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Development of Construction Planning Strategies for Coastal Project using Monte Carlo Simulation

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Abstract:- In Turkey it is obvious that due to the risk of damage and uncertainties inherent in the construction of harbor projects that there is a substantial overrun in the project targets. So, it is very hard to find one of coastal construction projects which is completed within the determined time and budget as compared to classical construction projects on land. Therefore. The main purpose of this study is trying to achieve the project objectives on time and budget, by applying the Monte Carlo simulation (MCS) concept to the activities in the critical path that introduced from classical construction network that based on critical path method and to the costs of breakwater, quays, and boatyard. In the MCS model, the completion time and cost of activities are modeled as random variables by using normal probability distribution which is fitted statistically from akin projects carried out in Turkey, to represent the effects of total uncertainty that resulted from the design stage and the construction stage of harbor structures. In this study also, another important objective is to help decision maker to managing risks in a coastal construction projects by using practical techniques of risk management that dealing with risks and uncertainties which inherent in a coastal construction project. The suggested approach MCS and the risk management framework are applied to the construction operation of Arsin fishery harbor. Finally, the results of the analysis of this study are presented with discussion of risk response strategies by selecting one or more appropriate strategies from alternative strategies of risk management.

***Keywords**:- Construction Strategies, Coastal Projects, Scheduling, Network Planning, Cost Simulation, CPM, MCS, Risk Analysis, Breakwaters.*

I. INTRODUCTION

A coastal project can be defined as a unique collection of multiple work tasks that are interrelated through a technological structure and sequence in order to provide protection from the impacts of sea [1]. A coastal construction projects in the first side is considered as alike for the other construction projects, that involves similar activities and involves work packages fundamental to accomplishment of structures. On the other side, a coastal construction projects are considered not similar for the other construction projects that executed in the land, where it is uncertainties and risk that inherent in a coastal construction projects are much more than the other construction projects.

Generally, the success of construction projects management depends on estimating duration and costs of the project. So, in construction projects, project management is defined as a series of actions embodied in the process of reaching the project schedule, cost, and performance objectives [2]. But, in fact it's very difficult to see a construction projects especially, a coastal construction projects are completed within preliminary time and cost estimates; due to uncertainties and risk that inherent in construction projects. This leads to project risk management concept. Risk management process is defined as a techniques and tools that help the construction project management team to identify the sources of the risk and uncertainty in the project, after that responding for these risks. Different frameworks for a risk management process in construction projects are proposed by writers and researchers. In any way and according to many writers and researchers in essence, risk management process is concerned with four important parts: identifying risk, classifying risk, analyzing risk, and responding to risk, such as given in figure 1.

Fig 1: - Risk management process

The main purpose from risk management strategies consider the ability to absorb the risk and the incentives being offered to carry it. So, the strategies of response option to project risks and uncertainties must be differs from one project to another upon the environment that surrounds the project. For instance, when we execute the project in the sea as harbor differs when we execute the project in the land. so, the researchers are recommended alternative risk management strategies which give better control and reduce the impact of risks. Virtually all writers and consultants on risk suggest, many basic forms to response for risk. In 1990 Al Bahar and Crandall develop alternative strategies to response for risk that include Risk avoidance, loss reduction and risk prevention, Risk retention, Risk transfer (noninsurance or contractual), and Insurance [3].

When attempting to determine or optimizes time and cost for any construction projects, whatever it be the project in the land or in the sea, it is necessary to timetable all the activities that make up the task, that is to say, a plan must be prepared. One of the attempts a formal planning system is network planning system. Network planning can be defined as a project management tool used for coordination and organization of activity groups in order to achieve project's objectives such as time and cost. Depending on the project requirements several network planning can be used in construction project management such as, the Program Evaluation and Review Technique (PERT), the Modified

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Program Evaluation and Review Technique (MPERT), the Critical Path Method (CPM), Monte Carlo Simulation Method, and etc. These techniques have different characteristics, for example, CPM is deterministic method, assumes that the activity durations are fixed, and has one critical path; so, CPM can be used in well-defined project which have relatively small uncertainties and one dominant organization. whereas, PERT is a probabilistic method, estimates the activity duration as based on probability and may be introduce more than one of critical path. So, the PERT is used in projects which have multiple and overlapping responsibilities of the organizations involved, and a large degree of time and cost uncertainties. The Monte Carlo Simulation Model is considered as a leading tool for quantitively risk analysis that can be defined as a tool to treat uncertainty explicitly. This mean MCS is probability simulation used to understand the impact of risk and uncertainty in project management that effect on a project objective such as time and cost. So, MCS, generally is used as a valuable tool when forecasting an unknown future.

II. STATEMENT OF THE PROBLEM

The main problem in the construction of a coastal projects such as a harbor projects, which are considered the most common type of a coastal projects, are the clear overruns in time and cost of the projects; due to the risks and the uncertainties in the design and construction phases. For example, in Turkey when we follow the construction of harbor projects, it is very hard and it’s almost impossible to see a coastal project which is completed within the preliminary time and cost estimates. confirm that you have the correct template for your paper size.

