ESOURCE CONSTRAINT PROBLEMS FACED ON CONSTRUCTION PROJECTS AND PROPOSAL FOR BALKAN CONSTRUCTION SECTOR

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Abstract

Considerıng project plans to affect cash flows of construction projects will be aimed necessarily to use constraint resources providing a maximum financial benefit as a research study. Resource-constrained project scheduling is the most appropriate method of planning of a project activities use limited resources without destroying their precedence relationships. The aim of this study is to propose a solution to the problem of the time value of cash flows under resource-constrained project scheduling. For this purpose, cash flows and their net present value graphics of a solid waste transfer station construction project were established under different scenarios. Dividing into phases of time-based scheduling and resource-constrained scheduling were compared giving some examples for model and algorithms analyzing cash flows and maximum net present value problems, time based scheduling and resource-based scheduling of a solid waste transfer station construction project was formed. The generated planning were evaluated under different scenarios and examined for different objective functions. The data obtained from the each scenario were presented with their graphics. These data were described by comparing the results obtained. The initiation of this study is caused importantly by the applications of irregular and unmethodical understanding of planning techniques applied in Turkish construction sector. As a result of this study, scenarios using constrained resources forced less the budget limits, but it was observed that it formed lower net present value than the scenarios which do not have resource constrained in equal time intervals. This study is proposed to discuss Balkan construction sector projects with the problems of the time values of cash flows under resource-constrained scheduling.

Keywords: *Resource-constrained Scheduling, Planning, Construction Management, Net Present Value, Cash Flow*

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Introduction

Sequencing the activities of a construction project on a time scale in a sense developing the plan is the initial circumstance for determining the cost and completion time of a construction investment. The growing complexity of the projects and increasingly competitive environment requires to obtain the most effective and efficient planning. Planning techniques ensued with Gantt/Bar Chart during the 1920 and has increased the significance by the revelation of network planning technique as CPM (Critical Path Method) in the 1955s. Chronologically resource allocation, resource-constrained, profit maximization and net present value problems were researched under the title of project planning on behalf of developing the most effective plans.

Given the fact that cash flows of the construction project are affected by the project plans, to develop a plan which aims to use the constrained resources to ensure maximum financial benefits. In this study, it is studied this important issue and the interaction between project planning problem and net present value factor and cash flows are included.

The aim of this study is to examine the resource utilization, cash flows and net present value at the project planning and to propose the project planning problem for Balkan construction sector with analyzing different scenarios including cases that have constrained resources in a solid waste transfer station construction project in Turkey. For this purpose, each scenario’s cash flow and net present value included in this study was diagramed and studied the conformity of the objective functions (budget limits, maximum net present value, e.t.) (Dursun, 2010).

Case Study of Solid Waste Transfer Station (Swts) Construction Project

In order to plan a construction project, work breakdown structure (WBS) which is defined “the progressive hierarchical breakdown of the project into smaller pieces to the lowest practical level” should be prepared (Halphin and Senior, 2011). As shown in Table 1, case study of solid waste transfer station construction project was divided into 17 activities to plan the project. The logic relationship of the (precedence and immediately precedence relationships) activities were determined. The activities were sequenced by precedence relationships on the process of network diagram taking into consideration to supplemental-specifications mentioned below. Supplemental-specifications; Fences and gates of the jobsite will be the first activity, the fire hydrants must be built after water supply, galvanized girder will be placed after the electricity supply, weighbridge will be installed after the installation of galvanized girder, the superstructure construction works of asphalt and concrete sidewalks will be built after the construction of rainwater canals, asphalt and concrete sidewalks must be built in order to start landscaping, installation of prefabricated staff building is the predecessor activity of installation the waste press building, To start with considering the scheduling, durations have been appointed to the activities. Resource (workman) assignment was determined according to the duration of the activity. Resource costs and payments were added to Table 1 to be used in financial analyses which would be held in further chapter of the study (Dursun, 2010).

