IMPLEMENTATION OF EARNED VALUE MANAGEMENT IN UNIT-PRICE PAYMENT CONTRACTS

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ABSTRACT

The Earned Value Management (EVM) method is considered an international standard tool in the project management field, enabling professionals to plan and control cost-and-schedule in an integrated manner. However, evidence indicates that EVM is not typically implemented by contractors when the payment agreement is based on unit-prices. In this payment approach, the owner pays the quantities actually executed according to the pre-agreed rate established in the contract for each unit or task; the income received by the contractor from the owner (generally named production) is neither proportional to costs nor fixed a priori, as in cost-reimbursable and lump sum contracts, respectively. Therefore, contractors have to control not only cost but also

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production. The current formulation of EVM does not allow controlling production; an additional baseline is needed. In response, this paper presents a proposal for adapting EVM to contractors when using the unit-prices payment agreement. Using a case study to illustrate, an additional baseline to account for production and profitability, as well as new indicators, are applied to allow contractors using EVM with this payment approach; this is the contribution of this paper to the body of knowledge. The proposed EVM formulation provides information not only in terms of cost (as traditional EVM approach) but also in terms of production.

KEYWORDS: Contractor; Control; Cost; Earned Value; Production; Unit-Price

INTRODUCTION

Contract Payment Approaches

In any contract, the party (owner or contractor) taking more risks will be understandably the one more interested on the best ways of planning and controlling the project; these risks depend highly on the contractual payment approach (Fleming and Koppelman 1997, 2010; Christensen-Day 2010). The most common contract payment approaches are cost-reimbursable, lump-sum, and unit prices (Ibbs et al. 2003, PMI 2013). Cost-reimbursement requires that a contractor be paid by the owner for all legitimate actual costs incurred plus an additional payment fee (PMI 2013). In this case, the party who takes more risks is the owner. All the actual costs incurred by the contractor are paid by the owner. Therefore, the owner needs to control the actuals costs regarding its planned cost. For the contractor, the profit is going to be the fee, or part of this fee if the overhead is also included in the fee; therefore, this profit is either proportional to the cost or fixed (or any combination of both), but always easy to compute by the contractor. With this open-book approach, the contractor may not look at cost control as an essential part of the management of the project.

Lump-sum or fixed-price approaches are those in which the contractor is paid a pre-set price by the owner in spite of the actual expenses incurred (PMI 2013). On this occasion, the party that has more at stake is the contractor, who will likely be the one more interested on planning and controlling the project (Fleming and Koppelman 2002; Christensen-Day 2010; Hanna 2012). The total price of the project is fixed and it will not vary from the contractual budget (unless the contract is modified). Therefore, the contractor will be interested on planning the costs as accurately as possible, and controlling the deviation of planned costs versus actual costs as best as possible. Any additional cost overrun decreases the profitability of the contractor, because the contractual price (lump sum) is fixed. The profit is computed easily by the contractor as the fixed price minus the actual costs.

Finally, unit-price is a contract payment agreement where the owner pays periodically to the contractor according to preset (contractual) unit rates that are applied to the actual measured quantities. These unit rates include, in addition to the estimated cost of the product/service, the overhead and profit. This is a hybrid payment approach that encompasses features of lump-sum and cost-reimbursable approaches (PMI 2013). In the unit-price approach the risk is more balanced between both parties; the quantities may vary during the development of the contract depending on the actual work (PMI 2013), but the unit price rates are fixed from the start. In this type of contract, both parties have some risks at stake; therefore, both contractor and owner can benefit from applying planning and control procedures (Valderrama and Guadalupe 2010). From the point of view of the owner, the contractual budget is the one bid by the contractor and awarded by the owner, distributed in periodic payments throughout the project life. However, this budget is not a constant figure, as in the fixed-price agreement, and it can vary depending on the measurement of the actual quantities (Missbauer and Hauber 2006); for the owner, the difference between the planned cost and the actual payment made to the contractor will provide the deviation in costs.