From the above we conclude that, in order to achieve the project’s objectives on the expected time and on estimated budget, the accurate planning of construction including the risk factors must be performed. This mean that in the planning stage reliable risk assessment studies must be performed.

III. SCOPE OF THE PROJECT

The main scope of this project is to help contractors and clients to obtain more accurate estimates of the project's duration and budget, and to optimize the construction works of coastal structure by considering risk factors during the construction phase, through applying the Monte Carlo Principle which are performed both for the network planning based on project management and the reliability based on risk assessment. And also, another important objective is to help decision maker to managing risks in a coastal construction projects, by using practical techniques of risk management that dealing with risks and uncertainties which inherent in a coastal construction project.

IV. METHODOLOGY

Coastal projects are multi-functional projects with high construction costs. It may be possible to complete these projects in due time and budget. Due to the fact that coastal construction projects interact with complex natural conditions starting from the very first stage, risk elements should be investigated and analyzed for these projects prior to making network planning, time and cost estimates. In this context, the new construction strategies are applied on Arsin Fishing Port.

In order to attain the purpose of this study, the layout plan and sections of the project were received from the General Directorate of Railways, Harbors and Airports Construction operating under the Turkish Ministry of Transport, Maritime Affairs and Communication. The bill of quantities concerning the structure was obtained from a relevant company. The selected project consists of Arsin Fishing Port's sections of main breakwater, secondary breakwater, docks, lighthouses, electricity and water installations. MS Project software was used to make the network planning. The unit price analyses for the year 2014, obtained from the data-base of the Turkish Ministry of Transport, Maritime Affairs and Communications, were used for budget analysis. The Monte Carlo method was applied to analyze the risks and uncertainties that would disrupt the completion of this project in due time and budget.

The methods and general steps of this study are as follows:

A. Collection, identification and processing of data.

B. Development of network planning.

The network planning includes the following:

- Development of the work breakdown structure.
- Finding work quantities.
- Calculation of work efficiency.
- Calculation of the activity’s duration.
- Identifying the relationships among the activities.
- Application of the MS project software.
- Network diagram.
- Determination of the critical path based on the CPM Network and calculation of the project completion time under normal conditions.

C. Calculation of the most optimistic, most likely and most pessimistic times of the critical path and for all activities on the critical path.

- Most optimistic time (a): This is the shortest possible time to complete an activity in an ideal environment and when all things go well. The probability of completing the activity in less than (a) is about 1%.
- Most likely time (m): İs the estimated average time required to complete the activity and this the completion time we would expect under normal conditions.
- Most pessimistic time (b): This is the longest time to complete an activity when all things go badly and if most delay reasons will occur. The probability of taking longer than (b) is about 1%.

The estimations for the most optimistic and pessimistic times for the completion of activities arise from historical data and experience.

D. Calculation of the expected (average) completion time "μ (t) " and the standard deviation "σ (t)" by applying the Simple Average Methods.

Simple average is considered as a form of 3-point estimation technique and also called the triangular distribution, the advantage of the triangular distribution is that, the mean and the standard deviation in this distribution are given exactly in terms of three-Point estimation technique. i.e. there are no errors in the mean and the standard deviation expressions of triangular distribution. The activity's expected duration (Mean) and the activity's standard deviation can be calculated from these three values by the following formulas:

- *Expected time (Mean):*

$$\mu(t) = \frac{a + m + b}{3} \quad (1)$$

- *Standard Deviation:*

$$\sigma(t) = \sqrt[2]{\frac{(b-a)^2 + (m-a) + (m-b)}{18}} \quad (2)$$

E. Budget analysis.

The first estimate of the total cost of project is calculated by using 2014-unit prices according to Railways, Seaports and Airfields Construction General Directorate of Transportation Ministry.

F. Identification of the risks and uncertainties for coastal projects in Turkey and the parameters to be used in the simulation.

Statistical assessment is made for the data obtained from previous experiences and from similar projects carried out in Turkey and such data are prepared for use in simulation. The most appropriate value representing the mass consisting of different values and random variables, is determined. These values are the coefficients of variation for coastal activities "Šv'e".

The coefficient of variation is the standard deviation and the mean value ratio and is a dimensional measure. For example; in order to make the risk analysis for cost, the ratio of difference between the initial costs and early estimates was used for the 15 harbor projects carried out in Turkey between 1977-1988 as shown in table 2. Likewise, deviations in the estimated completion times, project time deviation factor, the ratio of deviation to the estimated completion time and the difference between the actual completion time and estimated completion time, were used for the 11-harbor construction and repair projects carried out in Turkey between 1987-1995 as shown in table 3.

G. Adjustment of probability distribution.

The aim is to fit these Xi values that represent every cost item or time item by a probability distribution in order to form a model. For our analysis, we are going to use Crystal Ball that has features which substantially simplifies the process of selecting a probability distribution and the results more accurately by estimated the parameters for the distribution were selected it. in this thesis we are going to fitted the available data to continuous distributions by a normal distribution. The most commonly used probability distribution in quantity risk analysis for construction project management by network planning is the normal distribution.

