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Case Report

Application of PERT in geo-scientific software development projects – few case studies

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ABSTRACT

A Program Evaluation Review Technique (PERT) chart is a project management tool used to schedule, organize, and coordinate tasks within a project. A PERT chart presents a graphic illustration of a project as a network diagram consisting of numbered nodes representing events, or milestones in the project linked by labelled vectors (directional lines) representing tasks in the project. The direction of the arrows on the lines indicates the sequence of tasks. It clearly illustrates task dependencies. This work presents application of PERT in development process of different software applications viz. 'Dishansh 2005', 'Vigat 2005', 'Starmiti 2005' and 'Kampan 2006'. These softwares are useful in various geo-scientific applications. Various utilities of these softwares and benefits accrued by application of PERT are discussed here.

Keywords: Program Evaluation Review Technique, Critical Path, Java, Software, Project Management, Vigat, 2005, Dishansh, 2005, Starmiti, 2005, Kampan, 2006, Geology, Geophysics, Geo-scientific, Geotechnical, Cross, section, network diagram

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INTRODUCTION

Project management consists of planning, designing, and implementing a set of activities to accomplish a goal or task. For many years, one of the most popular approaches to project management have been the Program Evaluation and Review Technique (PERT). PERT was developed by the U.S. Navy to manage the development of the Polaris missile.

PERT, the Project Evaluation and Review Technique, is a network aid for planning and scheduling the many interrelated tasks in a large and complex project.

Nowadays PERT techniques are routinely used in large projects such as Research and development, software development, newly developed industries etc.

Program Evaluation and Review Technique (PERT) is a project management technique for determining how much time a project needs before it is completed. A distinguishing feature of PERT is its ability to deal with uncertainty in activity completion time (Cay et al., 2004). Each activity is assigned a best, worst, and most probable completion time estimate.

These estimates are used to determine the average completion time. The average times are used to figure the critical path and the standard deviation of completion times for the entire project. There may be several paths within one project.

In software development projects, completion times of different activities can be highly variable. As PERT, can deal with uncertainty in activity completion time, it is helpful for planning and managing a software development project.

PERT and critical path

The critical path is the path (sequence) of activities, which represent the longest total time required to complete the project. A delay in any activity in the critical path causes a

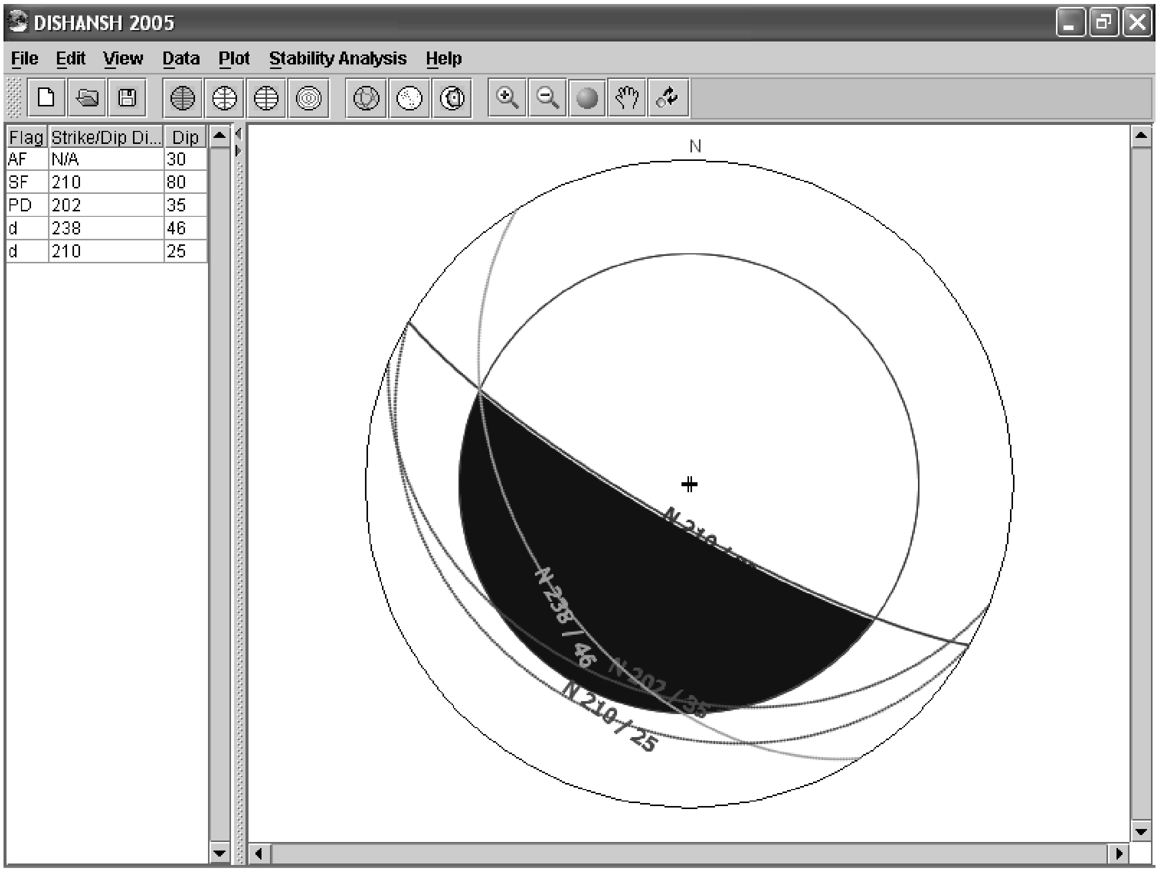

Figure 1. Plotting geological discontinuities for geotechnical interpretations by 'Dishansh 2005' (After Thakor et al., 2005)

delay in the completion of the project. There may be more than one critical path depending on durations and workflow logic. Sequence is the order in which activities will occur with respect to one another. This establishes the priority and dependencies between activities. Successor and predecessor relationships are developed in a network format. This allows those involved in the project to visualize the work flow. A critical activity has zero or negative float. This activity has no allowance for work slippage.