Table 1: SWTS Construction Project Activity List

Activity	Description	Duration	Workman/ Day	Immediately Precedence Activiy (IPA)	Workman*Day	Workman*Day Cost	Direct Cost	Payment
A	Peeling the soil	5	4	I	20	25,00 €	500,00 €	625,00 €
B	Excavation works	2	2	A	4	25,00 €	100,00 €	125,00 €
C	Compaction works	2	3	B	6	25,00 €	150,00 €	187,50 €
D	Earth-moving operation	7	5	B	35	25,00 €	875,00 €	1.093,75 €
E	Subbase construction for asphalt and concrete sidewalks	2	5	A	10	25,00 €	250,00 €	312,50 €
F	Asphalt paving and compaction for sidewalks	2	5	E	10	25,00 €	250,00 €	312,50 €
G	Concrete works for sidewalks	5	5	E,H	25	25,00 €	625,00 €	781,25 €
H	Rainwater canal construction	10	3	I	30	25,00 €	750,00 €	937,50 €
I	Installation of fences and gates	5	3	-	15	25,00 €	375,00 €	468,75 €

J	Placement of galvanized girder	4	4	M	16	25,00 €	400,00 €	500,00 €
K	Installation of prefabricated staff building	15	4	B	60	25,00 €	1.500,00 €	1.875,00 €
L	Installation of waste press building	12	6	C	72	25,00 €	1.800,00 €	2.250,00 €
M	Electric works	10	5	I	50	25,00 €	1.250,00 €	1.562,50 €
N	Installation of weighbridge	5	5	J	25	25,00 €	625,00 €	781,25 €
O	Landscaping	3	3	F,G	9	25,00 €	225,00 €	281,25 €
P	Water supply	5	4	I	20	25,00 €	500,00 €	625,00 €
R	Establishment of fire hydrants	5	2	P	10	25,00 €	250,00 €	312,50 €

As shown Figure 1, it was calculated the activities early start, early finish, late start, late finish durations and total and free floats by forward and backward calculation due to critical path method (CPM). The project completion date was 27 days according to the network diagram as seen Figure 1.