From the point of view of the contractor, two concepts have to be considered. Firstly, the contractor needs to control the actual costs against the planned costs, as in lump-sum contracts. Secondly, the contractor needs to forecast the payment or income received from the owner due to the execution of the tasks according to contract terms; this is generally acknowledged as “production” (Missbauer and Hauber 2006). Both cost control and production control are different concepts in unit-price contracts from the point of view of the contractor, because the owner pays the quantities actually executed (if they conform to the specifications and plans), according to the pre-agreed rate (established in the contract for each unit or task). The ratio between preset (contractual) rate and actual cost can vary for each unit or task, as well as the actual quantities;

therefore, an overall ratio for the entire project cannot be computed (as in cost-reimbursement approaches) until completion of the project. Therefore, the income received by the contractor from the owner (production) is neither proportional to costs nor fixed a priori, as in cost-reimbursable and lump sum contracts, respectively.

Earned Value Management

Earned Value Management (EVM henceforth) has long been used as a planning and control tool (Fleming and Koppelman 1997; PMI 2013). EVM is considered one of the most appropriate methodologies to simultaneously control project cost and time while providing early warning signals of potential problems, leading to an effective management of the project (McConnell 1985; Fleming and Koppelman 2010; Ponz-Tienda et al. 2012; Chen 2016).

Depending on the payment agreement between the owner of the project and the contractor, not only the manner EVM is applied can significantly vary, but also the parties who use it. EVM was first designed for, and applied in, cost-reimbursable payment approaches (Fleming and Koppelman 1997; Anbari 2003); public agencies also recommended its use for this type of contracts (DoD 2003; Kwak and Anbari 2012; NASA 2013; DoD 2015). Further research demonstrated its usefulness in lump-sum contracts too (Fleming and Koppelman 2002; Christensen-Day 2010; Hanna 2012). For cost-reimbursable and lump-sum approaches, EVM formulation can be considered straightforward (Fleming and Koppelman 2002, 2010).

However, formulation and application of EVM in unit-prices contracts is basically overlooked by the scientific literature (Fleming and Koppelman 1997, 2002, 2010) as well as by the official procedures (DoD 2003; NASA 2013). Kim and Ballard (2010) pointed out that EVM is not properly adapted to the variability and uncertainty of some projects, such as those in construction. De Marco and Narbaev (2013) recognized the difficulties of applying EVM to unit-price approaches without proposing any specific solutions. Xu (2009) and Valderrama and Guadalupe (2010) presented partial attempts to apply EVM to unit-prices contracts using the standard formulation; however, they failed to consider the contractor's need to control production independently from costs (Missbauer and Hauber 2006). This scarcity of contributions highlight the room for research in this topic, considering that unit-price approaches are widely used either in public or private procurement all over the world (Ewerhart and Fieseler 2003; Oviedo-Haito et al. 2014) and in different kind of industries, including in construction (Kim and Ballard 2010; Kim et al. 2016), defense (Fleming and Koppelman 2010), design (Chang 2001), publishing (Ewerhart and Fieseler 2003), and timber (Athey and Levin 2001), among many others.

Research Question

Given this knowledge gap, the research question is stated as follows: How can be the current EVM formulation enhanced so it can be effectively implemented by contractors in unit-price contracts? After introducing the basics of EVM in the second section, the third section of the paper aims to provide an answer to this question, where some additional indicators regarding production are proposed to enhance the current EVM formulation. To follow up, a case study highlights the differences of this proposal with the traditional approach whilst demonstrating its implementation. Finally, conclusions are drawn highlighting the potential advantages of the proposal, but also acknowledging the limitation of the research.

EVM INDICATORS

EVM defines three main indicators to evaluate project performance (PMI 2013; Kim 2015; Chen 2016): Planned Value (*PV*), Actual Cost (*AC*), and Earned Value (*EV*). The *PV* is the authorized budget planned for accomplishing an activity, which is determined during the planning phase of the project; the cumulative *PV* at the scheduled end represents the Budget at Completion (*BAC*). The *AC* is the total cost actually incurred and recorded in accomplishing an activity; it is measured during work execution. These two indicators (*PV* and *AC*) are the ones typically considered in traditional cost management (Fleming and Koppelman 1997, 2010; PMI 2013). In order to take into account the amount of work accomplished, EVM introduces the *EV* indicator, which measures the work performed during execution expressed in terms of the approved budget for that work (Fleming and Koppelman 1997, 2010; PMI 2013; Chen 2016). The relationship of *EV* with the traditional *PV* and *AC* allows, not only for cost control, but also for time control, using a set of integrated metrics (Anbari 2003; Fleming and Koppelman 2010; PMI 2013). Nevertheless, EVM schedule indicators use monetary values as the proxy of time and, therefore, they are not perceived as reliable as the cost indicators by practitioners (Pajares and López-Paredes 2011; de Marco and Narbaev 2013; Kim 2015); due to the limitations of EVM schedule indicators, which are not considered in the last version of the PMBOK either (PMI 2013), this research is only focused on cost related indicators, as displayed in Table 1.

