |  | 2 |  | 4 |  |  |  |  |  |
| 4 | 2 | 3 |  |  |  |  |  |  |  |  |  |
| 5 | 2 | 3 |  |  |  | 5 |  | 7 |  |  |  |
| 6 | 34 | 3 |  |  |  |  |  |  |  |  |  |
| 7 | 345 | 1 |  |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **A** | **t1=Optimistic** | **t2=Most Likely** | **t3=Pessimistic** | **E[Duration]**  **=(t1+4t2+t3)/6** | **V[Duration]**  **=[(t3–t1)/6]2** |
| 1 | 4.1 | 5 | 7.1 | 5.2 | 0.25 |
| 2 | 1.4 | 2 | 3.2 | 2.1 | 0.09 |
| 3 | 0.8 | 2 | 6.8 | 2.6 | 1.00 |
| 4 | 2.1 | 3 | 4.5 | 3.1 | 0.16 |
| 5 | 0.6 | 3 | 4.2 | 2.8 | 0.36 |
| 6 | 1.2 | 3 | 7.2 | 3.4 | 1.00 |
| 7 | 1 | 1 | 1 | 1 | 0 |

For example, for activity ‘1’: E[D] = ( 4.1 + 4(5) + 7.1 )/6 = 5.2

V[D] = [ ( 7.1 – 4.1 )/6 ]2  = 0.25

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **A** | **E[D]** | **V[D]** | **Use E[D]**  **Within CPM** | **🡪** | **Slack** | **Critical Path** | **E[D]** | **V[D]** |
| 1 | 5.2 | 0.25 | **Method to** | **🡪** | 0 | Yes | 5.2 | 0.25 |
| 2 | 2.1 | 0.09 | **Obtain** | **🡪** | 2.6 |  |  |  |
| 3 | 2.6 | 1.00 | **Solution** | **🡪** | 0 | Yes | 2.6 | 1.00 |
| 4 | 3.1 | 0.16 | **and** | **🡪** | 2.6 |  |  |  |
| 5 | 2.8 | 0.36 | **Slack** | **🡪** | 5.3 |  |  |  |
| 6 | 3.4 | 1.00 |  | **🡪** | 0 | Yes | 3.4 | 1.00 |
| 7 | 1 | 0 |  | **🡪** | 2.4 |  |  |  |
|  |  |  |  |  |  | Sum | 11.2 | 2.25 |
|  |  |  |  |  |  |  | E[TOC] | V[TOC] |

Assume TOC follows a normal distribution with mean 11.2 and variance 2.25. Then, for a fixed value of T, P[TOC<T]=P[Z<(T–11.2)/1.5]= where Z is the standard normal random variable and Z is the standard normal variate defined to be P[Z<Z]=. Thus,

|  |  |  |
| --- | --- | --- |
| **T** | **Z** | **P[TOC<T]= ** |
| 10 | –0.8 | 0.2119 |
| 11 | –0.133 | 0.4470 |
| 12 | +0.533 | 0.7031 |
| 13 | +1.2 | 0.8849 |
| 14 | +1.867 | 0.9690 |

**Process Decision Program Chart (PDPC)**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Program |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Processes |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Objectives |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Activities |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tasks |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| \_\_\_\_\_\_\_Risks  \_\_\_Responses  \_\_\_Outcomes |  | -  -  - |  | -  -  - |  | -  - |  | -  -  - |  | -  -  - |  | -  - |  | -  -  - |  | -  - |  | -  - |  | -  -  - |  | -  -  - |  | -  - |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

**Ishikawa’s 7 Basic Tools to Quality**

|  |
| --- |
| **The 7 Basic Tools**  1. Check Sheet  2. Pareto Analysis  3. Stratification  4. Cause and Effect Diagrams  5. Histograms  6. Scatter Diagrams  7. Control Charts |

