KICEM Journal of Construction Engineering and Project Management
Online ISSN 2233-9582

www.jcepm.org
http://dx.doi.org/10.6106/JCEPM.2017.9.29.001

An Integrated Expert Model for Delay Management in Construction Projects

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Abstract: Delay claim should actually be supported by a set of proper information so that the contractors could prove their validity. The so-called information should be able to clarify the relationship between delay events and how they impact on the whole project. Therefore, exploiting an integrated system by people who are involved in construction business would certainly prove helpful. In the present study, delay analysis methods have been investigated along with selecting a relatively comprehensive method which has been modified, and eventually, a novel model and its required modules have been proposed for evaluating delay claims. The suggested integrated model is formed to identify delayed events, to classify delays, to measure the impacts of delays on the project scheduling, and finally to estimate the damages which were caused by those so-called delays. A decision support system (DSS) model which is related to the integrated system is actually extracted from Iran's general contract conditions, that is, 4311 magazine (equivalent to red FIDIC book). It is then programmed and coded by C# program. This DSS model can be used as an input of Easy Plan program. In addition, at the end of this research, the coded DSS has been used along with the so-called program so that a modified and developed model could be generated.

Keywords: Integrated System, Delay analysis, DSS model, Construction project

I. Introduction

In recent years, construction projects have increasingly faced more complications and as a result projects have had numerous amounts of problems to meet their deadlines. One of the most significant project problems is delay i.e. delay in implementation and operation processes which commonly arouses claims between owners and contractors (Klee, 2014). Affected by some internal or external factors, delay is generally defined as going further than the scheduled agreement and is often the main reason why problems begin to intensify and why both parties, namely, the owners and the contractors feel the need to bring up their claims. This issue is even more noticeable and challenging for all the involved parties in developing countries. Furthermore, another important issue which should be taken into account is the way these delays are analyzed and assessed. In fact, there are diverse methods for analyzing delays including Global Impact Technique, Net Impact Technique, Collapsed As-Built Technique, and Windows Analysis Technique; however, they are considered quite challenging as well. (Kao& Yang, 2009, Yang& Huang, 2012). From among these methods, Windows Analysis (WA) Technique seems to be the one with more effectiveness and capability (Kao& Yang, 2009, Yang& Huang, 2012); thus, in the present study, certain methods with particular features have been extracted from this technique and put in table 1 in order to have a comparative study with other techniques. Each technique has been suggested to modify and improve the classic Windows method.

Indeed, it is worth mentioning that one important point in delay analysis seems to be lack of a particularly appropriate program and software for analyzing, registering, classifying, and identifying delay sources. In essence, using only one scheduling software makes it more complicated and inaccurate and at times it is even done manually.

Obviously, as computer researchers have found out certain computer programs are able to support decision-making activities. These systems or programs are called decision makers or experts. They are actually a well-organized collection of people, processes, soft wares, databases and tools used for supporting decisions relevant to a particular issue in a project (Stair& Reynolds, 2012, Yun& Wei. Jiong& Ruijun, 2009).

Significant improvements in computer technology have made it possible to collect and integrate massive volumes of information obtained during the different phases of a project (Parfitt et al., 1993, Yang& Tsai, 2011). Furthermore, it is evident that the construction industry has had a remarkable growth in utilizing computer software. These software packages including scheduling and database software cover a wide range of activities inside construction industry (Mubarak, 2010). However, they are designed only to be stand-alone elements rather than a part of an integrated system. As a result, an integrated system is required to connect these individual software packages around a common data core, with no inconsistent data conventions (Parfitt et al., 1993).

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TABLE I
Comparison of different Widows-based analysis methods (Parchami Jalal et al)

Row	Methods / Comparison Criteria		TWA (Yang & Kao, 2009)	DAMUDS (Kim, 2005. Yang & Kao, 2009)	EDAM (Yang & Kao, 2009)	DWDA Kao& Yan, 2009. Hegazy & Zhang, 2005)	MBU (Hegazy, & Menesi, 2008)
1	The requirement schedules	As-planned	●	●	●	●	●
		As-built	●	●	●	●	●
		Updated	●	●	●	●	●
2	Time of usage	Real time	×	×	×	●	●
		Project completion	●	●	●	●	●
3	Analysis period	Start time	First delay	First delay	First delay	First delay	First delay
		Updated period	Arbitrary	Delay section	When delay occurs, the period of scrutiny is as daily and when there isn't any delay, the timeframe is considered as a period.	Daily	Daily
4	Float consumption		×	●	●	●	●
5	Ownership approach float		For project	For project	For project	For project	For project
6	Consider to change of critical path		×	×	×	×	●
7	Identify delay and acceleration	Concurrent delay	×	●	●	●	●
		Pacing delay	×	●	●	●	●
		Project delay	●	●	●	●	●
		Contractor acceleration	×	●	●	●	●
		Owner acceleration	×	×	×	●	●
8	Consider to disruption		×	×	×	Always caused by contractor	Always caused by contractor
9	Amount of effort		Depend on window size	Effective	Much	Too much	Too much
10	Algorithm and approach for concurrent delays		50/50 dividing approach	50/50 dividing approach	Analyzed duration of each activity/ total analyzed duration of the two activity	50/50 dividing approach	50/50 dividing approach
11	Consider to over allocation resource		×	×	×	×	●
12	Analysis results		Intermediate	Good	Very good	Excellent	Excellent and fair

TWA: Traditional window analysis. DAMUDS: Delay analysis method under delay section
EDAMS: effect-based delay analysis method. DWDA: Daily window delay analysis.
●Has ability in the feature. ×Has not ability in the feature.

Although artificial intelligence techniques and decision support systems have had a remarkable growth, how they could efficiently be used to prevent and resolve construction problems have not been taken into account in real conditions so far (Hegazy, 2012). In fact, there are different types of tools which are currently being used in artificial intelligence researches, the most important of which include rule-based systems, fuzzy logic, case-based reasoning, neural network and genetic algorithms, and hybrid systems (Ilter& Dikbas, 2009).

In1999, Arditi used case-based reasoning technique for predicting the court verdicts and resolving construction claims (Arditi& Tokdemir, 1999). Also, Chau et al. proposed a neural network method to identify hidden relationships between different relevant factors. In fact this method has been used to predict the outcome of construction claims (Chau, 2007). An accurate prediction of court verdicts could effectively help reduce disputes and the need for costly legislation processes. Indeed, choosing an appropriate resolving method is only feasible when the disputes are fully assessed. This so-called assessment of disputes involves identifying the reasons of dispute in construction projects, the possibility of rising disputes and their impact on the projects. The possibility and effect of disputes can be numerically obtained from probability analysis or mathematical models; however, a project manager would prefer to interpret the possibility and effects of disputes through natural individual thinking process of the people involved in the issue. This way, a suitable environment is created in which fuzzy logic method can be properly utilized. (Cheung, 2001, Hafez& Nasr, 2015).

Yet, the main weakness of aforementioned methods is the lack of enough explanations and interpretations of a proposed solution; conversely, rule-based decision support systems can be associated with an explanation that can be used to analyze delays and determine all parties' responsibilities.

Kraiem has proposed an expert system called DISCON (a system for claims caused by different site conditions) which does play the role of a consultant. This system is able to determine whether the contractor is right or the owner (Kraiem.et al, 1989). In 2004, Abdelkhalek discussed two types of claim cases relevant to different site conditions so that there could be an expert system called GWSFC in order to assist engineers and mediators to reach a fair conclusion. Decisions and final results of this expert system is whether the time extension will be given to the contractor or not (Abdelkhalek& Arrashid, 2004, Hafez& Nasr, 2013).

