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Developing Computer Program to Implement Time-Cost Relationship for Planning Constructional Projects in Iraq

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Abstract

Today's project construction management faces many challenges due to the increased complexity and variety of projects. The need for continuous control of time, cost and performance of project to satisfy clients needs, gives rise to search for new concepts in projects construction management. Construction management makes time cost trade-off decisions every day in planning and managing their work. This paper describes the typical pragmatic approach that managers take in making time-cost trade-off. It then describes computerized crashing technique to be used easily by the construction management.

The objective of describing time-cost trade-off the critical path method analysis is to establish a minimum time requirement for projects, making use of durations of each activity at minimum cost.

This paper represents a developed computer program that based on crashing technique; the program has been used in four cases study.

It is concluded that, acceleration using time-cost analysis trade-off within critical path method is very important to perform the project at the specific time with the minimum cost by using crashing technique.

الخلاصـــــــة

تواجه الإدارة الهندسية اليوم العديد من التحديات بسبب التعقيدات المتزايدة وتنوع المشاريع . إن الحاجة للسيطرة المستمرة على كل من الوقت والكلفة وأداء المشروع لتلبيه حاجات الأطراف ذات العلاقة يؤدي إلى البحث عن مفاهيم جديدة في إدارة هندسة المشاريع.

إن إدارة هندسة المشاريع الإنشائية جعلت الوقت و الكلفة من الموارد المهمة في التخطيط وإدارة الأعمال، يتضمن البحث وصف النظرة الواقعية المثالية التي ينجزها مدراء المشاريع في تحديد وتقييم الوقت من خلال استخدام تقنية التقليص لفعاليات المشروع لتسهيل عملية الإدارة الإنشائية. توضح المحتويات أيضا طريقة التحليل باستخدام المسار الحرج للوصول إلى اقل وقت ممكن مع اقل كلفة لكل فعالية من فعاليات المشروع.

لقد تم بناء برنامج حاسوبي استخدم فيه تقنية التقليص وقد تم استخدام البرنامج في أربع حالات دراسية ولقد توصل الباحث إلى إن التعجيل في تنفيذ المشاريع باستخدام طريقة المسار الحرج مهم جداً لإنجاز المشاريع في الوقت المحدد لها بأقل كلفة ممكنة من خلال تقنية التقليص.

1. Introduction

Time and cost are two main concerns in construction projects. Therefore, in the construction projects, contractors usually are used previous experiences to estimate the project duration and cost of a new project [1].

Typically project is broken down into activities to which resources can be assigned and duration and costs are estimated. The activities are linked in plan according to work sequences to form a network. CPM technique is used to analyze the network to identify critical path (s) and project duration. In general, the more resources assigned to an activity, the less time is required to complete the activity, but cost is usually higher. This trade-off between time and cost gives construction planners both challenges and opportunities to work out the best construction plan that optimizes time and cost to complete a project [2].

In many cases, projects are required to be completed within certain duration. Adjustments are needed to change the resources assignment to optimize the resource allocations that yield the desired duration at a minimum cost. Since there are too many permutations of resources allocations, there is a need to develop tools and methods to assist construction planners in making resource allocation decisions that optimize time and cost.

2. Critical Path Method

The critical path method or CPM was originated in 1957 [3]. CPM was developed in an industrial setting and it gave relatively more emphasis to project cost.

A critical path technique provides details of the timing of activities and their resource requirements through out the duration of the whole project. The critical path is always considered as the longest path even though variances include the likelihood of other paths being longer [4].

Activities on the critical path are called "critical activities". A critical activity, not completed within the scheduled performance time, may cause completion of the project to be delayed. In construct, a non-critical activity's delayed completion may not affect the project completion date [5].

3. Calculation of the Critical Path Method

After a time duration has been assigned to each time-consuming activity on the logic diagram, the "critical" or the longest path through the logic is calculated. The critical path determines the period in which the project may be completed and the period of time within which each activity on the critical path must be accomplished if the predicted completion time is done [5].

Calculation of the critical path involves determining four event times for each activity: early start (ES); late start (LS); early finish (EF); and late finish (LF) [6].

The "early start" is the earliest time an activity can start after completion of the preceding activities. The early start is calculated by taking the project start date and adding each activity's duration following the logic diagram [7]. Notice that the four times calculated for each activity assume that actual time required to complete the work will match the durations placed on the activities [5].

