**Plantlocation**:Plantlocationisastrategicdecisionseveralfactorsinfluencethisdecision.Themainobjectiveofanybusinessistooptimizeitscostandrevenuethatis,minimizeitscostsandmaximizeitsreturns.

Thedegreeofsignificancefortheselectionoflocationforanyenterprisemainlydependsonitssizeandnaturelargescaleindustriesrequiringhugeamountofinvestmenttherearemanyconsiderationsotherthanthelocaldemandintheselectionproperplantlocationtheseplantscannotbeeasilyshiftedtootherplaceandanerrorofjudgmentintheselectionofsitecanbevaryexpensivetotheorganization.However,small-scaleindustrymainlyselectsthesitewhereinaccordancewithitscapacity;thelocalmarketisavailableforitsproducts.Itcaneasilyshifttootherplacewhenthereisanychangeinthemarket.

## Factorsaffectingplantlocation:

NearnesstoMarket:Iftheplantislocatedclosetothemarketthecostoftransportationcanbeminimized.Thisalsohelpstheproducerstohavedirectknowledgeoftherequirementsofthecustomers.

Nearnesstosupplyofrawmaterials:Asfaraspossiblethesiteselectedshouldbenearthesourceofrawmaterials,sothatthecostoftransportationcanbeminimizedandstoringcostcanbereducedduetoshorterleadtime.

Availabilityoflabour:Availabilityofrightkindoflabourforceinrequirednumberatreasonableratesisalsoadecidingfactorinselectionofsite

Transportand communicationfacilities:Generally, industries haveatendencytolocatetheindustrialunitsneartherailwaystation,highwayorportareas.

Availabilityofpowerandfuel:Coal,electricity,oilandnaturalgasaretheimportantsourcesofpowerintheindustries.

Ex:TataironandsteelindustryisestablishednearthecoalminesofBihar.Climaticconditions: Climaticconditionslargelyaffect certainproductionprocessesandalsotheefficiencyoftheemployees.

Ex:TextilemillsrequiremoistclimatethatwhytheseplantlocatedatMumbaiandAhmedabad.

Availabilityofwater:Waterisusedinindustriesforprocessingasinpaperinchemicalindustries,forgenerationofpowerinhydroelectricpower,plantsandalsorequiredfordrinkingsanitarypurposealso.

Ancillaryindustries:Manyindustriessuchasprocessingandassemblyindustriesarenotproducingalthepartsoftheirproductbutpurchasesomeofthepartsfromancillaryindustriesproducingit.

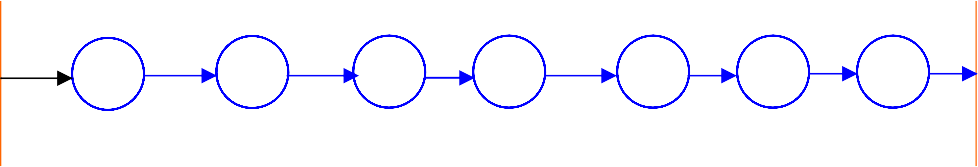
Financialandotheraids:Forthedevelopmentofbackwardregionscentralaswellasstategovernmentprovidecertainincentivesandfacilitiessuchascash-subsides,concessionfinancialassistance,land,powerandotherfacilitiesatcheaperrates,taxconcessionetc.

**PlantLayout**:Atechniqueoflocatingmachines,processesandplantserviceswithinthefactoryinorder tosecurethegreatestpossibleoutputofhighqualityatthelowestpossibletotalcostofproduction

## Typeofplantlayout:

**Productorlinelayout**: Thistypeoflayoutisdevelopedforproduct-focusedsystems.Inthistypeoflayoutonlyoneproduct,oronetypeofproduct,isproducedinagivenarea.Incaseof productbeingassembled,thistypeoflayoutispopularlyknownasanassemblylinelayout.

Theworkcentersareorganizedinthesequenceofappearance.Therawmaterialcentreatoneendofthelineandgoesfromoneoperationtoanotherrapidlywithminimumofwork-in-processstorageandmaterialhandling



Raw

Material

1

Cutting

2

3

4

5

6

7

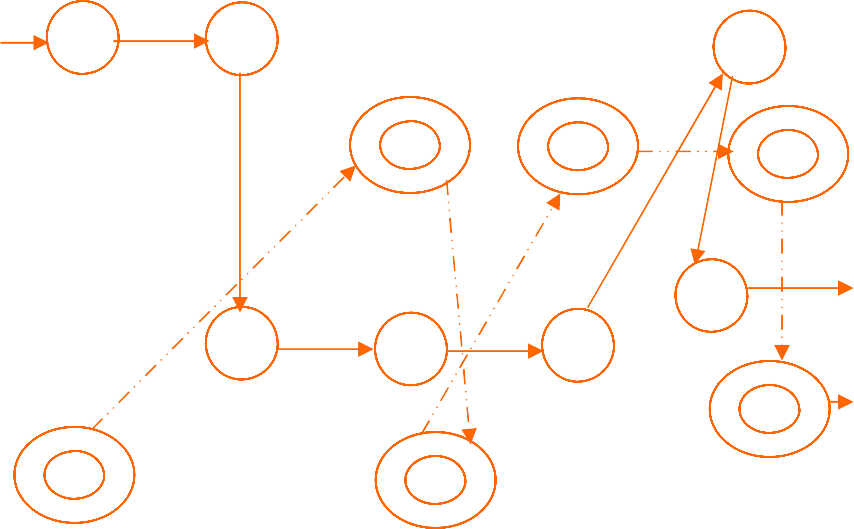
Finished

Goods

TurningMilling GrindingPaintingInspectpacking

**ProcessorFunctionallayout**:Thistypeoflayoutisdevelopedforprocessfocusedsystems.Theprocessingunitsareorganizedbyfunctionsintodepartmentsontheassumptionthatcertainskillsandfacilitiesareavailableineachdepartmentsimilarequipmentsandoperationsaregroupedtogether,e.g.,milling,foundry,drilling,plating,heattreatmentetc.

Theuseofprocess-focusedsystemsisverywideinbothmanufactureandotherservicefacilitiessuchashospitals,largeoffices,municipalservices,etc.



|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| RawMaterials | Foundry  1 | Turning  2 | Drilling  2 | Heattreatment  4 | Inspection  6  5 | FinishedGoods |
| 1  Forging | 3  Milling | 4  3  Grinding | 5  Painting | 7  6  Packing |

Product-AProduct–B

**Cellularorgrouplayout**:Itisspecialtypeoffunctionallayoutinwhichthefacilitiesareclubbedtogetherintocells.Thisissuitableforsystemsdesignedtousetheconcepts,principlesandapproachesof‘grouptechnology’.Suchalayoutofferstheadvantagesofmassproductionwithhighdegreeofautomationevenifthenumbersofproductsaremorewithflexiblerequirement.Insuchasystemthe facilitiesaregroupintocellswhichareabletoperformsimilartypeoffunctionsforagroupofproducts.