The normal distribution is the most important distribution in probability theory allows future uncertainty to be expressed by a number, so that the uncertainty of different events may be directly compared.

- A continuous random variable X has a normal distribution if for some μ and σ. The random variable has the following density function:

$$f(x) = \frac{1}{\sigma(2\pi)^{1/2}} \exp[-\frac{(x-\mu)^2}{2\sigma^2}] \quad (3)$$

H. Application of the Monte Carlo simulation.

We will discuss this step-in detail in the following sections.

I. Risk assessment.

We will discuss this step-in detail in the following sections.

➢ *TIME AND Cost Estimating with Uncertainty*

The primary objective during the construction process is completing the project on time and within the budget while meeting the established quality requirements and other specifications [4]. However, due to uncertainties inherent in construction activities of coastal structure as the risk of damage that the famous in coastal construction projects, duration and cost of a project is subject to increase.

The description of risks and risk sources associated with coastal construction projects in Turkey are examined by analyzing 11 harbor construction projects executed in Turkey between the years 1987 and 1995 as in table 1. According to table 1. it can be stated that, the deviations generally originate from the following main sources: funding problems, project revision, and site conditions.

These sources of uncertainties in harbor projects that executed in Turkey causes overrun of cost for projects and delay of completion project time as presented in table 2. and III respectively. Table 2. indicate the ratio of different between the first estimates and the realized values of the cost items for 15 harbor that executed in Turkey between the years 1977-1988. Table 3. indicate the deviations in expected completion time estimates of 11 harbor construction and repairment projects executed in Turkey between 1987-1995.

- In this table also, the bias factor of project duration is determined as the ratio of deviation to completion time estimate as:

$$ve = \frac{\Delta\mu}{\mu i} \quad (4)$$

Where, "Δμ": Deviations of the expected completion time estimates from the actual accomplishment time of coastal activities, that equal Δμ = μa- μi

"μa, μi": Estimate and actual accomplishment time of coastal activities.

As given in table 4., also for the quarry stone layer construction activities the bias factors are given in table 4. in percent. Bias factors (ν_e) that given in table 4. are rationalized by using quantities of quarry stones used in construction. Hence, unit bias factors (ν'_e) are obtained for the completion time estimates of each rubble mound construction activity having a unit of (10^-5 /tons) is given in table 5. and can be determined as:

$$ve = v'e * Q \quad (5)$$

where, Q: is the amount of quarry stone.

- The main values of unit bias factors (μ've) and standard deviation (σ've) is given in table 5. and by using (μ've) and (σ've) can be calculated variation coefficients (Šv'e) as below:

$$\check{S}v'e = \frac{\sigma've}{\mu've} \quad (6)$$

The inherent variabilities in the construction activities of harbor construction projects are specified by bias factor (v'e) and variation coefficients (Šv'e).

- The total variation coefficient also we can be obtained for linear functions of statistically independent random variables regardless of their distributions as:

$$\check{S}t = \sqrt{\check{S}e^2 + \check{S}x^2} \quad (7)$$

Št: Total coefficient of variation which indicates the uncertainties originating from the execution of construction activities, and from the risk factors and uncertainties evaluated at the design phase.

Šx: Coefficient of variation which denotes the risk of damage during the construction stage and uncertainties at the design phase.

Še: Coefficient of variation which signifies the uncertainties that exist in execution of construction activities in Turkey.

- After that, we can calculate the total standard deviation from below equation:

$$\sigma(t) = \check{S}t * m \quad (8)$$

V. MONTE CARLO PRINCIPLE

Monte Carlo simulation, a leading tool for quantitative risk analysis that can be defined as a tool to treat uncertainty explicitly. İn this tool, all variable factors are modelled as probability distributions, not as single, known values. Monte Carlo simulation, is a probability simulation used to understand the impact of risk and uncertainty in project management that effect on project objectives such as cost, time. Generally, Monte Carlo simulation can be a valuable tool when forecasting an unknown future.

The Monte Carlo simulation process proceeds through a number of stages as described in more detail below and in figure 2.

The basic steps of Monte Carlo simulation process are:

1. Assess the range for the variables being considered and determine the probability distribution most suited to that variable.

2. Select a value for each variable within its specified range; this value should be randomly chosen and must take account of the probability distribution for the occurrence of the variable. This is usually achieved by generating the cumulative frequency curve for the variable and choosing a value from a random number table.

3. Run a deterministic analysis using the combination of values selected for each one of the variables.

4. Repeat a number of times to obtain the probability distribution of the result. The number of iterations required depends on the number of variables and the degree of confidence required, but typically lies between 1000 and 10000 [5].

