https://doi.org/10.17221/65/2019-JFS

Application of time-cost trade-off model in forest management projects: The case of Oak decline project

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Citation: Zandebasiri M., Vacik H., Etongo D., Dorfstetter Y., Soosani J., Pourhashemi M. (2019): Application of time-cost trade-off model in forest management projects: The case of Oak decline project. J. For. Sci., 65: 481–492.

Abstract: Oak decline has been observed periodically in the different parts of the world. We conducted this study to evaluate the project control in this phenomenon. In this paper, the project control methods have proposed to be useful tools to deal with oak decline. The aim of the study is twofold: (*i*) define and schedule a set of activities and determine times for those activities in the Control of Forest Decline Project (CFDP) using the Project Evaluation and Review Technique (PERT) method; (*ii*) apply the Critical Path Method (CPM) within the context on how to reduce the project time by increasing operating costs and crashing the activities. In crisis management, "golden time" is defined for doing activities and controlling the crisis, which has a greater role than other times. The analysis confirmed that the problem of forest decline is an ecological problem and its root lies in participatory management with the local community. We also found that the time crashing is not economically efficient to the CFDP except for two activities: public information and stakeholder analysis.

Keywords: Forest die-back; PERT (Project Evaluation and Review Technique) method; CPM (Critical Path Method) method; linear programming; stakeholder analysis; public information; crisis management

List of the abbreviations: Activity Cost Slope (ACS); Control of Forest Decline Project (CFDP); Critical Path (CP); Critical Path Method (CPM); Earliest Time (ET); Forest Management Plans (FMPs); Forward Pass (FP); Local Communities (LC); Latest Time (LT); Non-Timber Forest Products (NTFPs); Project Evaluation and Review Technique (PERT); Total costs (TC); Traditional Forest Related Knowledge (TFRK); Stakeholder Analysis (SA)

"Zagros forests" is the name for forests of northwestern, western, and southwestern Iran. This region contains 5 million hectares of Iranian forests. The area of these forests amounted to 10 million hectares long ago. Because of the exploitation of these forests, their area decreased to only 5 million hectares in the present days. *Quercus* is the most habitual genus in these forests, being Brant's oak

Supported by the Supported by the Behbahan University and by the Lorestan University, Project No. 9217.

https://doi.org/10.17221/65/2019-JFS

(*Quercus brantii* Lindl.) ascendant (Sagheb Talebi et al. 2014; Pourhashemi et al. 2018). Coppice management of oak trees is an important feature in this forest ecosystem (Valipour et al. 2014).

Despite the opportunity for natural regeneration of Zagros oak forests through coppicing, the role of forests to local livelihoods to adjacent forests communities that are rooted in socio-economic issues have not allowed this potential to be fully maximized (Ghazanfari et al. 2004; Jafari et al. 2018). Ongoing activities in Zagros oak forests include illegal logging, construction of roads, harvesting of Non-Timber Forest Products (NTFPs) and livestock grazing in the form of traditional silvopastoral systems (Valipour et al. 2014; Soltani et al. 2014). The proposed management of Zagros oak forests was designed to respond to these challenges in order to ensure the provision of ecosystem goods and services while managing the forest sustainably. Some of the activities include soil conservation, amelioration of water quality through the protection of watersheds and sustainable harvesting of the NTFPs.

However, these proposed management objectives in addition to the rehabilitation of degraded forest areas can result in a community participation (ImaniRastabi et al. 2015). Aside from engaging local communities in a participatory management arrangement (Jafari et al. 2018), the management plans have to be respected especially on access and use of forest resources. Livestock grazing and pollarding have continued in Zagros oak forests – an indication that the management plans are not respected to the community participation (Valipour et al. 2014). Therefore, determining the forest management priorities in Zagros forests should concomitantly consider both the needs of local communities and conservation objectives. Rather than encouraging enclosures – use of barbed wire fencing to exclude livestock grazing – controlled grazing is a much better option to mitigate illegal access into the forest.

Additionally, forest die-back has been observed during the last seven years especially in the central and southern Zagros Mountain area. This die-back has been linked to factors such as aridity, drought, air pollution, etc. (Hoseinzadeh, Pourhashemi 2015). Nowadays, the management of Zagros oak forests promotes the storage of water from precipitation (Zandebasiri et al. 2017). The objective of this approach is that water should be reserved for the tree roots to support the growth of the declining oak forests in the arid and semi-arid areas. This has led to the adoption of two strategic management decisions: forest conservation and storage of water from precipitation (Ebrahimi Rostaghi 2006; Zandebasiri et al. 2017).