The above two research works have nothing to do with delay analysis methods and would only reach a result if there were some specific set of rules.

Between the years 2001 to 2007, Kumaraswamy and Palaneeswaran studied on a DSS to determine eligibility of delay claims in order to make the right decision to grant time extension in delay cases and to select appropriate assessment methods. Also, they have argued about the amount of time extension which should be given to the contractor. For the entitlement evaluation of the time extension, they used Hong Kong contract general conditions (Kumaraswamy et al, 2001, Palaneeswaran& Kumaraswamy, 2008). In method assessment section, the so-called system is explained to the user only through a few questions. Then all the stages of this method are also elaborated and in fact, this will be the steps for the user through which he could analyze the delay cases.

In 2008, Ieyer et al. modeled a DSS for resolving disputes related to delays. Since this system contains a large database, it presents a checklist to contract responsible for predicting disputes before going for litigations. Based on previous studies, in this study seven cases of delay causes commonly occurred in India's projects are categorized. According to arbitrators' opinions, magazine and arbitration reports related to the delay and the time extension, a set of rules is provided for this scope. As a kind of logical decision diagram, this set of rules shows the relation between claims and origins, and then it explains the likelihood of claims and the probable consequences. For determining the responsible part, the most important question being asked from the user is whether the delay is on the critical path or not (Palaneeswaran& Kumaraswamy, 2008).

In fact, this system keeps predicting only with the help of these questions instead of using delay analysis methods. However, the above mentioned model has a drawback, namely, it has not specified which method is being used in delay analysis so that it could answer whether the delay of activity is on critical path or not. It is important because different delay analysis methods may determine different critical paths.

Likewise, in 2012, Chaphalkar et al. modeled a DSS in the scope of those disputes caused by change clauses in India's construction contracts (Chaphalkar& Smita, 2012). In this DSS model, the results are explained based on the mediators' decisions and then have been categorized as a set of rules. Ultimately, decisions made in the DSS are that whether applied changes should be considered as overtime work or not and whether contractors will be eligible for more payments.

II. Research Methodology

In this paper, Windows-based analysis methods are first compared through using their capabilities and performances. Along with these methods, all influential features in selected methods are presented in Table1. Considering all advantages and disadvantages, the method has almost the highest performance in delay analysis processes. Yet, this method does have certain limitations which will be discussed later in this paper. In addition to that, the different causes of delays in view of many researchers (Dayi, 2010, Menesi, 2007) are classifies in Table2. This classification has been adopted with risks extracted from the Iran's general conditions in construction contracts (Magazine4311, 1999) equivalent to red FIDIC book, and then a frame of decision support system has been derived accordingly. Also, in the scope of claim management, an investigation on information systems and the DSS is done. Afterward, an integrated model is proposed for reducing delay claims and its management. This model not only fixes the limitations of the delay analysis method but also makes decision making and delay causes classification easier through the DSS. The relation between the causes and effects has been recognized and then coded in C# environment.

III. An Integrated Model Proposed for Delay Management of Construction Projects

Certainly, the proposed model pursues four major objectives including identifying delayed activities, classification of delays, measuring delays' impacts on project scheduling, and calculating damages caused by the delays. The main framework of this model is being shown in Figure1.

First of all, user must enter all the project information including planned schedule, allocated resources on a daily basis, actual progress with day-to-day changes into the model by using scheduling software. Then, certain key elements should be used in order to achieve the results related to the responsibilities and costs. In addition, this model will provide all the involved parties with sufficient reports. The main objective of the integrated model is reducing time and cost of preparing and submitting claims through facilitating delay analysis process. The model evaluates claims based on delays, can effectively retrieve required data, and help and support the management team and analyzers of the delay evaluate claims.

The proposed model consists of six elements as follows: 1) user, 2) graphical user interface, 3) decision support system, 4) calculation procedure, 5) scheduling software Microsoft project (MSP) and, 6) Microsoft Access (MS access) as a database. Each of these elements is explained as below:

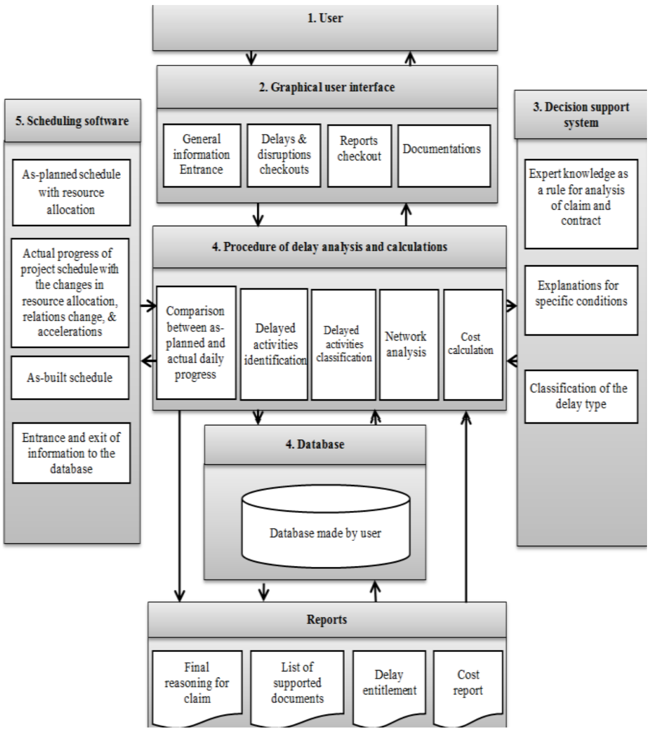

FIGURE I
The proposed integrated model for managing and analyzing delay claims

A. User

Each of the involved parties including owner, contractor or even consultant can be a model user. The user must enter the information correctly into the model, and is in charge of observing all the changes. Also, he/she will be able to control report production to ensure that the results are obtained based on the facts and delay events.

B. Graphical User Interface

Proper design of a user interface such as the use of proper presentation which is compatible with the model components will enable the user to have an appropriate communication with the model and modules control.

C. Decision Support System (DSS)

The decision support system does classify delays and by so doing, plays an important role in the proposed model. Classification of delays requires the analyst's close attention. The DSS is designed to simplify the process of classification and to remove ambiguities. In essence, this system presents some of the main reasons of the delay, yet the user selects the best reason for the specified delay. It should be noted that this system works only if the user chooses one reason. Then the user is given a set of questions based on the reason of the delay. Every yes-no question leads the user to the next one and eventually, a proper decision is made about the real cause of the delay. Some part of this process is shown in Figure2. When assessing the delay claims, collecting data is actually the most important step since it will help support the claims. In order to support decision making process, this system can remarkably help attach the relevant documents to the cause of the delay.

D. Delay Analysis Procedure and Calculation

The duty of this section is receiving all required inputs from the user interface panel and estimations by algorithms, and doing calculations for the processing. In fact, this section is considered not only as a connecting part between the start and end points of the integrated model, but also it is considered as an interface between the DSS and scheduling software. All raw data are transferred from the scheduling software to the model and before it is transmitted to the DSS for the classification, a calculation and detection is carried out regarding the amount of the delay activities.