<TABLE 1 HERE>

Regarding the implementation to cost reimbursable contracts, EVM is very straightforward: *PV* is defined as the planned costs prepared and approved by the owner before the contract started; *AC* is the actual cost incurred by the contractor; and *EV* the expected cost according to the work performed. In lump-sum contracts, *PV* is defined as the planned costs forecasted by the contractor at the beginning of the project; providing the final actual cost (*AC*) is lower than the fixed-price, the contractor will make a profit. For cost-reimbursable and lump-sum the three EVM indicators and the metrics obtained from them work perfectly well for the party with more risk at stake, and they have thoroughly been analyzed in the literature previously cited. Finally, for unit-price contracts, the cost control dimension can be computed as in lump-sum contracts; however, there is no way to control production without introducing an additional dimension and indicators in the formulation, as it will be detailed in the next section.

PROPOSED EVM FOR CONTRACTORS IN UNIT PRICES APPROACHES

Some modifications in EVM formulation are necessary in order to meet the contractor's requirements and improve the communication between owner and contractor. The proposal presented henceforth aims to keep EVM formulation as close as possible to standard EVM but adding new indicators responding to contractor's needs. As stated previously, regarding cost control, the classical indicators *PV*, *EV* and *AC* are used (PMI 2013; Kim 2015; Chen 2016); they are described as follows. *PV* is defined as the sum of the multiplication of the planned quantities of the units to execute (*pq*) and the unit rate agreed with the owner (also known as budgeted unit price, DoD 2015) (*up*). The cumulative *PV* at the scheduled end represents the budget at completion (*BAC*). *AC* is defined as the sum of the multiplication of the actual quantities executed (*aq*) and the unit actual cost (*ac*). The cumulative value of *AC* at the end of the project corresponds to the actual cost at completion (*ACAC*). And finally, *EV* is defined as the sum of the multiplication of the actual quantities executed (*aq*) and the agreed unit rate (*up*).

In order to monitor production, two main indicators are proposed: *PP* (planned production) and *AP* (actual production). The *PP* is defined as the sum of the multiplication of the planned quantities (*pq*) and the contractor's planned rate (*pc*). From the contractor point of view, the cumulative *PP* at the end of the project represents the planned production at completion (*PPAC*). Actual production (*AP)* is defined as the sum of the multiplication of the actual quantities (*aq*) and the contractor's planned rate (*pc*). Combining these new indicators with the standard EVM indicators, additional information related to contractor profitability can be generated. Thus, three new indicators are proposed: *PB* (planned profitability), *AB* (actual profitability) and *PPI* (production performance indicator). *PB* provides the planned economic benefit as the difference between *PV* and *PP*. *AB* is the economic benefit calculated as the difference between *AP* and *AC*, and finally, *PPI* is calculated as the *AC divided by AP*. Regarding the standard EVM variance and performance indicators, those related with cost (i.e. *CV* and *CPI*) are consider appropriate. Table 2 summarizes all the indicators proposed.

<TABLE 2 HERE>

CASE STUDY

Definition and scenarios

In order to analyze the capability of the proposed EVM approach, a case study is used to implement the proposal. This case study is a simplification of a real project, involving the construction of a concrete retaining wall. Figure 1 shows the work units with their corresponding unit price and quantity. Additionally, information about the Gantt diagram and scheduled quantities to be executed each month is also provided in Figure 1. From the contractor point of view and considering the formulation proposed in Table 2, the planned production at completion (*PPAC*) is € 1,117,100.

<FIGURE 1 HERE>

Scenario simulations are often used in project management research to check the feasibility of a proposal (Kim and Ballard 2010; Pajares and López-Paredes 2011; Kim 2016; Kim et al. 2016). In this paper, this simplified project is used as a case study where a set of scenarios is analyzed. These scenarios simulated different performances of the project during its execution, accounting for possible scenarios faced by the contractor. Table 3 contains the definition of these scenarios, in which different combinations between planned and real unit cost and quantities are explored. In order to better explain the characteristics of these scenarios, Table 3 shows the relation between the unit rate agreed with the owner and actual unit cost (*up* versus *ac*) and quantities (*pq* versus *aq*) considered in each scenario.