Given the challenges faced by Zagros forests, the managers are looking for programs for managing and controlling the forest decline. The forest decline is driven by oak die-back together with illegal logging activities, uncontrolled grazing, developmental activities, unsustainable harvesting of NTFPs and recurrent forest fires under the impacts of a fast changing climate. Therefore, the aim of this study is twofold: (*i*) define and schedule a set of activities and determine times for those activities in the Control of Forest Decline Project (CFDP) using the Project Evaluation and Review Technique (PERT) method, (*ii*) apply the Critical Path Method (CPM) on how to reduce the project time by increasing operating costs and crashing the activities.

Control of Forest Decline Project (CFDP)

To design appropriate solutions to the CFDP, we applied a combination of the executive management's previous activities and expert solutions for the CFDP. Gathering expert opinions from those that are knowledgeable about issues around the Zagros oak forests – such as ongoing activities in or adjacent to the forests and possible drivers of forest decline – was the entry point of this study. Additionally, a comprehensive review of the forest management plans of Zagros forests was conducted. In this design, collecting and distributing information are followed by a stakeholders based on the expert analysis.

Social participation activities, thinning, sowing and precipitation storage are needed together in order to control the forest decline after the stakeholder analysis. Since the control of forest decline is the ending event in this network, it is necessary to create dummy activities to connect the ending event to the final activities. If these dummy activities are not considered for this project, then the intended activities will start from an event and achieve an event that contradicts the rules of the network. Additionally, questionnaires were sent to three experts to collect data for the CPM analysis. In this phase of the study, the experts were asked

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to estimate three time periods – pessimistic estimate, optimistic estimate and most likely time estimate – for each forest decline network activity. In this research, the time unit was considered as the month which is capable of covering work processes for preventing and managing the forest decline.

Necessary activities in the CFDP

Public information, stakeholder analysis, community participation, thinning, sowing, and precipitation storage are the necessary activities for the CFDP. All of them should be done to implement the CFDP in Zagros forests, Iran. In detail, the collection includes:

Public information

In the forest die-back phenomenon, there is a critical condition for the forests because of the interruption of the normal life of forest trees. Hence, we need crisis management in these circumstances. In crisis management, "golden time" is defined for doing activities and controlling the crisis which has a greater role than other times. The first step in crisis management is public information (Zandebasiri et al. 2017). Public information includes two parts: the collection and distribution of information. Information distribution is required both at the specialized level for an executive management team and at the public level through the media for the general public (Zandebasiri et al. 2015). Both people and managers should be aware of the CFDP. The purpose of public information is to inform the people and society, especially the rural communities in related areas with respect to the CFDP and executive management team so that the executive management can utilize the potentials of people and society for the CFDP.

Stakeholder analysis (SA)

SA helps to identify problems and develop forest management options, and opportunity for different solutions to be presented to the problem (Salam, Noguchi 2006). In SA, a decision model of the problem is formulated bywith environmental groups, farmers, tourism operator groups, forest recreation groups, and other groups (Ananda, Herath 2008). It is necessary to use SA for the CFDP as the second step after public information.

Community participation

Table 1 describes the necessary activities for the CFDP. Their immediate predecessors are also listed.

In Table 1 due to the high estimated duration, among the activities which need to be discussed, community participation (C activity) is without a doubt of central importance. The main problems with implementing the community participation in Zagros forests are: (1) socio-economic studies, investigation of the Traditional Forest Related Knowledge (TFRK) of the local community; (2) conduct decision-making meetings with local inhabitants; (3) set up a spatial-temporal program for local inhabitant participation; and (4) organization of the human resources.

The first step of the community participation in Zagros forest is the study of TFRK of local inhabitants. The recordation of the TFRK is a key way of entering into the socio-economic problems and public participation in Zagros forests. This process is very time-consuming in Zagros forests (Valipour et al. 2014; Zandebasiri, Pourhashemi 2018) and takes at least 12 months (Ghazanfari et al. 2004).

Regarding the role of organizing the activities of local communities in the forest decline crisis, the acceptance of TFRK is a precondition for this sub-

Table 1. Relationship between the immediate predecessors of the Control of Forest Decline Project (CFDP)

Activity	Necessary activity	Immediate predecessors	Estimated duration (months)
A	Public information	-	4
B	Stakeholder analysis	A	7
C	Community participation	B	21
D	Thinning	B	9
E	Sowing	B	17
F	Precipitation storage	B	16

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ject. It may be thought that forest decline management projects are more likely to come from biodiversity and pests and diseases, but the result of this research has determined that the management of the forest decline projects depends more on socio-economic problems than on the above issues. Local participation is the use of forestry capabilities and communities around the villages to collaborate in decision making and implementation of work processes.