E. Database

Clearly, database does retrieve the required information from the available stored data. In fact, the so-called database is able to record any delay based on the responsibility of the involved parties, date of occurrence, corresponding cost, and so on, so forth. The database is updated and completed during the analysis process. When the database is developed, the system's performance is enhanced to a great degree and can assess the project delays more efficiently. This database includes necessary data of the project and relevant information obtained from different documents. Access to this type of documents and the ability of using an appropriate delay analysis method are two key factors in obtaining a delay claim settlement in any project. In every project Access software can be used for this database.

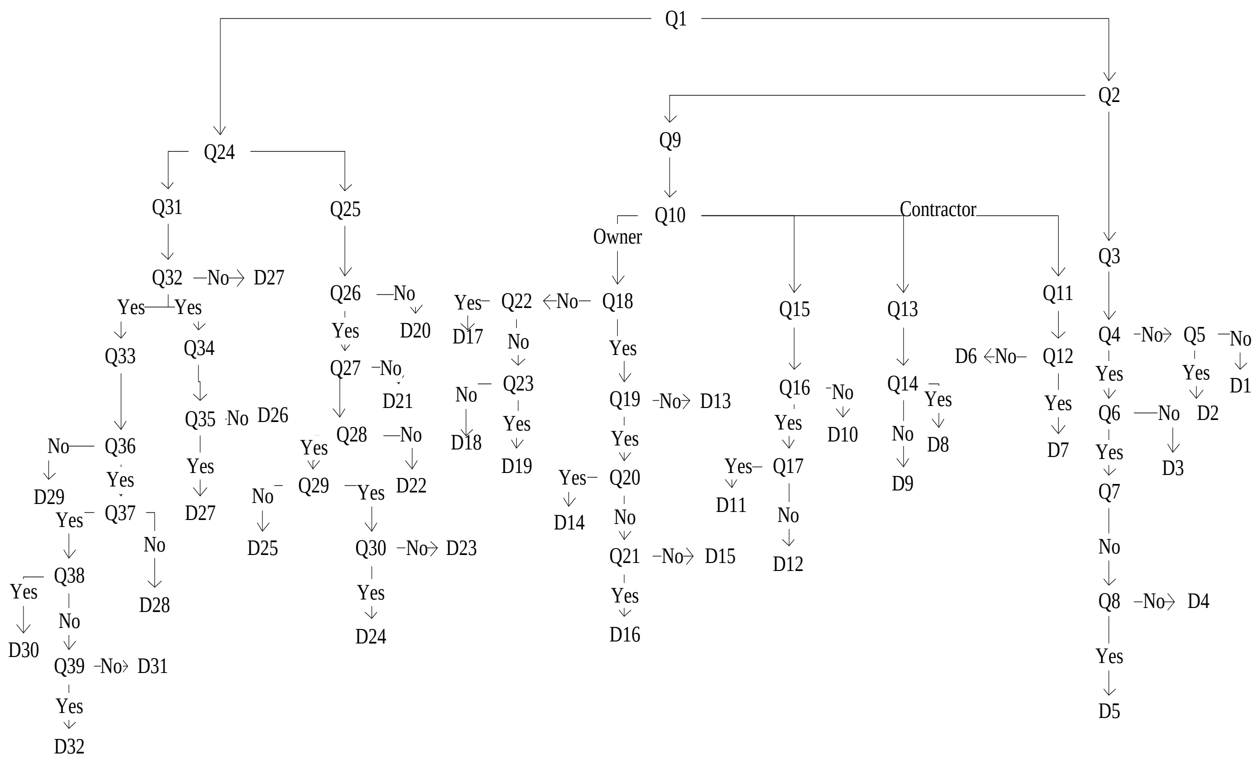

FIGURE II
The created decision tree in scope of delay cause of change order and drawing

F. Scheduling Software

Microsoft Project software is used for integrating the model and is able to import and export essential information to other software programs. Since this software is in the Microsoft environment, it is compatible with Access program as well.

IV. Model Development Process

Figure3 and 4 show the diagram for the development process of the model. The proposed integrated model consists of four separate phases including collection of initial information of the project, identification of delays, their classification, delay analysis phase in the project, and finally cost estimation phase.

A. Data Collection Phase

This phase can be divided into two modules, namely, project detail module and activity module. Basically, in the project detail modules information such as the names of the project, owner, and contractor, the location of the project, the beginning and the ending date based on the contract, preliminary duration of the project, actual start and finish dates, actual duration needed for the project implementation, and ultimately type and conditions of the contract are actively utilized. It is worth mentioning that when using a DSS system in this study, only the three-party contracts (contractor-owner-consultant) are taken into account according to 4311 article; however, it is feasible to classify delays and develop the system in other contracts such as FIDIC.

The user stores a file of the project which makes the data accessibility easier. After requesting and completing the project detail module, the user select activities module. The purpose of this module is identifying delayed activities and providing their list hierarchically. The user can receive this information from the scheduling software and then enter it into this system.

Basically, at first, as- planned schedule is entered by user request. Then, day by day information of as- built schedule is recorded in the MSP. Differences in progress percentage indicate disturbances or slow progress, delays or no-delays in activities and acceleration of the project. If actual percentage of the progress is lower than planned percentage, the model records delay or slowness in the progress and looks for the cause of such slowness or stop in DSS. In conclusion, the model identifies and compares the actual progress of the activities with as- planned schedule. It should be mentioned that unlike MBU methods which were developed by Hegazy in frame of a program called Easy Plan (Hegazy, 2007) and always attribute the slowness of daily progress only to the contractor and doesn't consider the effects of these disruptions, in this model it is suggested that not only the contractor but also the owner and the third party are considered as the cause of these disturbances. However; disturbance and slowness in the execution can be divided among the owner, contractor and the third party.

Furthermore, since this model utilizes MSP for scheduling and timing, unlike Easy Plan, it does not have limitations present in relationships between activities.

Once delays are identified, the system begins classifying them into two categories, namely, independent and concurrent (simultaneous) delays as it is indicated below:

B. Delays Classification Phase (Decision Support System)

Developing this system is done in three steps as follows:

1- Study of the cause and effect relation.

2- Creating a scope in which all causes are included.

3- Creating detailed connections inducing these claims.

In order to prepare the DSS framework, responsibilities and delay origins are extracted from general contract conditions and classifications of delay causes mentioned in several papers and are presented in table2. Moreover, required knowledge for developing the DSS has been extracted from these causes, reports, questions and responses in the general contract principles and expert opinions are also taken into consideration.

TABLE II
Comparing different delay causes from different expert points of view and Iran's general conditions of construction contracts(magazine4311,1999), (Dayi, 2010, Menesi, 2007).

Row	Classification in expert system	Classification causes of delays
1	Delay and rework because of plan and order	Design errors Delay in design Weak design In complete architect's plan Slow Approval of plans Waiting for receiving information Delay in approval of shop drawings
2	Delay and stop in work because of incident	Inappropriate weather condition
		Unforeseen site conditions (such as the detection of antique objects, installation subterranean, ...)
		Damage to a third person or equipment Damage to properties and neighbor installations
3	Delay because of changes	Change orders
		Change in drawings and design
		Scope extension of work
		Changes ordered by owner
4	Delay in site delivery and mobilization	Slow pace in Equipment
		site delivery
5	Delays in payment	
6	Delay because of Shortage of material - equipment and human resource and rework of them	Resource shortage
		Breakdown and problem maintenance of equipment
		Poor execution
		Resource shortage
7	Others	Delay in obtaining permission, legal payment and acquisitions of construction permission
		Delay because of project manager and owner's decision
		Do not performing on time tests or preparation of consultant or observer Time claims because of changes in law and roles

TABLE III
Decision tree is tabulated by this table

Questions			
Code	Description	Code	
Q1	Delay and rework because of drawings and works order	Q21	Has the contractor requested those drawings from the consultant based on the detailed schedule planned?
Q2	Delay induced by the issuance of orders and drawings	Q22	Whether the owner (consultant) has prepared and then delivered the drawings to the contractor?
Q3	Works order	Q23	Has the contractor requested those drawings from the consultant based on the detailed schedule plan?
Q4	Does the consultant convey written works order to the contractor?	Q24	Drawings and works orders.