Product-AProduct-B

Product-CProduct-D

LatheMilling

Shaper

Drilling

Drilling

Milling

Lathe

Milling

Drilling

Forging

GrindingBoring

Hardening

Testing

Inspection

Tempering

Packing

ABCD

**JobShopLayout**:Itisa layoutforaverygeneralflexible system thatisprocessing jobproduction,Thepreparationofsuchalayoutisdependentontheanalysisofthepossiblepopulationsofordersandisarelatively,complexaffair.

**ProjectorFixedpositionLayout**:Thisisthelayout forprojecttypesystemsinwhichthemajorcomponentiskeptatafixedpositionandallothermaterials,components,toolsmachines,worketc.arebroughtandassemblyorfabricationiscarriedout.Thistypeoflayoutisnownotusedverycommonlyasthemachinesrequiredformanufacturingworkarebigandcomplicated.Thefixedpositionlayoutisusedonlywhenitisdifficulttomovethemajorcomponentandfabricationistobecarriedout.Ex:productionofships.

Tools

HandlingEquipment

Machine–1

Machine–2

Main

Assembly

Worker–1

Worker–2

## Factorsinfluencingplantlayout:

Managementpolicy:Managementhastodecideonmanymatterse.g.natureandqualityofproducts,sizeoftheplant,integrationofproductionprocess,plansforexpansion,amountofinventoryinstock,employeefacilities

Manufacturingprocess:Thetypeofmanufacturingprocesse.g.synthetic/analytical,continuous/intermittentandrepetitive/non-repetitive,willgovernthetypeofplantlayout.

Natureofproduct:Smallandlightproductscanbemovedeasilytothemachines,whereasforheavyandbulkyproductsthemachinesmayhavetobemoved.

Typeofequipment:Theuseofsinglepurposeandmulti-purposemachinesubstantiallyaffectstheplantlayout.Similarly,noisyandvibratingmachinesrequirespecialattentionintheplantlayoutdecision.

Typesofbuildings:Theplantlayoutinasinglestoreybuildingwillbedifferentfromthatinamultistoreybuilding.Thecoveredareas,thenumberofstorey’s,elevatorsandstairs,parkingandstorageareaallaffectthelayout.

Availabilityoftotalfloorarea:Theallocationofspaceformachines,work-benches,sub-storeaislesetc.,ismadeonthebasisoftheavailablefloorareauseofoverheadspaceismadeincaseofshortageofspace.

Arrangementofmaterialshandingequipment:Providesufficientaislesforfreemovementofmaterialhandlingequipmentsuchashandtruck,forktrucketc.

Servicefacilities:Thelayoutoffactorymustincludeproperservicefacilitiesrequiredforthecomfortand welfareofworkers.Theseinclude canteen,lockers,drinkingwater,firstaidetc.

Possibilityoffutureexpansion:Plantlayoutismadeinthelightoffuturerequirementandinstallationsofadditionalactivities.

## Principlesofplantlayout:

Principleofintegration:Thebestlayoutisonewhichintegratesthemen,materials,machinery,supportingactivitiesandanyothersuchafactorsthatresultsinthebestcompromise.

Principleofminimummovement:Thenumberofmovementofworkersandmaterialsandthedistancemovedshouldbeminimized.Thematerialsshouldbetransportedinbulkratherthaninsmallamounts.

Principleofsmoothandcontinueflow: Itstatesthatbottlenecks,congestionpointsandbulktrackingshouldberemovedbyproperlinebalancingtechniques.Principleofcubicspace: Spaceofaroom,ittheceilingheightisalsoutilized,morematerialscanbeaccommodatedinthesamespace.

Principleofsatisfactionofsafety:Workingplaces-safe,well-ventilatedandfreefromdust,noisefumes,odorsandotherhazardousconditions,helptoincreasetheefficiencyoftheworkersandimprovetheirmorale.

Principleofflexibility:Itmeansthebestlayoutinonewhichcanbeadoptedandre-arrangedataminimumcostwithleastinconvenience.

## Productivity:

Definition:Productivityisdefinedastherateatwhichthegoodsandservicesareproduced.

Itreferstotherelationshipbetweentheinputsandtheoutput.Itiscalculated asaratiobetween theamount producedandthe amountofresources(land,labour,capital,technologyetc.)usedinthecourseofproductioninotherwords

Pr*oductivity**Output*

*Input*

Andalsodefinedproductivityashumaneffortstoproducemoreandmorewithlessandlessinputsofresourcesasaresultofwhichthebenefitsofproductionaredistributedamongmaximumnumberofpeople.

## MethodofProduction:

**Jobproduction**:Inthissystem,goodsareproducedaccordingtotheorderswiththismethod,individualrequirementsoftheconsumerscanbemet.Eachjoborderstands aloneand is not likelyto be repeated.Thistypeof production hasalotofflexibilityofoperationandhencegeneralpurposemachinesarerequired.Factoriesadoptingthistypeofproduction,aregenerallysmallinsize.

Advantages:

1. Itistheonlymethod,whichcanmeettheindividualrequirement.
2. Thereisnomanagerialproblem,becauseofvery lessnumberofworkers,andsmallsizeofconcern.
3. Suchtypeofproductionrequireslessmoneyandiseasytostart.Disadvantages:
4. Thereisnoscopeforcontinuousproductionanddemand
5. Asthepurchaseofrawmaterialsisless,hencecostofrawmaterialsperunitwillbeslightlymore.
6. Forhandlingdifferenttypeofjobs,onlyskilledandintelligentworkersareneeded,thuslabourcostincreases.

**Batchproduction**:Thistypeofproductionisgenerallyadoptedinmediumsizeenterprise.Batchproductionisinbetweenjobproductionandmassproduction.Batchproductionisbiggerinscalethanthejobproduction.Whileitissmallerthanthatofmassproduction,batchproductionrequiresmoremachinesthanjobproductionandfewermachinesthattheofmassproduction.

Advantages:

1. Whilecomparingwithmassproductionitrequireslesscapital
2. Comparingwithjobproduction,itismoreadvantageouscommercially.
3. Ifdemandforoneproductdecreasethenproduction,foranotherproductmaybeincreased,thustheriskoflossisveryless.