Thinning

The die-back process often begins with crown cover defoliation. Hence, a reduction of the crown volume can be considered as one of the CFDP mechanisms. Of course, the identification of trees which require thinning operations as well as the coppice silvicultural treatments are influential for the viability of the tree crowns (Hoseinzadeh, Pourhashemi 2015).

Sowing

As may be expected, among the estimated times in Table 1, sowing (planting and seeding) has a duration of 17 months (E activity).

The purpose of this activity is to enhance and enrich the planting and the seeding in Zagros forests. These activities (planting and seeding) are supported by executive management to compensate for the declining trees and increase forest potentials.

Precipitation storage

The estimated time of precipitation storage would be long because the processes of the building systems are development projects. One reason for the forest die-back of Zagros forest was the aridity stress on Zagros Mountain in the past years (Mahdavi et al. 2015). Precipitation storage is designed to provide the water that is stored by digging water pits for the rainfall.

The results obtained from the estimated duration by experts show that community participation, sowing, and precipitation storage have the longest time in the CFDP.

MATERIAL AND METHODS

Study area

The study project is the watershed of Tang-e Solak in the Kohgiluyeh and Boyer Ahmad province, western Iran. This area located in Likak (Bahmaee) city is approximately 15 km south of the Kohgiluyeh and Boyer Ahmad province. The area of the forest is 1000 ha (Zandebasiri, Parvin 2012). Before 1998, the management units of Zagros forests were more concerned with large catchment areas, but current management units in these forests have changed due to other aspects of local livelihoods and rural development. The majority of locals residing there have removed from this region due to the hardships of living in migration, the lack of facilities and low income form this lifestyle. The local inhabitants adjacent to the forests migrate to the tropical region located in the southwest of Iran during the period of October to late February.

Methods

In this study, we applied the PERT and CPM methods to the management and control of decline projects in Zagros oak forests of Iran. To the best of our knowledge, the application of these methods simultaneously to assess forest decline seems to be the first in Iran and elsewhere. Specifically, in order to investigate the activities necessary to control the decline of the crisis, we estimated the time in a network analysis and determining the critical path was evaluated based on the PERT method. A stakeholder analysis based on Zagros experts was conducted for designing a network to identify necessary activities of the CFDP.

In Zagros forests 3 kinds of stakeholders are more effective than the other stakeholders that include: Forest and Rangeland Organization (FRO) or Executive management, Agricultural Research, Education and Extension Organization (AREEO) and the Zagros related Universities.

In section 1, for designing a network to identify necessary activities of the CFDP, we selected 7 experts form all of three kind stakeholders based on questionnaire and interview. The experts were selected by willingness to cooperate, the knowledge of the analyst team of Zagros experts and collaborate at the right time with research criteria. The

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objective of the research was not the quantitative of the results. Based on the issues we follow a reputation approach (Zandebasiri, Hoseini 2019) for estimating of the CPM time-cost trade-off model. In this section 2, 3 experts were selected.

In section 1 for designing a network to identify necessary activities of the CFDP, the experts were selected by willingness to cooperate, knowledge of the analyst team of Zagros experts and collaborate at the right time with research criteria. In this section experts from Forest and Rangeland Organization, Agricultural Research, Education and Extension Organization and its provincial subsystem universities were selected. The object of the research was not the quantitative of the results. Based on the issues a reputation approach (Zandebasiri, Hoseini 2019) to estimating the CPM time-cost trade-off model was used.

The application of these two methods was modified from two previous studies and is presented in detail in the next section (Dubois et al. 2003; Hajshirmohammadi et al. 2014):

PERT method

The PERT method constitutes a three-time approach that is used for a time study, so that when it is used to carry out an activity, the average weight of the pessimistic estimate, optimistic estimate and most likely (ml) time estimate allows the most likely time estimate to have more weight (Hajshirmohammadi 2014; Kaiyan et al. 2015). The formula for time estimating in the PERT method is presented in Equation (1).

$$T_m = \frac{t_{\min} + 4t_{\mathrm{ml}} + t_{\max}}{6} \quad (1)$$

where:

$t_{\min}$ – optimistic estimate,

t_{ml} – pessimistic estimate,

$t_{\min}$ – the most likely time estimate.

