**Networkanalysis**:Itisreferstoanumberoftechniquesfortheplanningandcontrolofcomplexprojects.Thebasisofnetworkplanningistherepresentationofsequentialrelationshipsbetweenactivitiesbymeansofanetworkoflinesandcircles.Theideaistolinkthevariousactivitiesinsuchawaythattheoveralltimespentontheprojectiskepttoaminimum.

## FeaturesofNetworkAnalysis:

Logicalbase ofplanning: Network analysisis highlyapplicableat severalstagesofprojectmanagementrightfromearlyplanningstageofselectingrightoptionfromvariousalternativetoschedulingstageandoperationalstage.

Simpleinnature:Networkanalysisisstraightforwardinconceptandcanbeeasilyexplainedtoanylaymen.Datacalculationsaresimpleandforlargeprojectscomputerscanbeused.

Improves coordinationand communication: Thegraphsgenerated outofnetworkanalysisdisplaysimplyanddirectwaythecomplexnatureofvarioussub-divisionsofprojectmay,quicklyperceivefromthegraph

Widerapplication:Thenetworkanalysisisappliedtomanytypesofprojects.Moreover,theymaybeappliedatseverallevelswithinagivenprojectfromasingledepartmentworkingonasub-systemtomulti-plantoperationswithincorporation.

**Gantt’sbarchart**:BeforePERTandCPMweredeveloped,Ganttchartsandmilestonechartswereusedtoolstomonitortheprojectprogressincomplexprojects.Ganttchartisabarchart,whichwasdevelopedbyHenaryGanttaround1900.

Itisconsistsoftwocoordinateaxes,onerepresentsthetimeandtheotherjobsoractivitiesperformed.

A

|  |  |  |  |
| --- | --- | --- | --- |
|  | | | |
|  | 5days | | |
| 5days | | | |
|  | | |  |
|  | | | |
|  | |  | |
|  | | |  |
|  |
|  |

B

Activitiesin Cjobx

DE

4days

7days

3days

Durationoftime

TheabovefigureshowsjobxwhichcontainsfiveactivitiesABCDEthedifferenttimedurationsactivityAisanindependentactivityfollowedbyactivitiesB,activityBisfollowedbyactivityC,activitiesD,Ehavenosuchsequence.Activities C,D andEreach completiontogether.However the totalnumberodaytakenforcompletingthejobis14days.

## LimitationofGanttChart:

1. ThisGanttbarchartsnotusefulforbigprojects,consistingoflargenumberofcomplexactivities
2. Itdoesnotshowtherelationshipbetweenvariousoperations.ItisverydifficulttofindthesequenceofvariousoperationsontheGanttchartorthemostprobabledateofcompletion.
3. Doestoindicatetheprogressofwork
4. Itcannotreflectuncertaintyortoleranceinthedurationtimeestimatedforvariousactivities
5. Itsimplyaschedulingtechnique,butnoteffectiveplanningtool.

**Milestonechart**:MilestonechartisanimprovementoverGanttchart.IthasbecomesagoodlinebetweenGanttchartandPERTandCPMnetwork.EverytaskrepresentedbyabarinGantt’sbarchart,issubdividedintermseventorpointintime.

A

B

Activitiesin Cjobx

D

5days

5days

1

3

5

6

7

8

10

11

2

4

9

3days

7days

E 4days

Durationoftime

IntheGantt’sbarchartsbarrepresentinganactivityisdividedintocertainmilestones.Theyareidentifiedwithamajorevent,andconsecutivelynumberedsuchabreakdownenhancestheawarenessabouttheinterdependenciesamongallmilestones.

Networkanalysisundergoneseveralchangesandmanyvariantsexist,whichevaluatetherandomnessduetoimperfectioninallhumanandphysicalsystems.PERTandCPMcontinuetobeverypopular,inhandlingthebasicfactorsliketime,cost,resources,probabilitiesandcombinationsofallthesefactors.

## PERTANDCPM:

**PERT**:Programmeevaluationand reviewtechnique(PERT)isatooltoevaluateagivenprogrammeandreviewtheprogressmadeinitfromtimetotime.Aprogrammeisalsocalledaproject.Aprojectisdefinedasasetofactivitieswithaspecificgoaloccupyingaspecificperiod.Itmay beasmallorbigproject,suchasconstructionofacollegebuilding,roads,marriage,picnicsetc.

Itisconcernedwithestimatingthetimefordifferentstagesinsuchaprogrammeoraprojectandfindoutwhatthecriticalpathis,whichconsumesamaximumresources.