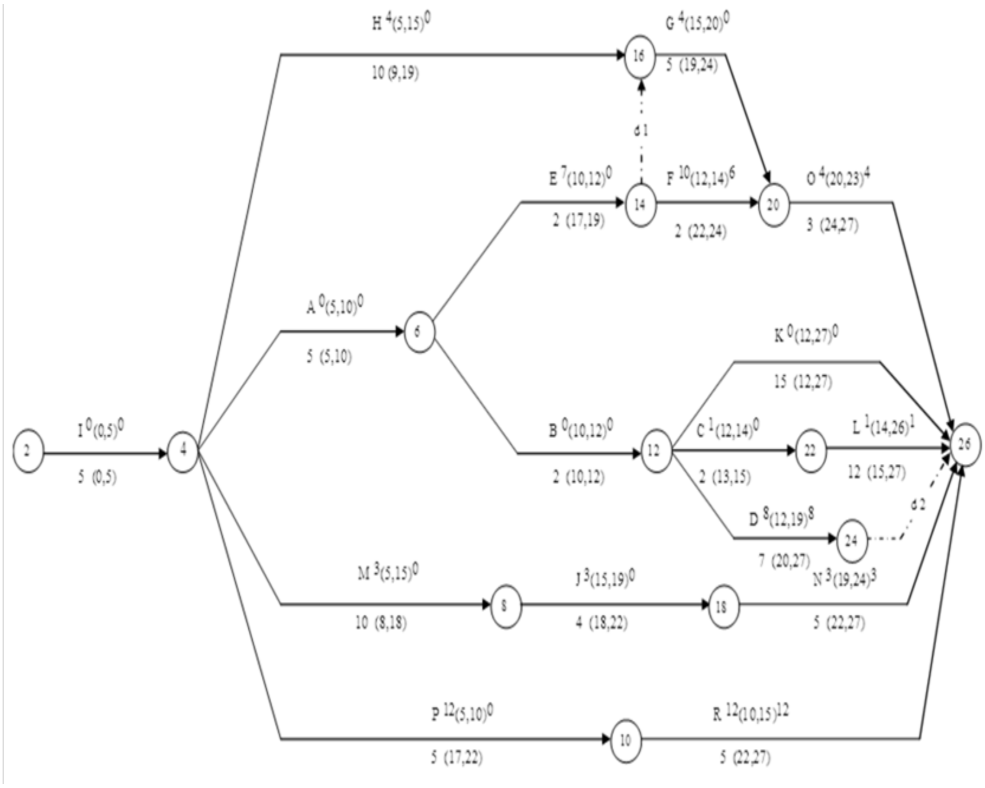

Figure 1: SWTS Construction Project Network Diagram

Resource Constrained Planning 0f Solid Waste Transfer Station (Swts) Construction Project

Based on time-based scheduling, as shown in Figure 2, the maximum daily workman resource of the project was 27. Assuming that the project has a constrained resource with the number of 20 workmen without changing the project deadline of 27 days, the activities was shifted using its floats and it was shown in Figure 3.