It must be finished on time or the whole project will fall behind schedule. Non-critical activities have float or slack time and are not in the critical path.

In PERT, three time estimates are required for each activity. The time estimates represent a pessimistic time (a), an optimistic time (b), and a most likely time (m) for duration of the activity. The pessimistic time is assumed to equal the 0.00 fractile of the distribution, the optimistic time equal to the 1.00 fractile, and the most likely time equal to the mode. The mean completion time of each activity is then estimated as

$t_e=(a+4m+b)/6$

and the standard deviation as

$s=(b-a)/6$

Using the estimated mean of each activity time, the network is analyzed in the same manner as the CPM method. The PERT method assumes that the sum of the mean completion times of activities on the critical path is normally distributed. This allows the calculation of the probability of completing the project within a given time.

Application of PERT in software development processes

PERT has been applied to various software development processes pertaining to utility softwares 'Dishansh 2005', 'Vigat 2005', 'Starmiti 2005' and 'Kampan 2006' {developed by Thakor et al. (2005), Solanki et al. (2005), Doshi et al. (2005) and Dharwa et al. (2006)}.

'Dishansh 2005'

Spatial relations in the geosciences are commonly represented by projecting the orientation of planes and lines on to a horizontal surface. 'Dishansh 2005' plots planer and linear structural features, for seismological and geotechnical interpretations (Figure 1). The name 'Dishansh' is derived from the Gujarati words "disha" (direction) and "ansh" (degree). Equal area and equal angle projections provided by this software can be used to

Table 1. Details of activities pertaining to 'Dishansh 2005'

Activity	Description	Predecessor Activity
A	Draw equal area net	-
B	Draw equal angle net	-
C	Draw orthographic net	-
D	Kalsbeek net	-
E	Plotting Planes	A, B, C
F	Plotting Poles	E
G	Multiple database connectivity	E, F
H	Plotting Beta Diagram	E
I	Angle between two poles	F
J	Finding Density of Poles for contouring	D, F
K	Generation of Beach Boll Diagram	E
L	Markland test for plane failure	E
M	Markland test for Wedge failure	E
N	Slope stability analysis for plane failure	L
O	Slope stability analysis for wedge failure	M
P	Variuos Utility options	E, F
Q	GUI for all functionality	P
R	Softaware Testing	Q

present and analyze geometrical and angular relationships between lines and planes. Stereographic projections provide easy solutions of the problems dealing with the angular relationships between lines and planes in space. Joints, bedding planes and faults are represented by lines or points on the projection of a reference sphere. Design and development process of 'Dishansh 2005' strictly followed the concept of software engineering. For proper planning, scheduling and control of activities of this software development project, PERT (Program Evaluation Review Technique) has been implemented. It is an interactive multi purpose tool to meet various requirement of user. It allows the user to analyze and visualize structural data following the same technique used in manual stereonets.

Tools and Technology

Development of Dishansh 2005 has strictly followed SLDC (Software Development Life Cycle). The fundamental reason that necessitated the utilization of core Java for the development of software is that in Java, GUI (Graphical User Interface) provides excellent interactivity with user. Besides this Java is an object-oriented programming language (Palmer, 2001). It is simple, secure, portable, robust, multithreaded, architecture neutral, high performance, interpreted, distributed and dynamic programming language. Like the successful computer languages that came before, Java is a blend of the best elements of its rich heritage combined with the innovative concepts required by its unique environment (Schildt, 2001). Today, Java is used not only for web programming, but also to develop standalone applications (Liang, 1998).

Application of PERT for the development of 'Dishansh 2005'

Variability of project duration in PERT analysis is measured by variance or its square root, standard deviation (Chandra, 2005). PERT is an acronym for Program Evaluation Review Technique. It is eminently suitable for research and development programmes, aerospace projects, and other projects involving new technology. In such projects the time required for completing various jobs or activities can be highly variable. Hence the orientation of PERT is 'probabilistic'. PERT in a way supercedes the older technique known as the Gantt chart. Contrary to Gantt chart in PERT every individual item of work can be accommodated and displayed in the logical sequence. (Arogyaswamy, 1988)

Procedure adopted in applying PERT:

- Key activities and their sequence are identified.
- Activities are listed in logical sequence (Table 1).
- For every activity three time estimates are considered for computation of expected duration (Table 2).
- Expected duration for each activity is considered for the construction of network diagram (Figure 2).
- Standard deviation of duration is computed for each activity.
- Network diagram is constructed.
- Critical path is identified.

Probability of completion of project (Dishansh 2005) in 60 days

Here, $\sigma = (b - a) / 6$

The expected duration of the critical path $\mu = 12 + 5 + 5 + 15 + 6 + 5 + 4 = 52$ Days

$\sigma^2 = (2.00)^2 + (0.333)^2 + (0.333)^2 + (1.667)^2 + (0.667)^2 + (0.333)^2 + (0.667)^2$

$= 4 + 0.111 + 0.111 + 2.779 + 0.445 + 0.111 + 0.445$

$= 8.002$

Probability $\Pr[(t - \mu) / \sigma]$

$= \Pr[(60 – 52) / \text{sqrt}(8.002)]$

$= \Pr[8 / 2.83]$

$= \Pr [Z <= 2.83]$

$= 0.9977$

Table 2. Three time estimates of different activities pertaining to 'Dishansh 2005'