Figure 1 illustrates the positions of the three times in this study. The distance between the pessimistic estimate and the optimistic estimate based on statistical relationships is 6 times the standard deviation. Therefore, the relation in Equation 1 in this discussion can be used. Fig. 1 shows a three-time approach to time estimating.

Earliest Time (ET)

The ET associated with an event is when that event can occur, provided that all of its prior activities are carried out in the longest path.

Forward Pass (FP)

FP calculations are used to calculate the earliest time. In the forward pass calculations of the trail events, we start and move forward. In this move, it is assumed that the previous event occurred at the earliest time possible.

Latest Time (LT)

The LT for the occurrence of an event is the latest time when all activities that are likely to occur take place without affecting the completion time of the project. To calculate the LT the backward pass was used. The backward pass was started from the ending event of the network and was moved to the starting event from the network.

The ET to happen an event is the earliest date when all the activities that lead to the event have been completed but the LT to happen an event is the longest date when all the activities that lead to that event can take place without affecting the completion date of the project.

Critical Path (CP)

In each network, there is at least one path that includes the longest time. This way is called the critical path (CP). The total time needed to carry out CP is equal to the time it takes to complete the project (Hajshirmohammadi et al. 2014). CP is the concept of the PERT method. CP is the longest path in the network when all activities of the network from start to finish and the project will be done.

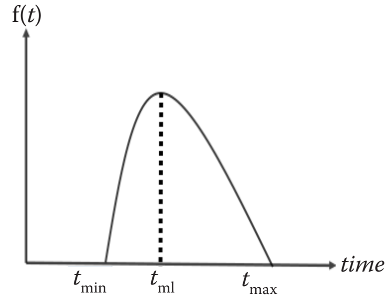

Fig. 1. Three-time approach to time estimate ($t_{\min}$ – optimistic estimate, t_{ml} – pessimistic estimate, $t_{\min}$ – the most likely time estimate)

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Slack (S)

Slack or float is the difference between ET and LT. A slack event is an indication of the length of time that the event can be delayed, without delaying the total project time, i.e. Equation (2).

In this research, time unit was considered as the month which is capable of covering work processes for preventing and managing the forest decline.

$$S_i = LT_i - ET_i \quad (2)$$

where:
LT_i – latest time,
ET_i – earliest time.

Critical Path Method (CPM)

In CPM, the aim is to spend on a crash activity time more costs than on a normal activity time. In this way, two types of activity costs are defined: normal activity cost for normal activity times, and crash activity cost for crash activity time (Nikoomaram et al. 2010).

Normal activity time (D_n)

The normal activity time of an activity is the time it takes for the activity to be carried out and the direct costs of the activity are in the minimum amount possible. The normal activity time of an activity is the time it takes for the activity not for ET/LT. ET and LT are times of network calculations and they are not the times for an activity.

Crash activity time (D_f)

Crash activity time is the result of compression of the normal time provided that the execution of the activity is feasible in the conditions of the project implementation. Crash activity time is the concept of the CPM. Crash activity time means the shortening of the minimum time to do an activity according to costs of an activity. Managers can shorten the time by increasing resources to a minimum but increasing resources have an additional cost. In the CPM method increasing resources are equalled with increasing costs of the activities. CPM method has been promoted as a methodological framework to include costs in order to mitigate the time of the project.

Normal activity cost (C_n)

Normal activity cost is the sum of the direct costs of an activity in the normal period.

Crash activity cost (C_f)

Crash activity cost is the sum of the direct costs of an activity in situations where the activity is carried out at a crash activity time.

Activity Cost Slope (*ACS*)

ACS is the amount of direct cost that is attributable to the reduction of a unit of time from the duration of the activity (Fig. 2) (Hajshirmohammadi et al. 2014).

The Equation 3 for calculating the ACS is as follows (Hajshirmohammadi et al. 2014):

$$C_{ij} = |(C_f - C_n)/(D_f - D_n)| \quad (3)$$

where:
D_f – crash activity time,
D_n – normal activity time,
C_f – crash activity cost,
C_n – normal activity cost.

Data analysis

The experts' time in each estimate (pessimistic estimate, optimistic estimate and most likely time estimate) was entered into Equation (1). After that, CPM issues were examined. In the CPM calculations, the average expert opinions of a team of experts were used to estimate costs in Zagros forests, to estimate the crash time and cost of the problem.