<TABLE 3 HERE>

Scenario 0 reflects a project performance in which actual costs and quantities equal values agreed with the owner (*up* = *ac* and *pq* = *aq*). Similarly, Scenario 1 accounts for a scenario in which actual costs equal values agreed with the owner (*up* = *ac*) but there are differences between planned and actual quantities (*pq* ≠ *aq*). Two variants of this scenario are explored (scenario 1A and 1B). In the first variant (1A), the actual cost at completion is lower than the planned cost at completion (*BAC* > *ACAC*), resulting in a profitable project to the contractor. The second variant (1B) represents a non-profitable project to the contractor because *ACAC* is higher than *BAC*. Scenarios 2 and 3, each of them with its variants (2A, 2B, 3A, and 3B), cover the rest of possible combinations of unit cost and quantities.

Results and discussion

This section shows the results obtained applying the proposed formulation to the case study. Due to the space limitation, only one of these scenarios is described in detail. The scenario chosen for the detailed analysis is Scenario 3, as it reflects the general scenario in which all the possible deviations (both in terms of unit cost and quantities) affect project performance. Specifically, variant 3B (where *ACAC* is higher than *BAC*) will be analyzed, as it is the most unfavorable scenario for the contractor.

As described in Table 3, Scenario 3B has deviations in both unit costs and quantities. For instance, the actual earth volume to be removed is 73,500 m^3, which is higher than the originally estimated (70,000 m^3). In terms of cost, the actual cost (4.73 €/m^3) also exceeds its planned value (4.50 €/m^3). Similar deviations have been simulated for the other tasks, considering a variance of ±10%. In addition to deviations between planned and actual costs and/or quantities, deviations between planned costs and unit prices may also exist. In this regard, this case study considers units in which the contractor's planned rate (*pc* in Figure 1) differs from the unit rate agreed with the owner (*up* in Figure 2). From the contractor point of view, these deviations may be both positive (e.g. steel unit in Figures 1 and 2) or negative (concrete unit in Figures 1 and 2), reflecting the competitiveness of the company in the production of the tasks. In global terms the planned profitability of the project, from the contractor point of view, will be determined by the difference between planned production and budget at completion (*PPAC* and

BAC). Similarly, the actual profitability of the project will be provided by the difference between actual cost at completion and budget at completion (*ACAC* and *BAC*).

<FIGURE 2 HERE>

Overall, deviations considered in this case study lead to an unfavorable scenario for the contractor because the *ACAC* is higher than *BAC*. A detailed description of contractor planning and actual performance and progress in scenario 3B is described in Figure 2. It is important to note that the existing deviation in quantities in Scenario 3B does not lead to variations in the project duration, as both the planned and actual project duration is five months (Figures 1 and 2, respectively). The project is completed on time and, because of the reasons stated at the end of section 2, schedule control will not be analyzed in this paper.

<FIGURE 3 HERE>

Considering traditional EVM indicators (*PV*, *AC* and *EV*) it could be concluded that scenario 3B corresponds to a good performance of the project in terms of cost: earned value is higher than actual cost (*EV* > *AC* in Figure 3) and, therefore, the cost performance is higher than planned (*CPI* > 1 in Figure 4). With respect to Figure 3, it is important to note that *PV* and *EV* at the end of the project have not the same value, as it would be expected in a typical application of EVM in a project like this without any delay. This difference between *PV* and *EV* is explained by the variations of quantities in some work units ($pq \neq aq$), which is usually the case in unit-prices approaches, but not considered in traditional EVM approach. By solely relying on traditional EVM indicators, the contractor would thus conclude that project performance in terms of cost is good while, as it will be explained later, this is not the case in this project.

<FIGURE 4 HERE>

There is some additional information for the contractor that traditional EVM is not processing. Indeed, although *EV* is higher than *AC*, the contractor needs to know whether this project is profitable or not and whether the actual profitability is higher or lower than the planned profitability. In order to cover this gap, the proposed EVM formulation provides information not only in terms of cost (as traditional EVM approach do), but also in terms of production and profitability. Indeed, information related to production and profitability is the cornerstone for the contractor in dealing with the project as a business enterprise.

