Simulating time performance indexes by Earned Duration Management

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Abstract: despite the high development of project management software and methods, more deviation is observed between the actual performance of many projects and their schedule. Such deviations not only results in high cost but also cause stakeholders' distrust and lack of their investment on the next projects. Such deviations can result from lack of attention to environmental conditions and possibilities in project planning and make a definitive plan only at the beginning of work and of course lack of a criteria to review the project plan before starting working. The present study by taking advantage of Monte Carlo simulation model is seeking to enter the uncertainties in project schedule. In addition, this simulation provides a basis for creating duration performance indicators before starting working, the indicators also provide a suitable model to evaluate project plan and assess the need to review the project.

[Farnoosh Khaledian, Akbar Alam Tabriz. **Simulating time performance indexes by Earned Duration Management.** *Stem Cell* 2016;7(2):72-82]. ISSN: 1945-4570 (print); ISSN: 1945-4732 (online). http://www.sciencepub.net/stem. 13. doi:10.7537/marsscj07021613.

Keywords: Project management, Monte Carlo simulation, Earned Duration Management

1.0 Introduction

Construction and operation of the projects is one of the factors affecting growth and development of the country. Hence, project's proper planning is of more importance. Project management regardless of the project management knowledge dates back to at least 4500 years ago. The creators of the Maya pyramids and temples are the first director of the project (Sabzeparvar, 2010) Integrated and accurate control of a project depends on timely access to relevant and accurate information about the project (Alamtabriz and Rahimi, 2011). Managers who do not have the right information about the status of the project will face with many problems. Therefore, a systematic process for collecting information is necessary. So over the years many methods, procedures and software are emerged for better, more accurate and more detailed control of the project. But the question that arises is that why, despite the development of methods still we faced with problems such as lack of programs compliance with the actual performance of the project. One of the things that can be pointed to it; is the definitive project plan, only on beginning, regardless of the possibilities and of course without any real vision about the future of project. In addition, the lack of criteria for assessing the accuracy of the plan before starting work can be considered another factor to the problem. Such programs not only are not a guide to managers, but in some cases cause their confusion and concern.

1.1 Problem statement

Considering the high volume of projects under construction and their utilization and the beneficiaries' special attention to the cost and the time spent to do projects, project management is an issue which receives more academic and empirical attention. One of the important objectives of the project management team is that they be able to complete the project according to predetermined plan and budget and covers the entire range (Savoji and Kheirkh, 2008). At this point it should be noted; if the plan don; has a logical base and be in trouble; project team efforts even before starting working will fail. This paper tries using employed methods brought program closer to reality. To do this we make use of mentioned project expert's opinion to Monte Carlo simulation. Simulation causes that a project before start, done several times from beginning to end. This gives broader view to project managers on both project planning and its control. In this study, data obtained from Monte Carlo simulations are used to estimate project duration performance indicators; these indicators are useful because each project is unique and there is no pre-implemented example to compare. Thus project duration performance indicators achieved through simulation can be used as a pre-implemented example that guide managers and act as a warning signal. Also, such indicators show the accuracy of the program during simulation and will be a benchmark for reviewing programs. The questions raised in this study include:

1-How to gather and use expert opinions?
2- How to simulate project?
3- How to estimate project duration indicators and the end of project?
4- What is the concept of each of the project duration indicators?

1.3 The importance of issue

So far, more research has been done on predicting the project duration and cost through different methods. But in many of these researches, environmental conditions are not considered to express duration and final budget, and the final amount will be announced with confidence. This means that the probability and uncertainty in estimating duration and cost is necessary. It should be noted wrong scheduling and prolong the project cause additional costs. So in this research, simulation is used to account these possibilities, such that when managers face with project risk will not surprise; but when face with low efficiency in project performance measurement indicators such as project scheduling indicators , that in this research special attention is pay on them, will be able to solve the problems. It should be noted, not violating planning and budget announced to beneficiaries cause their more trust and they will even invest in future projects.

1.4 Research goals

1.4.1 The main objective

- Project duration performance indicators simulator using earned duration method

1.4.2 Secondary objectives

- Project simulator
- assess the status of projects through earned duration method
- predict project end time