The “early finish” time is the earliest times an activity can be completed if it is started at its early start time and is completed using its estimated duration. Early finish time is calculated by adding the activity’s duration to its early start time [7].

The “late finish” is the latest time an activity can be completed without delaying the scheduled project completion time. Late finish is calculated by working backward through the logic, starting at the schedule’s end date and subtracting in turn each activity’s duration to determine the latest completion time which will not cause a delay in the project [5].

The “late start” is the latest time an activity can be started without delaying the project. Late start is calculated by subtracting the activity’s duration from the late finish time [5].

When the early start and late start are identical and the early finish and the late finish are identical, that activity is on a critical path. Critical paths through the logic are determined by comparing early and late times for each activity [5,8].

The four times necessary for each activity can be calculated as follows:

Early start time = early event time ………………….…………………………….. (1)

Early finish time = early start time + activity duration …………………….. (2)

Late finish time = late event time ……………………….…………………….…. (3)

Late start time= late finish time - activity duration ………………………... (4)

Activities with early and late times, which do not match, are flexible. Such activities do not have to begin or end with the early start and finish times to permit completion within the scheduled completion date. This flexibility is a measure of the ability of a given activity to have its performance time extended and is called “float” or “slack” [5].

Float measures the amount of time a particular activity’s performance can be delayed while still permitting the project to be completed within the scheduled times. Another way to look at float is as a measure of “criticality“. The less float an activity has, the more critical it is. Activities, which have no float, are critical and cannot be delayed without delaying the project’s scheduled completion date [6,8].

The typical construction schedule has many possible logic chains or paths. Not all paths will be critical, but there may be more than one critical path [5]. Two classifications of float are generally recognized: total float and free float.

Total float of an activity indicates the amount of time by which an activity may be delayed without affecting the project’s scheduled completion date. The second type of float, “free float,” is the amount by which that activity can be delayed without delaying the early start of any following activity or affecting any other activity in the network [9]. The calculation for free float can get by subtracting the early finish for the specific activity from the early start of the subsequent activity.

The limited value of free float is for busy subcontractors juggling efforts at multiple job sites. Free float is not an important number in the field. However, free float can be useful when selecting activities for resource levelling [5].

Total float is calculated either by subtracting the early finish time from the late finish time or by subtracting the early start time from the late start time.

4. Construction Project Scheduling and Optimization

A construction project "schedule'' may mean different things to the designers, contractors, suppliers, subcontractors and owners involved in the construction process. The schedule may mean the completion date stated in the contract, or interim completion date required for phases of the work. The schedule may mean the schedule of values, the contractor submits against which monthly progress payments will be calculated, or any of the many other lists itemized or required by the contract. The schedule may also refer to the process of sequencing and phasing individual activities required to complete the project.

A construction schedule means a tool to determine tile activities necessary to complete a project and the sequence and the time frame within which the activities must be completed in order to obtain timely and economical project completion [5].

5. Time-Cost Optimization

Optimization in a general sense involves the determination of the highest or the lowest value over some range.

Many methods have been introduced to determine optimum procedures or policies. This paper is fundamental and considers that the minimum cost with the optimum time can be obtained from:

1. Analyzing the network.
2. Graphing the results of the analysis.
3. Finding the optimum point of the cost.

There are many circumstances and the project must be complete at a specific time before the contract completion date, which the contractor may wish to speed up work on a contract.

In many cases the contractual time requirements have been established by the engineer or owner without regard to a reasonable assessment of activity durations. It is then imperative that the scheduler attempt to adjust activity durations and sequences to fit within the contractual requirements, even if inefficient adjustments such as multiple shifts, overtime, or large crew sizes are required [5].

The process of expediting a project is often called "crashing" the project. The term crashing refers to reduction of activity durations with the overall effect of reducing duration. The crashing process is a deliberate, systematic, analytical process that involves examining all the activities in the project and focusing on those activities on the critical path [10].

The crashing process uses an assessment of activity variable cost with time to determine which durations to reduce to economically minimize the overall project duration [5].

6. System Study and Data Collection

Oil Project Company (Karkh/Anbar Pipe Line Project) has been assigned by the Ministry of Oil according to work of fast in activities in some projects, which take time, cost and quality, as contract specification.