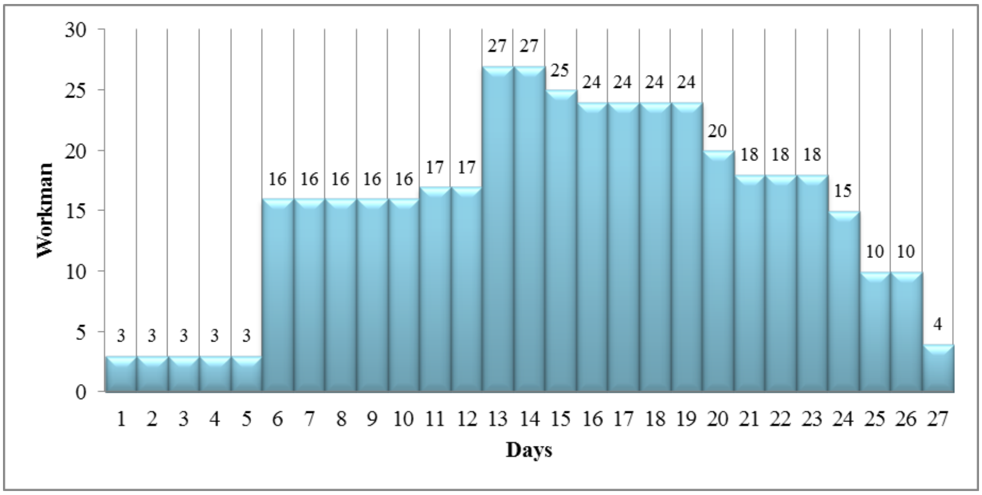

Figure 2: Time-Based Scheduling Resource Allocation

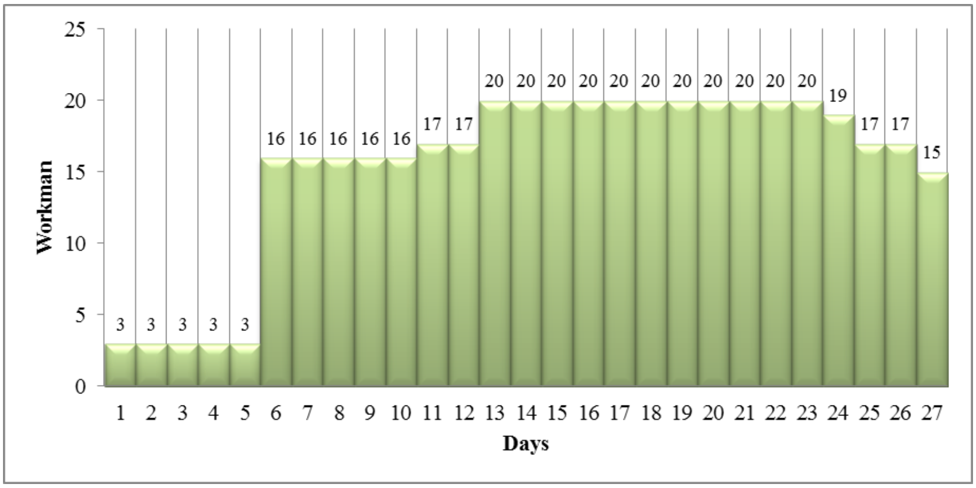

Figure 3: Resource-Constrained Scheduling Resource Allocation

In case of resource-constrained scheduling, the completion days of the project activities was shown in Table 2.

Table 2: Activity Completion Time Due To Time-Based and Resource-Constrained Scheduling

Activity	Time-Based Scheduling Activity Completion Time (TBSACT)	Resource-Constrained Activity Completion Time (RCACT)
A	10	10
B	12	12
C	14	14
D	19	27
E	12	12
F	14	14
G	20	20
H	15	15
I	5	5
J	19	19
K	27	27
L	26	27
M	15	15
N	24	24
O	23	23
P	10	10
R	15	27

Financial Analysis of Solid Waste Transfer Station (SWTS) Construction Project Below Different Scenarios

In this chapter, solid waste transfer station construction project was examined under different scenarios in cases of time-based scheduling and resource-constrained scheduling. First of all, cash flows were calculated and then analysis of net present value was obtained using cash flow calculations. According to the assumption that the annual nominal interest rate was 20% and time unit was day. Equation 1 was utilized in the analysis of the net present value.

$$P = F/(1 + \frac{r}{365})^{365n} \quad (1)$$

Phase-1 (Time-Based Scheduling Using Single Resource)

Based on the network diagram shown in Figure 1, cash flows and net present value analysis calculations of the solid waste transfer station construction project were established under three different scenarios. The following conditions were common for the Scenario 1, Scenario2 and Scenario 3; Cash outflow of the project was daily workmen cost, and progress payment that calculated on a weekly basis was cash inflow. The amount of the progress payment was calculated by adding the profit of

25% on the workmen cost up to the progress payment period. The periods of progress payment were 7th, 14th, 21st, and 27th days. As shown in Table 1, daily workman cost was 25€, hence the price of workman was calculated as the 25% profitable 31,25€. The amount of cash outflow was calculated as multiplied by the total daily workman unit with workman cost (25€). Only the completed activities subsidized during the progress payment period in Scenario 2. The progress payment of the project would be paid lump sum after the delivery of the project in Scenario 3.

Phase-2 (Single and Resource-Constrained Usage Scheduling)

Cash flows and net present value analysis of the scheduling status to the three different scenarios by using the resource-constrained scheduling resource allocation as shown in Figure 3. The conditions of phase-1 were common for Scenario-4, Scenario-5 and Scenario-6 of Phase 2. Only the completed activities subsidized during the progress payment period in Scenario 5. The progress payment of the project would be paid lump sum after the delivery of the project in Scenario 6.

Phase-3 (Time-Based Scheduling Using Double Resource)

Phase-1 was based on only single resource utilization. In Phase-3, workman resources as well as a new material resource in the name of "R" were assigned to the activities of the project. Thus, more scenarios were enabled. Material resource called "R" was directly proportional to the workman resource and 2 per R resource was assigned to the one workman. The following conditions were common for the scenarios; Resource R procurement was at the beginning of the project in Scenario 7, 9, 11 and 13. Resource R procurement was on a daily basis in Scenario 8, 10, and 12. The periods of progress payment were 7th, 14th, 21st, and 27th days in Scenario 7, 8, and 13. Only the completed activities subsidized during the progress payment period in Scenario 11 and 12. The progress payment of the project would be paid lump sum after the delivery of the project in Scenario 9, 10 and 13. Only one unit price was the price of the workman and "R" resource. The workman and "R" resource unit prices were calculated by adding 25% profit. Cash outflow of the project was daily workmen cost and "R" resource cost, and progress payment that calculated on a weekly basis was cash inflow. The workman unit cost was 25 € and "R" resource unit cost 5 €.2 per R resource was assigned to the one workman so that total cost was 35 €. The unit price was 43,75 € by adding 25% profit on the total cost.