Activity	Optimistic Time (a)	Most Likely Time (m)	Pessimistic Time (b)	Expected Duration (t_e)	Standard Deviation of Duration (σ)
A	6	12	18	12	2.000
B	5	7	9	7	0.667
C	7	9	17	10	1.667
D	4	5	6	5	0.333
E	4	5	6	5	0.333
F	4	5	6	5	0.333
G	10	15	20	15	1.667
H	4	6	8	6	0.667
I	4	5	6	5	0.333
J	4	5	6	5	0.333
K	4	5	6	5	0.333
L	4	5	6	5	0.333
M	4	6	8	6	0.667
N	2	4	6	4	0.667
O	2	4	6	4	0.667
P	4	6	8	6	0.667
Q	4	5	6	5	0.333
R	3	3.5	7	4	0.667

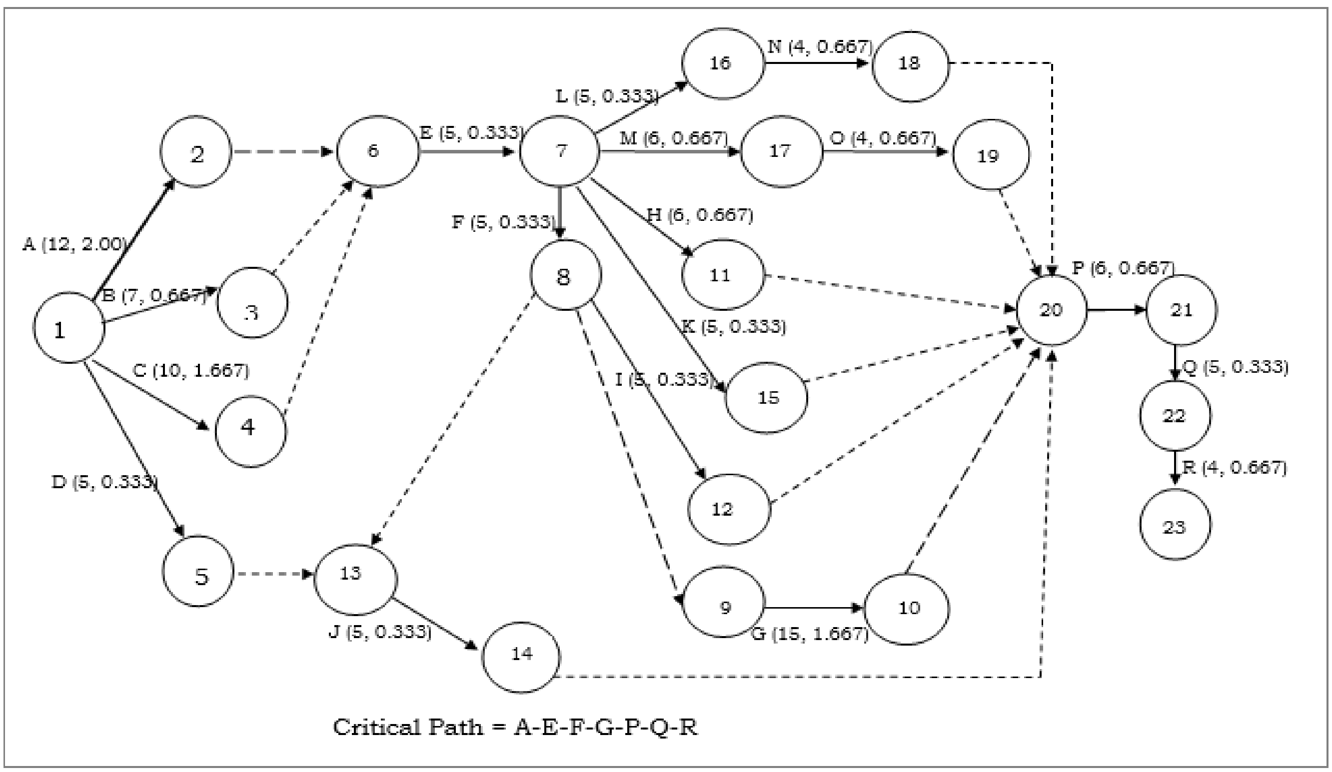

Figure 2. Network diagram of 'Dishansh 2005'

So, it can be said that the probability of completion the project in 60 days is **99.77 %.**

'Vigat 2005'

Cross section can be described as a two-dimensional dataset where the horizontal distances are represented on the x-axis and the depth on the y-axis. A cross-section is a window into the subsurface. 'Vigat 2005' constructs cross sections from contour map without digitization of contours (Fig. 3). It is a Visual C ++ based software application. The term 'Vigat ' means profile or information in Gujarati language. Its main purpose is to provide cross sectional view of geoscientific features within the area of study. In geological context, profile or cross section is an exposure of the ground, showing depositional strata. Geological