As stated before, traditional EVM does not alert the contractor because the project cost performance in Scenario 3B seems to display an optimistic situation ($EV > AC$ in Figure 3, and $CPI > 1$ in Figure 4). However, this information may be misleading because in terms of production, the project is not profitable to the contractor yet. Indeed, the actual cost at completion (*ACAC*) exceeds the planned budget at completion (*BAC*). This poor performance, which cannot be tracked using traditional EVM indicators, has been indeed present during all the project duration (as $AC > AP$ in Figure 3).

Actually, the actual production is lower than the actual cost (*AC* > *AP* in Figure 3 and, therefore, *PPI* < 1 in Figure 4). Therefore, whilst the cost performance identified using traditional EVM did not alert the contractor (*CPI* > 1 in Figure 4), the proposed indicators informed the contractor that there was a problem with the project profitability (*PPI*<1 in Figure 4). The contractor has planned to earn 78,950 € at the end of the project, obtained as the difference between *PP* and *PV* at completion (Figure 5). Nevertheless, due to the “poor” performance of the project in terms of profitability, the contractor is not gaining as much as expected albeit the project cost performance seemed to be right when traditional EVM indicators are considered.

<FIGURE 5 HERE>

The proposed formulation enables a more accurate analysis of the project performance in terms of profitability, constantly informing the contractor about the project profitability. The inclusion of the proposed indicators to those considered in traditional EVM provides contractors under unit-price contracts with additional information that would enhance the management of the project. As it can be seen from this case study, the proposed formulation enables to analyze the production performance, as well as the profitability, of the project, which are not considered in traditional EVM.

CONCLUSIONS

EVM formulation can be directly applied to cost-reimbursable and lump-sum approaches, either by the owner or the contractor. However, EVM cannot be implemented by contractors when the payment agreement is based on unit-prices. In this payment approach, the owner pays the quantities actually executed according to the pre-agreed rate established in the contract for each unit or task; the income received by the contractor from the owner (production) is neither proportional to costs nor fixed a priori, as in cost-reimbursable and lump sum contracts, respectively. Therefore, contractors have to control not only cost but also production. The current formulation of EVM does not allow controlling production; an additional baseline is needed. Given this knowledge gap, this paper developed a rigorous methodology to enable application of EVM philosophy by contractors in unit-prices contracts; this is the contribution of this paper to the body of knowledge in project management. This way, contractors in unit-price approaches can apply EVM. The proposed EVM formulation relevant information for the contractor that traditional indicators do not capture:

- The planned production (*PP*) provides information about the expected monthly production, which can compared against the expected cash flow. Additionally, this value allows estimating the planned profitability (*PB*).
- The actual production (*AP*) enables to track the profitability of the project. The comparison of *AP* with the actual cost (*AC*) enables the contractor to know whether the project is profitable or not.

- The difference between actual (*AB*) and planned profitability (*PB*) gives the contractor information regarding the project performance in terms of profitability.
- The production performance indicator (*PPI*) assesses the ratio between actual production and cost. Similarly than *CPI*, a value of *PPI* below 1 should provide the contractor with an early warning system, in terms of production performance.

Based on the results obtained in this study, it can be concluded that the proposed formulation enables contractors to generate further information from their project(s) compared to that of the traditional EVM alone and hence use them as a management tool for the contractor in unit-prices approaches. The information provided by the proposed formulation enables a more informed decision making and hence better management of the project, particularly in terms of cost. This formulation needs to be tested in different project scenarios providing further insight on the effect of uncertainty. Conversely, the proposed indicators focus only on cost, because of the limitations of the schedule indicators in traditional EVM; work-in-progress by the authors includes the extension of this proposal considering the Earned Schedule concept. Furthermore, when the payment approach is unit-price, determining the percent complete for unit items is a key issue; further research is going to be focused on this topic too.