Phase-4 (Double and Resource - Constrained Usage Scheduling)

In the previous phase, cash flow and net present value calculations were analyzed on the basis of time-based scheduling. In this phase, cash flow and net present value calculations were analyzed based on resource-constrained. The following conditions were common for the scenarios; Resource R procurement was at the beginning of the project in Scenario 14, 16, 18, and 20. The periods of progress payment were 7th, 14th, 21st, and 27th days in Scenario 14, 15, 18, 19, 20. Resource R procurement was on a daily basis in Scenario 15, 17, and 19. Only one unit price was the price of the workman and "R" resource. The workman and "R" resource unit prices were calculated by adding 25% profit. Only the completed activities subsidized during the progress payment period in Scenario 18, and 19. Cash outflow of the project was daily workmen cost and "R" resource cost, and progress payment that calculated on a weekly basis was cash inflow. The workman unit cost was 25 € and "R" resource unit cost 5 €.2 per R resource was assigned to the one workman so that total cost was 35 €. The unit price was 43,75 € by adding 25% profit on the total cost.

Phase-5 (Scheduling By Resource Combination Options)

It may be considered that utilization of resources can change an activity duration and cost in construction projects. Such as there is cost and time differences between performing excavation works by 10 workmen and with using an excavator. In this phase the resource options were available as described in Table 3. Utilizing different resources was possible for the activities of A and K. The resources called "R_3" and "R_4" were assigned to the activities different from the previous phases. The cost of these resources were respectively 40 € and 50 €. In addition, according to the assumption in this phase for the scenarios, given the fact that the project was completed earlier from the completion date of 27, it was rewarded %0,3 per day completed in early days. In case of delaying of the project, %0,3 per day penalty for the delay was given in scenarios. %0,3 of the cost of the project was calculated approximately 55 €.

Table 3: Resource Combinations

Activity	Resource Combination	Resource 1 (R_1= Workman)	Resource 2 (R_2= R)	Resource 3 (R_3)	Resource 4 (R_4)	Daily Cost (€)	Total Cost (€)	Daily Payment (€)	Total Payment (€)
A	Base	4	8	-	-	140	700	175	875
	Option 1	2	8	-	-	90	630	175	875
	Option 2	3	8	1	1	205	820	175	875
	Option 3	3	8	2	2	295	885	175	875
B	Base	2	4			70	140	87,5	175
C	Base	3	6			105	210	131,25	262,5
D	Base	5	10			175	1225	218,75	1531,25
E	Base	5	10			175	350	218,75	437,5
F	Base	5	10			175	350	218,75	437,5
G	Base	5	10			175	875	218,75	1093,75
H	Base	3	6			105	1050	131,25	1312,5

I	Base	3	6			105	525	131,25	656,25
J	Base	4	8			140	560	175	700
K	Base	4	8	-	-	140	2100	175	2625
	Option 1	3	8	-	-	115	1955	175	2625
	Option 2	2	8	2	1	220	2420	175	2625
	Option 3	3	8	3	2	335	3015	175	2625
L	Base	6	12			210	2520	262,5	3150
M	Base	5	10			175	1750	218,75	2187,5
N	Base	5	10			175	875	218,75	1093,75
O	Base	3	6			105	315	131,25	393,75
P	Base	4	8			140	700	175	875
R	Base	2	4			70	350	87,5	437,5

Conclusion

In this study, the interaction between resource constrained problems and limited budget cases were researched and presented proposals for solutions by taking into consideration of resource utilization, cash flows and net present value under the theme of project planning. It was examined 35 different scenarios under 5 different planning phase. Cash flows and net present value graphics belonging all of the scenarios were established. By utilizing the generated graphics compliance with budget constraints, the objective of maximum net present value and project time constraint were examined for all scenarios due to case studies. Scenarios which were examined according to aforementioned objective function, obtained results were indicated in the tables below.