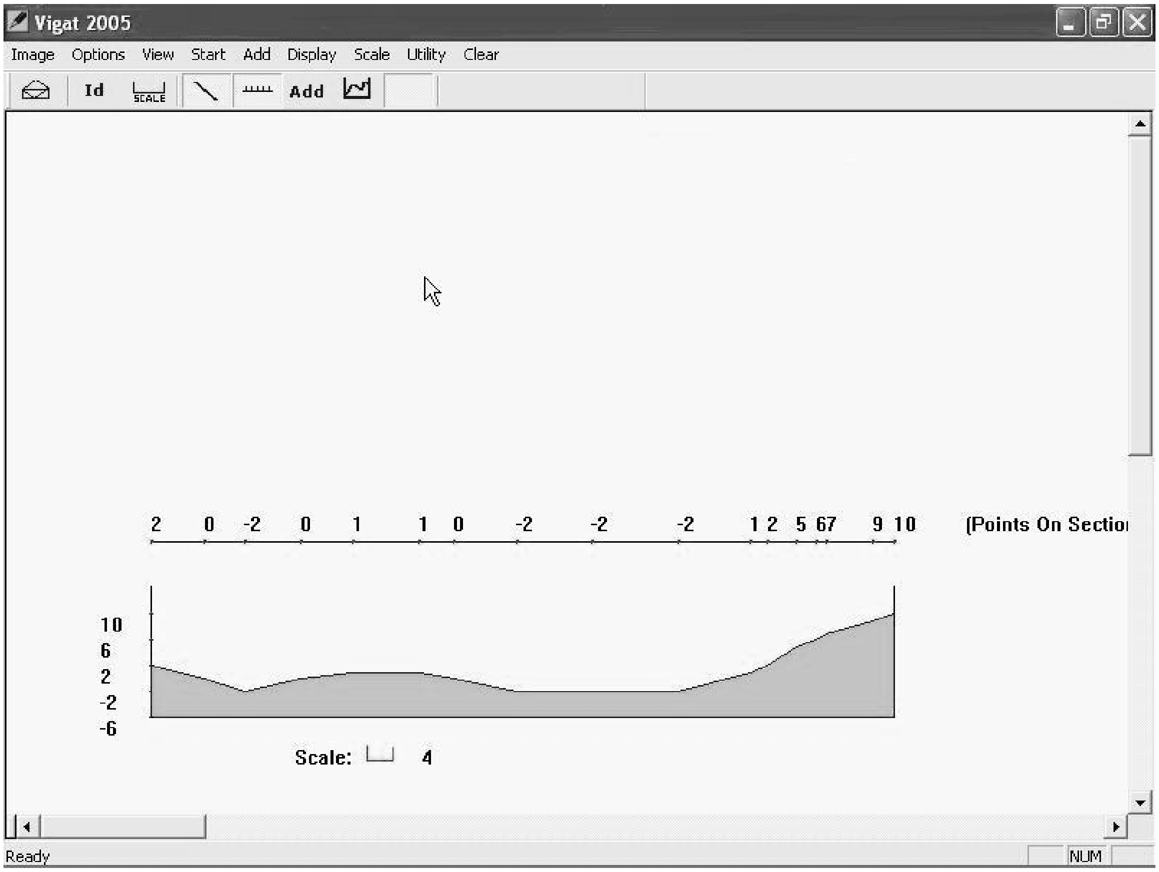

Figure 3. Cross-section generation from contour map by Vigat 2005'
(After Solanki et al., 2005)

cross sections are a very powerful means of conveying structural geometries. It is a planar, usually vertical, graphic representation of a section of the earth showing the stratigraphic succession, age, structure and rock types present in the subsurface. Geological cross sections allow for better conceptualization of the 3-D geometry of the structures. By using 'Vigat 2005', a cross section graphic can be displayed at the user's whim with a simple click of the mouse. It offers much easy to use functionality to facilitate completion of desired task. Specific boundary conditions to represent the movement of rock block over the fault can be displayed using Graphical user interface. Relief or slope variation of the study area can also be viewed. A topographic map provides an aerial (overhead) view of a landscape. It is possible to create a more pictorial representation of the landscape by making a topographic profile of the region. A topographic profile is a cross section showing elevations and slopes along a given line. A precise method to determine the variation in slope is to construct a profile or cross section through the topography. Strong programming capabilities of Visual C++ have been utilized to full extend for the development of 'Vigat 2005'.

Application of PERT for the development of 'Vigat 2005'

Key activities pertaining to 'Vigat 2005' and their sequence are identified. These activities are listed in logical sequence (Table 3). For every activity three time estimates are considered for computation of expected duration (Table 4). Expected duration for each activity is considered for the construction of network diagram (Figure 4).

Probability of completion of project (Vigat 2005) in 40 days

Here, $\sigma = (b - a) / 6$

The expected duration of the critical path $\mu = 5 + 5 + 4 + 7 + 7 + 4 + 4 = 36$ Days

$\sigma^2 = (0.333)^2 + (0.333)^2 + (0.667)^2 + (0.667)^2 + (0.667)^2 + (0.667)^2 + (0.667)^2$

$= 0.11 + 0.11 + 0.44 + 0.44 + 0.44 + 0.44 + 0.44$

$= 2.42$

Probability $Pr[(t - \mu) / \sigma]$

$= Pr[(40 – 36) / sqrt(2.42)]$

$= Pr[4 / 1.55]$

$= Pr [Z <= 2.58]$

$= 0.9951$

So it can be said that the probability of completion the project in 40 days is **99.51 %.**

Table 3. Details of activities pertaining to 'Vigat 2005'

Activity	Description	Predecessor Activity
A	Open Image File	-
B	Takes a Section line	A
C	User input - contour value	B
D	User input - angle	C
E	Submit all parameter	C
F	Connection with database	D
G	Fetch the data from database	E
H	Save the profile	F, G
I	Print the profile	H

Table 4. Three time estimates of different activities pertaining to 'Vigat 2005'

Activity Code	Optimistic (a)	Most likely (m)	Pessimistic (b)	Expected duration (Days) (t_e)	Standard deviation of duration (σ)
A	4	5	6	5	0.333
B	4	5	6	5	0.333
C	2	4	6	4	0.667
D	5	7	9	7	0.667
E	2	4	6	4	0.667
F	5	7	9	7	0.667
G	4	5	6	5	0.333
H	2	4	6	4	0.667
I	2	4	6	4	0.667