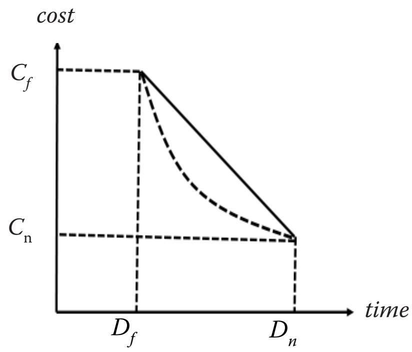

Fig. 2. Activity cost slope parameters (D_f – crash activity time, D_n – normal activity time, C_f – crash activity cost, C_n – normal activity cost)

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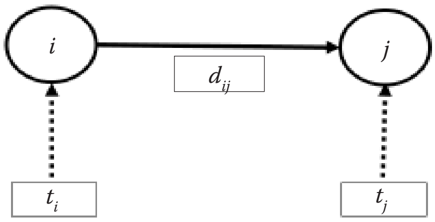

Fig. 3. Trail event and implementation of the activity (i – trail event, j – head event, d_{ij} – time for implementation of the activity, $t_{i,j}$ – time of the event)

The data in this phase was entered into Equation 2. Data modelling was then performed for time-cost trade-off. There are several methods for time-cost trade-off, including test and error algorithms for reducing CP, Siemens algorithm and Linear Programming (LP). Among these methods, LP is more widely used due to the comprehensiveness of the analysis and access to various software applications. To use Linear Programming, the cost function is defined as Equation (4).

$$Z = H(t_n - t_1) + \Sigma\Sigma\, C_{ij}(D_{n(ij)} - d_{ij}) + K_n \quad (4)$$

where:

Z – cost function of the project,

H – project overhead costs,

$(t_n - t_1)$ – total time of project implementation,

$H(t_n - t_1)$ – total indirect costs (indirect costs include administrative and accounting costs and others),

$\Sigma\Sigma\, C_{ij}(D_{n(ij)} - d_{ij})$ – total additional cost due to the reduction of the project time, which is considered for all crash activities,

K_n – direct cost of the project.

Hence, Equation (5) is redundant.

$$Min\ Z = H(t_n - t_1) + \Sigma\Sigma\, C_{ij}(D_{n(ij)} - d_{ij}) + K_n \quad (5)$$

Eq. (5) is a linear programming function and it is called an objective function. The limitations of Eq. (5) can be explained according to the following planning principles:

(i) The implementation time of any activity cannot be greater than the difference between the time of the occurrence of the trail events and the head events of that activity.

If we introduce trail event with i and head event with j, Fig. 3 will illustrate the trail event and implementation of the activity.

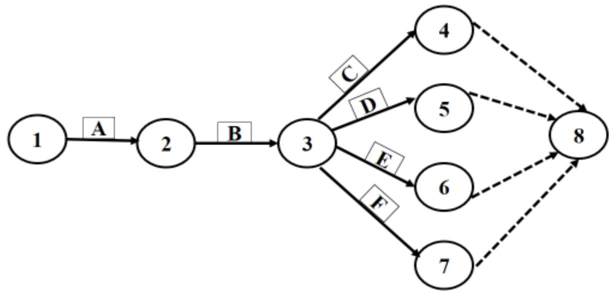

Fig. 4. The Control of Forest Decline Project (CFDP) network for Zagros forests, Iran (1-8 – events, A-F – activities)

Based on the times defined in Fig. 3, the $t_j - t_i \geq d_{ij}$ relation as a constraint, it adds the space of time to the problem.

(ii) Time implementation of the activity has the quantitative of the time between normal activity time (D_n) and crash activity time (D_f) or equal to one of them. Therefore the $D_{f(ij)} \leq d_{ij} \leq D_{n(ij)}$ constraint will also encounter the problem.

(iii) In addition to the functional constraints above, a non-negative constraint is added to this problem in such a way that the occurrence of network events cannot be less than zero (Eq. 6–9).

In this way, the LP is obtained for the time cost exchange problem discussed in this paper.

$$Min\ Z = H(t_n - t_1) + \Sigma\Sigma\, C_{ij}(D_{n(ij)} - d_{ij}) + K_n \quad (6)$$

Subject to:

$$t_j - t_i \geq d_{ij},\ i, j = 1, 2, ..., n \quad (7)$$

$$D_{f(ij)} \leq d_{ij} \leq D_{n(ij)} \quad (8)$$

$$t_i \geq 0,\ i, j = 1, 2, ..., n \quad (9)$$

The above problem is solvable by the simplex method in Linear Programming. In order to solve the LP problem, Lingo software (Lingo, Version 15) was used in this research.

According to Table 1, record study as well as expert assumptions the CFDP network for Zagros forests is shown in Fig. 4.