Q5	Whether the contractor request detailed schedule plan from the consultant?	Q25	Investigation and control of works order.
Q6	Is owner approval necessary?	Q26	Does the contractor approves the correctness and hence the owner has no responsibility regarding this issue?
Q7	Does the owner approve the works order?	Q27	Whether the contractor has informed the consultant according to the detailed schedule?
Q8	Does the contractor execute the work without considering owner approval?	Q28	Does the contractor approve the correctness of document and works order?
Q9	Drawings	Q29	Whether the contractor has still problem with it?
Q10	Which one of the owner or the contractor is the responsible of drawings preparation?	Q30	Has the contractor informed the owner?
Q11	Instruction of execution, repairmen and maintenance	Q31	Drawings, technical specifications, ground level and target points.
Q12	If the contractor has delivered the execution, maintenance instructions to the consultant before temporary deliver?	Q32	Whether the contractor has checked the drawings and has problem with the correctness of the drawings, technical specifications, target point and ground level?
Q13	As- built drawings	Q33	Problem with the correctness of calculation, material and facilities specification
Q14	Does the contractor gradually prepare as- built drawings according to the consultant and deliver?	Q34	Lack of drawings
Q15	Shop drawings	Q35	Whether the contractor has requested problem solution from the consultant?
Q16	Does the contractor prepare and deliver shop drawings to consultant while doing works according to the execution drawings, technical specifications and producer instruction in time?	Q36	Whether the contractor has informed the consultant according to the detailed schedule?
Q17	Whether the consultant control, revise and issue the shop drawings in time?	Q37	Does the contractor approve the correctness of document and works order?
Q18	Whether providing technical specifications and maintenance instructions and launching these facilities for which the contractor is responsible for producer is required for preparing these drawings by the consultant?	Q38	Whether the contractor has still problem with it?
Q19	Whether the contractor has received specifications and instructions in time from the p producer?	Q39	Has the contractor informed the owner?
Q20	Whether the consultant prepares and issues those execution drawings of facilities installation place according to the planned schedule to the contractor?		

Decisions

Code	Description	Code	Description
D1	Oral works order is not valid for the contractor. The contractor is the responsible of already performed works and can't claim.	D17	The contractor hasn't delay.
D2	The Consultant should issue the written works order according to the detailed schedule plan, otherwise owner is the responsible of delay. Of course no money is paid to the contractor due to cost increasing. (clause22,30)	D18	Contractor is delay responsible (clause30).
D3	Delay induced claim is not in the works order issuance.	D19	The owner is delay responsible and no money is paid to the contractor due to the cost increasing (clause30).
D4	The consultant has written issued works order, owner approval is necessary, owner hasn't approved the order in accordance of the detailed schedule plan and hence owner is delay responsible.	D20	Works order has correctly been assumed and from this aspect the owner has no responsibility.
D5	If the consultant engineer decides to issue the mentioned works order, without having the owner approval and obeying regular approach, the owner has still authority in accepting or rejecting the issued orders.	D21	The contractor is delay responsible.
D6	The contractor has no delay. The contractor must give 3 copies of the maintenance instructions to the consultant. (clause 22)	D22	The owner is delay responsible. The consultant should correct it in time and give it to contractor.
D7	Delay is caused in temporary delivery (clause22) for which the contractor is responsible and can't claim.	D23	All responsibilities are on the contractor. Works may not have required quality in case of reworking; the contractor will be the looser and can't claim.
D8	Contractor doesn't delay and must give 3copies of the as- built drawings to the consultant.	D24	According to the owner opinion the contractor must do the work. All works are the owner's responsibilities (clause 22).
D9	In the evaluation final payment status a disruption is created and therefore in its payment a delay is caused. The contractor can't claim at all.	D25	The owner isn't responsible and the delay in scheduling and cost increasing due to not recognizing problems is of contractor's responsibilities (clause 19, 22).
D10	Contractor is responsible.	D26	Delay causes bye the contractor. The lake of drawings in it selection doesn't reduce the contractor's commitments for complete execution of the tasks. Any kind of loss exerted to the contractor is the contractor's responsibilities (clause 22).

D11	There is no claim due to delay in preparing and issuing the drawings.	D27	The contractor approves the correctness and hence the owner has no responsibility regarding this issue
D12	Owner is delay responsible but no money is paid to the contractor because of cost increment (clause30).	D28	The owner is delay responsible. The consultant should correct it in time and give it to contractor.
D13		D29	The contractor is delays responsible and can't claim at all.
D14	The contractor is responsible for the delay.	D30	The owner isn't responsible and the delay in scheduling and cost increasing due to not recognizing problems is of contractor's responsibilities (clause 19, 22).
D15	The contractor is responsible.	D31	All responsibilities is for the contractor. Works may haven't require quality in case of reworking, the contractor will be loss and can't claim.
D16	The owner is delay responsible; no money is paid to the contractor due to the cost increment (clause30).	D32	According to the owner opinion the contractor must do the work. All works are in the owner's responsibilities (clause 22).

For coding this DSS, decision trees of each of these scopes are created which one of them is given in Figure2 and table3.

Developed DSS must be able to evaluate concurrent delays. Initial delay classification is done based on the owner, contractor and the third party's origins, then these delays are categorized based on the concurrency and finally are divided based on contract clauses, agreements or the mentioned approaches in the concurrent delays analysis. This concurrent delay is stored in the model and is used for executing delay analysis. Figure3 Shows a part of the program which is coded for the DSS module.

As shown in table1, based on the performed comparisons, the most appropriate method for delay analysis is multiple baseline update (MBU). However, this method does face certain limitation, that is, the disruptions and slowness in the execution progress is always attributed to the contractor while clearly the slowness can be due to the other parties. Therefore, slowness in the progress should be seen not only due to the contractor but also the owner and the third party. This limitation is somewhat corrected by the DSS. In the next section, through studying a case study in Easy Plan program along with DSS model, a comparison of the results will be provided

C. Delay Analysis Phase

When delays are classified based on the concurrency and the origins, results are directly sent to the delay analysis module. In this module, the user must specify and then enter the start and finish dates of the analysis. Afterward, the user enters the information of each period daily. Figure 4 shows the process of delay analysis and identification.