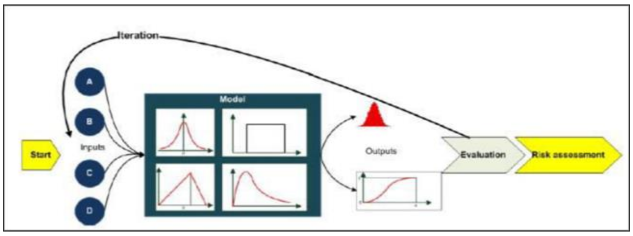

Fig 2: - Monte Carlo simulation process [6].

Source	Explication	%
Funding problems	Insufficient budget allocations to projects	29,80
Project revisions	Modifications in Project scope or WBS, amendments in works	21,60
Site conditions	Weather and sea conditions	18,90
Quarry problems	Quarry efficiency problems	5,40
	Access to quarry	5,40
Official and regulatory agencies	Bureaucratic detainment and legal constrains	5,40
Structural damage	Damage during construction	5,40
Machinery and equipment	Acquisition, maintenance and renovation	2,70
Project organization	Organization problems and Corporation conflicts with companies involved	2,70
Logistic	Site location and access	2,70

Table 1. Dıstrıbutıon of major detainment sources categorıes in harbor projects executed in turkey [1].

	Main Breakwater				Secondary Breakwater			Quay		
	(0-0.4) Ton	(0.4-2) Ton	(2-6) Ton	(6-10) Ton	(0-0.4) Ton	(0.4-2) Ton	(2-6) Ton	(0-0.4) Ton	(0-0.250) Ton	(50-200) Kg
Project A	1.123	1.7756	1.5444	4.9429	1.6846	1.7851	1.344	1.3617	0.370083	0.89153
Project B	0.7645	0.693	1.1718	0	0.4158	0.506	1.2711	1.6674	1.659211	1.48588
Project C	0.7391	2.0137	2.4883	2.1067	1.5347	1.2392	1.9984	0.524	0.386182	0.6
Project D	0.6412	0.9666	1.2842	0	0.4852	0.7827	0	0.8547	0.700147	0.05315
Project E	1.0647	1.2315	1.06	1.4645	1.8967	1.5552	1.7704	3.3312	0.329938	0.60827
Project F	0.9803	1.1614	1.2511	1.1863	1.4704	1.1677	1.0888	1.153	1.714875	0.49457
Project G	1.432	0.3252	0.8115	1.2188	1.483	0.8732	0.817	0.5192	1.978268	3.97577
Project H	1.5236	1.6226	1.6041	1.3695	0.8099	2.995	1.011	5.1155	2.144	3.82468
Project I	1.9636	1.8721	1.5229	1.0785	13.283	1.2833	1.9599	0.4779	0.617284	0.61728
Project J	1.5373	2.2098	2.2083	0	1.949	1.9581	1.751	0.57	0.596788	0.86602
Project K	1.1209	3.2638	2.2485	0	1.6813	3.2814	1.9568	0.2114	1.229513	0.16008
Project L	1.3159	0.7972	1.12	0	0	0	0	2.8389	2.300821	2.10681
Project M	1.5495	1.5336	1.4622	0	0	0	0	1.41	1.410139	1.41
Project N	0.8537	1.0853	1.0315	0	0	0	0	2.2533	0	0
Project O	1.5883	1.8677	1.8748	1.7683	0	0	0	0	0	0

Table 2. The ratio of different between the first estimates and the realized values of the cost items for 15 harbor that executed in turkey between the years 1977-1988 [7].

Project Name	Expected completion time "μi "	Real completion time "μa"	Deviation "Δμ"	Bias Factor "ve"
Fıstıklı	600	1650	1050	1.75
Ünye	800	2280	1480	1.85
Yakakent	650	1857	1207	1.8569231
Çatalzeytin-	1000	2165	1165	1.165
Çayeli	600	1265	665	1.1083333
Pazar-Kirazl	550	997	447	0.8127273
Doğanyurt	400	1307	907	2.2675
Antalya	730	1150	420	0.5753425
Samandağ	600	850	250	0.4166667
Kurucaşile	700	1045	345	0.4928571
Enez	600	1443	843	1.405

Table 3. The deviations in expected completion time estimates of 11 harbor construction and repairment projects executed in turkiye between 1987-1995 [1].

	Stone Categories (Ton)						
Project Name	*(0-0.4) Ton*	*(0.4-2) Ton*	*(2-6) Ton*	*(6-10) Ton*	*(10-15) Ton*	*(6-15) Ton*	*Block*
Fıstıklı	2.05	1.88	1.88	*	*	*	
Ünye	2.32	2.17	2.13	2.17	0.3	*	
Yakakent	2.76	1.83	1.83	2	2	*	
Çatalzeytin-G	3.38	3.21	3.29	3.29	2.93	*	
Çayeli	1.5	2	2	3.2	1.15	*	
Pazar-Kirazlık	0.99	1.67	1.67	1.67	1	*	
Doğanyurt	3.5	0.86	2.56	2.83	4	*	
Antalya	*	0.2	0.5	*	*	*	
Samandağ	1.6	1.17	0.56	*	*	*	
Kurucaşile	*	*	*	*	*	0.55	-0.15
Enez	0	0	0	1.35	*	*	
"μ_{ve} "	2.0111	1.499	1.64	2.36	1.9	0.55	-0.15
"σ_{ve} "	1.13	0.96	1.01	0.76	1.37	*	*

Table 4. Bias factors (ve) for the completion time estimates of rubble mound construction activities (in percent) [1].