Disadvantages:

1. Comparingwithmassproductioncostofscalesandadvertisementperunitismore
2. Rawmaterialstobepurchasedareinlessquantitythanthatinmassproduction;thereforeitisslightlycostlierthanthatofmassproductionbecauselessquantitydiscountisavailable.

**Massproduction**:Thismethodofproductionisusedbyconcernswheremanufacturingiscarriedoncontinuouslyinanticipationofdemandthoughdemandoftheproductmaynotbeuniformthroughtheyear.

Inmassproduction,simplificationandstandardizationofproductsaremadewiththehelpofspecialized(onepurpose)machine,articlesofstandardizednaturecaneasilyandeconomicallybeproducedonalargescale.

Thereisasmalldifferencebetweenmassproductionandcontinuousproduction.Thisismainlyinthekindofproductanditsrelationtotheplant.Inmassproductionplantandequipmentareflexibleenoughtodealwithotherproducts,involvingsameproductionprocess.Whereasincontinuousorprocessproductiononlystandardizedproductinasequenceproduced.Inthismethodlayoutandrequirementofadditionaltoolsandequipment

Advantages:

1. Asmoothflowofmaterialsfromoneworkstationtothenextinlogicalorder.
2. Sincetheworkfromoneprocessisfeddirectlyintothenext,smallinprocessinventoriesresult
3. Totalproductiontimeperunitshort
4. Simpleproductionplanningcontrolsystemarepossible
5. Littleskillisusuallyrequiredbyoperationsattheproductionline,hencetrainingissimple,shortandinexpensive.

Disadvantages:

1. Abreakdownofonemachine may leadtoacompletestoppageofthelinethatfollowsthemachine.Hencemaintenanceandrepairischallengingjob.
2. Sincetheproductdictatesthelayout,changesinproductdesignmayrequiremajorchangesinthelayout.
3. Generallyhighinvestmentarerequiredowingtothespecializednatureofthemachinesandtheirpossibleduplicationintheline

**WorkStudy**:Workstudyisoneofthe mostimportantmanagementtechniqueswhichis employedtoimprove the activitiesintheproduction.Themain objectiveofworkstudyistoassistthemanagementintheoptimumuseofthehumanandmaterialresources.

Definition:Workstudyrefersto themethodstudyand work measurement, whichareusedtoexaminehumanworkinallitscontextsbysystematicallyinvestigating intoallfactorsaffectingitsefficiency andeconomytobring forththedesiredimprovement.

WorkMeasurementToassesshumaneffectiveness

MethodStudyToimprovemethodofproduction

WorkStudy

## MethodStudy:

Definition:Thesystematicrecordingandcriticalexaminationofexistingandproposed ways of doing work,asameansofdevelopingand applyingeasierandmoreeffectivemethodsandreducingcostitisalsocalledmotionstudy.

## WorkMeasurement:

Definition:Workmeasurementistheapplicationoftechniquesdesignedtoestablishtimeforaqualifiedworkertocarryoutaspecifiedjobatadefinedlevelofperformance.

Workstudyhastwoparts,MethodStudyandWorkMeasurement.Methodstudydealswiththetechniquesofanalyzingthewaytodoagivenjobbetter,WorkMeasurementseekstomeasurethetimerequiredtoperformthejob.

**BasicprocedureforMethodStudy**:Select: Theworktobestudied

Record:Alltherelevantfactsofthepresentorproposedmethodstudybyobservation

Examine:Therecordedfactscriticallyeverythingthatisdone,consideringinturn,thepurposeoftheactivity,theplacewhereitisperformed,thesequenceinwhichitisdone,thepersonwhoisdoingitandthemeansbywhichitisdone.

Develop:Themostpractical,economicalandeffectivemethodconsideringallthecircumstances.

Define:Thenewmethodsothatitcanalwaysbeidentified.Install:Themethodasstandardpractice

Maintain:Thatstandardpracticebyregularroutinechecks.

**Recording**:Thecurrentprocessofdoingthejobhastoberecorded,whiledoingsoeverydetailhoweversmallitmaybe,hastobeidentified.

Wherethe process is too long,involvingmanystages ofproduction,inspectionortransportation,thepresentprocessofdoingthejobisrecordedsufficientlytogetherwithalltherelevantinformation,usingtheprocesschartsymbols.

|  |  |
| --- | --- |
| Symbol | Meanings |
|  | Operation:Operationinvolvingchangesintheconditionofaproduct  Ex:Assemblyofspareparts |
|  | Transport:SomethingfromthelocationtoanotherEx:AssemblePCismovedtoinspectionsection |
|  | Storage:(permanent)Tostorethematerials,goodsetc.Ex:WhenPCisputintothestoreafterinspection |
|  | Delay:(Temporarystorage)Ariseswhentheproductwaitsfornextstageintheprocess  Ex:Machinerybreakdownetc. |
|  | Inspection:Tocheckwhetherthequalityandquantityoftheproductissatisfactoryornot |
|  | Operation–cum–Inspection:Inspectionistakenplaceduringtheproductionprocess |
|  | Operation–cum–Transportation:Assembleistakingplacewhilethebeltconveyertransportsthespares. |

**RecordingTechniques**:Therecordingtechniquesareofthreetypes

1. Processchart b)Diagrams c)Motionandfilmanalysisd)Models

## ProcessCharts:

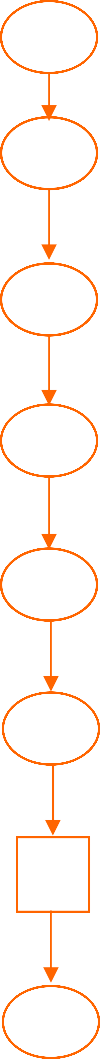
* + 1. Outlineprocesschart: Thischartoutlinesthemaineventssequencewiseconsideringonlyoperationsandinspectionsinthegivenjob

**Ex**: TASK :ChangingrefillofaBallPointpenChartbegins:Unscrewthecap

Chartends :ScrewthecapChartby :--------------

ChartEnds :--------------

UnscrewcapUnscrewneck



1

2

3

4

5

6

1

7

Removetheoldrefill

Assemblethespringonnewrefill

Placetherefillinthebarrel

Screwtheneck

|  |  |
| --- | --- |
| No.ofoperations | 7 |
| No.ofinspections | 1 |
| TotalNo.ofactivities | 8 |

Checkif theballpenwrites

Screwthecap

* + 1. Flowprocesschart:Thesearescaledrawingsoftheworkplace,whichindicatewhereeachactivitytakesplace.Thischartiscapableofreflectingunduedelaysintransferringworkbetweenworkstationsduplicationofwork,andunfairworkassignment,whichmaydelaythecompletionprocess.Itclassifiedintothreetypes

ManType :ItrecordswhattheworkerdoesMaterialsType :ItrecordswhathappenstothematerialsEquipmentType :Itrecordshowtheequipmentused.