**CPM**:Criticalpathmethodassumesthatthetimerequiredtocompleteanactivitycanbepredictedfairlyaccurately,andthus,thecostsinvolvedcanbequantifiedoncethecriticalpathhasbeenidentified.Sincetimeisanimportantfactor,CPMinvolvesatrade-offbetweencostsandtime.Itinvolvesdetermininganoptimumdurationfortheproject,thatis,aminimumdurationthatinvolvesthelowestoverallcosts.

## ApplicationofPERTandCPM:

* Constructionofprojectssuchasbuilding,highways,housesorbridges
* Preparationofbidsandproposalsforlargeprojectssuchasmultipurposeprojects
* Maintenanceandplanningofoilrefineries,shiprepairsandothersuchaslargeoperations
* Developmentofnewweaponsystemsandnewproductsandservices
* Manufactureandassemblyoflargeitemssuchasaeroplanesorshipsrepairsandothersuchaslargeoperations
* Simpleprojectssuchashomeremodelinghousekeepingorpaintingandsoon.

## PERTBasicTerminology:

Event:Aeventisspecificinstantoftimewhichindicatesthebeginningorendoftheactivityeventisalsoknownasajunctionornode.Itisrepresentedbyacircleandtheeventnumberiswrittenwithinthecircle.

Tailevent Headevent

Predecessorevent Successorevent

Activity:Everyprojectconsistsofnumberofjoboperationsortaskswhicharecalledactivity.

**Ex**:Startmachineinstallation - AneventMachineinstallation - AnactivityCompletionofmachine - Anevent

## Classificationofactivities:

1. Criticalactivity
2. Non-Criticalactivity
3. Dummyactivity

Criticalactivity:Inanetworkdiagramcriticalactivitiesarethosewhichifconsumemorethantheirestimatedtime,theprojectwillbedelayed.Itshownwiththickarrow.

Non-criticalactivity:Suchactivitieshaveaprovisionoffloatorslacksothat,eveniftheyconsumeaspecifiedtimeoverandabovetheestimatedtime.

Dummyactivity:WhentwoactivitiesstartatthesameinstantoftimelikeAandBtheheadeventarejointedbydottedarrowsandthisisknownasdummyactivity.

2

DummyActivity

1

3

4

5

## CPMBasicterminology:

CriticalPath:Criticalpathisthatpathwhichconsumesthemaximumamountoftimeorresources.Itisthatpathwhichhaszeroslackvalue.

Slack:Slackmeansthetimetakentodelayaparticulareventwithoutaffectingtheprojectcompletiontime.Ifapathhaszeroslackthatmeansitisthecriticalpath.

Slack=LFT–EFT

EarliestStartTime(EST):Itistheearliestpossibletimeatwhichanactivitycanstart,andiscalculatedbymovingfromfirsttolasteventinthenetworkdiagram.EarliestFinishTime(EFT):Itistheearliestpossibletimeatwhichanactivitycanfinish

EFT=EST +Durationofactivity

LatestStartTime(LST):Itisthelatestpossibletimebywhichanactivitycanstartwithoutdelayingthedateofcompletionoftheproject.

LST=LFT–Durationoftheactivity

LatestFinishTime(LFT):Itisthelatesttimebywhichtheactivitymustbecompleted.Sothatthescheduleddateforthecompletionoftheprojectmaynotbedelayed.Itiscalculatedbymovingbackwards.

**Float**: Floatsinthenetworkanalysisrepresentthedifferencebetweenthemaximumtimeavailabletofinishtheactivityandthetimerequiredtocompleteit.

Thebasicdifferencebetweenslackandfloattimesisaslackisusedwithreferencetoevent,floatisusewithreferencetoactivity.

Floatsarethreetypes:

1)Totalfloat 2)Freefloat 3)Independentfloat

1. Totalfloat:Itistheadditionaltimewhichanoncriticalactivitycanconsumewithoutincreasingtheprojectduration.Howevertotalfloatmayaffectthefloatsinpreviousandsubsequentactivities.

Totalfloat=LST–EST or LFT–EFT

1. Freefloat: Freefloatreferstothetimebywhichanactivitycanexpandwithoutaffectingsucceedingactivities.

Freefloat=ESTofHeadEvent–EST ofTrailEvent–Activityduration

1. Independentfloat:Thisthetimebywhich activitymaybe delayed orextendedwithoutaffectingtheprecedingorsucceedingactivitiesinanyaway.