	Stone Categories (Ton)						
Project Name	*(0-0.4) Ton*	*(0.4-2) Ton*	*(2-6) Ton*	*(6-10) Ton*	*(10-15) Ton*	*(6-15) Ton*	*Block*
Fıstıklı	2.16	7.31	4.44	*	*	*	
Ünye	1.21	4.67	1.73	1.93	1.73	*	
Yakakent	2.6	3.27	2.12	2.44	6.67	*	
Çatalzeytin-G	3.05	5.01	5.09	6.74	10.17	*	
Çayeli	10.76	57.14	44.44	5	28.75	*	
Pazar-Kirazlık	15.48	38.08	18.83	15.5	9.28	*	
Doğanyurt	4.67	8.6	6.42	11.18	57.14	*	
Antalya	*	1.63	3.76	*	*	*	
Samandağ	1.45	1.67	0.92	*	*	*	
Kurucaşile	*	*	*	*	*	0.31	-3.25
Enez	0	0	0	22.25	*	*	
"μ'_{ve} "	4.6	12.74	8.78	9.29	18.96	0.31	-3.25
"σ'_{ve} "	5.14	19.1	13.62	20.84	20.84	*	*

Table 5. Unit bias factors (v'e) for the completion time estimates of rubble mound construction activities (in 10-5 / tons) [1].

Stone categories (tons)	Mean values of (μ've) (10^-5/ton)	Standard deviation of (σ've) (10^-5/ton)	Coefficient of variation (Šv'e) %
(0-0.25)	4.6	5.14	111.74
(0-0.4)	4.6	5.14	111.74
K.A.T.	4.6	5.14	111.74
(0.4-2)	12.74	19.1	150
(2-4)	8.78	13.62	155.13
(4-6)	9.29	7.48	80.52

Table 6. Unit bias factors for the completion time estimates of rubble mound construction activities (in 10-5 / tons) for arsin fishery harbor.

VI. APPLICATION

Arsin Fishing Port is planned to be built in the coastal filling area within the boundaries of Fatih District in Arsin Town of Trabzon Province. This project is carried out by the General Directorate of Railways, Harbors and Airports Construction operating under the Turkish Ministry of Transport, Maritime Affairs and Communication. The intended capacity of the fishing port is 80 fishing boats. It is planned to have a 485-meter-long main breakwater and 165-meter-long secondary breakwater. Three piers: 70-meter-long and (-5 meter)-deep, 40-meter- long and (-3) meter-deep; 40-meter-long and (-3) meter-deep. There is a 210-meter-long boatyard. Electricity and water installations are available. There are also two lighthouses at the fishing port. The total project area is 90,000 m2.

A. Completion time estimation by using the Monte Carlo simulation.

- *Work breakdown structure*

The main breakwater of Arsin Fishing Port consists of 6 distinctive sections. Likewise, the secondary breakwater consists of 4 distinctive sections. Likewise, the piers consist of 2 distinctive sections. Likewise, the boatyard consists of 2 distinctive sections. The sub-activities of the work packages for the construction of the breakwaters are done according to the method that used in construction.

- *Calculation the Work Hours for activities*

Total amount of each activity is divided by the daily amount of work to find the time needed for the completion of such work. For example; if a total amount of 213101.96 tons of rocks with a daily average of 4000 tons, is needed for rock filling with (0-0.4) tons of rocks, the time required is, (213101.96/4000) = 53.3 days. The same operation is applied on each activity's item to find the time required for their completion.

- *Networking and Identification of the Critical Path*

Following the establishment of the work breakdown structure, identification of the activities, determination of the work amounts, calculation of the work efficiencies and identification of the orders and relations among the activities, CPM-based MS Project 2016 could be used to establish the network (work schedule). There are some issues that should be kept in mind prior to the start of the establishment of the network (work schedule). Site delivery date, that is, work start date is February 28, 2014. According to the project schedule, non-working days are specified between January 01 – March 15 every year. Considering that there will be 5 working days per week and a work-day will consist of 8 working hours a week, Saturday and Sunday are defined as holidays. It was decided not to work on official holidays. It was estimated that, with continuous work starting from February 28, 2014, the project would have been completed in 534 days, on the 11th of August, 2016 at 18:00.

Activities with zero total float (TF = 0) were selected in network diagram (CPM) to determine the current critical path of the work schedule.