It is necessary to mention that most company's projects follow the direct execution means to execute and manage their projects using engineering experience.

Executing Karkh/Anbar Pipe Line which extends from Baghdad/Al-Karkh towards Al-Anbar, the pipe is line with 12 nods for diameter and 100 Km distance.

The first planning of pipe line company according to the estimated time and cost engineering is as follows:

Table (1) Planning of Karkh/Anbar pipe line project

Activity Name	Symbol	Predecessor	Normal Duration (day)	Normal Cost
Surveying & alignment right	A		30	$4,000
Right of way	B	a	90	$4,500
Unloading & handling & stringing	C	a	90	$14,500
Welding	D	b,c	150	$40,000
Ditching	E	b,c	90	$8,500
Air test	F	b,c	90	$5,000
Wrapping & lowering & backfilling	G	d,e,f	60	$11,500
Tie in after coating & bending	H	g	75	$15,000
Catholically protection	I	g	60	$1,500
Hydrostatic test	J	h,i	30	$3,000
Total			**435**	**$107,500**

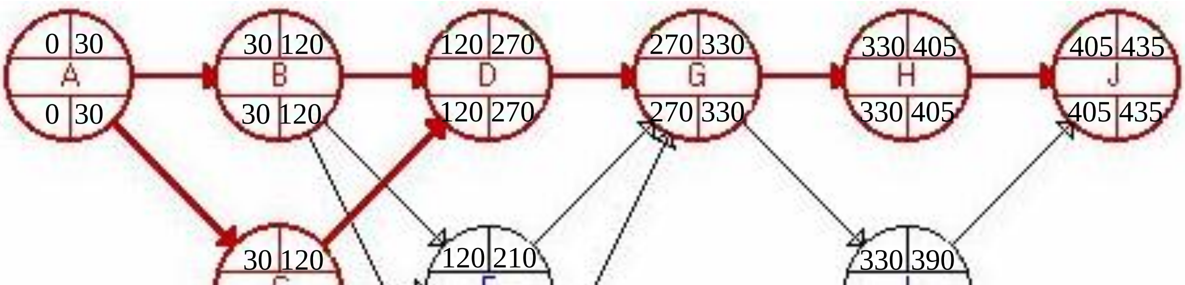


Figure (1) Network of Karkh/Anbar pipe line project

After executing project in accordance with the execution project using fast work, the following table explains the way of reducing activities from time view which meets cost increasing as a result to the increase in working hours, worker number and the equipment used in some activities. First project (Karkh / Anbar Pipe Line) according to outline.

Table (2) Executing planning for Karkh/Anbar pipe line

Activity Name	Predecessor	Crash Duration (day)	Crash Cost
A		25	$4,425
B	a	75	$6,075
C	a	80	$15,875
D	b,c	125	$46,375
E	b,c	75	$10,875
F	b,c	80	$6,500
G	d,e,f	50	$12,700
H	g	60	$17,115
I	g	50	$2,100
J	h,i	25	$3,350
Total		**365**	**$125,390**

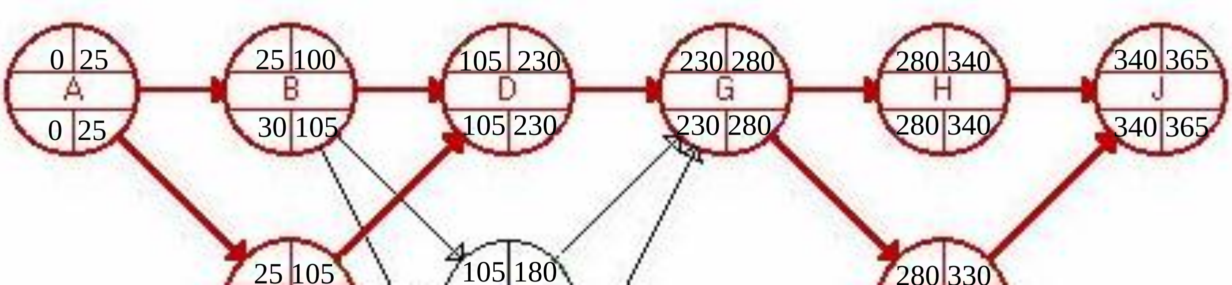


Figure (2) Network of executing planning for Karakh/Anbar pipe line project

7. Steps of Project Time Completion Reduction

1. Drawing relation net and determined time of start end of each activity.
2. Determining lengths of all paths in the net (including critical paths).
3. Determining activities, which can reduce their time on the critical path and the extended time of reduction for each.
4. Starting with reduction activities of low direct cost first then determining critical paths after each reduction.
5. Repeating steps (2-4) until the low time possible is reached.