2.0 MATERIALS AND METHODS

2.1 Monte Carlo simulation

Nowadays the use of a variety of simulation methods in the field of science has become popular. Among the various methods of simulation, Monte Carlo method for financial and economic research and analysis is more appropriate than other approaches (Salami, 2004). The uncertainty and risk, is a phenomenon that today is considered as one element of project management. Decision making in risky situations requires predict future. Monte Carlo simulation project management knowledge has been introduced as one of the quantitative risk analysis methods (Shahbaznia and Taleghani, 2012). In this method we can model phenomenon with two specified (project activities) and random (duration and cost of activities) components. In random component some features such as probability distribution, mean and variance and confidence interval are introduced. Then the designed model is used to calculate forecasts. The simulation tries to provide condition to create behavior similar to actual behavior of random component and predict can be calculate with degree of certainty and on the other hand with its risk degree (PMBOK, 2008). In Monte Carlo simulation method instead of considering the average duration of each activity on calculation we assume that the project is running, so any activity will be done in a certain duration in [a, b] interval. This definitive duration for each activity is produce using the reverse interval [a, b] related to that activity (Sabzeparvar, 2010). This definitive duration is considered as duration of each activity and route calculations ahead and after is done identically to CPM algorithm. This activity is done in large number and at the end the results will are collected and evaluated. Because that the numbers produced on the interval [a, b] of each activity are random, thus at each time the activities duration will be different from the previous case. In other word, if the process is repeated hundreds of times, is like that the project has done hundreds of times and every time because that the activity duration is different from the previous activities, the project critical path and end time will be different from before.

Monte Carlo simulation algorithm

Step1: duration cumulative distribution function histogram is drawn for each activity

Step2: for each simulation, a random number is produced for each activity as duration of that activity considering its histogram (if the project has n activity, so n random number must be done for each simulation)

Step3: generated random durations are considered as definite duration of the activity and CPM calculations are done, project total duration also is specified by activities located on the critical path.

Step4: Repeat steps 2 and 3 to N time and results are collected in an appropriate table (Sabzeparvar, 2010).

The question that must be answered here is that "how much simulation repetition is enough?"

This will depend on the potential use of the information.

When the main purpose of analysis is to estimate the time to same time thus less repetition is needed, but if the accuracy of distribution of results is very important, more repetition is required (Taheri and Alborzi, 2000).

2.2Earned Duration Management and time performance indexes

In this method two dimension of project, time and schedule, are decoupled. Actually, this method is measured in two, micro and macro, level which are defined in progress (Khamooshi and Golafshani, 2014):

A. Focus on the micro level

- Base Line Planned Duration of scheduled activity$_i$ (BPD_i), is the authorized duration assigned to the scheduled work to be accomplished for activity$_i$. BPDi is independent of the status date.
- Planned Duration of scheduled activity$_i$ (PD_i): at any point in time, is the authorized duration assigned to the Scheduled work to be accomplished for activity$_i$. This variable for EDM method is the duration counterpart or equivalent to PV of an activityin EVM.
- Activity Progress Index, for activityi (API_i) :at any point in time, measures the progress of activity.

1 $$API_i=AD_i/(AD_i+EDTC_i)$$

EDTC represents the estimated time to complete the activity program. It should be noted (API_i) measures the program progress of an activity and is always less or equal to one. Its value starts from 0 and when becomes closer to the final completion gets closer to one.

- Earned Duration of scheduled activityi (ED_i): at any point in time, is the value of work performed expressed as proportion of the approved duration assigned to that work for activityi. This variable for EDM is the duration counterpart or equivalent to EV of an activity in EVM.

2 $$ED_i=BPD_i \times API_i$$

- Actual Duration of scheduled activityi (AD_i): This variable represents the time between actual start duration of activity to any point of time that the activity continues, at calendar unit.

B. Focus on macro level

- Baseline Planned Duration (BPD): is the approved duration assigned to the scheduled work to be achieved for the whole project independent of the status date.
- Total Planned Duration (TPD):

3 $$TPD= \sum_{i=1}^{n} PD_i$$

N is the number of ongoing and completed activates on a point of time where TPD is measured.

- Total Earned Duration (TED):

4 $$TED= \sum_{i=1}^{n} ED_i$$

N is the number of ongoing and completed activates on a point of time where TPD is measured.

- Earned Duration (ED (t)): for the project, at any point in time, is the duration corresponding to Total Earned Duration (TED) on Total Planned Duration S-curve, which mathematically could be expressed as:

T is found such that:

5 $$TED= \sum_{i=1}^{n} ED_i$$

$$TED<TPD_{(t+1)(\text{calendar unit})}$$

$$ED_{(t)}=t+\left(\frac{(TED-TPD_{(t)})}{TPD_{(t+1)(\text{calendar unit})}-TPD_t}\right)\times 1(\text{calendar unit})$$

- Total Actual Duration (TAD):

6 $$TAD= \sum_{i=1}^{n} AD_i$$

N is equal to the number of ongoing and completed activities up to desired time.

C. Performance measures of time and cost progress at the micro level

- Duration Performance Index, for activityi (DPIi): it shows how well the project is doing in achieving the target completion date

7 $$DPI_i=ED_i/AD_i$$

If DPI_i be greater than one this indicates that the performance is better than the program.