- *Calculation of Durations for activities that find on the Critical Paths with Uncertainties and Damage Risks*

The following calculations are made in order to be able to include the risks and uncertainty factors in the project, to assess the duration of project in terms of statistics, to use the Monte Carlo simulation where probability distributions are assessed and to find out the standard deviation and mean values of certain data required for analysis:

1. Total amount of each activity is divided by the daily amount of work to find the time needed for the completion of such activity.
2. When a damage occurs in the section, the completion time of the armor layer cannot be less than the first estimate (t_1) of the expected completion time. So, the total amount each activity is divided by the daily amount of such activity to obtain the most optimistic time estimate as value (a), i.e. $t_1 = a$.
3. The main reason for delay in the completion time of the harbor construction project, is the additional time required for the maintenance works in case of damage. The designers predict 5% damage during the construction period of the breakwaters. Therefore, it is essential to know the level of damage during the construction period of the breakwaters. Taking the level of damage at the armor layer as DL = 5%, the ultimate repair time (Δt) of the damage is assessed by calculating the time required for the change of the most damaged stage. Then, considering the final repair time, the second estimate of the time required for the replacement of the damaged section could be calculated as, $t_2 = t_1 + \Delta t$.
4. If the highest level of damage under normal conditions and at construction stage, is considered as DL = 5%, then the most likely time estimate (m) is obtained, i.e. $t_2 = m$.
5. The sources of uncertainties in harbor projects carried out in Turkey are shown in Table 1. as distribution percentages. It presents the deviations in the estimated completion times of the 11-harbor construction and repair projects carried out in Turkey between 1987-1995, as shown in Table 3. The ratio of the difference between the estimated completion time and the actual completion time is called as the bias factor. And it was calculated with equation 4. Table 4. presents the mean (μ_{ve}) and standard deviation (σ_{ve}) values for each rock category. Using equation 5, the bias (ν'_e) factors with unit for each rock category, are calculated and (μ'_{ve}) and (σ'_{ve}) values available in Table 5. From table 5 we can determined (μ'_{ve}) and (σ'_{ve}) values for Arsin fishery port and by using Equation 6, coefficients of variation (Šν'e) are obtained for each stone category, as shown in Table 6.
6. As the coefficients of variation (Šν'e) and the most likely time estimate, i.e., the mean value (m) are known and by using equation 8, it is possible to calculate the individual standard deviation (σ) values of the critical path and the activities on such critical path.
7. Consequently, the most pessimistic time (b) value is obtained by adding 4σ to the most likely time estimate.
8. As it was rather difficult to estimate the absolute limits of the optimistic and pessimistic estimates of activity times depending on past data, optimistic and pessimistic time estimates of all activities were calculated, accepting, in the optimistic estimate that each activity would have been completed 30% earlier than expected, and accepting, in the pessimistic estimate that, each activity would have been completed 40% later than expected.
9. Following the above steps, a, m and b values are calculated for each activity. As a, m and b values are known, it is possible to calculate the parameters to be used for the Monte Carlo analysis based on the three-point estimation technique by using the simple average method as given in equation 1 and 2.

- *Simülasyon*

Activities carried out for Arsin Fishery Port were; establishment of the project work breakdown structure, identification of the activities, determination of the work amounts, calculation of the work efficiencies and identification of the orders and relations among the activities, networking (work schedule) by using CPM-based MS Project 2016, determination of the critical path and the critical activities on such critical path, making time estimations under normal conditions, then using the list of a, m, b values and statistical parameters to determine the mean values as the values to be simulated and then, these were entered into the analysis software. Then, the schedule can be estimated using normal distribution and the aid of MCS. The resulting report with 15000 iterations is given in table 7. and table 8.

B. Monte carlo simülasyonu yardımı ile maliyet riskler değerlendirmesi

In this study, the cost data for Arsin Fishery Port were determined based on the bill of quantities concerning the structure, using the unit price analysis results received from the Turkish Ministry of Transport, Maritime Affairs and Communication. The unit prices for the year 2014 were taken as basis and the bill of quantities was stated. The total project cost consists of the sum of the costs of the 92 activities. Accordingly, the total project cost is 9,048,697.69 TRY.

This analysis is based on the difference between the costs at the tender stage and at the end of the project. As shown in Table 2., the ratio of change between the costs at the tender stage and at the end of the 15 projects carried out in Turkey between 1977-1988, was used to find out the data required for analysis, such as the standard deviation and mean values. For practical reasons, 17 cost elements were selected to perform the simulation.

The list of statistical parameters was used to determine the mean values as the values to be simulated and these were entered into the analysis software. Then, normal distribution was used to make cost estimation with the aid of MCS. The resulting report with 15000 iterations is given in Tables 9 and 10.

Statistics	Value
Trials	15,000
Basic condition	534.00
Mean	775.33
Median	775.64
Standard deviation	48.21
Variance	2,324.50
Skewness	-0.0247
Kurtosis	2.99
Coeff. Of variability	0.0622
Range Minimum	563.55
Range Maximum	959.49
Range Width	395.94
Mean Std. Error	0.39

Table 7. Statistical results of completion time simulation.

Percentile	Expected duration
0%	563.55
10%	713.30
20%	734.60
30%	749.77
40%	763.24
50%	775.64
60%	787.92
70%	801.09
80%	816.47
90%	836.82
100%	959.49

Table 8. Percentile values of the completion time simulation.