This technique for time reduction is useful for engineering so as to use workers and resources to reach the specific time in the optimum cost [1].

8. Using Crashing Technique for (Karakh/Anbar) Pipe Line Project

Project Karkh/Anbar pipe line, **Table (3)** shows the planning technique for Karkh/Anbar pipe line.

Table (3) The planning technique for Karkh/Anbar pipe line

Activity Name	Predecessor	Normal Duration (day)	Crash Duration (day)	Normal Cost	Crash Cost
A		30	15	$4,000	$6350
B	a	90	70	$4,500	$6,850
C	a	90	75	$14,500	$16,741
D	b,c	150	115	$40,000	$49,220
E	b,c	90	60	$8,500	$11,315
F	b,c	90	80	$5,000	$6,500
G	d,e,f	60	50	$11,500	$12,700
H	g	75	55	$15,000	$18270
I	g	60	50	$1,500	$2,100
J	h,i	30	25	$3,000	$3,350

Table (4) Planning of crashing technique for Karkh/Anbar pipe line

Activity Name	Critical Path	Normal Duration (day)	Crashed Duration (day)	Additional Cost	Normal Cost	Suggested Cost
A	Yes	30	15	$2,350	$4,000	$6,350
B	Yes	90	90	0	$4,500	$4,500
C	Yes	90	90	0	$14,500	$14,500
D	Yes	150	130	$5,268	$40,000	$45,268
E	no	90	90	0	$8,500	$8,500
F	no	90	90	0	$5,000	$5,000
G	Yes	60	50	$1,200	$11,500	$12,700
H	Yes	75	55	$3,270	$15,000	$18,270
I	no	60	55	$300	$1,500	$1,800
J	Yes	30	25	$350	$3,000	$3,350
Overall	**Project:**		**365**	**$12,738**	**$107,500**	**$120,238**

Network for Planning of Crashing Technique for Karkh/Anbar pipe line can be show in **Fig.(3)**.

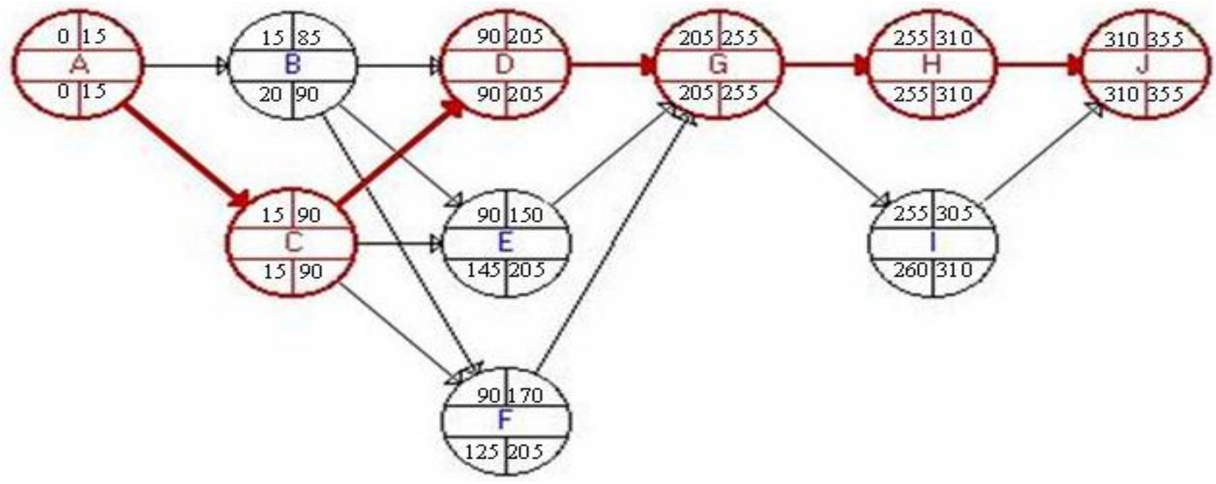


Figure (3) Network for planning of crashing technique for Karkh/Anbar pipe line

The optimum point for time with direct cost can be obtained from the relationship between cost and time from the graph shown in **Fig.(4)**.