D. Cost Calculation Phases

This module calculates the approximate cost of delay damages. Taking contract conditions and terms into account, calculation of delays cost can be different. For example, in some contracts, owner incurs costs and excusable delays. Thus, depending on contract conditions, cost calculation is performed. According to the Iran’s general conditions in construction contracts (similar to red FIDIC book), delay costs are devoted to the following three cases:

1- Delay in land delivery.
2- Occurrence of natural disasters.
3- Suspension (work stop ordered by the owner)

For running this module, the following costs must be considered based on the assumptions and formulas defined in the general conditions of contract:

1. Initial cost of contract
2. Average work presumably done monthly which is actually the initial cost of the contract divided to the initial duration of the contract.
3. Cost of delayed activities (for calculating this delay, direct costs, i.e. overhead resources and other costs are calculated).
4. Overhead costs (including total overhead costs and those overhead costs for each day according to the days mentioned in the initial duration of the contract).
5. Costs of machinery rentals, i.e. resources.
6. Apart from the above cases, the contractor can ask for accelerating of his activities whose cost will be added on a daily basis according to the fifth clause of general conditions of contract.

V. SIMULATING THE DSS AS THE INPUT OF EASY PLAN PROGRAM

In this section, along with Easy Plan program, a designed DSS is used for revising the delay analysis method. First, a sample case is studied step-by-step without the help of decision support system. Table 4 shows eight activities, relations, estimations and resources needed for each activity. For a number of activities, two estimations have been considered, i.e. first estimation including the usual period of an activity with lower cost and the second estimation including less time with higher cost.

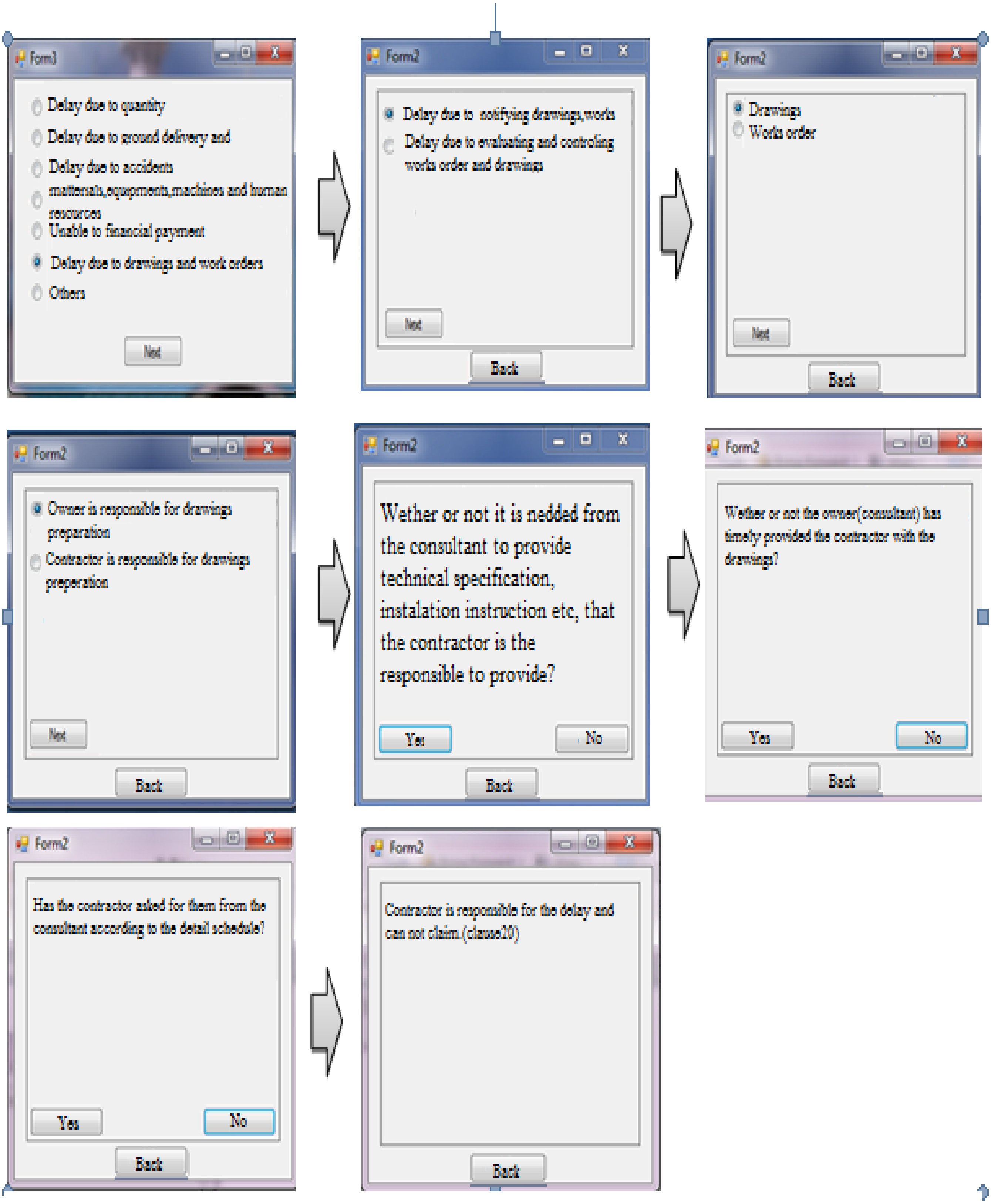

FIGURE III
A part of programmed decision support system in the scope of delays in drawings and change orders