Statistics	Value
Trials	15,000
Basic condition	1,554,345.41
Mean	1,939,384.11
Median	1,940,644.90
Standard deviation	106,117.48
Variance	11,260,919,731.20
Skewness	-8.8543E-04
Kurtosis	2.97
Coeff. Of variability	0.0547
Range Minimum	1,513,820.57
Range Maksimum	2,329,148.31
Range Width	815,327.74
Mean Std. Error	866.45

Table 9. Statistical results of the total cost simulation.

Percentile	Expected duration
0%	1,513,820.57
10%	1,801,791.47
20%	1,850,082.23
30%	1,883,794.99
40%	1,913,109.17
50%	1,940,617.21
60%	1,966,673.64
70%	1,994,923.68
80%	2,027,743.80
90%	2,074,973.77
100%	2,329,148.31

Table 10. Percentile values of the total cost simulation.

VII. DISCUSSION OF RESULTS

A. Discussion of construction period results

A case study in this thesis is carried out for Arsin Fishery harbor construction project as an application. The construction duration of a coastal construction project is estimated by using the Network Planning-based CPM, and by applying the Monte Carlo Simulation to critical path in the generally employed construction network. To include uncertainties which inherent in the construction phase in network, the activities of the network modelled by Three-Point Estimation Technique, which are determined by using past experiences obtained from previously projects in Turkey.

The results of the study which were obtained based on two different methods, reveal out a significant difference in terms of the project completion time. As is shown in this study; whereas the project completion time is 534 days according to the Critical Path Method (CPM), it is 775 days according to the MCS. The reason for this variation is that, these techniques have different properties. For example, the CPM is a deterministic method assuming that activity times are fixed and there is one critical path. For this reason, the number of uncertainties is relatively small in the CPM. In the Monte Carlo Simulation Model, it is a key tool for the quantitative risk analysis and can be defined as a tool explicitly eliminating the uncertainty. This means a simulation of probability that is used to understand the impacts of uncertainty and risk in project management, which

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affect MCS's project goals, such as time and cost. So, MCS is often used as a valuable tool in estimating an unknown future.

B. Discussion of cost results

A case study in this thesis is carried out for the total cost of quarry stone in Arsin harbor construction project as an application. The construction cost of a coastal construction project is estimated by using the 2014-unit prices, and by applying the Monte Carlo Simulation to total the cost of quarry stone. To include uncertainties which inherent in the construction phase in cost estimating, the past experiences obtained from previously projects in Turkey are used, which are based on the difference between the estimated and realized costs of 15 harbor's projects.

The mean value of the distribution by using Monte Carlo Simulation is 1,939,384.11 $ and standard deviation is 106,117.48 $. At the same time, the estimated cost was 1,554,345.411 $. This means that we can expect an average increase of 24.8 % in the total cost of quarry stone. The median of the distribution is 1,940,644.90 $, which means that this value will be exceeded by 50% probability.

C. Discussion on the Risk Categories

As indicated in table 5.1 which refer to each risk category that inherent in coastal construction projects in Turkey. These combined risks make the coastal construction projects suffer from the problem of delay in the duration and the overrun cost of the project. At the beginning of the project the availability of data is always few; so, it is difficult to say that this risk category is responsible from delay in duration or overrun of cost in project without other categories, but we can take an idea about the relative importance of each risk category. In Turkey, according to table 5.1 the value of the financial and economic risks is 29.8% as a greatest percentage of the risks that cause the deviations, the second greatest percentage are the design risks (project revisions) with value of 21.6% and this risk what interests us and the place of study as engineers, the third greatest percentage are the risk that related site condition (Extreme Events), and other risks as Quarry problems, official and regulatory agencies, structural damage, machinery and equipment, project organization, and logistics risks as auxiliary detainment sources, which may concurrently develop with main sources.

If we examine the risks and uncertainties that inherent in construction projects in general and in harbor construction projects in particular, we will find that these risks and uncertainties are considered as a result or because of each other. So, the risks and uncertainties are interrelated with each other's, this mean that these risks are considered as a series, i.e. that the occurrence of any kind of kinds of risks may lead to the other related kind of risk.

Depending on proposed plans and cross-section the first cost estimates are no longer valid. So, it's very important to performance the project revisions in coastal projects to make the contractor able to prepare a comparative cost estimate. In other word, the estimations after project revisions mean that the design risks are almost eliminated and the expected deviation in project's objectives from this estimate would not be as much as before.

VIII. CONCLUSION AND RECOMMENDATION

The main scope of this thesis is to help the contractors and clients make more accurate estimations of project times and budget and to optimize the coastal construction works, using the Monte Carlo principle for network planning based on project management and for reliability based on risk assessment, considering the risk factors at the construction stage. It also aims to help the decision maker in the management of the risks of coastal projects, using the practical risk management techniques related to the risks and uncertainties faced in coastal projects.

