

Advantages of using EMV in Auditing Construction Processes

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Abstract — Audit process is the final stage of the construction process chain for the execution of the civil engineering works. At this stage are certified or not all the cash flows, the technical parameters of the project, the quality of work and compliance with laws and regulations. It is important that during the audit phase to gather reliable evidence in order to have uncontested recommendations and to be in accordance with reality. The integration of Earned Value Method, during the auditing phase, in order to measure the performance of the implemented engineering interventions and restoration of works which are considered monument of culture; it results in the increase of efficiency and effectiveness of the construction process. This paper shows the calculation of performance indexes, based on international auditing standards, laws and regulations in force, all the technical, financial and legal documentation of the civil engineering and restoration projects that will be applied.

Keywords: Civil Engineering Projects, Restoration Projects, Audit, Earned Value Method, Performance Index.

I. INTRODUCTION

The audit process is mainly applied during the recent years in the cycle of civil engineering projects, but it is not directly related to the construction stages and its processes. The audit of civil engineering projects is generally performed post factum, which means when all the works are completed. Application of EVM can also be performed during the execution phase of the project, where can be calculated the performance indexes, in order to draw conclusions in forecasting its future performance of it. [1], [4].

We analyzed the reconstruction and restoration works of the "Former Kinostudio Building", Cultural Monument of the Second Category, shown in Figure 3.1 [8]. The works which will be subject to restoration, since it is a monument of culture and based on the law of cultural heritage, represents a high risk in terms of performance of reference prices, quality and quantity specified in the project. The object is located in Tirana and the process of restoration was carried out in 270 days, the original deadline for its completion has been 180 days. As evidenced, the reconstruction and restoration process was completed 90 days later. The value execution of the reconstruction and restoration project is 103,258,474 ALL. Engineering intervention and restoration work was carried out during the years 2013 -2014.

II. METHODOLOGY USED

For the realization of this paper are used two different methods: "Desk research" and "Field research", which helped in drawing the final conclusions. Initially, with the "Desk research" method, it is reviewed the available literature, which address the issues of managing civil engineering projects with public investments, monitoring, controlling and auditing them. In these books there are important and plenty information about the Earned Value Method and calculation methods of quantitative project progress [2]. Also, from the theoretical part, there are outlined several important empirical formulas for calculating the performance indexes of costs and schedules. These formulas help us to present in the quantum way the results obtained from the implementation of the project. "Field Research" Method consists in preparing a specific questionnaire divided into 3 parts: directed to the civil engineers of the company that are implementing the engineering and restoration part of the project, and officials of the public institution that procured and constantly controlled the restoration process and the engineering intervention.

III. CASE STUDY. RESULTS ANALYSIS.

According to the definition of PMBOK 2008, Earned Value Method is a method used to measure the performance of the project, by integrating deadlines, costs and real physical progress of the project [1], [3]. As part of EVM:

Earned Value- EV express the value of work performed at a point in time T "Time now" according to the estimated BOQ price.

- *Planned Value-PV* or *Budgeted cost of the work scheduled*, expresses the total value of works included in the bill of quantities of reconstruction and restoration activity to be performed by the end date.

- *Actual Cost-AC* or *Actual Cost of Work Performed* expresses the paid cost for the works performed by the time T "Time now" [7].

In the meantime, the calculation of the performance index of the project takes into consideration the costs and deadlines stated as follows [2], [5]:

- *Cost Variance- CV* = Earned Value – Actual Cost:

$$CV = EV - AC \quad (1)$$

• *Schedule Variance- SV* = Earned Value – Planned Value:

$$SV = EV - PV \quad (2)$$

• *Cost Performance Index - CPI* = Earned Value /Actual Cost:

$$CPI = EV / AC \quad (3)$$

• *Schedule Performance Index - SPI* = Earned Value/Planned Value:

$$SPI = EV / PV \quad (4)$$

The purpose of this paper is to measure the performance i of the project in the point time T (06.10.2014), by integration of the above formulas in the computer software PROING®. The software is developed to calculate the performance indexes of the project, and enabled in obtaining the data in Table 3.2.

The difference in quantity and volume of the work performed, for those works that had had a lower performance are argued as follows:

- *Construction of reinforced concrete roof with wooden frames and tiles:* The Final Statement presents 290 m² and the Measurement Sheet presents in an analytical way a total quantity of 290 m². These works are carried out only on the sides of the building frame, closing the spaces after the demolition of existing chimneys and removal of ventilation tubes, respectively 15.31 m² + 7.88 m² + 2.25 m². Whereas, from the photos found in the technical file and during the check of the project, the construction of this type of roof (reinforced concrete roof) with surface (132.41 + 132.41 m² = 264.82 m²) turns out that is not performed in the main buildings. In this part are performed works for setting tiles and hydro isolation. By subtracting these works, the price for unit goes to 4200 lek/m² - 1590 lek/m² (tile) - 1100 (hydro isolation) = 1,510 lek/m². Also, in this section is laid a concrete leveling layer of 10 cm, which is presented in a special voice for the work. The difference in quantity is 290 m² - 25.18 m² = 264.82 m². From the calculation of PROING® computer software, Cost Performance Index for this type work is $CPI = 0.087 < 1$. This value indicates that the amount paid is higher than the real value of the works, where the quantity of the work performed is smaller than the one presented in the Measurement Sheet.