If DPI_i be smaller than one this indicates that the performance is lower than the program

And if DPI_i be equal to one this indicates that the performance is in accordance with the program.

If this index be measured during the complementation of an activity indicates how was the overall performance to achieve an activity in reality compared with that activity plan. On the other hand, the end value of DPI for each activity indicates the accuracy of the original duration estimate.

- Earned Duration Index, for activity$_i$ (EDIi): at any point in time, is a measure of duration earned compared to what was planned to be done up to that point in time

8 $$EDI_i=ED_i/PD_i$$

At any point in time, one activity has been done more or less or in accordance with plan, so this index will be larger, smaller or equal to one, respectively.

D. Measuring performance and progress of time and cost at the macro level

- Project Duration Performance Index (DPI): it shows how well the project is doing in achieving the target completion date in consideration of the critical path

9 $$DPI= ED_{(t)}/AD$$

If DPI be greater than one it means that the project is ahead of plan.

If DPI be smaller than one it means that the project is behind plan.

If DPI be equal to one it means that the project is running as plan.

- Project Earned Duration Index (EDI): at any point in time, is a duration-based measure of overall work performed in

terms of Earned Duration, in comparison with the work planned up to that point in time.

10 EDI= TED/TPD

The value of EDI can be greater than 1 or equal to 1 or less than one 1.

It should be noted, always the scheduled time has not 100 per cent confidence level, and sometime some deviation in the index DEI will be accepted. In certain projects, during estimating time and costs higher confidence level and lower risk of latency will be accepted. This is different in probable projects (such as research, engineering and development); such projects are estimated to have less confidence level and expected performance deviations exist (Khamooshi and Cioffi, 2012).

2.3 Research method and tools for data collection

This research in terms of objective is an applied developmental research and in terms of nature is an analytic descriptive study. To collect information through meetings with experts of the project a questionnaire was used. MSP, Pertmaster software was used for data processing and Excel is used for reporting information. General framework and research process is shown in Figure 1:

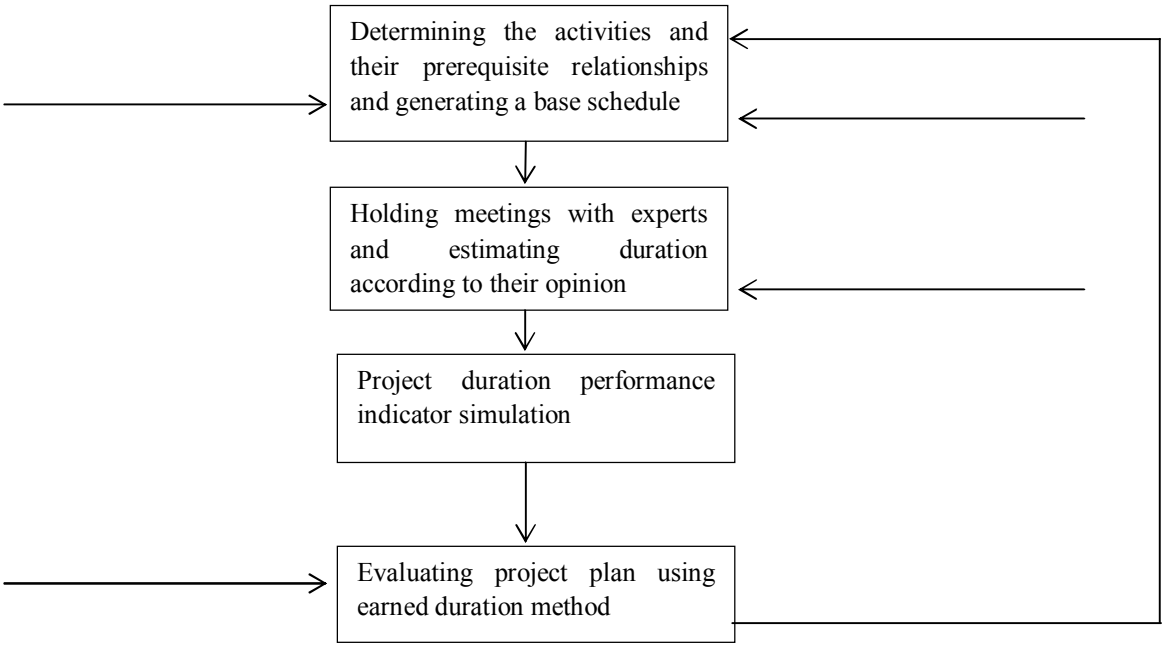


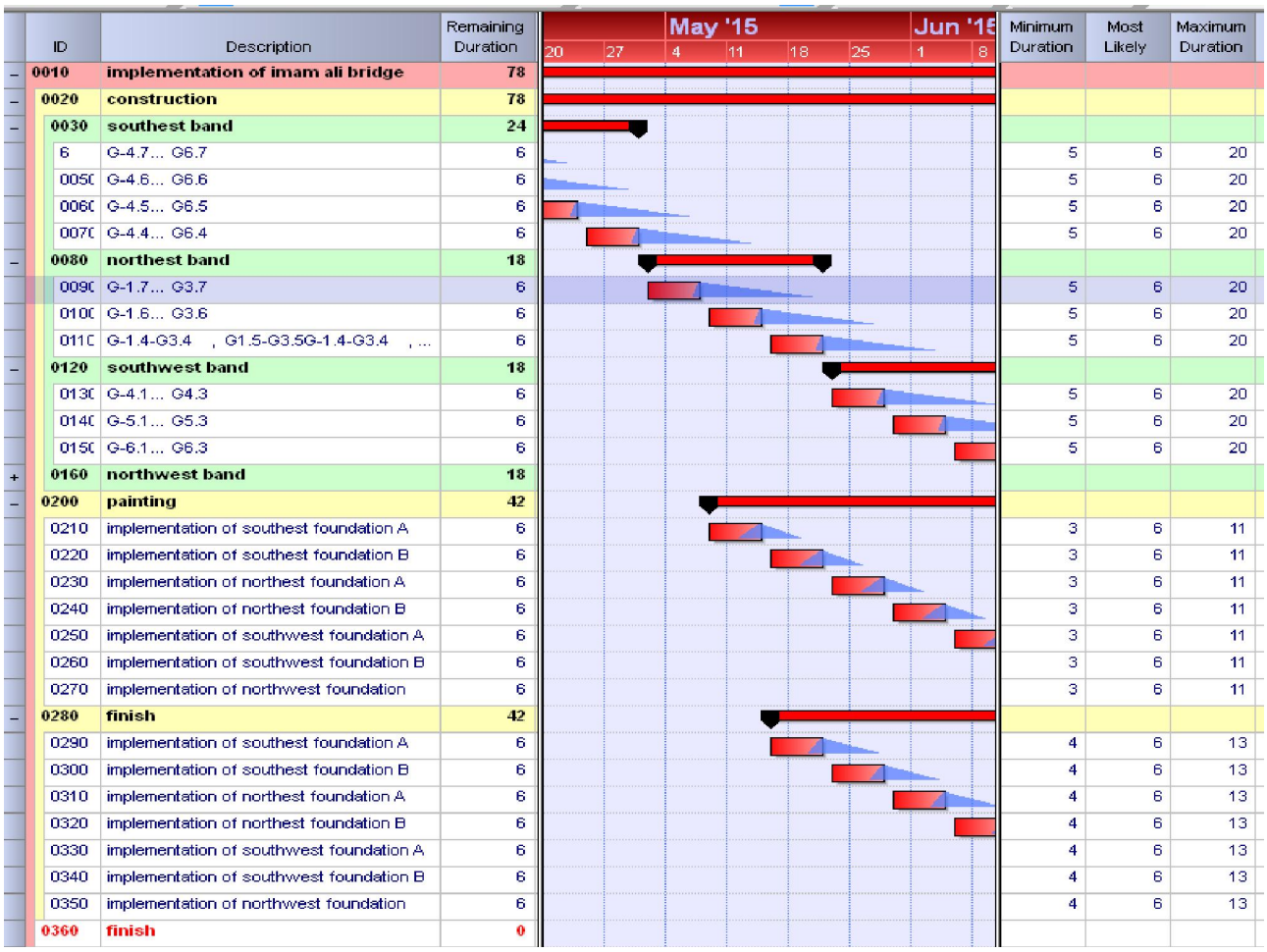
Fig 1: general framework and general process of research

2.4 Project introduction and schedule base plan

The schedule of studied project in this research is related to a vehicle bridge construction. Mentioned bridge has only a central column, and according to base schedule it should be completed over 27 activities, it should be said that each of such activities according to schedule must be completed during 6 working days, and the whole project should be finished within 78 working days.

3.0 Research findings

The experts' opinions about the most likely and the most pessimistic and most optimistic duration on implementing project activities were collected through questionnaires. The average confirmed duration as Monte Carlo simulation input was entered into Pertmaster software. Figure 2 depicts a part of the project plan.