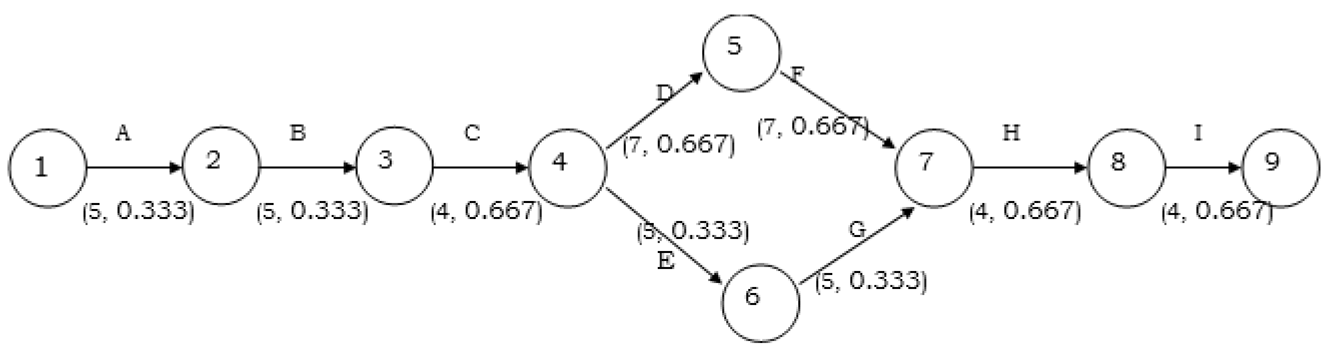

Figure 4. Network diagram of 'Vigat 2005'

'Starmiti 2005'

The term 'Starmiti' means measurement of layer {star(layer) + miti (measurement)}in Gujarati language. Seismic methods are the most commonly conducted geophysical surveys for geotechnical investigations. The seismic refraction method utilizes sound waves. Sound travels at different velocities though different materials and is refracted at layer interfaces. Seismic refraction provides engineers and geologists with the most basic of geologic data via simple procedures with common equipment. In the refraction method, greater details, of the smaller subsurface structures, are brought out with the use of waves from explosives at shallow depths. 'Starmiti 2005' presents interactive graphical display of data processing pertaining to seismic refraction method. It is a Java based software application. It provides user with full control regarding plotting and analyzing data. It measures various attributes of data and displays it in a manner easily understandable to user (Fig. 5). Relevant information is available to user.

Modern instrumentation for measuring seismic wave activity includes seismographs with sophisticated digital processing to remove noise and record the highest fidelity signal for measuring both wave velocity and ground acceleration. Here, disturbance on passage of the seismic energy is recorded and then displayed as amplitude variations with time. The seismic data are analyzed by plotting the first arrival time of the compressional wave at each geophone versus the distance from the seismic

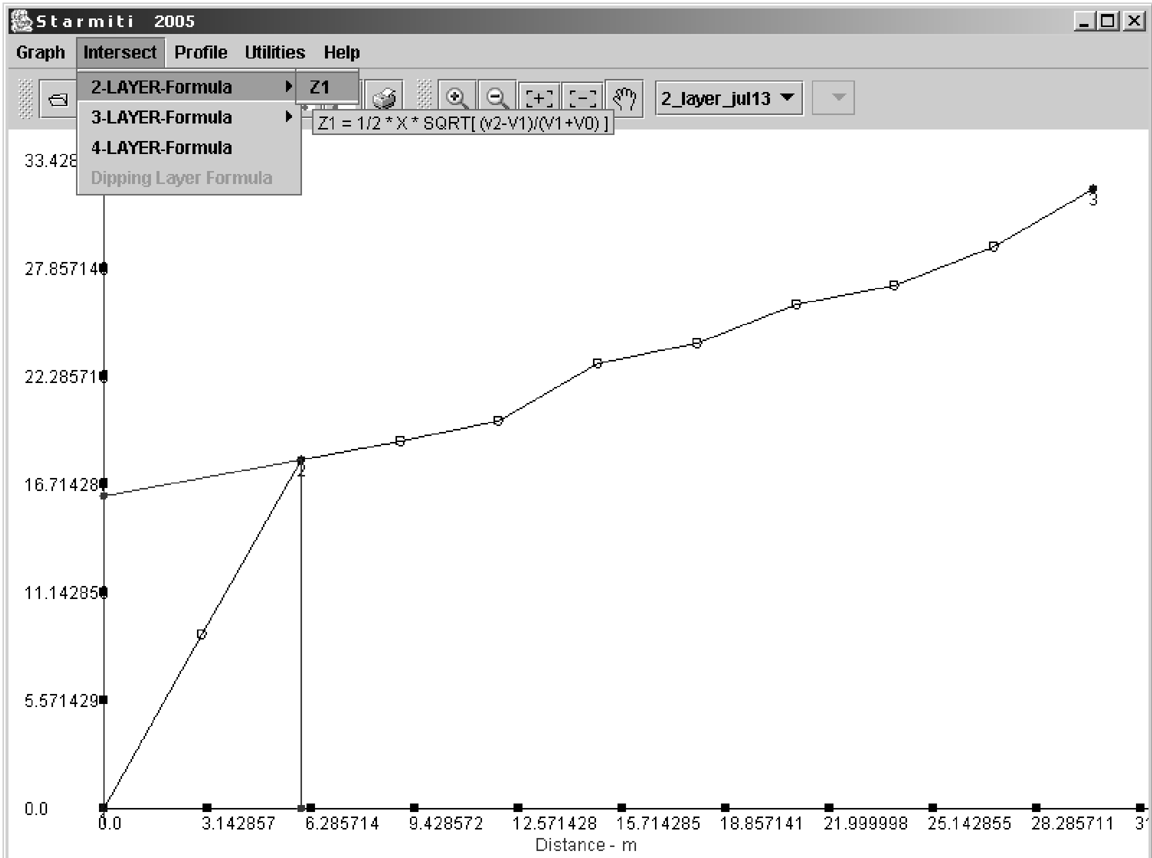

Figure 5. Display of seismic refraction data processing by 'Starmiti 2005' (After Doshi et al., 2005)

source to the geophone. These graphs are commonly known as travel-time plots. Here, data are distributed as linear segments. Each line segment corresponds to a different stratigraphic layer.

Objectives of data processing consist of the measurements of "attributes" of the data viz. velocity, depth of interface etc. Data should be displayed in a manner easily understandable by an interpreter. Display parameters include the use of optimum scale for the interpretation objectives. Data processing of seismic information can be as simple as tabular equations for seismic refraction. Processing is normally the most substantial matter the geophysicists will resolve, except for the interpretation.