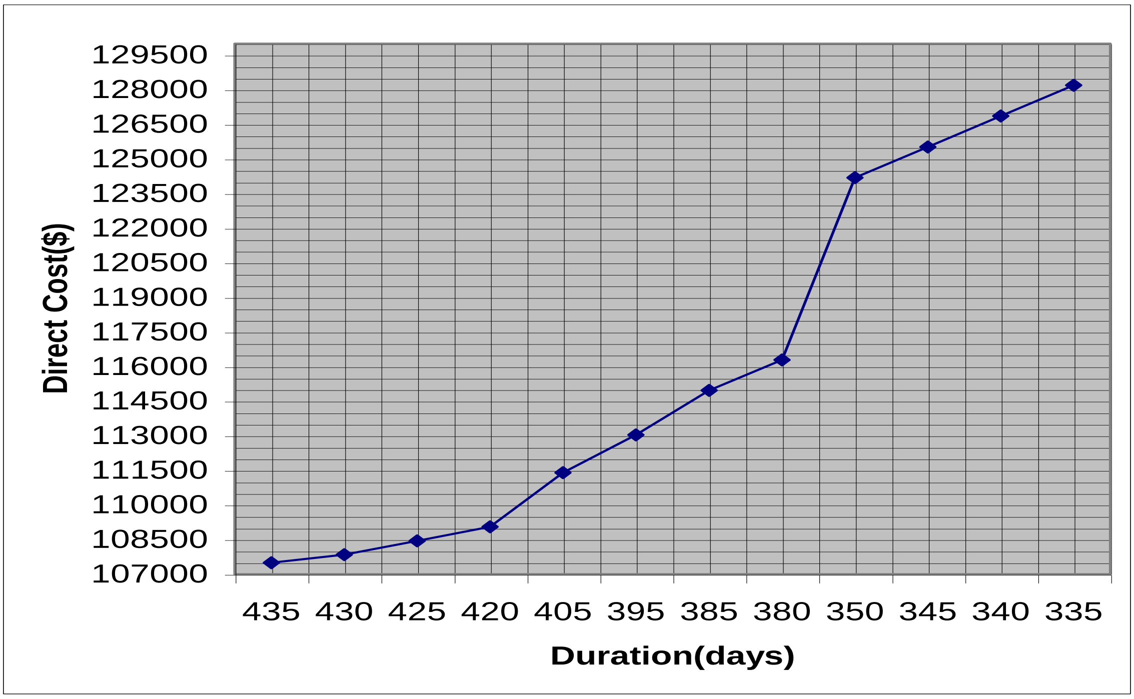


Figure (4) Optimum point for planning of crashing technique for Karkh/Anbar pipe line

9. Development of Computer Program

This paper presents developing a computer program that can be based on crashing technique and using "Visual Basic" and the Microsoft Access. Programming language is used to perform the calculation that the user needs to provide necessary input data at the activity level.

The main aim of the building this program is that it can be used easily and even in the field of the work. The main program is written by using visual basic language and the Microsoft access.

The program can show all the important information that help to know the optimum point for the project and other information that are necessary to control and perform the project at the specification. **Figure (5)** shows the structure of the program.