ID	Description	Remaining Duration	Minimum Duration	Most Likely	Maximum Duration
0010	implementation of imam ali bridge	78			
0020	construction	78			
0030	southest band	24			
6	G-4.7... G6.7	6	5	6	20
005(	G-4.6... G6.6	6	5	6	20
006(	G-4.5... G6.5	6	5	6	20
007(	G-4.4... G6.4	6	5	6	20
0080	northest band	18			
009(	G-1.7... G3.7	6	5	6	20
010(	G-1.6... G3.6	6	5	6	20
011(	G-1.4-G3.4 , G1.5-G3.5G-1.4-G3.4 , ...	6	5	6	20
0120	southwest band	18			
013(	G-4.1... G4.3	6	5	6	20
014(	G-5.1... G5.3	6	5	6	20
015(	G-6.1... G6.3	6	5	6	20
0160	northwest band	18			
0200	painting	42			
0210	implementation of southest foundation A	6	3	6	11
0220	implementation of southest foundation B	6	3	6	11
0230	implementation of northest foundation A	6	3	6	11
0240	implementation of northest foundation B	6	3	6	11
0250	implementation of southwest foundation A	6	3	6	11
0260	implementation of southwest foundation B	6	3	6	11
0270	implementation of northwest foundation	6	3	6	11
0280	finish	42			
0290	implementation of southest foundation A	6	4	6	13
0300	implementation of southest foundation B	6	4	6	13
0310	implementation of northest foundation A	6	4	6	13
0320	implementation of northest foundation B	6	4	6	13
0330	implementation of southwest foundation A	6	4	6	13
0340	implementation of southwest foundation B	6	4	6	13
0350	implementation of northwest foundation	6	4	6	13
0360	finish	0			

Fig2: project base plan and possible duration

The project is simulated 1000 times; it seems that the project is done under different conditions and with different possibilities. It should be noted that the changes in time intervals has been applied to the project based on a triangular distribution.

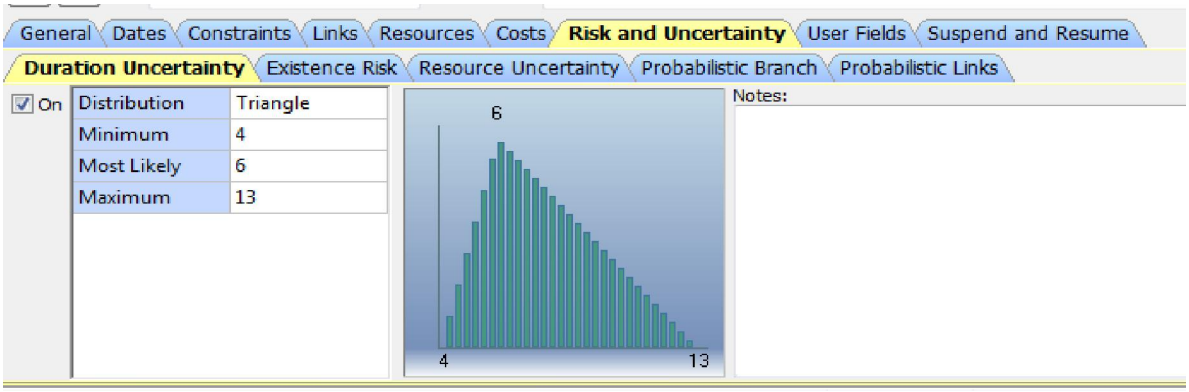


Fig3: the status of activity duration in a triangular distribution

Finally, after simulation, start time and end time and duration of each project's activities and in particular whole project have been achieved as simulation outputs.