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FIGURE CAPTION LIST:

Table 1. Calculations of variances, performance and forecasting indices

INDICES	CALCULATION
Cost Variance (*CV*)	*CV = EV-AC*
Cost Performance Index (*CPI*)	*CPI = EV/AC*
Cost Estimation at Completion (*EAC*)	*EAC* = *AC* + *(BAC-EV)/CPI*

Table 2: Proposed EVM indicators for contractor cost management in unit prices approaches

TYPE	INDICATOR	DESCRIPTION
Planning indicators	$PV = \sum pq * up$	Planned Value
	$PP = \sum pq * pc$	Planned Production
	$PB = PV - PP$	Planned Profitability
Main indicators	$EV = \sum aq * up$	Earned Value
	$AC = \sum aq * ac$	Actual Cost
	$AP = \sum aq * pc$	Actual Production
Variation indicators	$CV = EV - AC$	Cost Variance
	$AB = AP - AC$	Actual Profitability
Performance indicators	$CPI = EV / AC$	Cost Performance Indicator
	$PPI = AP / AC$	Production Performance Indicator

Note: *pq* is the planned quantity of the units to execute; *aq* is the actual quantity of the executed units; *pc* is the contractor's planned rate; *ac* is the actual cost; and *up* is the unit rate agreed with the owner.

Table 3: Scenarios explored in the case study

ID Scenario	UNIT RATES (*up versus ac*)	QUANTITIES (*pq versus aq*)	VARIANT	COST AT COMPLETION
0	$up = ac$	$pq = aq$	0	$BAC = ACAC$
1	$up = ac$	$pq \neq aq$	1A	$BAC > ACAC$
			1B	$BAC < ACAC$
2	$up \neq ac$	$pq = aq$	2A	$BAC > ACAC$
			2B	$BAC < ACAC$
3	$up \neq ac$	$pq \neq aq$	3A	$BAC > ACAC$
			3B	$BAC < ACAC$

UNIT	BUDGET		PLANNED PROGRESS (MONTHS)				
	Planned quantity (*pq*)	Planned cost (*pc*)	1	2	3	4	5
m^3 of earth removal	70,000	5.00	**70,000**				
kg of steel in base slab	200,000	0.90		**200,000**			
m^2 of formwork in base slab	750	18.00			**750**		
m^3 of concrete in base slab	3,500	50.00			**3,500**		
kg of steel in stem	280,000	0.90				**280,000**	
m^2 of formwork in stem wall	1,200	18.00					**1,200**
m^3 of concrete in stem wall	2,500	50.00					**2,500**
	PPAC =	1,117,100					

Figure 1: Contractor's planned budget and progress

UNIT	CONTRACTOR PERFORMANCE			ACTUAL PROGRESS				
	Actual quantity (*aq*)	Rate agreed with the owner (*up*)	Actual cost (*ac*)	1	2	3	4	5
m^3 of earth removal	73,500	4.50	4.73	**73,500**				
kg of steel in base slab	210,000	0.75	0.79		**210,000**			
m^2 of formwork in base slab	825	17.00	17.85			**825**		
m^3 of concrete in base slab	3,675	55.00	57.75			**3,675**		
kg of steel in stem	294,000	0.75	0.83				**294,000**	
m^2 of formwork in stem wall	1,320	17.00	18.70					**1,320**
m^3 of concrete in stem wall	2,625	55.00	52.25					**2,625**
		BAC = 1,1091,715	*ACAC* = 1,144,010					