* + - 1. ManType

## Ex:

Job :Writingaletterusingshorthandtypist

Chartbegins :Typistinownoffice-awaitingdictation

Chartends :Typistputsletterandcopyinouttray

Typistoffice : 6metersmanager’soffice

To author’s office 1

1 Takedictation

2 Toownoffice

* + - * 1. PrepareTypeSet
        2. TypeletterandcopyRemovefrommachine
        3. andseparatecopy

1 Checkthecopy

1. Placeinafileforsignature

## Summary

|  |  |  |  |
| --- | --- | --- | --- |
| **EVENT** | **NO** | **TIME** | **DISTANCE** |
|  | 8 |  |  |
|  | 1 |  |  |
|  | 4 |  | 24meters |
|  | 1 |  |  |

To author’s office 3

1 Delayforsignature

4 Toownoffice

1. Typeenvelopes
2. Lettertoenvelopes
3. Letterandcopyasidetoouttray
   * + 1. MaterialType:

**Ex:** Job :MakingthecastingreadyformachiningChartbegins:Castinglyinginfoundry

Chartends :Castingreadyformachining

Activity

Operations

Distancemovedmts

Time

Remarks

Costinglayinginfoundrystore

-

-

-

Movedtogascuttingmachine

10

3

ByTrolley

Wait,cuttingmachinebeingset

-

5

-

Risescut

-

20

-

Waitfortrolley

-

10

-

Movedtoinspectiondepartment

6

2

-

Inspectionbeforemachining

-

15

ByTrolley

Movetomachineshop

10

3

-

## Summary

|  |  |  |  |
| --- | --- | --- | --- |
| Event | No. | Time | Distance |
|  | 1 | 20 | - |
|  | 1 | 15 | - |
|  | 1 | - | - |
|  | 2 | 15(5+10) | - |
|  | 3 | 8 | 26 |

activitiesofaworkershandarerecorded,intheirrelationshiptooneanother. Itiscommonlyusedforrepetitiveandshortoperations.

**Ex:** Job :AssembletowashersandnuttoboltChartbegins :Handemptymaterialinboxes

PartNo. :-------------

Chartends :CompletedassemblyasidetoboxOperationNo. :-------------

Method :Present/proposed

Tobolt 1

Pickupbolt 1

ToPosition 2

ToBox 1

AsidetoBox 3

ToBolt 2

1 Tofirstwasher

1 Pickupwasher

2 Toposition

1. Assembletobolt
2. Tosecondwasher

3 Pickupwasher

4 Toposition

1. Assembletobolt
2. ToNut

5 PickupNut

1. ToPosition
2. Assembletobolt

1 Delay

Tofirstwasher

ofmore thanoneitem(worker,machineor equipment)are recorded on acommontimescaletoshowtheirinterrelationship.

Byusingseparateverticalcolumnstorepresenttheactivitiesofdifferentoperatorsormachinesonacommontimescale,thechartshowsveryclearlytheperiodofidlenessonthepartofanyitemsduringtheprocess.

**Ex**:

ChartNo.-----------------SheetNo.-------------------Department---------------------

|  |  |  |  |
| --- | --- | --- | --- |
| Material | :B201casting | Job | :Makingaslotonthecasing |
| Machine  Chartedby | :Slotted  :------------ | Operation  Date | :XYZ  :------------ |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Time(min.) | Man |  |  | Machine | Time(min.) |
| 0.2 | Removesfinishedcastingcleanswithcompressedair |  |  | Idle | 0.2 |
| 0.4 | Gaugesdepthofslotonsurfaceplate |  |  | Idle | 0.4 |
| 0.6 | Breakssharpedgeswithfilecleanswithcompressedair |  |  | Idle | 0.6 |
| 0.8 | Placeinaboxobtainsnewcasting |  |  | Idle | 0.8 |
| 1.0 | Cleansmachinewithcompressedair |  |  | Idle | 1.0 |
| 1.2 | Locatescastinginfixture,startsmachineandautomaticfee |  |  | Idle | 1.2 |
| 1.4 | Idle |  |  | Cuttingslot | 1.4 |
| 1.6 | Idle |  |  | Cuttingslot | 1.6 |
| 1.8 | Idle |  |  | Cuttingslot | 1.8 |
| 2.0 | Idle |  |  | Cuttingslot | 2.0 |

|  |  |  |
| --- | --- | --- |
| **Summary**:  Cycletime :2min. |  | |
| WorkingTime:  a)Man :1.2min. | Utilization:  a)Man | :60% |
| b)Machine :0.8min.  Idletime: | b)Machine | :40% |
| 1. Man :0.8min. 2. Machine :1.2min. |  |  |

## Diagrams:

* + 1. Flowdiagrams:Flowprocesschartonlyshowsthesequenceofvariousactivitiesnecessaryforperformingthespecifiedwork.Itdoesnotshowclearlythepathofmovementofmenandmaterialsfromonelocationtoanother.

Definition:Itisadiagrams, drawn toscale,intended to showthe relative positionoftheproductionmachineryandmarkstheroutefollowedbythemachines,materialsandmen.

* + 1. Stringdiagrams:Theworkersaremovingatirregularintervalsbetweenanumberofpointsinaworkingareawithorwithoutmaterialsinmanyindustrialactivities.

Definition:Thestringdiagramisascaleplanormodelonwhichatreaditsusedtotraceandmeasurethepathofworkers,materialsorequipmentduringaspecifiedsequenceofevents.

* + 1. Cyclegraph:Inthismethodasmallelectricbulbisattachedtoeachpartofthebody,whichmakesthemovementforcarryingoutanoperation.Thepathofmovementisphotographedbyhigh-speedcamera.
    2. Chronocyclegraph:Thisisaphotographicrecord,whichtracesthepathofmovementontoaphotographicplace.Inprinciple,itissimilartothestringdiagram,andismosteffectivewhenrecordingshort,rapidmovements.
  1. **MicromotionStudyandfilmanalysis**:Micromotionstudyisasetoftechniquesintendedtodividehumanactivityintogroupsofmovementsormicromotions (therbiligs) andthestudyofsuchmovements helptofindforan operatoronebestpatternofmovementsthatconsumeslesstimeandrequireslessefforttoaccomplishthetask.

Filmanalysis:Oncetheactivityhasbeenfilmedandthefilmprocessed,aprojectorrunsthefilmveryslowlyandthefilmcanbestoppedorreversedwheneverrequired.