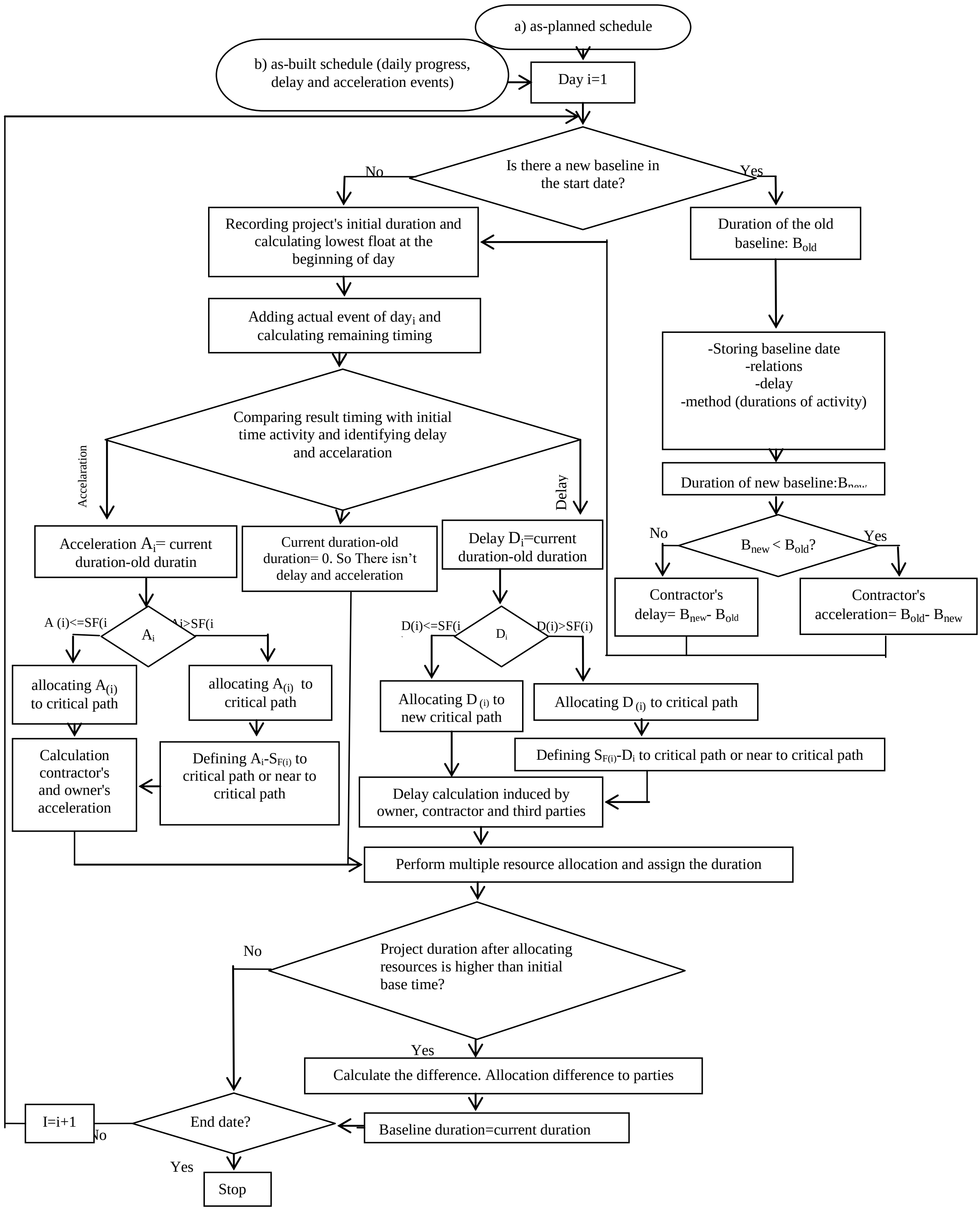

FIGURE IV
The process of delay analysis

Activities for which the second estimations are not suitable can be performed only by the use of one method.

Contractor assigned 15 days as the as-planned schedule considering the resources limitation which is confirmed by the owner, too. The resource type for all activities is considered as L1 and the maximum number of sources is considered as 6 units for each day. Table 5 shows the delay events during the execution.

In order to analyze delays through MBU, the basic information of the project is given to the program according to the tables and as shown in Figures 5 and 6.

TABLE IV
Relations between activities and resources cost

No	Activity	Predecessors	Estimation1			Estimation2		
			Cost	time	Resource	Cost	time	Resource
1	A	-	6000	2	3	-	-	-
2	B	1	6000	3	1	5000	2	1
3	C	1	6000	3	1	5000	2	1
4	D	1	6000	3	2	5000	2	2
5	E	-	6000	5	2	5000	4	2
6	F	2,3,5	6000	4	3	5000	3	3
7	G	2,3,5	6000	7	3	5000	6	3
8	H	4,6,7	6000	3	3	-	-	-

TABLE V
Delay events during the project implementation

Day	Description
2, 3 and 4	In these days, the contractor has a delay in activity A and consequently it is expected the project to be completed in 18 days. For compensating this 3-day delay, the contractor found that the best choice is that activity G to be done parallel with the activity H such that the project duration is 15 days again.
6	The owner has delayed in the start of activity D, so additional resources are expected in the future days.
9	The Contractor has delayed the start of activity G. Because, due to the limited resources, activities D and F and G cannot be performed simultaneously. So, the contractor voluntary chooses to use more expensive methods for expediting activity G by a day.
11	The owner and the contractor have caused delays in the project. The owner delayed on activity G while the contractor has delayed on activity F.
12	The contractor has delayed in the activities G and F.
14	Activity F is delayed due to the slow progress of the contractor, while the activity G stopped due to an adverse weather conditions.
16	Project has been accelerated in activity G from the owner side and the contractor accelerated activity H.

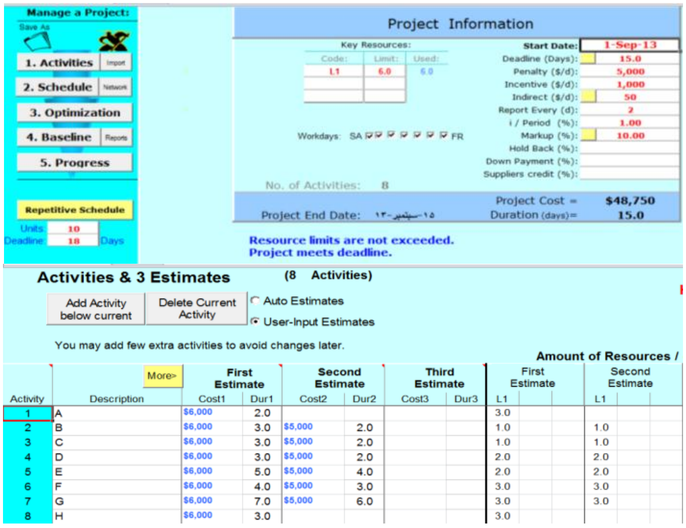

FIGURE V
Entering initial information of activities

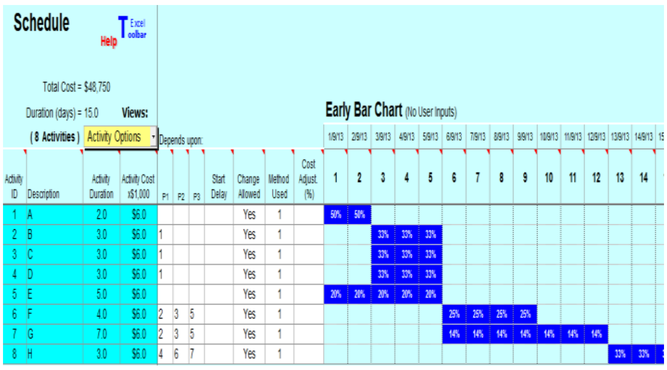

FIGURE VI
Entering time as-planed schedule of project

After entering as-planned schedule, data of the actual progress of the project is entered day by day as given in Table 5. On day 1, the progress has been exactly as programmed. As shown in table5, the contractor has delays in the activity A for days of 2, 3, and 4. Hence, project duration is 18 days instead of 15 days. While in the activity E, the progress is absolutely punctual according to the schedule. This information is also presented in Figure7. The upper bar displays the as-planned schedule of each activity, while the lower bar displays the as-built schedule of each activity.

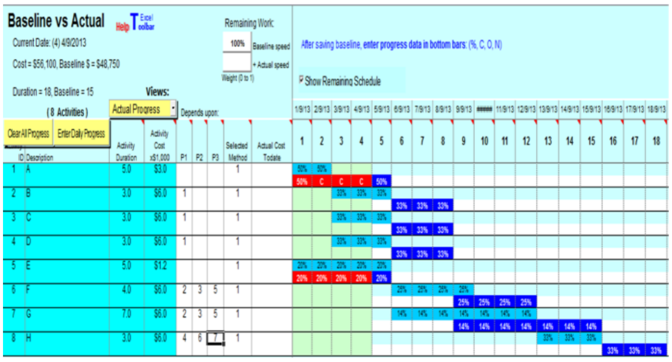

FIGURE VII
Actual progress of project till day 4

After day 4, in response to these events, contractor decides to execute the activity H parallel with the activity G and immediately after doing the activity F, activity H has been done. As a revisory act, this task expedites the project by 3 days and therefore the project could be finished on time in accordance with the plan. Since the owner and the contractor agree on this change, a new baseline is considered after changing these relations and then this second baseline is stored. Figure 8 shows this adjustment.