**Check Sheet**

Injuries by Department

|  |  |  |  |
| --- | --- | --- | --- |
|  | Department #1 | Department #2 | Department #3 |
| Month 1 | ||| | ||||| | ||||| ||||| || |
| Month 2 | ||||| | || | ||||| ||| |
| Month 3 | || | ||| | ||||| ||||| |||| |

**Pareto Chart**

Injuries by Department

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
| Department: | 3 | 1 | 2 |

**Pareto Chart**

Injuries by Department

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
| Department: | 3 | 2 | 1 |

**Stratification**

Types of Injuries in **Department #3**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
| Types of Injuries: | Eye | Hand | Back |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Eye Injuries by **Shift**   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  |  |  |  |  | |  |  |  |  |  | | Shift: | 3 | 1 | 4 | 2 | | Eye Injuries by **Machines**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | |  |  |  |  |  |  | |  |  |  |  |  |  | | Machine: | 2 | 5 | 1 | 4 | 3 | | Eye Injuries by **Operators**   |  |  |  |  | | --- | --- | --- | --- | |  |  |  |  | |  |  |  |  | | Operator: | Al | Ed | Bob | |

**Cause and Effect Diagram**

**(Fishbone Chart)**

**(Ishikawa Diagram)**

Manufacturing Example

People

Quality

Effect

Methods

Materials

Machinery

Administrative/Service Example

Procedures

Policies

Quality

Effect

Equipment

People

**Histograms**

You are monitoring the output of a project that produces a large quantity of armatures for special magnetometers for the government. One quality characteristic that is important is the length of the device. Suppose there are three machines producing these armatures. A histogram of the lengths of a batch should look like:

|  |
| --- |
|  |

Now suppose a histogram from a batch resulted in:

|  |
| --- |
|  |

Stratifying histograms on machines produced:

|  |
| --- |
| Machine 1: |
| Machine 2: |
| Machine 3: |

**Scatter Diagrams**

A project requires precision welds in critical structures. To monitor and maintain the quality of the welds, certification scores were used to analyze the likelihood of future quality.

A certification score can be one input in the assurance of quality welds.

**Control Charts**

Conduct an experiment to measure a quality characteristic and obtain its mean and standard deviation of the mean. Construct the chart and monitor production.

|  |  |
| --- | --- |
| Upper Control Limit: (Mean + 3 \* Standard Deviations of Mean) |  |
|  |
| Center Line: (Mean) |  |
| time |
| Lower Control Limit: (Mean – 3 \* Standard Deviations of Mean) |  |
|  |

**P-Chart**

Highly sensitive transistors are being produced in a project. You monitor the defectives the process produces by using a control chart of the proportion of defective items in a large batch. Suppose an experiment on the process that is in control produces 102 defectives in a large batch of 8500 transistors. Construct a P-chart for defectives for a sample size of 1665 transistors. [Note: The P-chart is based on a binomial assumption. Thus, the variance of a proportion, P, is ‘P(1-P)/N’]

|  |  |
| --- | --- |
| Center Line, CL= (102/8500)=0.012  Upper Control Limit, UCL=0.012+3\*sqrt[(1-0.012)\*0.012/1665]=0.020  Lower Control Limit, LCL=0.012-3\*sqrt[(1-0.012)\*0.012/1665]=0.004 | |
| Upper Control Limit=0.020 |  |
|  |
| Center Line=0.012 |  |
| time |
| Lower Control Limit=0.004 |  |
|  |

**C-Chart**

Documentation of results in a project as deliverables at pre-specified milestones are critical for a specific project. To monitor the production of these large documents, each one estimated to be 2450 pages in length, an editing team is being checked for errors per page of document. An experiment was conducted on past documents produced by this team and 18 errors were observed in 3 documents at 1200 pages each. Construct a C-chart for errors for a sample size of 2450. [Note: The C-chart is based on a Poisson assumption. Thus, the variance and the mean are equal.]