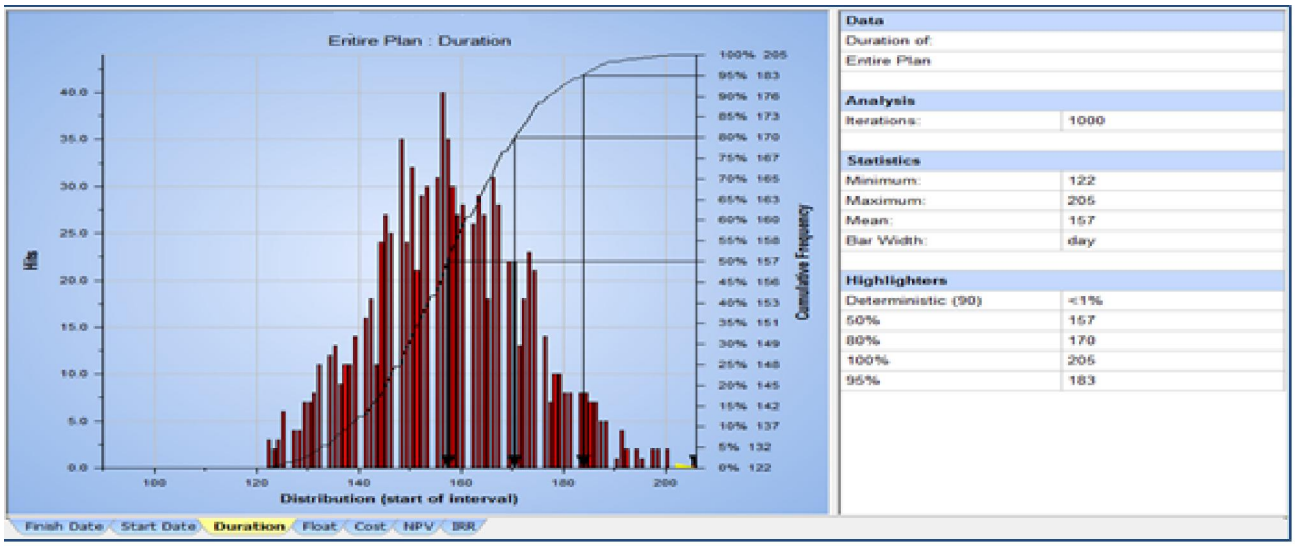


Figure 4: status of project duration simulation on Pertmaster software

Output of software is provided with different confidence percentages; for the present research the confidence level is 50 percent. Then, in order to achieve duration performance indicators, it is assumed that the stimulated project has been happened in reality; so from the first day EDM approach was used to reporting then the values of two Micro and Macro levels were calculated. In Figure 5, the DEI and DPI of activities level is listed:

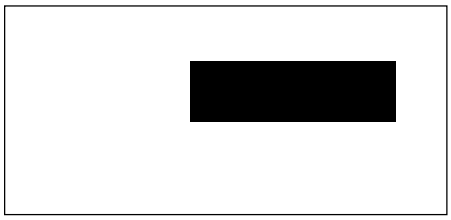
Task Mode	فعالیت	Baseline Duration	simulated duration	DPI	DEI
	G-4.7... G6.7	6 days	10 days	0.6	0.6
	G-4.6... G6.6	6 days	10 days	0.6	0.6
	G-4.5... G6.5	6 days	10 days	0.6	0.6
	G-4.4... G6.4	6 days	10 days	0.6	0.6
	G-1.7... G3.7	6 days	10 days	0.6	0.6
	G-1.6... G3.6	6 days	10 days	0.6	0.6
	G-1.4-G3.4 , G1.5-G3.5	6 days	10 days	0.6	0.6
	G-4.1... G4.3	6 days	10 days	0.6	0.6
	G-5.1... G5.3	6 days	10 days	0.6	0.6
	G-6.1... G6.3	6 days	10 days	0.6	0.6
	G-1.1... G1.3	6 days	10 days	0.6	0.6
	G-2.1... G2.3	6 days	10 days	0.6	0.6
	G-3.1... G3.3	6 days	10 days	0.6	0.6
	implementation of southest foundation A	6 days	7 days	0.86	0.86
	implementation of southest foundation B	6 days	7 days	0.86	0.86
	implementation of northest foundation A	6 days	7 days	0.86	0.86
	implementation of northest foundation B	6 days	7 days	0.86	0.86
	implementation of southwest foundation	6 days	7 days	0.86	0.86
	implementation of southwest foundation	6 days	7 days	0.86	0.86
	implementation of northwest foundation	6 days	7 days	0.86	0.86
	implementation of southest foundation A	6 days	8 days	0.75	0.75
	implementation of southest foundation B	6 days	8 days	0.75	0.75
	implementation of northest foundation A	6 days	8 days	0.75	0.75
	implementation of northest foundation B	6 days	8 days	0.75	0.75
	implementation of southwest foundation	6 days	8 days	0.75	0.75
	implementation of southwest foundation	6 days	8 days	0.75	0.75
	implementation of northwest foundation	6 days	8 days	0.75	0.75

Fig5: the activities level on simulated project

Activities level was calculated, then, project level was also assessed. It should be noted, when speaking about project level (Macro), this does not mean that the project should be examined on its last day, but from the first day of its inception the project can be evaluated and measured. In this section to avoid prolixity, in order to show the performed calculation on macro level real calculation percentages (here simulated) {10،20،30،40،50،60،70،80،90،100} are used.