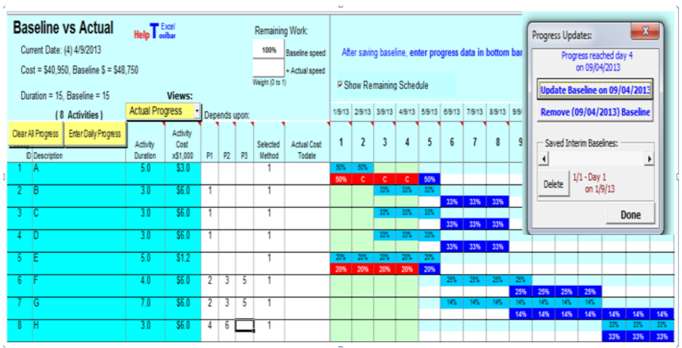

FIGURE VIII
Alteration in the relations after the day 4

On day 6, the owner has one day delay on the activity D. Although this delay has no effect on the project duration, it leads to an over-allocation of resources in day 9

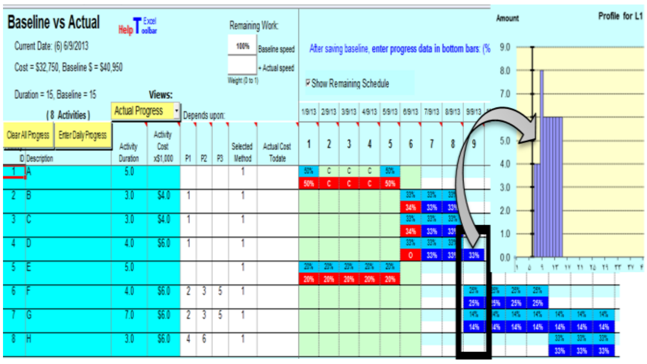

FIGURE IX
Over allocation of resources in day 9 induced by the delay of day 6

The over-allocation, caused by the owner for a delay in day 6, makes the contractor change the plan or even create delays in some activities in order to prevent limitations and over allocation of resources.

On day 9, since the resources are limited, the contractor doesn't initiate the activity G. Therefore, the project duration is 16 days. For compensating this one day delay, the contractor decides to accelerate the activity G; therefore, the total duration of the project is accelerated. By the second faster method, the duration of activity G is reduced from 7 days to 6 days and therefore, once again, the project duration becomes 15 days. This change is stored as a new baseline (third baseline) at day 9. Figure 10 and 11 show the above proceedings.

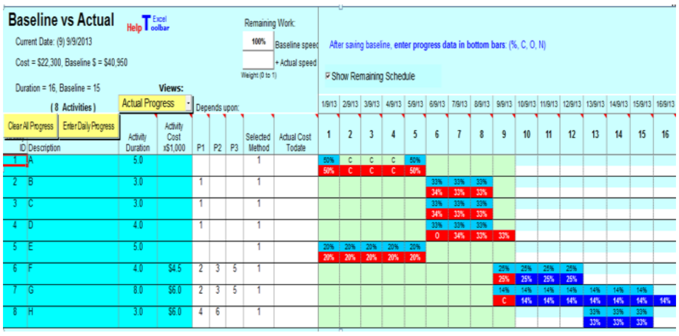

FIGURE X
Delay in ninth day induced by the contractor

FIGURE XI
Accelaration in the activity of G

Figure 12 displays the project progress until the end of the project and also the analysis results show 2 days delay and the total duration of project have been reached to 17 days.

It is worth mentioning that for the concurrent delay analysis, 50 to 50 dividing approach has been used in this program. On day 6, the owner has delayed, but the delay is not on the critical path and doesn't change the duration on that time, so the delay caused by the owner is not recorded. However, this delay will cause a resource over allocation in the future; therefore, on the 7th day, delay N is recorded (i.e. delay is not only due to the contractor but also due to the owner). N represents a time extension with no cost compensation provided for the contractor.

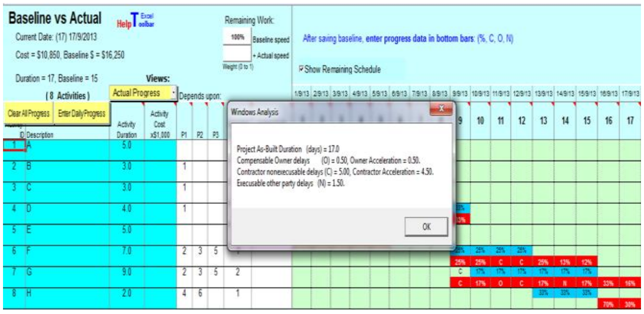

FIGURE XII
As-built schedule, complete project progress, and the results obtained from the program

Day to day analysis results are given in table 6.

TABLE VI
Results obtained from the analysis of sample case in Easy Plan program

Day	Owner- O		Contractor-C		Third party-N
2	-	-	1	-	-
3	-	-	1	-	-
4	-	-	1	-	-
5	-	-	-	3	-
7	-	-	-	-	1
10	-	-	-	1	-
11	Concurrent-0.5	-	Concurrent-0.5	-	-
12	-	-	1	-	-
14	-	-	Concurrent-0.5	-	Concurrent-0.5
16	-	Concurrent-0.5	-	Concurrent-0.5	-
Sum	0.5	0.5	5	4.5	1.5

As seen in this case and also as mentioned briefly in the previous section, in this program, the contractor is always to blame for the slowness in the execution of days 14 and 15. However, in fact, the slow progress or any kind of disruptions are not always caused by the contractor. Disruption is different from the pacing delay. In fact, disruption is a set of factors causing the slow progress in the contractor performance.

In Figure 13, the developed DSS is used as an input of this program. Yet, in each part where the daily actual progress is lower than that of planned progress, it is referred to the DSS looking for a cause for not having such compliance. In fact, it is assumed that the user has no accurate information regarding the origin of the delays. Therefore, for making decisions about the delays origin, this system is indeed referred to.

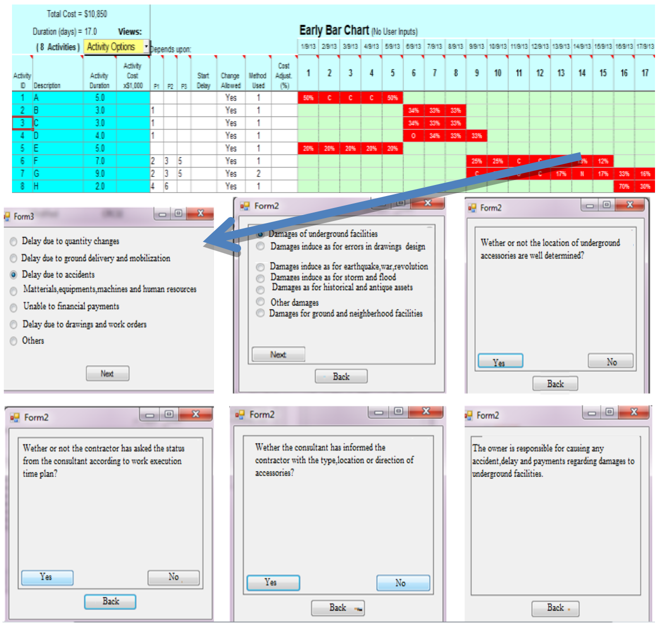

FIGURE XIII
The use of intelligent system in identifying disruption on the fourteenth day

TABLE VII
Results obtained from the corrected Easy plan program and MBU method.