Fig. 4 shows the necessary activities for the CFDP in a network analysis. As indicated in Fig. 4, at the first time, public information (A activity), and SA (B activity) should be done, respectively. Then, four activities begin in parallel paths including: community participation (C activity),

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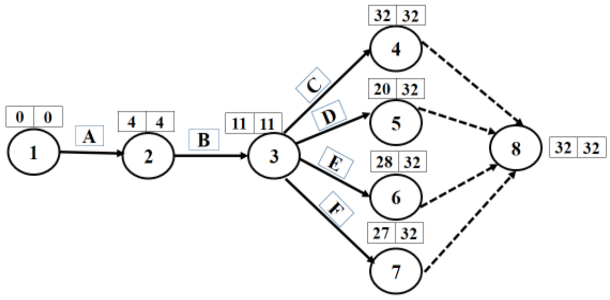

Fig. 5. The earliest time (ET) and latest time (LT) of the project events (1-8 – events, A-F – activities)

thinning (D activity), sowing (E activity), and precipitation storage (F activity). These four activities cannot start until their immediate predecessors (A and B activities) could be completed. As a basic principle of the PERT method, the activities which do not depend on each other can be done simultaneously. Hence, community participation, thinning, sowing and precipitation storage activities could be done simultaneously in Fig. 4. However, there is a dependence between these activities and stakeholder analysis activity. Hence, stakeholder analysis activity must be started before these activities.

Table 2. The slack of the Control of Forest Decline Project (CFDP) events (in months)

Events	Earliest time	Latest time	Slack
1	0	0	0
2	4	4	0
3	11	11	0
4	32	32	0
5	20	32	12
6	28	32	4
7	27	32	5
8	32	32	0

Table 3. Various paths of the network

Number of the path	Network path	Time (months)	Slack (months)
1	A-B-C	32	0
2	A-B-D	20	12
3	A-B-E	28	4
4	A-B-F	27	5

A-F – activities

RESULTS AND DISCUSSION

To avoid the contradiction with the network drawing rules (Hajshirmohammadi 2014; Kaiyan et al. 2015), dummy activities have been used to end the network as a dotted point. Earliest time (ET) and latest time (LT) of the CFDP events (from 1 to 8) are displayed from left to right, respectively, on events as shown in Fig. 5.

All of the elements in Fig. 4 and Fig. 5 except ET and LT are similar. In Fig. 5, ET and LT of the CFDP events are displayed on events from left to right, respectively. Table 2 reports the slack of the CFDP events.

The results of Table 2 show that precipitation storage and sowing (see 6 and 7 lines in Table 2) also have a low slack and can be critical after community participation. The various paths of the network are given in Table. 3.

Tables 2, 3 show the slack of the events and paths of the network, respectively. Zero-sized slacks represent the bottlenecks in the CFDP. Results of Table 3 clearly illustrate that the CP of the CFDP is located on the community activity (Number 1 in Table 3) because of the zero-sized slack in the path. It seems to be an unpredictable result in examining the CP of the CFDP. Table 4 specifies normal and crash time as well as normal and crash cost.

As indicated in Table 1, the time of community participation is very important for the CFDP. The Activity Cost Slope (ACS) in Table 4 shows that it is not possible to crash the community participation normal activity time because of the high quantity in ACS for that activity (see C activity in Table 4). The results of the LP model according to the Lingo software are presented in Table 5.

In Table 5, dX denotes the optimal quantity of the X activity. The results of Table 5 are obtained from the LP model (Eq. 10–23, see Appendix). Also, optimal cost is extracted from crash/normal cost in Table 4. In cases it is possible to crash an activity, the crash cost is recorded to optimal cost and in cases it is not possible to crash an activity, the normal cost is recorded to optimal cost. Based on the comparison of the results of normal times in Table 4 and the results of Table 5, it is clearly illustrated that only two activities – public information and the stakeholder analysis can have less time. The other activity times in Table 5 and normal times in Table 4 are the same. In other words, the other times can be shortened, but shortening them is not economic.