|  |  |
| --- | --- |
| Proportion = 18/(3\*1200) = 0.005  Center Line, CL= (0.005\*2450)=12.25  Upper Control Limit, UCL=CL+3\*sqrt(CL)=12.25+3\*sqrt(12.25)=22.75  Lower Control Limit, LCL=CL-3\*sqrt(CL)=12.25-3\*sqrt(12.25)=1.75 | |
| Upper Control Limit=22.75 |  |
|  |
| Center Line=12.25 |  |
| time |
| Lower Control Limit=1.75 |  |
|  |

**Other Control Charts**

**Deming’s 14 Points to Quality**

Deming offered fourteen key principles for transforming business effectiveness. The points were first presented in his book *Out of the Crisis* in 1986 by MIT Press.

1. Create constancy of purpose toward improvement of product and service, with the aim to become competitive and stay in business, and to provide jobs.
2. Adopt the new philosophy. We are in a new economic age. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change.
3. Cease dependence on inspection to achieve quality. Eliminate the need for massive inspection by building quality into the product in the first place.
4. End the practice of awarding business on the basis of price tag. Instead, minimize total cost. Move towards a single supplier for any one item, on a long-term relationship of loyalty and trust.
5. Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs.
6. Institute training on the job.
7. Institute leadership (see Point 12 and Ch. 8 of "Out of the Crisis"). The aim of supervision should be to help people and machines and gadgets to do a better job. Supervision of management is in need of overhaul, as well as supervision of production workers.
8. Drive out fear, so that everyone may work effectively for the company. (See Ch. 3 of "Out of the Crisis")
9. Break down barriers between departments. People in research, design, sales, and production must work as a team, to foresee problems of production and in use that may be encountered with the product or service.
10. Eliminate slogans, exhortations, and targets for the work force asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, as the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the work force.
11. a. Eliminate work standards (quotas) on the factory floor. Substitute leadership.  
    b. Eliminate management by objective. Eliminate management by numbers, numerical goals. Substitute leadership.
12. a. Remove barriers that rob the hourly worker of his right to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality.  
    b. Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, *inter alia," abolishment of the annual or merit rating and of management by objective (See Ch. 3 of "Out of the Crisis").*
13. Institute a vigorous program of education and self-improvement.
14. Put everybody in the company to work to accomplish the transformation. The transformation is everybody's job.

**Production Control**

* Schedule-based vs. JIT(just-in-time)
* Push system (EOQ) vs. Pull system (JIT)

Consider the production process:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 🡪 |  | WC#1 |  | WC#2 |  | WC#3 |  | 🡪 |

1. Push system: Produce on upstream availability.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 🡪 | oooo  ooooooo  ooooooooo | WC#1 | ooo | WC#2 | ooooo  oooooo  ooooooo | WC#3 | o  oo | 🡪 |

2. Pull system: Produce on downstream need.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 🡪 | o | WC#1 | o | WC#2 |  | WC#3 | o | 🡪 |

3. Single-card Kanban system. T-kanban card (Transportation)

🡨 Flow of Information 🡨

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  | T-loop |  |  |  |  |
|  | \_T\_ |  |  | 🡨 | TT\_ |  |  |  |
| 🡪 | o | WC#2 | T | 🡪 | oo | WC#3 | TTT | 🡪 |

🡪 Flow of Material 🡪

4. Dual-card Kanban system. T-kanban and P-kanban (Production)

🡨 Flow of Information 🡨

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | PPP\_ |  |  |  |  |  |  |  |
|  | ooo | P-loop | T\_\_ | T-loop |  |  |  |  |
|  | \_T\_ |  | P | 🡨 | TT\_ |  |  |  |
| 🡪 | o | WC#2 | o | 🡪 | oo | 🡪 |  |  |

🡪 Flow of Material 🡪

5. Kanban rules: Only transport or produce when authorized by kanban card.

6. Favorable conditions for kanban system: Large constant demand, small set-up times, reliable equipment, small number of defectives.

7. Advantages of kanban system: manual system, worker involvement, quality control.