* + 1. SIMO Chart(simultaneousmotioncyclechart):ASIMOchartis basedon filmanalysis,itisagraphicrepresentationofthecoordinatedactivitiesofanoperatorsbodyembers.Theactivitiesaredescribedintermsofbasicorfundamentalmotions.Thetimerequiredforcompletionofthesemotionsisalsorecordedonthechart.
  1. **Models**:Sometimesthepictureoftheexistingconditionsisnotclearbytheuseofflowprocesschartorflowdiagram.Insuchcasesinsteadofthescalesplansoftheshopfacilitiesmodelsareusedtoprovidevisualrepresentationoftheproposedlayoutbeforeproceedingwithactualrearrangementoftheworkplace.

**WorkMeasurement**:Workmeasurementistheapplicationoftechniquetoestablishthetimeforaqualifiedworkertocarryoutaspecifiedjobatadefinedlevelofperformance.

## ProcedureforWorkMeasurement:

* + 1. Sect:Theworktobestudiedanddeterminetheobjectivesofthestudy
    2. Record:Alltherelevantdatarelatingtocircumstancesinwhichtheworkisbeingdone,themethodstobeusedbreakdownthejobintoitselements
    3. Examine:Therecordeddataandthedetailedbreakdowncriticallytoensurethemosteffectivemethodandmotionsarebeingusedandthatunproductiveelementsareseparatedfromproductiveelements.
    4. Measure:Thetimerequiredtocompleteeachelementusingtheappropriateworkmeasurementtechniquesandcalculatethetimerequiredtocompetetheworkcyclewhichisknownasbasictime.
    5. Compile:Thestandardtimefortheoperationorworkplace,incaseofstopwatchtimestudythevariousallowancestocoverrelation,personalneedsetc.areaddedtothebasictimetoestimatethestandardtime.

## Techniquesofworkmeasurement:

1. Timestudy
2. Synthesisfromstandarddata
3. PredeterminedMotionTimeSystem(PMTS)
4. Analyticalestimating
5. WorkSampling
6. **Timestudy**:Itisdefinedastheartofobservingandrecordingthetimerequiredtodoeachdetailedelementofallindustrialoperation.

Timestudyequipment:Timestudyequipmentcanbebroadlygroupedtwocategories

A)TimemeasuringdeviceB)Timestudyboardsandtimestudychart

1. Timemeasuringdevices:
   1. StopWatchb)Motionpicturecamerac)Timerecordingmachine

d)Electronictimer.a)StopWatch:

1. Decimalminute stopwatch:In this type ofwatch themovementsisstartedandstoppedbymovingtheslide“A”,forwardandbackwardrespectivelyarecompleterevolutionoflargehandrepresents1minuteandsincethedialisdividedinto100partsreadingtowithin0.01minutescanbeobtained.Everytimethelargehandmakeonerevolutionthesmallhandwillregister1minuteandisabletoregisterupto30minutes.
2. Decimalhourstopwatch:Thedialinthiswatchisdividedinto100parts.Theneedlecompletes10revolutionsinonehour.Theleastcountinthiswatchis

0.001hours.Thesmalldialofthiswatchisdividedinto30equlspaces(representing0.01hour)andthesmallneedlemakes31/3revolutionsinonehour.

1. Motionpicture camera:Everyelementoftheoperationinvolvingmotionoftheworkersismadeintofilmthroughmotion picture camera when thisfilm is runataslowspeedthroughaprojector;thetimeofeachelementisrecordedusingastopwatch.
2. Timerecordingmachine:Amovingtapeisrunisthismachineatauniformvelocityof10inches/minuteswiththehelpofelectricmotor.Themachinehastwokeys:onekey,whenpressed,indicatesstartingofanoperation,andtheotherkeyusedtotakeaprintonthescaledtapeattheendofelements.
3. Electronictimer:Thetimingofstartingandendingofanoperationofanelementisautomaticallyrecordedthroughelectronictimers.

## B)Timestudyboardsandtimestudycharts:

Timestudyboard:Thesearesimpleandhandyhardwoodboardsequippedwithstopwatchholdersandclampsforholdingtheobservationsheetsandtimestudyforms.Theseboardshelptoseeandrecordtheobservationandtimeatthesameinstant.

Observationsforms:Printedorcyclostyledformsareusedforrecordingtheobservationduringthattimestudy.Itensuresthattimestudyaremadeina

standardmannerandthatnoessentialdataareomitted.Theseformsareattachedtothestudyboardbymeansofclipprovided

1. **Synthesisfromstandarddata**:Thisonetechniqueofworkmeasurementtoobtainedsynthetictimesthataresynthesisfromelementtimespreviouslyobtainedfromdirecttime studies.Theanalysisandmeasurementstagearethusconductedpriortotheactualstudy.
2. **Predetermine motiontimesystem(PMTS)**:Everyelement ofworkiscomposedofsomecombinationofbasichumanmotions.Apartfrommentalactivityallworkscanbrokendownintoelementsthatusuallyafundamentalmovementofthebodyorbodymembers.Afterthisanalysisstagethebasicmotionsthathavebeenisolatedhaveatimeallottedtothemonthebasisofpredeterminemotiontimes.
3. **Analyticalestimation**:Analyticalestimatingservesasbestformeasuringwork.IntheanalysisstagewefindtheusuallythesebasicelementsormuchlargerascomparedtotheelementsinPMTSortimestudy.Formeasuringstagesthetime,whichwillbeoccupiedbytheelementataspecificspeedofworkingisestimated.
4. **WorkSampling**:Itisworkmeasurementtechniquewhichlargenumberofinstantaneousobservationaremaderandomintervaloveraspecifiedperiodoftimeofagroupofworkers,machineandprocesses.Eachobservationrecordswhatis happeningat thatinstantantandthe presentobservationsrecordedforaparticularactivityordelayisameasureofthepercentageoftimeduringwhichthatactivityordelayoccurs.

It can also definedas a methodoffindingthe percentageoccurrenceofacertainactivitybystatisticalsamplingandrandomobservations.**Procedureforconductingtimestudy**: Forconductingtimestudyaverageworkersandaveragemachinesareselected.Thisstudyidconductedbythetimestudyexpert,whoshould befamiliarwithalltheinformation relatedto thejobandtheconditionsinwhichitisbeingdone.

Timestudyisperformedinthefollowingstages.