- *Supply and fixing of the Vertical Rain Gutter:* The Final Statement presents 340 ml and the Measurement Sheet presents in an analytical way a total quantity of 340 ml. From the verification on the ground and the technical design of the project in electronic version, showed that are fixed in total 19 vertical rain gutters, where fifteen (15) of these have the length of 8 ml, and the other 4 have the length of 15 ml. In conclusion, (15 x 8ml + 4 x 15 ml) = 120 ml + 60 ml = 180 ml vertical rain gutter fixed in the object. The difference is 340 ml - 180 ml = 160 ml. From the calculation of PROING® computer software, Cost Performance Index for this type of work is $CPI = 0.525 < 1$. This value indicates that the amount paid is higher than the real value of the works, where the quantity of work performed is smaller than the one presented in the Measurement Sheet. This work has had the lowest performance in relation to the cost, also not

the highest impact during all the reconstruction and restoration process.

- *Supply and Fixing of the Marble Wall Covering:* The Final Statement presents 120 m² and the Measurement Sheet presents in an analytical way a total quantity of 120 m². From the verifications done on the ground, it results that these floor tiles are not placed in the cove of the object, and the cove is in its previous state. Cost Performance Index for this type of work is $CPI = 0.0 < 1$, this value indicates that the work is not performed. The quantity presented in the Measurement Sheet does not correspond to the facts. This work has had the biggest negative impact on the performance of the costs of the entire reconstruction and restoration process.

- *Transport of inert and solid waste:* The Final Statement presents 2500 m³ and the Measurement Sheet presents in an analytical way a total volume of 2500 m³. From the verification of the Final Statement, the Measurement Sheet for all the works of demolition-removal and after the calculations, it results that are 1111 m³ of wastes to be transported, shown at the table below:

TABLE 3.1

Description	Area	Thickness	Quantity
	m ²	m	m ³
Removal of the tiles	1750	0.1	175
Demolition and Removal of the ground floor	280	0.1	28
Demolition and Removal of the brick wall	196	0.25	49
Demolition and Removal of the interior brick wall	2200	0.1	220
Removal of the external plastering	1519	0.1	152
Removal of the ornamental plastering	150	0.1	15
Removal of the column patching	60	0.1	6
Removal of the ceiling plastering	437	0.1	43.7
Removal of the floor tiles	190	0.05	9.5
Removal of the wall tiles	43	0.05	2.15
Removal of the wooden window	230	0.1	23
Removal of the wooden doors	52	0.1	5.2
Removal of the window iron bars	70	0.14	9.8
Removal of the windows marble	80	0.05	4
Removal of the air conditioning equipment	10	0.5	5
Removal of the rain gutter	525	0.2	105
Removal of the sanitary equipment	1	1	1
Removal of the wiring	1	10	10
Removal of the plumbing fixture	1	5	5
Wall openings	85	0.2	17
Decoration cleaning	1	20	20
Demolition and removal of the walls under the roof	49.44	0.25	12.36
Dismantling works	52	0.05	2.6
Removal of the back window	1	5	5
Demolition and Removal of the roof	414	0.2	82.8
Demolition and Removal of reinforced layer of the roof	414	0.25	103.5
Total Quantity			1111