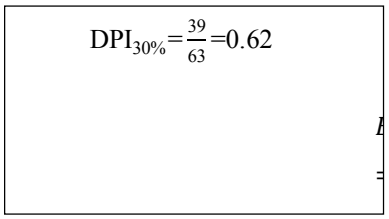
Table 1: status of project level in simulated project

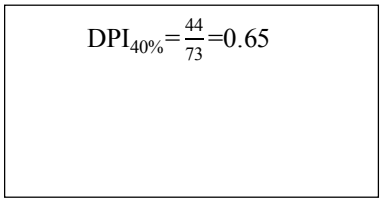
PC	TAD	TPD	TED	Date
0.00	1	1	0.6	1
0.01	2	2	1.2	2
0.01	3	3	1.8	3
0.01	4	4	2.4	4
0.02	5	5	3	5
0.02	6	6	3.6	6
0.03	7	7	4.2	7
0.03	8	8	4.8	8
0.03	9	9	5.4	9
0.04	10	10	6	10
0.04	11	11	6.6	11
0.04	12	12	7.2	12
0.05	13	13	7.8	13
0.05	14	14	8.4	14
0.06	15	15	9	15
0.06	16	16	9.6	16
0.06	17	17	10.2	17
0.07	18	18	10.8	18
0.07	19	19	11.4	19
0.07	20	20	12	20
0.08	21	21	12.6	21
0.08	22	22	13.2	22
0.09	23	23	13.8	23
0.09	24	24	14.4	24



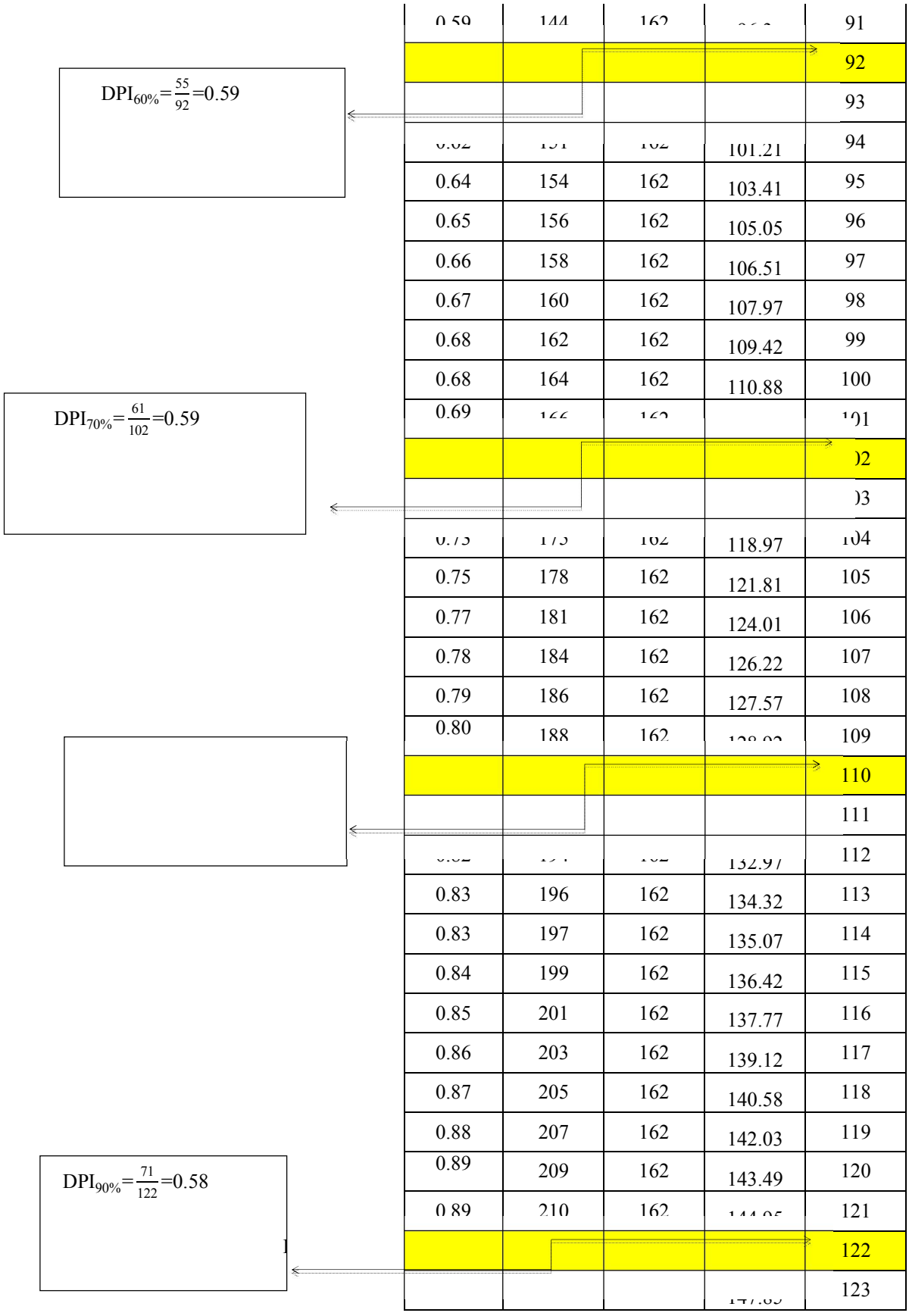
0.09	25	25	15	25
0.10	26	26	15.6	26
0.11	30	30	18	30
0.11	31	32	18.6	31
0.12	32	34	19.2	32
0.12	33	36	19.8	33
0.13	34	38	20.4	34
0.13	35	40	21	35
0.13	36	42	21.6	36
0.14	37	45	22.2	37
0.14	38	48	22.8	38
0.14	39	51	23.4	39
0.15	40	54	24	40
0.15	40	57	24	41
0.15	41	60	24.6	42
0.16	42	63	25.2	43
0.16	43	66	25.8	44
0.16	44	69	26.4	45
0.17	45	72	27	46
0.17	46	75	27.6	47
0.17	47	78	28.2	48
0.18	48	81	28.8	49
0.18	49	84	29.4	50
0.19	50	87	30	51
0.19	52	90	31.46	52
				53
				54
0.22	58	99	35.83	55
0.23	60	102	37.92	56
0.24	62	105	38.74	57