Independentfloat=ESTofHeadevent–LFTofTrailevent–Activityduration

## Problems:

1. Asmallengineeringprojectconsistsof6activitiesnamelyABCDE&Fwithdurationof4,6,5,4,3and3daysrespectively.DrawthenetworkdiagramandcalculateEST,LST,EFT,LFTandfloats.Markthecriticalpathandfindtotalprojectduration.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Activity | A | B | C | D | E | F |
| Precedingactivity | - | A | B | A | D | C,E |
| Duration | 4 | 6 | 5 | 4 | 3 | 3 |

10

10

EST

LFT

0

0

4

4

15

15

18

18

**Solution**:

B

3

C

6

5

F

1

4

2

5

3

6

A

4

3

D E

4

8

12

## Criticalpath=A-B-C-FProjectduration=18days

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Activity | Duration | EST | LST | EFT | LFT | Totalfloat | Freefloat | Independentfloat |
| ABCDEF | 4  6  5  4  3  3 | 0  4  10  4  8  15 | 0  4  10  8  12  15 | 4  10  15  8  11  18 | 4  10  15  12  15  18 | 0  0  0  4  4  0 | 0  0  0  0  4  0 | 0  0  0  0  0  0 |

**Note**:LST=LFT–activitydurationLFT=EST+activityduration

Totalfloat=LST–EST orLFT–EFT

Freefloat=ESTofHeadEvent–EST ofTrailEvent–ActivitydurationIndependentfloat=ESTofHeadevent–LFTofTrailevent–Activityduration

1. Asmallengineeringprojectconsistsofsixactivities.Thethreetimeestimatesinnumberdaysforeachactivityaregivenbelow.

|  |  |  |  |
| --- | --- | --- | --- |
| Activity | to | tm | tp |
| 1-2 | 2 | 5 | 8 |
| 2-3 | 1 | 1 | 1 |
| 3-5 | 0 | 6 | 18 |
| 5-6 | 7 | 7 | 7 |
| 1-4 | 3 | 3 | 3 |
| 4-5 | 2 | 8 | 14 |

## Findout:

* 1. Calculatethevaluesofexpectedtime(te),aSn.dDv(aσrtiance(v i)ofeachactivity
  2. Drawthenetworkdiagramandmarkteoneachactivity
  3. CalculateESTandLFTandmarkthemonthenetworkdiagram
  4. Calculatetotalslackforeachactivity
  5. Identifythecriticalpathandmarkonthenetworkdiagram
  6. Probabilityofcompletingprojectin25days.

## Solution:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Activity | to | tm | tp | *to* 4*tm* *tp*  *te*   6  (Duration) | *S*.*D**t**tp* *to*  6 | *Varianc*(*ev*)*t*2  *i* |
| 1-2 | 2 | 5 | 8 | 5 | 1 | 1 |
| 2-3 | 1 | 1 | 1 | 1 | 0 | 0 |
| 3-5 | 0 | 6 | 18 | 7 | 3 | 9 |
| 5-6 | 7 | 7 | 7 | 7 | 0 | 0 |
| 1-4 | 3 | 3 | 3 | 3 | 0 | 0 |
| 4-5 | 2 | 8 | 14 | 8 | 2 | 4 |

EST

LFT

6

6

5

6

0

0

23

13

20

20

2

3

1

5

7

1

3

5

6

8

7

4

3

5

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Activity | EST | LFT | LST | EFT | Slack |
| 1-2 | 0 | 5 | 0 | 5 | 0 |
| 2-3 | 5 | 6 | 5 | 6 | 0 |
| 3-5 | 6 | 13 | 6 | 13 | 0 |
| 5-6 | 13 | 20 | 13 | 20 | 0 |
| 1-4 | 0 | 5 | 2 | 3 | 2 |
| 4-5 | 3 | 13 | 5 | 11 | 2 |

**Criticalpath=1-2-3-5-6=20days**

Probabilityforcompletingprojectin25days:

*Z**ts**te*

**

Herets =25days,te=20days,** 

1090

10

*z* 

2520

1090

 5

# 3.33

5

10

1.50

Fromthetablevalue(z=1.50)=**93.32%**

## ProjectManagement–II

**Projectcrashing**:Inthischapter,wewilldiscusstheconceptsofdirectandindirectcosts, therelationshipbetweenproject time and projectcost, the conceptofcostslopeandhowtheoptimumcostandoptimumdurationareensuredforagivenprojectswhilecrashing.

**Projectcosts**:Costsassociatedwithanyprojectcanbeclassifiedintotwocategoriesa)Directcostb)Indirectcost

1. Directcost:Thesecostsarethose,whicharedirectlyproportionaltothenumberofactivitiesinvolvedintheprojectEx:Rawmaterialcost

Directcost

Crashtime Normaltime

1. Indirectcost:Indirectcostarethosecoststhataredeterminedperday.Someofexamplesforindirectcostsaresupervisorypersonnelsalary,supplies,rent,interestanborrowings,ads,depreciation.Thesecostsaredirectlyproportionaltothenumberofdaysofthedurationoftheproject.Iftheprojectdurationisreducedtheindirectcostalsocomesdown.