Day	Owner- O		Contractor-C		Third party-N
	Delay	Acceleration	Delay	Acceleration	Delay
2	-	-	1	-	-
3	-	-	1	-	-
4	-	-	1	-	-
5	-	-	-	3	-
7	-	-	-	-	1
10	-	-	-	1	-
11	Concurrent-0.5	-	Concurrent-0.5	-	-
12	-	-	1	-	-
14	Concurrent-0.5	-	-	-	Concurrent-0.5
16	-	Concurrent-0.5	-	Concurrent-0.5	-
Sum	1	0.5	4.5	4.5	1.5

As noted above, this program always considers the contractor as responsible for the slowness in the project progress. In order to correct this, on the 14th day, it is referred to the DSS and the cause of slow progress is recorded in the program to be analyzed more accurately.

Table 7 displays the differences of the results in 14th day with the results obtained from the program without considering the origin of disruptions.

As seen in the figure 13 on 14th day, the owner has been identified as the responsible party for the delay. Since it is concurrent with the delay induced by the third party in the activity G, then it is divided as 50/50.

As seen in Table 6 and 7, delay analysis is improved through the proposed model and its partial execution;

therefore, claim management is facilitated with the help of the DSS.

VI. CONCLUSION

In each delay evaluation, technical and legal knowledge of analyst are the two main factors in the evaluation correctness. People who are involved in the project must have a comprehensive understanding about these techniques; otherwise, incorrect results are inevitable. Due to the lack of technical and legal knowledge, some experts are prevalently asked to be the delay consultant in construction companies. However, hiring these expert consultants is not only hardly affordable but also retrieving a large volume of relevant information from the project documents needs too much time and is even impossible at times. Hence, the development and use of the proposed integrated model reduces time and cost of delay analysis and provides correct analysis and delay claims along with the organization of the project data in a suitable format. In fact, this model helps construction industries and executives in identifying and classifying delays, delay analysis and the cost calculation. The required data is entered from scheduling software for identifying delay and then calls upon the DSS module for classifying delayed activities.

Clearly, this system not only creates integration among different parts and helps ease the process of proving correct and reasonable delays; it also does reduce the limitations of Easy Plan program and does a successful delay analysis based on the multiple baselines update (BMU).

As complete implementation of the proposed system is indeed costly and time consuming, it could not be studied in this section of study and only the part which contains decision support system has been implemented as an input of Easy Plan program.

REFERENCES

[1] Kao, C.K. and Yang, J. B., Comparison of windows-based delay analysis methods. *International Journal of Project Management*, 27(4), pp. 408-18, 2009.

[2] Yang J.B., Huang, K.M. and Chen, C.M., Implementing schedule delay analysis methodology on project management system. *14th International Conference on Computing in Civil and Building Engineering*. Moscow, Russia, 2012.

[3] Alkass S, Mazerolle M, Tribaldos E, Harris F., Computer aided construction delay analysis and claims preparation. *Constr Manage Econ*,13(4).pp.335–52, 1995.

[4] Parchami Jalal. M, Golabchi. M, Yousefi. E., In Press, Analysing Windows- based Delay Analysis Methods in Easy Plan Program and Offering a Framework in Selecting the Best Delay Analysis Method, *Sharif journal civil engineering*, 2016.

[5] Kim, Y. and Kim, K., Delay analysis method using delay section. *Journal of construction engineering and management*, 131(11), pp. 1155-64, 2005.

[6] Yang, J.B. and Kao, C.K., Critical path effect based delay analysis method for construction projects. *International Journal of Project Management*, 30(3), pp. 385- 97, 2012.

[7] Hegazy T. and Zhang, K., Daily windows delay analysis. *Journal of construction engineering and management*, 131(5), pp. 505-12, 2005.

[8] Hegazy T. and Menesi W., Delay analysis under multiple baseline updates. *Journal of Construction Engineering and Management*, 134(8), pp.575-82, 2008.

[9] Hegazy S., Delay analysis Methodology in UAE construction Projects. PM World Journal, 1(2), pp 1-21, 2012.

[10] Klee,L. Management of Contractor's Claims in Construction Projects. Economic section, 6(1), pp40-50.Mubarak, S. 2010. Construction project scheduling and control. Wiley, 2013.

[11] Parfitt, M. K., Syal, M. G., Khalvati, M., and Bhatia, S. Computer-integrated design drawings and construction project plans. *Journal of Construction Engineering and Management*, 119(4), pp729-742, 1993.

[12] Stair R. and Reynolds, G., *Information Systems*, Boston: Jonathan Hulbert Press, pp. 11-40, 2012.

[13] Yun, L., Wei, X., Jiong, T. and Ruijun, J., Preliminary Study of the Systematic Management of Project Claim. *IEEE Global Congress on Intelligent Systems*. pp. 572-6, 2009.

[14] Yang, J.B. and Tsai, M.K., Computerizing ICBF method for schedule delay analysis, *Journal of Construction Engineering and Management*, 137(8), pp. 583-91, 2011.

[15] Ilter D. and Dikbas, A., A review of the artificial intelligence applications in construction dispute resolution, *ITC Digital Library*, 2009.

[16] Arditi D. and Tokdemir, O.B., Using case-based reasoning to predict the outcome of construction litigation. *Computer-Aided Civil and Infrastructure Engineering*, 14, pp. 385-93, 1999.

[17] Chau, K., Application of a PSO-based neural network in analysis of outcomes of construction claims. *Automation in Construction*, 16(5), p. 642–6, 2007.

[18] Cheung, S.O., A fuzzy sets model for construction dispute evaluation. *Construction Innovation: Information, Process, Management*, 1(2), pp. 117-27.

[19] Hafez, Sh. and Nasr, I., Simple delay analysis methodologies selection advisor for construction practioners. *International Journal of Education and Research*, 1(8), pp. 1-8, 2013,

[20] Kraiem, Z.M., Dagli, D. and Diekmann, J., DISCON: an expert system for the analysis of differing site conditions claims. *Knowledge-Based Systems*, 2(3), pp. 159-163, 1989.

[21] Abdelkhalek, H. and Arrashid, A., Expert system for claims of ground water and soil conditions. *Alexandria Engineering Journal*, 43(6), pp. 821-35, 2004.

[22] Kumaraswamy, M.M., Nadarajah, R., Palaneeswaran, E. and Rahman, M. Dealing with delays in evaluating extensions of time. *17th Annual ARCOM Conference*, University of Salford, England, 2001.

[23] E. Palaneeswaran and M. Kumaraswamy, "An integrated decision support system for dealing with time extension entitlements," *Automation in Construction*, Vol. 17, p. 425–438, 2008.

[24] Chaphalkar N.B. and Smita, K., Decision support system for dispute resolution in construction contracts. *KSCE Journal of Civil Engineering*, 16(4), pp. 499-504, 2012.

[25] Dayi, S., Schedule delay analysis in construction project, *PhD thesis*, Middle East of technical university, pp. 14-17, 2010.

[26] Menesi, W., Construction delay analysis under multiple baseline updates", *PhD thesis*, University of Waterloo, Waterloo, Canada, 2007,

[27] Iran's general conditions in construction contracts, *Magazine 4311*, *Vice presidency for strategic planning and supervision*, pp3-53, 1999,

[28] Hegazy, T., Easy plan project management system, Available at: *http://www.civil.uwaterloo.ca/tarek/Easy Plan.html*, 2007.

[29] Iyer.k. c, Chaphalkar. N.B, Joshi. G.A, Understanding time delay disputes in construction contracts, *International Journal of Project Management*, 26.pp.174-184, 2008.