The first step in processing/interpreting refraction seismic data is to pick the arrival times of the signal, called first break picking. A plot is then made showing the arrival times against distance between the shot and geophone. This is called a time-distance graph. In contrast with the seismic reflection method, the seismic refraction method uses recordings of seismic waves at large distances from the source relative to the depth of investigation. The waves of interest propagate roughly horizontally over most of their path, and provide information about the velocity of the medium in which they propagate. This information is used to determine the velocity and thickness of crustal layers in the study area. A seismic wave is usually generated by a small explosive charge, a shotgun shell, or a sledge hammer. The wave's travel time from the sound source to refracting layers, along those layers and back to detectors (called geophones) is precisely measured. From the time-distance relationships, subsurface layer velocity and thickness can be calculated.

Application of PERT for the development of 'Starmiti 2005'

Logical sequence of activities is shown in Table 5. Three time estimates for every activity is given in Table 6. Network diagram based on PERT is shown in Figure 6.

Probability of completion of project (Starmiti 2005) in 60 days

Here, $\sigma = (b - a) / 6$

The expected duration of the critical path $\mu = 15 + 5 + 6 + 4 + 15 + 10 = 55$ Days

$\sigma^2 = (1.667)^2 + (0.333)^2 + (0.667)^2 + (0.667)^2 + (1.667)^2 + (1.667)^2$

$= 2.779 + 0.111 + 0.445 + 0.445 + 2.779 + 2.779$

$= 9.338$

Table 5. Details of activities pertaining to 'Starmiti 2005'

Activity	Description	Predecessor Activity
A	Entering time and distance data into database	-
B	Database Connection	A
C	GUI building	A
D	Computation of intercept time and critical distance	B
E	Computation of velocities	D
F	Pan utility	C
G	Zoom utility	C
H	Computation of depth of refractor	E
I	Draw the profile	H
J	Display details pertaining to velocity of different layers	E
K	Zoom to select	G

Table 6. Three time estimates of different activities pertaining to 'Starmiti 2005'

Activity Code	Optimistic (a)	Most likely (m)	Pessimistic (b)	Expected duration (Days) (t_e)	Standard deviation of duration (σ)
A	10	15	20	15	1.667
B	4	5	6	5	0.333
C	2	3	4	3	0.333
D	4	6	8	6	0.667
E	2	4	6	4	0.667
F	5	7	15	8	1.667
G	7	9	17	10	1.667
H	10	15	20	15	1.667
I	5	10	15	10	1.667
J	2	3	4	3	0.333
K	5	6	13	7	1.333

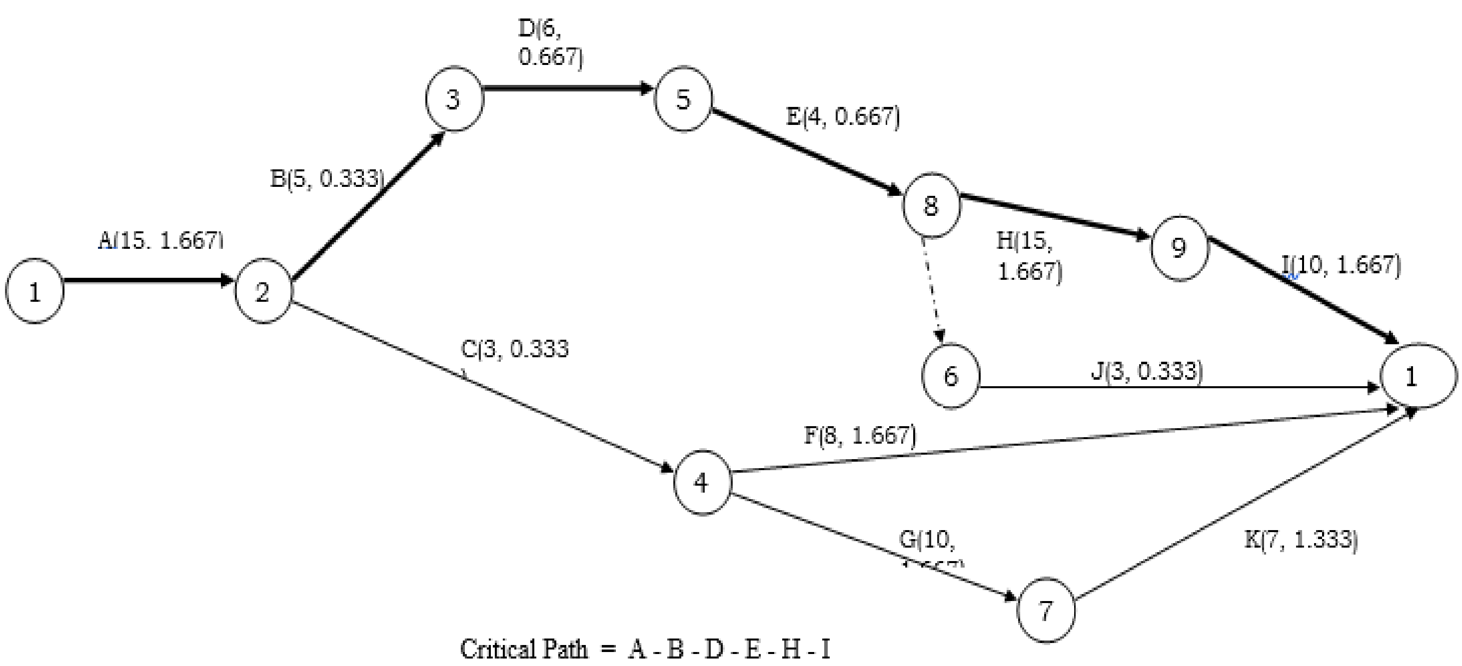

Figure 6. Network diagram of 'Starmiti 2005'