A)AnalysisofworkB)Standardizationofmethods

C)Makingtimestudy

1. Analysisofwork:Itincludesallthetasksperformedbytheworkers,notjusttheeffectivework.Intheend,timerequiredforjobpreparation,cleaningofmachine,etc.shouldalsobeincluded.
2. Standardizationofmethods:Relatedtomaterials,equipment,tools,workingconditionstoensureanacceptablemethodwhichiseasy,safeandthefastest.
3. Makingtimestudy:Timestudyisdoneonaprintedtimestudyrecordsheet,whichisfixedonaboardknownastimestudyboard.Ononecorner,astopwatchisplaced.

Differenttimereadingsofelementare recordedinthecorrespondingcolumnoftherecordsheet.Severalsetsofreadingaretakentoarriveatanaccurateresultafternotingallthesereadings,averagetomeiscalculated,neglectingabnormalvalues,ifany.

Standard time:it is thetime, whichis takenbya normal workerfora specifictaskorjob,workingundermoderateconditionsandincludingotherallowances.Suchasfatiguesettingoftoolandjob,repairingoftoolandcheckingofjobetc

Standard timeisthebasisforthecalculationofwagesand

incentives.

Standardtime=Averagetime\*Ratingfactor+otherallowances

Ratingfactor:thestudyengineermultipliesactualtimewithafactorknownasRatingfactororlevelingfactortosettheaveragetimewhichanormalworkerwouldtake.Thisisexpressedasapercentageoftheeffacingofrepresentativeoperator,whichisincomparisontosomeofhisaveragefellowworkers.

**Performancerating**:performanceratingisthatprocess,duringwhichthetimestudyengineercomparestheperformanceoftheoperatorofnormalperformance.

# Observedpersormance

Performancerating= 100Normalperformance

## Theratingcanbe

* 1. Standardrating:Aqualifiedworkerwillnaturallyworkifheismotivatedtoapplyhimselftohisworkattheaveragerateofpace.
  2. Normalrating:Itistheaveragerateorpaceatwhichaqualifiedworkerwillnaturallyworkevenifhehasnospecificmotivationtoapplyhimselftothiswork.

## Ratingtechniques:

* + 1. Speedrating:Speedratingconsistsofdeterminingthespeedoftheoperator’smovementsinrelationtoanormalpaceasafactorandapplyingittoeachelementsoastogetthenormaltimefortheelement.

# ObseredtimeRating

Normalorbasictime=

# Standardrating

Rating =Worker’sspeed

Standardrating =Speedexpectedfromtheworker

* + 1. Westing-housesystemofrating:Itisbaseduponfourfactors-systemcomprisingskill,effort,conditionsandconsistencyandarrivesatcumulativerating.
    2. Syntheticrating:Itistheratioofthestandardtomefortheelementtothatofobservedtime.
    3. Objectiverating;Itisdeterminedintwostages-firstthespeedratingandsecondtheadjustmentforjobdifficulties.
    4. Psychologicalevaluationofperformancelevel:Inthisratingweconsidertheamountofoxygenconsumed,changeofheartrateetctodetermineratingfactor.**Typesofallowancesintimestudy**:

1. Processallowances:Processallowancestocompensateforenforcedidlenessduetonoworkpowerfailure,faultymaterialortoolsandequipment.
2. Personal allowances: It comprises personal needs andfatigue.Fatigueallowancecontains,inturn,aconstantportionandavariableportion.
3. Interferenceallowances:Whenaworkerisattendingmorethanonemachine4)Contingency allowances: These allowances are to meet legitimatebutirregularorinfrequentitemsofworkordelays.

5)Specialallowances:Specialallowancesdecidedasapolicymatter,coveringactivitiesthatareessentialforsatisfactoryperformanceofworkbutmaynotbepartofthejob,likestartup,shutdown,changeover,cleaning,setup,toolchangingetc.

## STATISTICALQUALITYCONTROL

**Introduction**:Qualityisthedeterminingfactorthesuccessofanyproductorservicelargeresourcearecommittedineveryorganizationtoensurequality

**Definition**:Itisdefinedascustomersatisfactioningeneralandfitnessforuseinparticular.Boththeexternalconsumerwhobuytheproductandservicesandtheinternalconsumersthatis,alldivisionsordepartmentsofthebusinessorganizationareequallyinterestedinthequality.

**Statisticalquality control**:Theprocessofapplyingstatisticalprinciplestosolvetheproblemofcontrollingthequalitycontrolofaproductorserviceiscalledstatisticalqualitycontrol.

**Qualityelements**:a)Qualitydesignb)Qualityconformance

1. Qualitydesign:Qualityofdesignreferstoproductfeaturesuchasperformance,reliabilitydurability,easeofuse,serviceability
2. Qualityconformance:Qualityconformancemeanswhethertheproductmeetsthegivenqualityspecificationornot

**Inspection**:The process ofmeasuringtheout putandcomparing it tocheck whetheritmeetsthegivenspecifiedrequirementsornot,iscalledinspection.

**InspectionMethods**:Thefollowingarethemethodsofinspectionbasedonmerits

* 1. Incominginspection:Inthismethod,thequalityofthegoodsandservicesarrivingintotheorganizationisinspected.Thisensuresthatthematerialsuppliersadheretothegivenspecificationswiththisdefectivematerialcannotenterintotheproductionprocess.Thisfocusesonthevendor’squalityandabilitytosupplyacceptablerawmaterials.
  2. Criticalpointinspection:Inspectingatthecriticalpointsofaproductmanufacturegivesvaluableinsightintothecompletelyfunctionalprocess.Atthepointsofmanufacturethatinvolvehighcostsorwhichoffernopossibilityforrepairorrework,inspectioniscrucialfurtheroperationdependontheseresultscriticalpointinspectionhelpstodropthedefectiveproduction,andthereby,facilitateavoidingunnecessaryfurtherexpenditureonthem.
  3. Processinspection:Thisisalsocalledpatrollinginspectionorfloorinspectionorrovinginspection.Heretheinspectorgoesaroundthemanufacturingpointsintheshopfloortoinspectthegoodsproducedonrandomsamplebasisfromtimetotime.
  4. Fixedinspection:Itprovidesforacentralizedandindependentwhereworkisbroughtforinspectionfrom time totime.Thismethod isfollowedwherethe inspectionequipmentcannotbemovedtothepointsofproductions.
  5. Finalinspection:Thisiscentralizedinspectionmakinguseofspecialequipment.Thiscertifiesthequalityofthegoodsbeforetheyareshipped.