As shown in Table 4, green font color of Scenario-1, Scenario-4 and Scenario-5 for Case A ensured the objective function, red colored Scenario-2, Scenario-3 and Scenario-6 indicated a violation of objective function. Pairing with the cases of A, B and C, green fill color indicated the best scheduling phase.

Table 4: The Analyses of Phases

Case		**A**	**B**	**C**	**D**
Objective		Maximum Credit Limit (-5.500 €)	Final Period Maximum NPV (€)	Maximum Project Duration (27 Days)	With the evaluation all A,B,C cases
Phase-1	Scenario-1	-3106,25	2564,65	27	
	Scenario-2	-5983,75	2539,83	27	
	Scenario-3	-10425	2502,51	27	
Phase-2	Scenario-4	-2756,25	2564,07	27	
	Scenario-5	-5068,75	2539,84	27	
	Scenario-6	-10425	2507,09	27	
Case		**A**	**B**	**C**	**D**
Objective		Maximum Credit Limit (-7.500 €)	Final Period Maximum NPV (€)	Maximum Project Duration (27 Days)	With the evaluation all A,B,C cases
Phase-3	Scenario-7	-6688,75	3555,26	27	
	Scenario-8	-4348,75	3590,29	27	
	Scenario-9	-14595	3468,48	27	
	Scenario-10	-14595	3503,51	27	
	Scenario-11	-9001,25	3520,73	27	
	Scenario-12	-8251,25	3555,76	27	
	Scenario-13	-5345,75	3587,05	27	
Phase-4	Scenario-14	-6338,75	3552,83	27	
	Scenario-15	-3858,75	3589,69	27	
	Scenario-16	-14595	3473,06	27	
	Scenario-17	-14595	3509,92	27	
	Scenario-18	-8176,25	3518,92	27	
	Scenario-19	-7096,25	3555,78	27	
	Scenario-20	-5345	3586,62	27	
Case		**A**	**B**	**C**	**D**

Objective		Maximum Credit Limit (-7.500 €)	Final Period Maximum NPV (€)	Maximum Project Duration (27 Days)	With the evaluation all A,B,C cases
Phase-5	Base A, K-1	-4298,75	3568,75	26	
	Base A, K-2	-4683,75	3383,75	26	
	Base A, K-3	-5383,75	3123,75	26	
	A-1, Base K	-3193,75	3763,5	29	
	A-1, K-1	-3088,75	3937,5	31	
	A-1, K-2	-3753,75	3343,75	28	
	A-1, K-3	-4558,75	3083,75	28	
	A-2, Base K	-4993,75	3583,75	26	
	A-2, K-1	4993,75	3193,75	28	
	A-2, K-2	-5233,75	3318,75	25	
	A-2, K-3	5713,75	3058,75	25	
	A-3, Base K	-5583,75	3573,75	25	
	A-3, K-1	5483,75	3608,75	27	
	A-3, K-2	-5903,75	3308,75	24	
	A-3, K-3	-6363,75	3048,75	24	

According to the results of this study, Phase-1 and Phase-3 were compared to Phase-2 and Phase-4 that use the resource-constrained scenarios and Phase-2 and Phase-4 forced the credit limits less than Phase-1 and Phase-3, however Phase-2 and Phase-4 composed less net present value in equal time periods. When approximating the resource costs to the resource utilization times during the planning phase, net present value increased. Net present value increased and credit limits less forced, when positive cash flows approached to the initial period.

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