Table 7. Details of activities pertaining to ‘Kampan 2006’

Activity	Description	Predecessor Activity (P)
A	Literature survey	-
B	Feasibility Study	-
C	Database Creation	-
D	Find map	-
E	Read map	A, B, C
F	Design of Forms	E
G	Coding for data source table creation	E, F
H	Coding for manipulation of data source table	E
I	Query Builder coding	F
J	Geo-referencing of maps	D, F
K	Plot earthquake data on maps	E
L	Scheme creation	E
M	Charts and b-Value Graph	E
N	Testing & Evaluation	L

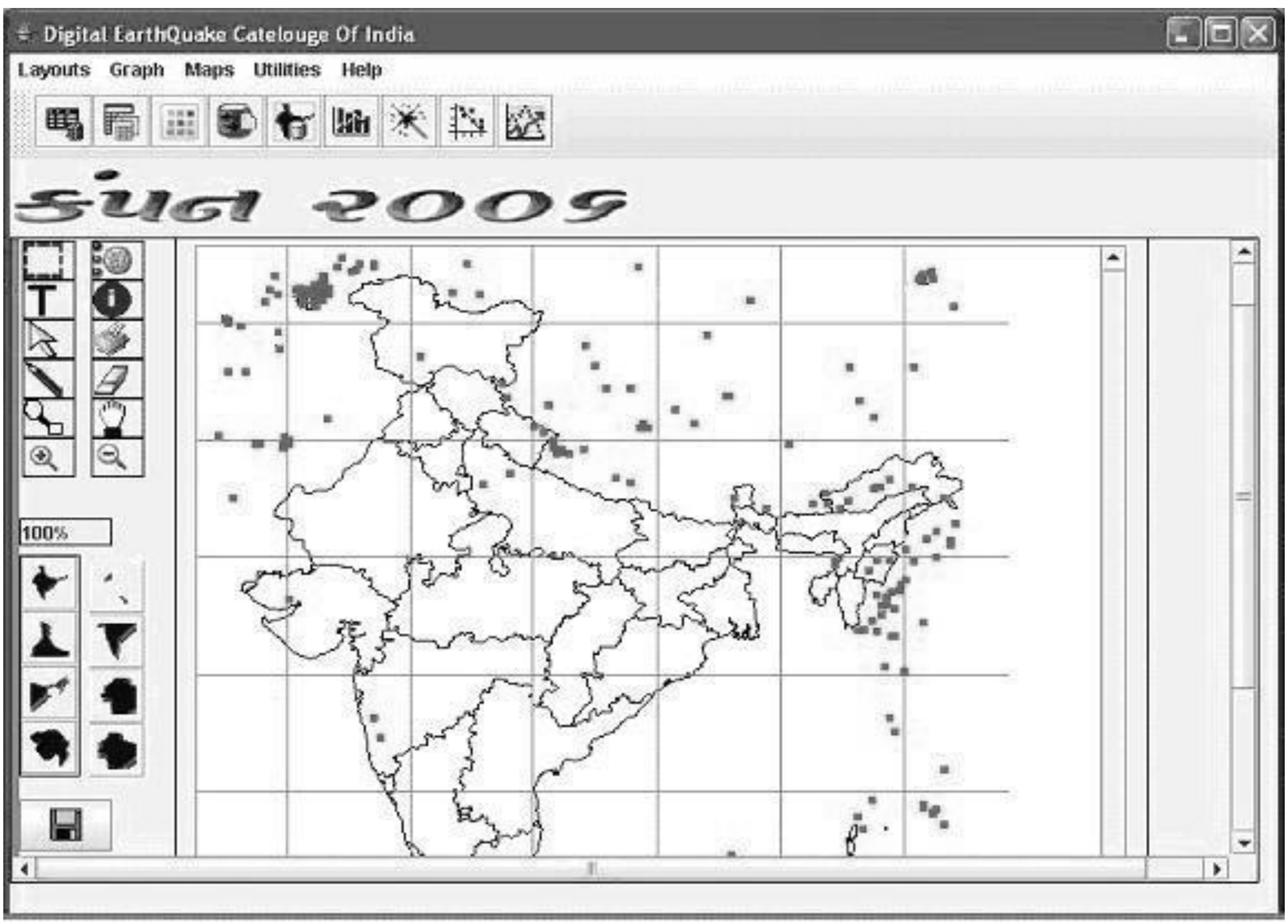

Figure 7. Display of earthquake data distribution by ‘Kampan 2006’
(After Dharwa et al., 2006)

Table 8. Three time estimates of different activities pertaining to 'Kampan 2006'

Activity	Optimistic Time (t_0)	Most Likely Time (t_m)	Pessimistic Time (t_p)	Expected Duration $t_e=(t_0+4t_m+t_p)/6$	Standard Deviation of duration σ	$\sigma^2=[(T_\Pi-T_0)/6]^2$
A	5	7	10	7.17	0.83	0.69
B	14	15	17	15.17	0.50	0.25
C	6	8	11	8.17	0.83	0.69
D	2	3	5	3.17	0.50	0.25
E	2	3	4	3.00	0.33	0.11
F	15	20	22	19.50	1.17	1.36
G	7	10	11	9.67	0.67	0.44
H	6	7	8	7.00	0.33	0.11
I	5	8	9	7.67	0.67	0.44
J	2	3	4	3.00	0.33	0.11
K	2	3	4	3.00	0.33	0.11
L	5	7	9	7.00	0.67	0.44
M	10	12	14	12.00	0.67	0.44
N	10	15	16	14.33	1.00	1.00