**ElementsofstatisticalQualityControl**:ThetechniqueunderSQCcanbedividedintotwopartsa)Processcontrolb)Acceptancesampling

* + 1. **Processcontrol**: Processcontrolisatechniqueofensuringthequalityoftheproductsduringthemanufacturingprocessitself.Ifaprocessconsistentlyproducesitemswithacceptableortolerablerangeofspecification. Itissaidtobestaticallyundercontrol. Processcontrolisachievedthroughcontrolcharts.Processcontrolaimstocontrolandmaintainthequalityoftheproductsinthemanufacturingprocess.Statistical controlcharts: A control chartcompares graphicallythe processperformancedatatocomputedstatisticalcontrollimits. Thesecontrollimitsactaslimitlinesonthechartcontrolchatsarethetoolstodeterminewhethertheprocessisundercontrolornot.

Thequalityoftheproductionprocessmaybeaffectedbychancecauseorassignablecause.

Chancecause:such causes,which mayormaynotaffectthe manufacturingprocessarecalledchance cause,chance cause cannoteven be identified.Itisnotpossibletoalwaysmaintainthegivenspecification.

AssignableCause:Assignablecausesaffectthequalityoftheproductionprocess.Thesecausescanbeidentifiedandspecified.Causessuchaschangeinthelabourshift,powerfluctuations,orexcessivetoolweararesaidtobeassignablecausesastheyaffectthequalityofmanufacturingprocessindifferentways.

Processcapability:Processcapabilityreferstotheabilitytoachievemeasurableresultsfromacombinationofmachines,tools,methods,materialsandpeopleengagedinproduction.

## Confidencelimitsandcontrollimit:

Confidencelimit:Itindicatetherangeofconfidencelevel.Aconfidencelevelreferstotheprobabilitythatthevalueofmeasurementorparameter,suchaslengthofscrew,iscorrect.

**Ex**:Ifacomponentisrequiredwithmeasurementof50mm.across,thenthebuyacceptallcomponentsmeasuringbetween48mmand52mmacross,consideringafivepercentconfidencelevel.

**Controllimit**:Controllimitsarefoundinthecontrolcharts.Therearetwocontrollimits1)Uppercontrollimit(UCL)and2)Lowercontrollimit(LCL).Thesearedeterminedbasedontheprinciplesofnormaldistribution

**Ex:**Inapilotinvestigationofthelengthofthenailsproducedintheshopfloor,itis

foundthatthemeanlengthXiscm,theS.D3σ,themeasureofvariabilityofthenailsproduced0.2cm.Howdoyouconstructthecontrolchartforthisdata.

+3σUppercontrollimit

4.6

Lengthofnail

4

3.4

x

-3σLowercontrollimit

Samplenumber

**Controlchartsfor variables**:Avariableisonewhosequalitymeasurementchangesfromunittounit.Thequalityofthesevariablesismeasuredintermsofhardness,thickness,length,andsoon.Thecontrolchartsforvariablesaredrawnusingtheprinciplesofnormaldistribution.Therearetwotypesofcontrolchartsforvariablesx

andRchart.

X**andRChart**:TheXchartisusedtoshowtheprocessvariationsbasedontheaveragemeasurementofsamplescollected.ItshowsmorelightondiagnosingqualityproblemwhenreadalongwithRchart.Itshowstheerraticorcyclicshiftsinthemanufacturingprocess.Itcanalsofocusonwhentotakearemedialmeasuretoset

rightthequalityproblems.However,collectingdataaboutallthevariablesinvolvesalargeamountoftimeandresources.

TheRchartisbasedontherangeoftheitemsinthegivenample.Ithighlightsthechangesintheprocessvariability.Itisagoodmeasureofspreadorrange.ItshowsbetterresultswhenreadalongwiththeXchart.

**For**x**charts**: UCL = x+A2R Whenx=Meanof Means

LCL= x-A2R R=MeanofsamplerangeA2=Constant

**ForRchart**: UCL =D4R D4,D3areconstantsLCL = D3R

Ristheaverageofsampleranges(Rangesisthedifferencebetweenthemaximumvariableandminimumvariable)

**EX**:ConstructxandRchartsfromthefollowinginformationandstatewhethertheprocessisincontrolforeachofthefollowingxhasbeencomputedfromasampleof5unitsdrawnatanintervalofhalfanhourfromanongoingmanufacturingprocess.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Samples | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| *x* | 24 | 34 | 35 | 39 | 26 | 29 | 13 | 34 | 37 | 29 |
| R | 23 | 39 | 14 | 5 | 20 | 17 | 21 | 11 | 40 | 10 |

**Solution:**Themeanofmeans x = x

# n

300

=

# 10

=30

Riscalculatedas R =

R

# n

20020

10

*x*Chart: *x*hcartUCLandLCL compute atsamplesize5A 2tablevalueis0.58

UCL=x+A2R=30+(0.58x20)=41.6LCL =D3R =30– (0.58x20)=18.4

60

50

40

Measurement

ofvariables 30

20

10

UCL=41.6

x=30

LCL=18.4

0

1 2 3 4 5 6 7 8 9 10

Numberofsamples

RChart: RchartUCLandLCLcomputeatsamplesize5,D4tablevalueis2.11andD3tablevalueis0

UCL =D4R =2.11 x20=42.2LCL = D3R =0 x20=0

45

25

20

Measurement

ofvariables 15

UCL=42.6

R=42.6

10

5

0

1 2 3 4 5 6 7 8 9 10

Numberofsamples

LCL=0

Therefore3,7pointstheprocessisoutofcontrol.

**Controlchartsforattributes**:Thequalityofattributescanbedeterminedonthebasisof‘Yes’or‘No’,‘Go’or‘Nogo’.Inotherwords,incaseofamirrorglass,evenifthereisonescratchitisnotconsideredtobeaqualitymirror,insuchacasequalityisdecidedbaseonwhetherthemirrorhasanyscratchornot.

Thecontrolchartsforattributesare‘C’chartand‘P’charts

‘C’Chart:‘C’chartisusewherethereanumberdefectsperunit.Thiscontrolchartscontrolsthenumberofdefectsperunit.Herethesamplesizeshouldbeconstant. Thiscalculateasbelow.

UCL =*c*+3

*c*

Wherethe*c*=

andLCL=*c*-3

*c*

*Totalnumberof defectsinallthesamples*

*Totalnumberof*

*samplesinspected*

## Ex:

|  |  |  |  |
| --- | --- | --- | --- |
| SampleNumber | No.ofdefects | SampleNumber | No.ofdefects |
| 1 | 5 | 11 | 4 |
| 2 | 4 | 12 | 6 |
| 3 | 9 | 13 | 7 |
| 4 | 7 | 14 | 3 |
| 5 | 8 | 15 | 5 |
| 6 | 9 | 16 | 3 |
| 7 | 4 | 17 | 3 |
| 8 | 5 | 18 | 1 |
| 9 | 2 | 19 | 7 |
| 10 | 6 | 20 | 2 |

Totalnumberofdefects = 100

*c*=1005

20

*c*

5

UCL =*c*+3

= 5 +3

=11.69

LCL=*c*-3

*c*

= 5 -3 =0

LCL=0means,LCLgotnegativevalue,takeitasequaltozero

5

20

15

10

No.defects

per each 8

sampledunit

6

5

4

2

0

2 4 6

8 10

12 14 15 18

UCL=11.69

*c*=5

LCL=0

20

Numberofsamples

‘P’Chart:‘P’Chartisusedwherethereisdateaboutthenumberofdefectivespersample.Itisalsocalledfractiondefectivechartorpercentagedefectiveschart.Hereeachitemisclassifiedon‘goornogo’basisthatisgoodorbad.Henceifthesamplesizeislarger,theresultscouldbebetter.