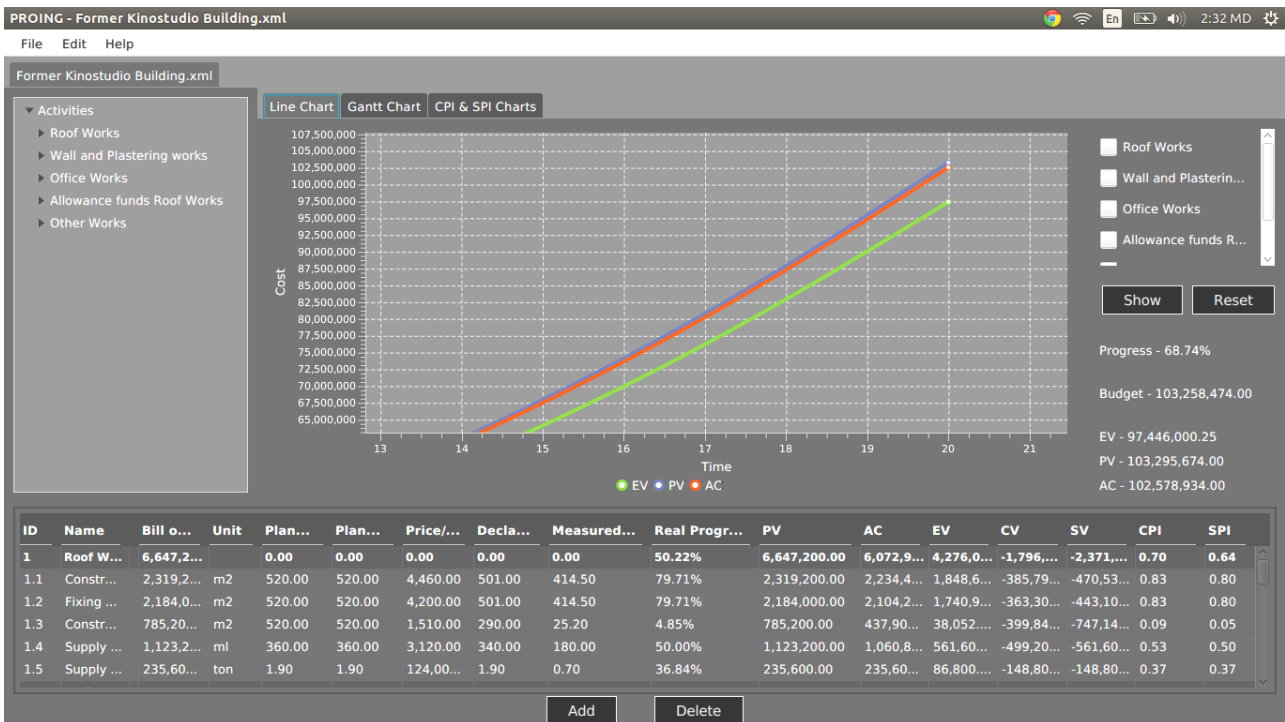


Figure 1. AC, PV and EV, Calculated in PROING®



Figure 2 CPI and SPI Chart

Table 3.2. Calculation of Cost Performance Index and Schedule Performance Index using PROING®

	Restoration of Kinostudio Building	Unit	Bill of Quantities	Price/ Unit	Planned Quantity	Declared Quantity	Measured Quantity	Declared Progress	Real Progress	PV	AC	EV	CV	SV	CPI	SPI
	Description		ALL	ALL	Unit	Unit	Unit	%	%	ALL	ALL	ALL	ALL	ALL		
A	Roof works															
1	Construction of the roof+ tiles H>12m	m2	2,319,200	4,460	520	501.0	414.5	96%	80%	2,319,200	2,234,460	1,848,670	-385,790	-470,530	0.8273	0.7971
2	Fixing of wooden frames + tiles	m2	2,184,000	4200	520	501	414.5	96%	80%	2,184,000	2,104,200	1,740,900	-363,300	-443,100	0.8273	0.7971
3	Construction of reinforced concrete roof + tiles H>12	m2	785,200	1510	520	290	25.2	56%	5%	785,200	437,900	38,022	-399,878	-747,178	0.0868	0.0484
4	Supply and fixing of the Vertical Rain Gutter	ml	1,123,200	3120	360	340	180	94%	50%	1,123,200	1,060,800	561,600	-499,200	-561,600	0.5294	0.5000
5	Supply and fixing of reinforcement rebars	ton	235,600	124000	1.9	1.9	0.7	100%	35%	235,600	235,600	83,204	-152,396	-152,396	0.3532	0.3532
B	Wall and plastering works															
1	Exterior plastering H-8m	m2	2,632,500	1620	1,625	1,584.0	1,549.0	97%	95%	2,632,500	2,566,080	2,509,380	-56,700	-123,120	0.9779	0.9532
2	Supply and fixing of the floor tiles	m2	300,900	2950	102	90.0	59.7	88%	59%	300,900	265,500	176,115	-89,385	-124,785	0.6633	0.5853
3	Supply and install of the parquet flooring	m2	1,781,040	4920	362	340.0	317.0	94%	88%	1,781,040	1,672,800	1,559,640	-113,160	-221,400	0.9324	0.8757
4	Supply and fixing of the Marble Wall Covering	m2	987,600	8230	120	120	0	100%	0.00%	987,600	987,600	-	-987,600	-987,600	0.0000	0.0000
5	Transport of inert and solid waste	m2	714000	340	2100	2500	1111	119%	53%	714,000	850,000	377,740	-472,260	-336,260	0.4444	0.5290
C	Office works															
1	Supply and fixing plasterboard	m2	558,000	3,100	180	190	177.4	106%	99%	558,000	589,000	549,940.0	-39,060.0	-8,060	0.9337	0.9856
2	Supply and fixing of the floor tiles	m2	978,200	2,920	335	335.0	286	100%	85%	978,200	978,200	835,120.0	-143,080.0	-143,080	0.8537	0.8537
3	Interior wall paint	m2	182,400	120	1,520	1,440.0	1,125	95%	74%	182,400	172,800	135,000.0	-37,800.0	-47,400	0.7813	0.7401
4	Supply and fixing aluminum doors	m2	558,000	12,400	45.0	39.5	35.4	88%	79%	558,000	489,800	438,960.0	-50,840.0	-119,040	0.8962	0.7867
D	Allowance funds															
D	Roof works															
1	Demolition of the old wooden roof	m2	221,850	435	510	510	414.5	100%	81%	221,850	221,850	180,307.5	-41,542.5	-41,543	0.8127	0.8127
2	Reinforced concrete leveling layer (applied on the roof)	m3	1,688,940	10,236	165	175	125	106%	76%	1,688,940	1,791,300	1,279,500	-511,800	-409,440	0.7143	0.7576
3	Demolition and removal of the old concrete layer under the roof	m2	405,125	231.5	1,750	1,750	414.5	100%	24%	405,125	405,125	95,957	-309,168	-309,168	0.2369	0.2369
4	Supply and fixing of reinforcement rebars	ton	210,800	124,000	2	2	0.0	100%	0%	210,800	210,800	-	-210,800	-210,800	0.0000	0.0000
5	Supply and fixing of the plasterboard under the ceiling	m2	1,271,000	3100	410	370	294	90%	72%	1,271,000	1,147,000	912,020	-234,980	-358,980	0.7951	0.7176
E	Other works	m3/m2 m/ton	84,120,919	Σ	Σ	Σ	Σ	100%	100%	84,120,919	84,120,919	84,120,919	0	0	1.0	1.0
	Summary		103,258,474							103,258,474	102,541,734	97,442,994.1	-5,098,740	-3,295,022	0.95	0.94