Projectcost

Indirect cost

Projectduration

**Normalcost(Nc)**:Itisthelowestcostofcompletinganactivityintheminimumtime,employingnormalmeansi.e.notusingovertimeorotherspecialresource.**Normaltime(NT)**:Itistheminimumtimerequiredtoachievethenormalcost**Crashcost(CC)**:Itistheleastcostofcompletinganactivitybyemployingallpossiblemeanslikeovertime,additionalmachinery,propermaterialsetc.

**Crashtime(CT)**:Itistheabsoluteminimumtimeassociatedwiththecrashcost.**CostSlope**:CostSlopeistheamountthathastobespentoverandabovethenormaldirectcostforreducingthedurationbyoneunitoftime(day,weeketc.).Costslopeisdefinedastheadditionalcostforreducingoneunitoftime,assumingagivenrateofincreaseindirectcostwithadecreaseinoneunitoftime.

|  |  |  |
| --- | --- | --- |
| CC | | |
| NC |  | |
| CT |  | N |

*Costslope**Crash*cos*t**Normal*cos*t*

*Normaltime**Crashtime*

*S**CC**NC*

*NT**CT*

ActivityCost

T

Activitytime

**CrashingofNetwork**:Afteridentifyingthecriticalpath,itisnecessarytoidentifytheprioritytocrashtheactivitiesbycalculatingthecostslope.

Forreducingthedurationextraexpendituretobeincurred,buttosaveresources,organizationskeepthisextraexpenditureataminimum.

CT=CrashTimeOT=OptimumTimeNT=NormalTime

TotalCost(A+B)

O

IndirectCost(B)

DirectCost(A)

ProjectCost

CT OT NT

Projectduration

Whenthedirectcost(A)decreasewithanincreaseintime,astheprojectdurationincrease,theindirectcost(B)likeoverheads,depreciation,insuranceetc.increases.Thetotalcost(A+B)curveisaflatU-shapedcurve,withimpliesthatonlyuptoa particularpoint(O)the crashingiseconomical, notbeyond.Thetimeduration,whichinvolvestheleasttotalcost,istheoptimumdurationatoptimumcost.Crashingthedurationofaprojectmaynotbepossiblebeyondaparticularpoint.

4

14

## Problems:

1. Giventhefollowingdata,workouttheminimumdurationoftheprojectandcorrespondingcost

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Activity | Job | Normaltime | Crashingtime | Normalcost | Crashingcost |
| A | 1-2 | 10 | 6 | 400 | 600 |
| B | 1-3 | 4 | 2 | 100 | 140 |
| C | 2-4 | 6 | 4 | 360 | 440 |
| D | 3-4 | 8 | 4 | 600 | 900 |
| E | 2-5 | 8 | 6 | 840 | 1100 |
| F | 4-6 | 6 | 2 | 200 | 300 |
| G | 5-6 | 10 | 8 | 1200 | 1400 |

## Solution:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Activity | Job | Normaltime(NT) | Crashingtime(CT) | Normalcost(NC) | Crashingcost(CC) | CostSlopeCCNC  NTCT | Priorities |
| A | 1-2 | 10 | 6 | 400 | 600 | 50 | 1 |
| B | 1-3 | 4 | 2 | 100 | 140 | 20 |  |
| C | 2-4 | 6 | 4 | 360 | 440 | 40 |  |
| D | 3-4 | 8 | 4 | 600 | 900 | 75 |  |
| E | 2-5 | 8 | 6 | 840 | 1100 | 130 | 2 |
| F | 4-6 | 6 | 2 | 200 | 300 | 50 |  |
| G | 5-6 | 10 | 8 | 1200 | 1400 | 100 | 3 |

EST

LFT

10

10

18

18

0

0

28

28

16

22

8

2

5

10

6

10

6

6

1

4

8

3

Criticalpathis1-2-5-6andDurationis28daysTotalcostis=Directcost+Indirectcost

=(10+4+6+8+8+6+10)+0=52/-

## 1-2activitycrashingby4days:

EST

LFT

6

6

14

14

0

0

24

24

12

18

8

2

5

10

6

6

6

6

1

4

4

8

3

4

10

Criticalpathis1-2-5-6andDurationis24daysTotalcostis=Directcost+Indirectcost

=(52+(4x50)+0)=252/-

## 5-6activitycrashingby2days:

EST

LFT

6

6

14

14

0

0

22

22

12

18

8

2

5

8

6

6

6

6

1

4

4

8

3

4

10

Criticalpathis1-2-5-6andDurationis22days

Totalcostis=Directcost+Indirectcost

=(252+(2x100)+0)=452/-

## 2-5activitycrashingby2days:

EST

LFT

6

6

12

12

0

0

20

20

12

14

6

2

5

8

6

6

6

6

1

4

4

8

3

4

6

Criticalpathis1-2-5-6andProjectDurationis20daysTotalcostis=Directcost+Indirectcost