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Table 4. The Critical Path Method (CPM) elements of the Control of Forest Decline Project (CFDP)

Activity	Normal time*	Crash time	Normal cost*	Crash cost	ACS
A	4	3	5	10	5
B	7	4	5	9	1/33
C	21	18	25	45	6/66
D	9	7	10	20	5
E	17	10	15	30	5
F	16	8	25	55	15

A-F – activities, *time unit is the month and cost unit is the money unit in Iran, ACS – Activity Cost Slope, overhead costs – 6 money units in time unit

Table 5. Results of the LP model

Variables	Optimal time	Appropriate optimal cost
dA	3	10
dB	4	9
dC	21	25
dD	9	10
dE	17	15
dF	16	25

LP – Linear Programming, *dA-dF* – variables of LP model, the optimal quantity of the objective function – 222/12

In assessing the time-cost trade-off, this study has also shown that the possibility of shortening for the normal time in the CFDP is limited. In order that the normal time could have been shortened, it will not be possible to spend more money for this project. There is no recognizable difference between the normal time in Table 4 and the optimal time in Table 5. Therefore, this circumstance is a "golden time" to the CFDP in the Zagros ecosystems.

In general, economic shortening of the activities depends on their *TC* which is shown in Fig. 6 (Hajshirmohammadi et al. 2014; Biswas et al. 2016).

As shown in Fig. 6, not only direct costs but also total direct and indirect costs of an activity (TC) should be minimum. In our application, the high ACS, as well as the higher cost of the activities (see Table 4) can be attributed to the fact that the shortening of the CFDP time is not economically feasible. Therefore, because of the results of the LP model in Equation 10 (see Appendix) and the results of Table 5, only two activities can be shortened. If the time of the other activities is shortened, their TC (see Fig. 6) will be increased from the minimum of TC. Hence, if the other activities are crashed, indirect costs of them would be increased. For example, in precipitation storage activity (see F line activity in Table 4) ACS is 15. When this activity is shortened, its costs will increase from 25 to 55. Therefore, precipitation storage crashing is not economically feasible. In optimization, the size of the objective function is 222 (see Table 5). This number can be a guide to budget allocations for FMPs policy makers in Zagros forests. The total crashing time for the CFDP is 4 months (compare the normal time in Table 4 and Table 5). This number is not big for the CFDP time. Accordingly, it could be concluded that time crashing is not economically efficient for the CFDP except two activities: public information and stakeholder analysis activities. Hence, the executive management of Zagros forests is located in the sensitive time of the Zagros forests planning.

This study describes a new method of forest modelling in time-cost trade-off: the combination of PERT and LP for forest management planning.

The results of this research are very different from those of the other related studies in forest decline (Temiño-Villota et al. 2016; Navarro-Cerrillo et al. 2016) because of using the managerial and mathematical methods and the previous forest decline models (Kabrick et al. 2008; Ríos-Saldaña et al. 2018). Compared to the previous forestry model studies, this study has targeted a different field of study in forest management. This paper has shown the time-cost trade-off model to be a suitable framework for a managerial assessment. Further, using Zagros forests as a case study, the paper has also described how the CPM method can be implemented in various phases of crisis management planning.

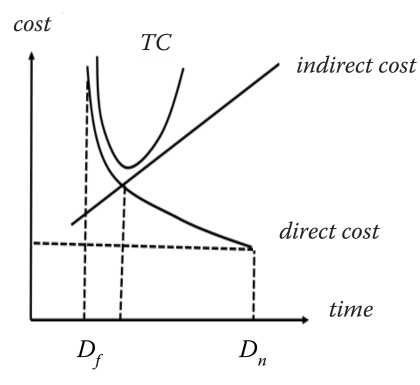

Fig. 6. Showing total costs (*TC*) associated with different costs (D_f – crash activity time, D_n – normal activity cost)

https://doi.org/10.17221/65/2019-JFS

Zagros forests have been governed by the state since 1963, but these forests have been managed by local communities (LCs) for NTFPs, livelihood requirements and traditional silvopastoral systems (Valipour et al. 2014). Nowadays forest management in Zagros forests faces complex management states (in terms of conditions): causes of forest die-back are complex and multilateral. Moreover, the social demands of local communities have contrary aspects to the goals of Forest Management Plans (FMPs). The executive management have tried and tested various FMPs for Zagros forests. However, in practice many of these FMPs could not achieve the social acceptance by the local inhabitants (Ghazanfari et al. 2004; Zandebasiri et al. 2010; Valipour et al. 2014).

Due to pollarding (disbranching and defoliation) for livestock requirements by local inhabitants, they have demands from the executive managers in Zagros forests. Hence, conflicts in goal-setting between the executive management and local communities are characterized by two contradictory views.

On the one hand, the executive management has officially enclosed (use of barbed wire fencing) the forests toward ending both traditional pollarding practices and traditional silvopastoral practices. On the other hand, local households have extracted forests for animal fodder, fuel wood, , livelihood requirements and NTFPs.