The difference is $2500 \text{ m}^3 - 1111 \text{ m}^3 = 1389 \text{ m}^3$. From the calculation of PROING® computer software, Cost Performance Index for this type of work is $CPI = 0.444 < 1$. This value indicates that the amount paid is higher than the real value of the works, where the volume of work performed is smaller than the one presented in the Measurement Sheet.



Figure 3.1 Frontal view of the building

- Reinforced concrete leveling layer (applied on the roof). The Allowance Fund Statement presents 175 m^3 and the Measurement Sheet presents in an analytical way a total volume of 175 m^3 . From the verification on the ground and the technical design of the project in electronic version, the photos and the Measurement Sheet, it results that are constructed a volume of 125 m^3 of Reinforced concrete leveling layers. During the construction of the concrete roof, it is not used reinforced concrete leveling layer $t = 10 \text{ cm}$ (applied on the roof), as a consequence, there is a difference of 50 m^3 . The difference in volume is $175 \text{ m}^3 - 125 \text{ m}^3 = 50 \text{ m}^3$. From the calculation of PROING® computer software, Cost Performance Index for this work is $CPI = 0.71 < 1$. This value indicates that the amount paid is higher than the real value of the works, where the volume of work performed is smaller than the one presented in the Measurement Sheet.



Figure 3.2 Roof leveling layer

From the results obtained from the calculation of performance index for each construction work, it is concluded that performance in respect to the plan of the entire process of restoration of the building is $SPI = 0.94 < 1$, which indicates that the forecast regarding the timing of completion has been smaller than expected. Also, the committed volumes are lower than those forecasted in the project. With regard to

performance cost index $CPI = 0.95 < 1$, the cost of the entire process of restoration is higher than the real cost, where the volume of work performed is smaller than the volume paid according to the Final Statement.

Cost Variance between the realized work value and the declared value of the works in the Final Statement, of the entire project is $CV = 5,098,740 \text{ ALL}$.

IV. CONCLUSIONS

1. Calculation of Performance indexes by using the Earned Value Method enables the measurement of the performance for the entire works that are performed in the object. The performance indexes can be calculated when the works are finished, but also in a certain point in time T (time now) when the works are being performed.
2. The use of the computer software PROING®, by integrating Earned Value Method (EVM), is an efficient and flexible tool that calculates rapidly and automatically the performance indexes of an executed project.
3. The use of EMV during the execution phase enables the creation of a management system, where its use, increases the level of involvement of all the stakeholders of the project.
4. The application of EVM improves the ability of the staff to identify and correct in all the construction processes the exposure to risks, where eventually in the processes that have had a poor performance, the impact of risks has been high.
5. By using the Earned Value Method in some projects, it is possible the creation of a database, where we can make comparisons between the performance indexes of a project that is in process and a finished project.
6. The use of the computer software PROING® enables simultaneous management of several engineering projects, by using the same human and financial resources.

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