=(452+(2x130)+0)=712/-

## Optimumcost =712/-OptimumDuration=20days

1. Thefollowingtablegivestheinformationrelatingtoaproject.Byusingthegivendatacalculatetheoptimumdurationoftheproject.WhereindirectcostisestimatedRs.2,000perday.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Activity | Normal | | Crash | |
| Time(days) | Cost(Rs.) | Time(days) | Cost(Rs.) |
| 1-2 | 4 | 1000 | 3 | 2000 |
| 1-3 | 2 | 1500 | 1 | 3500 |
| 2-4 | 2 | 500 | 1 | 900 |
| 2-5 | 5 | 1000 | 3 | 4000 |
| 3-4 | 3 | 1000 | 1 | 2000 |
| 4-5 | 2 | 800 | 1 | 1000 |

## Solution:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Activity | Normal | | Crash | | *CostSlope**CC**NC*  *NT**CT* | Priorities |
| Time(days) | Cost(Rs.) | Time(days) | Cost(Rs.) |
| 1-2 | 4 | 1000 | 3 | 2000 | 1000 | 1 |
| 1-3 | 2 | 1500 | 1 | 3500 | 1000 |  |
| 2-4 | 2 | 500 | 1 | 900 | 400 |  |
| 2-5 | 5 | 1000 | 3 | 4000 | 1500 | 2 |
| 3-4 | 3 | 1000 | 1 | 2000 | 500 |  |
| 4-5 | 2 | 800 | 1 | 1000 | 200 |  |
| Totaldirectcost | | 5800 |  |  |  |  |

EST

LFT

4

4

9

9

0

0

6

7

2

5

2

5

4

4

2

1

2

3

3

[www.specworld.in](http://www.specworld.in/) 17 [www.smartzworld.com](http://www.smartzworld.com/)

2

4

Criticalpathis1-2-5andProjectDurationis9daysTotalcostis=Directcost+Indirectcost

=5800+(2000x9)

=23,800/-

## 1-2crashingby1day:

EST

LFT

3

3

8

8

0

0

5

6

2

5

2

5

3

4

2

1

2

3

3

2

3

Criticalpathis1-2-5andProjectDurationis8daysTotalcostis=Directcost+Indirectcost

=(5800+(1x1000))+(2000x8)

=22,800/-

## 2-5(a)crashingby2days:

EST

LFT

3

3

7

7

0

0

5

5

2

3

2

5

3

4

2

1

2

3

3

2

2

Criticalpathsare1-2-4-5and1-3-4-5anddurationis7daysonly.Totalcost =Directcost+Indirectcost

=(6800+(2x1500))+(2000x7)

=23,800/-

Hereprojectcrashedby2daysandtotalcostincurredbythefirmis23,800/- butdurationisreducedbyonlyoneday.Soitissuggestedtocrashthenetworkbyonlyoneday,Itcanhelptoreducethecost.Sothat2-5activitycrashingbyonly1day.

## 2-5(b)activitycrashingby1dayonly

EST

LFT

3

3

7

7

0

0

5

5

2

4

2

5

3

4

2

1

2

3

3

2

2

Durationis7days

Totalcost =Directcost+Indirectcost

=(6800+(1x1500))+(2000x7)

=8300+14000

=22,300/-

Allactivitiescomesunderthecriticalactivities,thepriorityarechangedaccordingtothecostslope4-5activityhavingminimumcostslope.Sothatitispossibletocrashout4-5activitybyonedayonlyand2-5byonedaysimultaneously

## 4-5activitycrashingby1dayand2-5crashingby1dayonly:

EST

LFT

3

3

6

6

0

0

5

5

2

3

2

5

3

4

1

1

2

3

3

2

2

Durationis6days

Totalcost =Directcost+Indirectcost

=(8,300+(1x1500)+(1x200))+(2000x6)

=(8300+1700)+(12000)

=22,000/-

Thisnetworkdiagramnotpossibletocrashingfurther,Sothattheprojectdurationis6daysandoptimumcostisRs.22,000/-

## Optimumcost =22,000/-OptimumDuration=6days