In order to resolve this problem, there seems to be a need of community participation approaches in the CFDP so that the destruction impacts of the local utilization could be minimum. Hence, the executive management should be involved in community participation more than in ecological and silvicultural issues.

The CFDP is a plan for the control of oak tree mortality in Zagros forests of Iran. Mortality with participation of pests changes the forest ecosystem to a critical situation first from crown covers and second from tree trunks. The lack of attention paid to managerial and economic problems in the mortality issue in forest management constitutes a critical issue for Zagros forests. This plan designs the events and activities for the monitoring of tree mortality and the prevention of pest epidemic in these forests.

Previous FMPs of Zagros forests have had the participation in the implementation but local communities have not participated in decision-making processes (Ebrahimi Rostaghi 2006; Zandebasiri, Ghazanfari 2010; Valipour et al. 2014). Accordingly, it is necessary to change the processes of the FMPs in the Zagros region so that the social studies could find a higher position than today. Nowadays the first priority of executive management in the case study is to enclose the forests with barbed wire fencing to exclude the local community from livestock grazing and precipitation storage. Results from the study indicate that the CP of the CFDP is located on the community participation, however, in practice the executive management focused on the ecological problems for the CFDP. Therefore, executive management priorities should be changed to deal with socio-economic problems-goal-setting participatory in the Zagros forests. Although the presented model represents an expert approach that strongly builds on individual expert skills, it will be stretched for various stakeholders in forest management future researches.

We strongly advice to employ this approach to other states (conditions) such as commercial forestry or environmental management to identify the most preferable path for those projects

CONCLUSION

The first step after observing the forest die-back in the CFDP is public information. The purpose of this activity is to distribute the information for both mutual understanding and collaborative management. Information collection prevents the unplanned actions. This issue has been less addressed in the management of natural resource crises in Zagros forests.

The second step which has the ability of crashing is the Stakeholder Analysis (SA). SA determines the organizational roles of each stakeholder. Local inhabitants, local councils, natural resources research centres, nomadic bureau, environmental bureau, tourism administration, and other organizations are involved in SA. The past FMPs of Zagros forests have often suffered from the lack of stakeholder analysis. SA describes the demands and tasks of the organizations and groups involved in the CFDP. The executive management of Zagros forests cannot manage the CFDP alone. Hence, it is necessary that executive management should do SA for utilizing the potential of the other organizations and local communities for the CFDP. The second step of the CFDP is SA due to these reasons.

In assessing the time-cost trade-off, this study has also shown that the possibility of shortening the nor-

https://doi.org/10.17221/65/2019-JFS

mal time in the CFDP is limited. In order that the normal time could be shortened, it will not be possible to spend more money on this project. There is no recognizable difference between the normal time in Table 4 and the optimal time in Table 5. Therefore, this circumstance is a "golden time" to the CFDP in the Zagros ecosystems.

While the forest die-back in Zagros forest occurs on droughty sites (Zandebasiri et al. 2017), clearly the control of this phenomenon relates to socio-economic problems. Social studies are the bottleneck of decline control in Zagros forests, Iran. Accordingly, as may not be expected, the bottleneck of the CFDP is the socio-economic problem, however, the forest decline relates to the role of environmental factors (Kabrick et al. 2008).

In other words, although the problem of forest decline is an ecological problem, its root lies in participatory management with the local community. We strongly advise to employ this approach to other states (conditions) such as commercial forestry or environmental management to identify the most preferable path for those projects.

Appendix

The result of time-cost trade-off modelling is shown by the following LP model – Equation 10:

$$Min = 6\ (t_7 - t_1) + 10\ (4 - dA) + 2\ (7 - dB) + 10\ (21 - dC) + 10\ (9 - dD) + 4\ (17 - dE) + 6\ (16 - dF) + 85$$

Subject to:

Limitation	Equation No.	Limitation	Equation No.
$3 \le dA \le 4$	(11)	$t_2 - t_1 \ge dA$	(17)
$3 \le dB \le 7$	(12)	$t_3 - t_2 \ge dB$	(18)
$18 \le dC \le 21$	(13)	$t_4 - t_3 \ge dC$	(19)
$7 \le dD \le 9$	(14)	$t_5 - t_3 \ge dD$	(20)
$10 \le dE \le 17$	(15)	$t_6 - t_3 \ge dE$	(21)
$8 \le dF \le 16$	(16)	$t_7 - t_3 \ge dF$	(22)
		$t_1, ..., t_7 \ge 0$	(23)

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Received for publication May 28, 2019
Accepted after corrections December 3, 2019