$DPI_{20\%}=\frac{32}{53}=0.6$

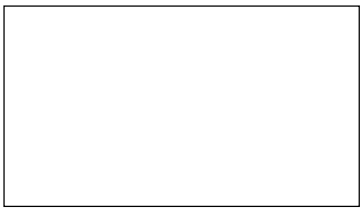




0.25	64	108	40.2	58
0.26	67	111	42.41	59
0.28	70	114	44.61	60
0.28	73	117	45.32	61
0.29	76	120	47.53	62
				63
				64
				65
0.34	87	132	55.5	66
0.35	89	135	56.85	67
0.36	91	138	58.2	68
0.37	93	141	59.55	69
0.38	95	144	60.9	70
0.38	97	147	62.25	71
0.39	98	150	63	72
				73
				74
				75
0.43	108	158	70.33	76
0.44	110	160	71.79	77
0.45	112	162	73.24	78
0.46	114	162	74.7	79
0.47	117	162	76.91	80
0.49	120	162	79.11	81
				82
				83
				84
0.54	131	162	87.34	85
0.55	134	162	89.55	86
0.56	136	162	90.9	87
0.57	138	162	92.25	88
0.58	140	162	93.6	89
0.59	142	162	94.95	90



0.59	144	162		91
				92
				93
			101.21	94
0.64	154	162	103.41	95
0.65	156	162	105.05	96
0.66	158	162	106.51	97
0.67	160	162	107.97	98
0.68	162	162	109.42	99
0.68	164	162	110.88	100
0.69				101
				02
				03
			118.97	104
0.75	178	162	121.81	105
0.77	181	162	124.01	106
0.78	184	162	126.22	107
0.79	186	162	127.57	108
0.80	188	162		109
				110
				111
			132.97	112
0.83	196	162	134.32	113
0.83	197	162	135.07	114
0.84	199	162	136.42	115
0.85	201	162	137.77	116
0.86	203	162	139.12	117
0.87	205	162	140.58	118
0.88	207	162	142.03	119
0.89	209	162	143.49	120
0.89	210	162		121
				122
				123



0.92	216	162	149.31	124
0.93	217	162	149.91	125
0.93	218	162	150.51	126
0.94	220	162	151.86	127
0.95	222	162	153.21	128
0.95	224	162	154.56	129
0.96	226	162	155.91	130
0.97	228	162	157.26	131
0.98	230	162	158.61	132
0.99	232	162	159.61	133
1.00	234	162	162	134

As you can see, two raised indicators on all activities and in all percentages of the project, it shows a significantly amount less than one, which means that the simulation is behind the project schedule. Due to the significant difference the necessity to review the project plan is clearly evident. In addition, it is suggested that, along with the project schedule, the simulated project schedule and its final duration according to software, be announced to stakeholders.

Conclusion

In this article, Monte Carlo simulations were used for more consistency of the schedule with the real performance of the project in the future; according to the mentioned simulation that was conducted by experts' opinion and of course, calculated indicators of earned duration method, that according to these indicators that simulated project being behind base reflects the weakness of the program, it is proposed that, in addition to announcement of base plan to stakeholders, the stimulated project scheduled plan and of course earned duration management indicators also along with predicted duration by software be presented for them. Besides that, duration indicators whether in activity level or project level can act as error signal and guide the mentioned project managers.

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6/9/2016