In this study; for the estimations of the completion times concerning the construction works of the rock category and the total project cost for Arsin Shipping Port Project, project management based on the Critical Path Method (CPM) and the Unit Price, and risk analyses based on the Monte Carlo principle, were carried out.

Doubtfulness and uneasiness in the design and the risk of damage of harbor structures during the construction stage can be included in the estimating of cost and schedule by using three-time estimate method, historical data, past experience and Monte Carlo principle. In the Monte Carlo simulation model, the completion time and cost of activities are modeled as random variables by using normal probability distribution which is fitted statistically from akin projects carried out in Turkey, to represent the effects of total uncertainty that resulted from the design stage and the execution of construction stage of harbor structures.

To calculate the total cost and the expected completion date involving uncertainty, it was suggested to use the Simple Average Method instead of the Weighted Average Method (PERT Formula) based on the three-point estimation technique. This is because the Simple Average Method is based on the Triangular Distribution and any beta error that might appear in the mean and standard deviation values, can be avoided when the triangular distribution is used.

In coastal projects to avoid overrun in time and cost the risk of damage must be reduce to the minimum during construction stage the and to reduce the risk of damage the construction must be implemented section by section before the stormy season starts, the section must be completed by crashing of activities, and the armor stone layers must be placed as soon as possible the placement of sublayers, since the armor layer is important layer for stability against damaging of sublayers and core layer.

The main target of construction of main breakwater is protect the harbor against the wave and current action during heavy weather period. So, the main breakwater will face the highest risk of failure and damage and must be interested in this part in construction stage as the most important element in harbor. For example, if the main breakwater is constructed without placing the armor layer, we cannot control in the risk of damage and will increases significantly. So, we can say that if the probability of the risk of damage is high, say > 5% the breakwater must be construct in calm season of the year. Otherwise if this risk is low, say < 5% the construction of breakwater can continue throughout the year even in the unfavorable season.

When harbor structures are considered, the importance of planning based on risk analysis that based on probability analysis by means of MCS shows clearly in the application chapter and as shown table 8 and 10, that illustrate the difference in results between these two alternative, for example, with the suggested approach, the probability of damage during the construction can be included side by side with the sources of uncertainties that inherent in coastal construction projects, subsequently, the performance of the project can estimated more accurately better than the traditional approaches that ignoring the assumptions about risk and uncertainty.

It is very important to having a good schedule and cost estimate but it's impossible with traditional methods, especially, when harbor structure is considered, because this kind of project include the same risks that inherent in construction projects which implemented in the land and more variety of risks that related with being project at sea environment, this lead us to risk management concept based on historical data and past experience. Risk management, is considered as a vital tool to give very satisfying results and have many benefits by giving more detailed perceptions of risk and their interactions over life cycle of project, so it does achieve better design and planning by selection of response to those risks to avoid or minimize overruns in project's targets and help the decision maker to take better decision making on right time. So, as a result, it is recommended that clients and contractors to cooperate to use risk management system that enable to achieve risk identification, analysis and response a systematic way by choosing one of alternative strategies to response for the risks such as Risk avoidance, loss reduction and risk prevention, Risk retention, Risk transfer (noninsurance or contractual), and Insurance.

In scheduling, this study is carried out for almost a whole Arsin harbor construction project, but in cost estimations, this study is carried out for the total cost of quarry stone used in breakwaters, yard boats and guays, since lack of historic data about other elements of harbor, so future studies must include a whole coastal construction project to determine effects and reactions of each risk category according to special project environment at the same time, propose new policies to face risks and avoid or minimize overruns in cost and time.

REFERENCES

[1] C.E. Balas, A Reliability-Based Risk Assessment Model for Coastal Projects. Phd Thesis, Middle East Technical University, Graduate School of Natural and Applied Science, Ankara, 1998.

[2] C.E. Balas, Application of Network Planning Techniques to Multiple Unit Construction Projects of Harbors.. Master Thesis, Middle East Technical University, Graduate School of Natural and Applied Science, Ankara, 1992.

[3] J. F. Al-Bahar, and K. C. Crandall, ''Systematic risk management approach for construction. Journal of Construction Engineering and Management,'' ASCE, vol. 116(3), pp 533-546, September 1990.

[4] W.J. Rasdorf, and O.Y. Abudayyeh, ''Cost and schedule control ıntegration: Issues and needs. Journal of Construction Engineering and Management,'' vol.117(3), pp. 486-502, September 1991.

[5] Perry, J. G. and Hayes, R. W. ''Risk and its management in construction projects,'' Engineering Management Group, Proceeding of the Institution of Civil Engineers, vol. 1(78), pp. 499-521, Jun 1985.

[6] N. S. Hojjati, and R.N. Noudehi, ''The use of monte carlo simulation in quantitative risk assessment of IT projects,'' Int Journal Advanced Networking and Applications, vol. 7(1), pp. 2616-2621, 2015.

[7] A.M. Esrarı, Risk analysis and cost simulation of coastal projects. Master Thesis, Middle East Technical University, Graduate School of Natural and Applied Science, Ankara, 199.