Figure 2: Scenario 3B - Contractor actual performance and progress

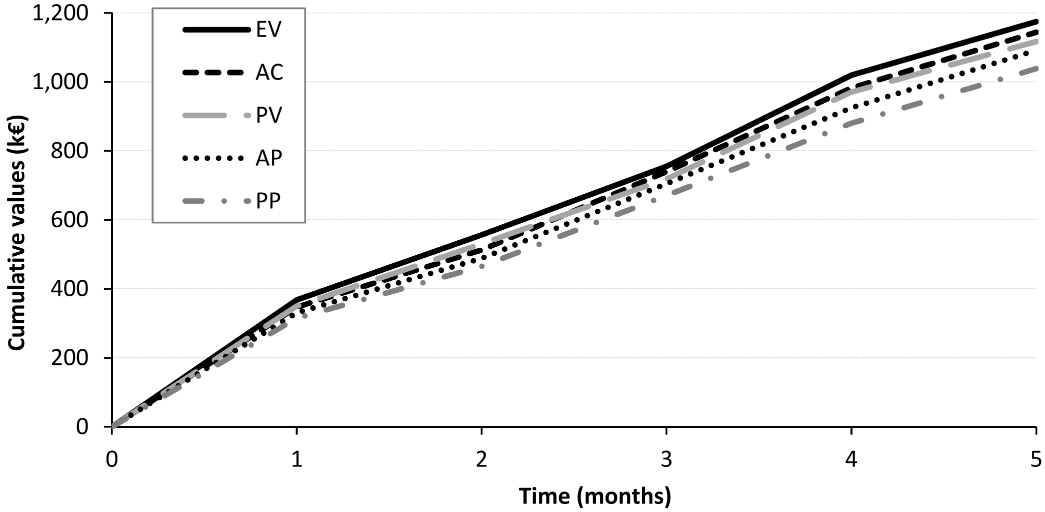

Figure 3: Scenario 3B – Traditional EVM indicators and proposed indicators

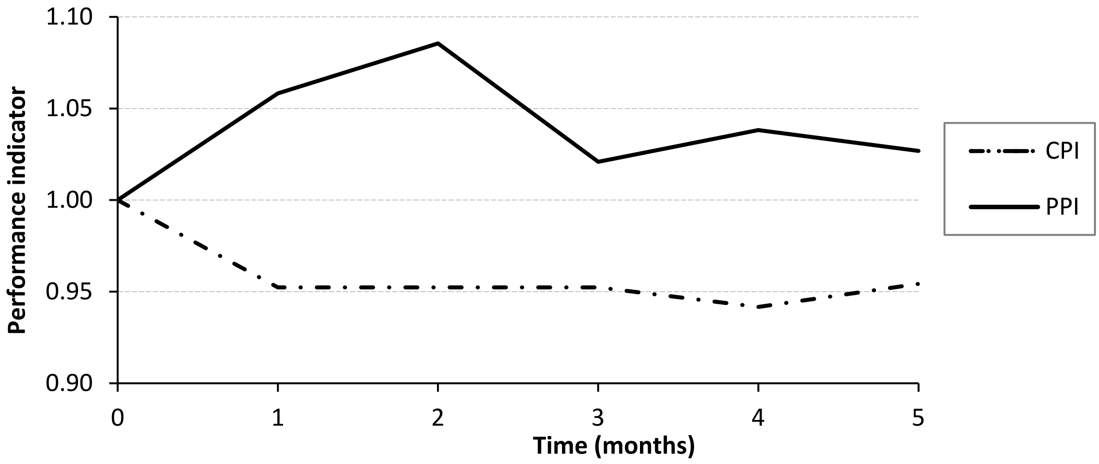

Figure 4: Scenario 3B – Production and cost performance indicators

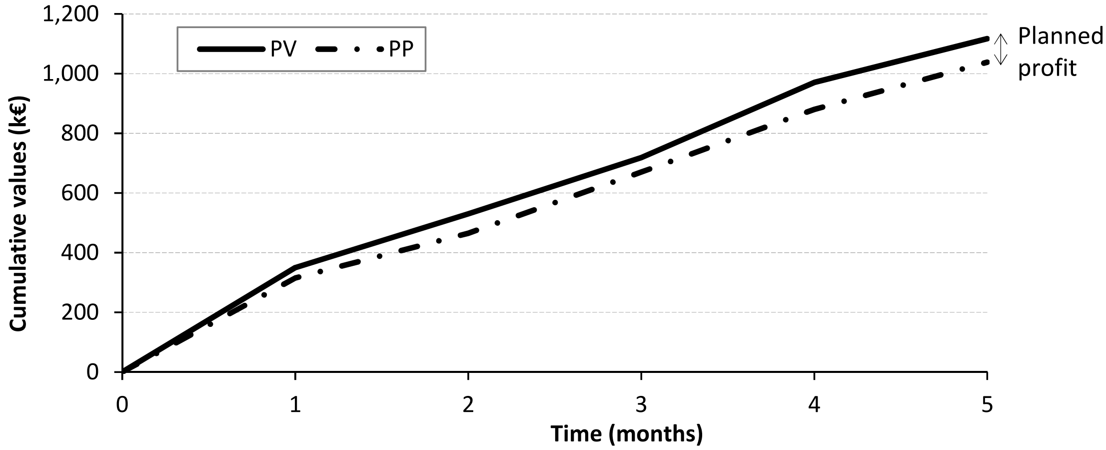

Figure 5: Scenario 3B – Planned production and value