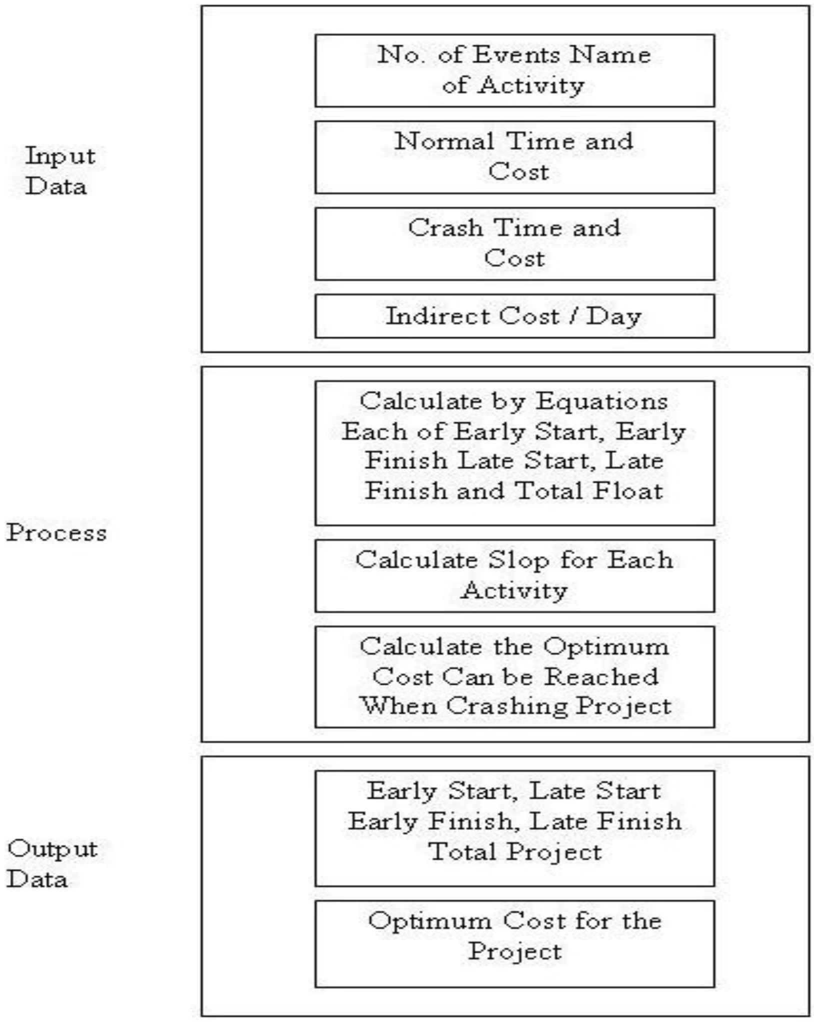


Figure (5) Program structure

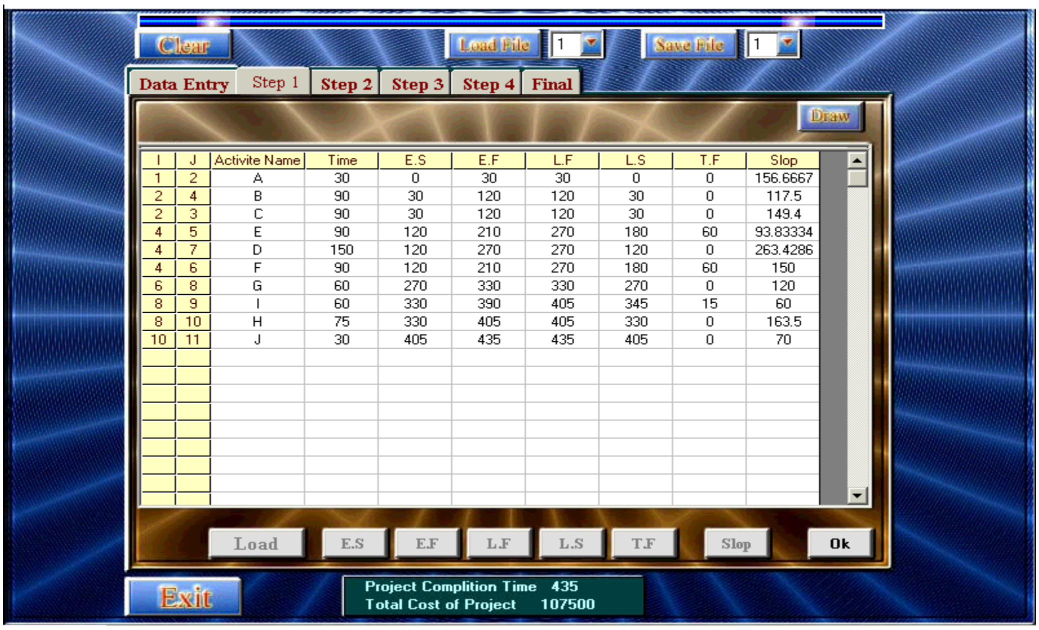
10. Program Operation

The program is started by representing the main menu for entry data of Karkh/Anbar pipe line project, as shown in **Fig.(6)**:

I	J	Activite Name	Time	Cost	Time	Cost
1	2	A	30	4000	15	6350
2	4	B	90	4500	70	6850
2	3	C	90	14500	75	16741
3	4	D*	0	0	0	0
4	5	E	90	8500	60	11315
4	7	D	150	40000	115	49220
4	6	F	90	5000	80	6500
5	6	D*	0	0	0	0
7	6	D*	0	0	0	0
6	8	G	60	11500	50	12700
8	9	I	60	1500	50	2100
8	10	H	75	15000	55	18270
9	10	D*	0	0	0	0
10	11	J	30	3000	25	3350

Figure (6) The input information of data window

After data entry, we can see all the details of early start, early finish, late start, late finish, total float, project completion time and total direct cost of project as shown in **Fig.(7)**:



I	J	Activite Name	Time	E.S	E.F	L.F	L.S	T.F	Slop
1	2	A	30	0	30	30	0	0	156.6667
2	4	B	90	30	120	120	30	0	117.5
2	3	C	90	30	120	120	30	0	149.4
4	5	E	90	120	210	270	180	60	93.83334
4	7	D	150	120	270	270	120	0	263.4286
4	6	F	90	120	210	270	180	60	150
6	8	G	60	270	330	330	270	0	120
8	9	I	60	330	390	405	345	15	60
8	10	H	75	330	405	405	330	0	163.5
10	11	J	30	405	435	435	405	0	70

Figure (7) Details window

The program calculates the minimum cost with its duration (optimum point), as shown in **Fig.(8)**:

Figure (8) The minimum cost with its duration (optimum point) window

11. Results and Discussion of Program Output

Crashing networks to meet specified target dates are extremely important in construction projects. Most contractors do not maintain cost duration charts for activities and this leads to the failure of their method.

This paper outlines conclusions drawn from the field study, concerning specific areas in Iraqi construction practice, experienced during the last decade and lists some recommendations that would help Iraqi construction engineers working within this field.

This project, when the company accelerated the project they concluded that the direct cost is 125,390$ in 365 days, while in this study when the statements and all the details are put in steps of crashing technique, the result is 120,238$ in 365 days.

In addition, the optimum (minimum) cost with time has been satisfied and the graph to show the minimum cost is drawn, the optimum can be done in 420 days from the life of the project, as shown in **Fig.(8)**.

When the slop has been changed at the first point which means this point represents the minimum cost at that time).

12. Recommendations

1. A specific planning to estimate both cost and duration to the projects.
2. Cementing the staff of engineering in planning department in Ministry of Oil.
3. Giving the staff engineering in planning department in Ministry of Oil. Continues courses to develop their information and to escort the world.
4. Suggest the previous points apply for all ministries to build a strong planning in their projects.

13. References

1. Alsamaraai, F. H., ***"Developing Computer Program to Implement Time-Cost Relationship for Planning Constructional Projects in Iraq"***, M. Sc. Thesis, University of Mustansiriya ,College of Engineering, Civil Engineering Department, 2005.

2. Balaguru, P. N., Ramakrishnan, V., and Naaman, A. E., ***"Cost and Time Scaled Network: Graphical Model"***, Journal of the Construction Division, Vol. 103, No. CO2, June, 1977.

3. Kelly, J. E., and Walker, M. R., ***"Critical Path Planning and Scheduling"***, Eastern Joint Computer Conference, Boston, 1959.

4. Nicholas, J. M., ***"Management Business and Engineering Projects"***, Prentice Hall Inc., 1990.

5. Callahan, M. T., Quackenbush, D. G., and Rowings, J. E., ***"Construction Project Scheduling"***, McGraw-Hill Inc., 1992.

6. Halpin, D. W., and Woodhead, R. W., ***"Construction Management"***, John Wiley & Sons Inc., 1998.

7. Dr. Abdul Qadir, M. S., and Dr. Al-Reeh, T. M., ***"Planning and Following up Projects by using Critical Path Method and PERT"***, Al-Kuwait University, Al-Qabas Inc., 1977.

8. Plicher, R., ***"Principles of Construction Management"***, McGraw-Hill Inc., 1976.

9. Edward, M. W., ***"Scheduling Construction Project"***, New York: Wiley, 1986.

10. Cooke, Brian and Williams, Peter, ***"Construction Planning Programming and Control"***, Macmillan Press LTD, 1998.