UCL=LCL=

Whereaveragedefective(*p*)=

*Totalno*.*of*

*defective*

*found*

*Totalno*.*of*

*pieces inspected*

‘n’=Numberofpiecesinspectedperday

**Ex:**Foreachofthe14daysanumberofmagnetsusedinelectricrelaysareinspectedandthenumberofdefectivesisrecorded.Thetotalnumber ofmagnetstestedis14,000.Thefollowingaretheparticularofthenumberofdefectivesfoundeveryday.

|  |  |  |  |
| --- | --- | --- | --- |
| Daynumber | Numberofdefective | Daynumber | Numberofdefective |
| 1 | 100 | 8 | 120 |
| 2 | 50 | 9 | 60 |
| 3 | 150 | 10 | 140 |
| 4 | 200 | 11 | 50 |
| 5 | 150 | 12 | 70 |
| 6 | 50 | 13 | 40 |
| 7 | 80 | 14 | 40 |

## Solution:

Totalnumberofdefectives=14000

Theaveragesamplesize(n)perday=14000/14days=1000

Percentageofdefectiveperday=

*Totalno*.*ofdefectivefoundperday*

*Totalno*.*of*

*pieces inspected*

*perday*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Daynumber | Percentageofdefectives | Numberofdefective | Percentageofdefectives | Daynumber | Numberofdefective |
| 1 | 100/1000=0.10 | 100 | 120/1000=0.12 | 8 | 120 |
| 2 | 50/1000=0.05 | 50 | 60/1000=0.06 | 9 | 60 |
| 3 | 150/1000=0.15 | 150 | 140/1000=0.14 | 10 | 140 |
| 4 | 200/1000=0.20 | 200 | 50/1000=0.05 | 11 | 50 |
| 5 | 150/1000=0.15 | 150 | 70/1000=0.07 | 12 | 70 |
| 6 | 50/1000=0.05 | 50 | 40/1000=0.04 | 13 | 40 |
| 7 | 80/1000=0.08 | 80 | 140/1000=0.14 | 14 | 40 |

(*p*)=

*Totalno*.*ofdefectivefound*

*Totalno*.*of*

*pieces inspected*

1400/14000=0.1

0.110.1

1000

UCL=0.1+3

=0.4

LCL=0.1 -3 =0

0.110.1

1000

Percentageofdefective

0.45

0.40

0.30

0.20

0.15

0.10

0.05

UCL=0.4

*p*0.1

LCL=0

1 5 10 15

DayNumber

**AcceptanceSampling**:Acceptancesamplingisatechniqueofdecidingwhethertoacceptthewholelotornotbasedonthenumberofdefectivesfromarandomdrawnsample.

Itiswidelyuseinbuyingfoodproducts,suchasrice,wheatetc.Beforebuyingtherandomsamplesdrawnfromthebagsofsayricearetested.Ifthequalityofsampledrawnlooksgoodorfreefromdefectsthenaccordingtotherequirementtheentirebagorpartofitcanbebrought

Theprocessofacceptancesamplingthroughoperatingcharacteristiccurve(OCC)

**Operatingcharacteristiccurve(OCC):**Thegraphicalrelationshipbetweenpercentagedefectiveinthelotsbeingsubmittedforinspectionandtheprobabilityacceptanceistermedas“operatingcharacteristicofaparticularsamplingplan”

Probabilityofacceptancepercentage

100

80

60

40

20

C=1(Acceptancenumber)n=50(samplesize)

1 2 3 4 5 6 78910

Actualpercentageofdefectives

Itgivesaclearpictureabouttheprobabilityofacceptanceoflotforvariousvaluesofpercentdefectivesinthelot.Theprobabilityofacceptanceofalotishighforlowvaluesofactualpercentagedecreaseanditislowforhighvaluesofactualpercentagedefectives.

**ConstructionofOCcurve**:Todevelopasamplingplanforacceptancesampling,anappropriateO.CcurvemustbeselectedtoconstructanOCcurveanagreementhastobereachedbetweentheproducerandtheconsumeronthefollowingfourpoint.

* + - 1. Acceptablequalitylevel(AQL):Thisisthemaximumproportionofdefectivesthatwillmakethelotdefinitelyacceptable.
      2. Lottolerancepercentagedefective(LTPD):Thisisthemaximumproportionofdefectivesthatwillmakethelotdefinitelyunacceptable.
      3. Producersrisk(α):Thisistherisk,theproduceriswillingtotakethatlotsofthequalitylevelAQLwillberejected,eventhough,theyareacceptableusuallyα=5%
      4. Consumerrisk(β):Thisistherisk,theconsumeriswillingtotakethatlotsofthequalitylevelLTPDwillbeaccepted,eventthough,theyareactuallyunacceptableusuallyβ=10%.

Probabilityofacceptance

Producersriskα=10%

α AQL=20%

LTPD=60%

Consumersriskβ=10%

β

20% 60% 100%

Percentageofdefectives(p)

**Samplingplans**:Basedonthenumberofsamplesdrawnfortakingaccept/rejectdecisions,thesamplingmethodsareused.Therearefourmethodsofacceptancesamplings.

1. Singlesamplingplan:Alotisacceptedorrejectedonthebasisofasinglesampledrawnfromthatcost
2. Doublesamplingplan:Ifitisnotpossibletodecidethefateofthelotonthebasisoffirstsample,asecondsampleisdrawnandthedecisionistakenonthebasisofthecombinedresultsoffirstandsecondsample.
3. Multiple samplingplan:Alotis accepted orrejectedbasedupontheresultobtainedfromseveralsamples(ofparts)drawnfromthelot.
4. Sequentialsamplingplan:(Itembyitemanalysis)

Sequentialsamplinginvolvesincreasingthesamplesizebyonepartatatimetillthesamplebecomeslargeenoughandcontainssufficientnumberofdefectivestodecideintelligentlywhethertoacceptorrejectthelot.