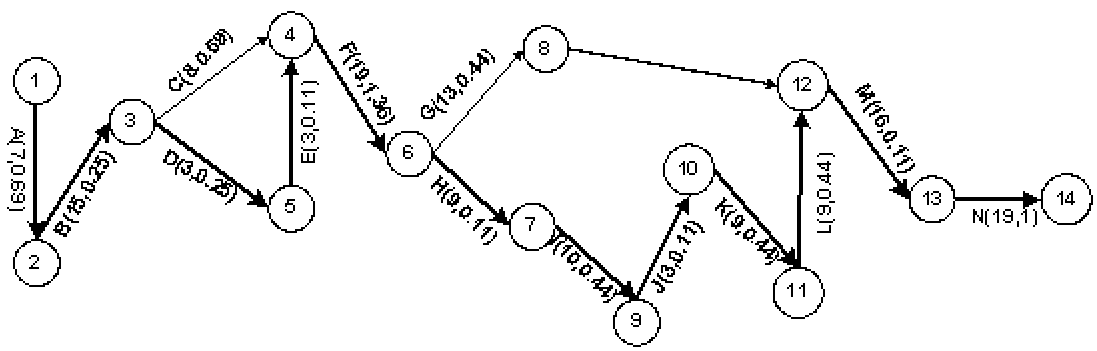

Figure 8. Network diagram of 'Kampan 2006'

Probability Pr[t <= 60] = Pr[(t - μ) / σ]
= Pr[(60 – 55) / sqrt(9.338)]
= Pr[5 / 3.056]
= Pr [Z <= 1.636]
= 0.9484

So, it can be said that the probability of completion the project in 60 days is **94.84 %.**

'Kampan 2006'

Historical seismological records of past events provide insight of seismic activities in an area. It helps to implement long-term preparations to avoid earthquake disasters. 'Kampan 2006' is a Java based software application to display and analyze historical seismological data. The term 'Kampan' means 'vibration' in Gujarati language. It offers various easy to use functionalities to facilitate completion of desired task. This interactive multi purpose tool meets various requirement of user. It allows to display and analyze seismological data at user's whim with a simple click of the mouse.

On account of their destructive power, earthquakes have attracted universal attention from the earliest time. For seismology, the greatest need has been to increase knowledge of earthquakes, so that destruction caused by them can be lessened. Historical seismological data can be used to address a fundamental question: when and where have earthquakes happened in the past? Historical seismicity is the historical records of earthquakes preserved in different form such as written history, chronicles, inscription etc. which plays an important role in the seismic hazard assessment because instrumentally recorded earthquakes are lacking before the current century. Previous research has uncovered evidence of destructive earthquakes in areas where only small events have been experienced recently (Ambraseys, 2002). The geographical distribution of seismicity illustrates the tectonically active regions of the earth (Lowrie, 2002). Some of the largest earthquakes of the world have occurred in India. More than about 60% of the land area of India is considered prone to shaking of intensity VII and above (MMI scale) (Jain and Nigam, 2000). Dr. Thomas

Oldham, the first Director of the Geological Survey of India (GSI), is credited with laying the foundation of the scientific studies of earthquakes in India (West, 1937). Some of the early Indian earthquakes also led to interesting insights into the subject. For instance, the 1819 Runn of Kutch earthquake (Oldham 1898) of M8.3 created a fault scarp about 100 km long and 3 m high (named Allah Bund: embankment created by the God); it provided the earliest clear and circumstantially described occurrence of faulting during earthquakes. Earthquake occurrence has been noted in historical records as far back as 1800 B.C. (Agrawal, 1991). The historical record confirms that some regions that are active today (e.g. the north Anatolian fault zone) were also active 2,500 years ago, demonstrating the long-term nature of their seismicity. It also shows that some regions that are at present quiescent (such as the Jordan Rift Valley), can generate relatively large earthquakes (Ambraseys, 2002). The use of the historical record is invaluable. Plate tectonics theory predicts that most the Earth's tectonic activity takes place at the margins of plates. It follows then, that the location of earthquake epicenters can be used to define plate boundaries (Kearey and Vine, 1990). Applications of high-speed computers cleared the way for major advances in data handling in seismology (Bullen and Bolt, 1987). Modern mini-computers are now providing valuable application of graphics methods to seismology. 'Kampan 2006' is a Java based software application. It provides display of earthquake data distribution with respect to space and time (Figure 7). Hence, the software is named as 'Kampan' (vibration). Start up screen of software has been kept simple, so that user can navigate through various available options.

Application of PERT for the development of 'Kampan 2006'

Logical sequence of activities is shown in Table 7. Three time estimates for every activity is given in Table 8. Network diagram based on PERT is shown in Figure 8.

Advantages and limitation of applying PERT

- It is easier to see precedence relationships of activities.
- There is a consideration of time variation of different activities which influences the completion of software development projects.
- Expected project completion time can be inferred.
- Probability of completion of software development project before a specified date can be obtained.
- The critical path activities (that directly impact the completion time of project) can be identified.
- Activity start and end dates can be obtained.
- The activity time estimates are subjective and depend on judgment.
- It presents communication mechanism to discuss the development process of 'Dishansh 2005'.

SUMMARY

Software developers can infer completion time of projects with the help of PERT. Distinguishing feature of PERT is its ability to deal with uncertainty in activity completion time. PERT has been applied to software development processes of 'Dishansh 2005', 'Vigat 2005', 'Starmiti 2005' and 'Kampan 2005'. 'Dishansh 2005' has been developed using Java programming language to plot and analyze data pertaining to structural discontinuities. 'Vigat 2005' offers user friendly interactive GUI (Graphical user interface) for construction of cross section. 'Starmiti 2005' provides Graphical representation of seismic refraction data and presents an easy way to derive relevant information. 'Kampan 2006' displays and analyze historical seismological data pertaining to India and adjoining regions. For proper planning and scheduling of activities of these softwares, PERT has been implemented. It provided various advantages to software developer like display of precedence relationship of activities, consideration of time variation of different activities.

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Disclaimer

Maps presented in this paper are indicative only. Maps are not to scale. External boundaries on the maps are not authenticated.

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