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# Quality: the third element of earned value management

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**Abstract**

This paper aims to contribute to studies seeking to add the quality component into earned value management method using as background a case study in agricultural operation. Thus, this case study considered harvesting soybean in a farm located in Brazil as a project. A methodology for calculating the Quality Earned Value (QEV) is proposed. It is proposed formulas to estimate the Quality Variance (QV), Quality Index Number (QIN), and Quality Performance Index (QPI). It was identified five quality indicators for harvesting soybean that were used to illustrate the proposed method. Also, it was evaluated the possibility of using the EVM to assess the operational performance of crops. The lack of quality resulted in a QIN as 0.67 (average), and an accumulated QEV as R$ 7,074.12. The results indicated a SPI as 0.07, the total cost as R$ 10,470.60, average CPI as 0.46, and an expense of R$ 2,519.25 higher than planned budget (R$ 7,950.90). The results indicated that it is possible to add the quality component in EVM method and that EVM can be used to measure the performance of harvesting soybean, however, further assessments are needed.


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*Keywords:* project management, earned value management, quality, agriculture.

## 1. Introduction

The actual business environment, with scarce resources and high competition, demands efficient managerial tools to delivery projects on time, on budget, and in accordance of the stakeholders' requirements. On this scenario, Earned Value Management (EVM) is recognized as an efficient tool to measure performance and provide feedback

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for ongoing project [12]. Another important EVM feature is its applicability in a range of project types from Aeronautics [10] to research projects [2].

However, the EVM methodology does not include the quality component in its method. In 2011, the North American government requested to the Department of Defense (DoD) to consider its inclusion in the Earned Value Management System (EVMS) of Dod's acquisition program [14]. [17] Explained the problem stating that while EVM is efficient to provide
information on the project budget and costs status, EVM is still weak to inform whether the custimers quality requirements has been met.

In order to address this issue, articles have been published trying to contribute with the efforts to include quality in the EVM sucha as [15]; [7]; [17]; and [8]. [15] Propose to use the Capability Maturity Model Integration to strengthen adherence to EVM principles, especially regarding quality assurance. [7] Used control chart to monitor variation in schedule and costs performances. [17] Proposed to integrate critical quality metrics into the EVM. [15] Suggested to use quality cost as quality variable and introduces it into the EVM.

On this scenario, this paper aims to contribute with the knowledge building efforts to add quality into the EVM. It is proposed a method that focuses on the actual cost to meet the project quality requirement. The method is described using as a project the soybean harvesting operation.

## 2. Brief Introduction on Agriculture Project Management

Agriculture is still an economic area where project management techniques (PMT) and EVM are not used as common managerial tool. [13] May be considered as pioneer in recommend PMT for agricultural project. He stressed that PM can be used in a wide range of agricultural cases such as in large-scale investments on individual farms to irrigation projects [13]. [9] found that PMT has been increasing in agriculture and food industry. Also, [16] use PMT to manage several investment on agricultural projects in developing nations.

However, it is small the amount of studies using PMT to manage crops. [6] Compared the crop life cycle and the project life cycle and concluded that crops could be considered as a project. Using the *A Guide to project management body of knowledge* - PMBOK® Guide 4th edition [11], [4] elaborated a project to manage a four years cycle of sugarcane crop. They concluded that not only is the methodology efficient for managing all farming operation activities but also does it ehance the quality and risk management of all farming operations. [3] stated "by integrating the PM knowledge areas through the crop life cycle is possible to achieve a more sustainable agriculture in which profit, stewardship, and quality of life are met (p.15)". By considering a crop as a project, a new range of operational performance assessment can be achieved by applying efficient managerial tools such as EVM. Therefore, the second objective of this study is show the applicability of EVM to evaluate farming operations.

## 3. Methodology

### *3.1. Earned Value Management*

This study followed the methodology found in these two publications: *Practice Standard for Earned Value Management [11]* and *Earned Value Project Management* [5]. The earned value (EV) was estimated using the percentage complete technique [3]. Table 1 summarizes the major EVM definitions and formulas utilized in this study.

Table 1. Description of EVM definitions and formulas.

| Name | Description | Formula |
|---|---|---|
| Planned value (PV) | The sum of budgets for al authorized work. Also known as the performance measurement baseline | |
| Earned value (EV) | The authorized work physically accomplished | EV=PV*% of completed work |
| Actual cost (AC) | The total costs to achieve the actual work performed to date | |
| Schedule variance (SV) | Determines whether the project is ahead of or behind schedule | SV=EV-PV |
| Schedule performance index (SPI) | Indicates how efficiently the time has been used when compared to the baseline | SPI= EV/PV |
| Cost variance (CV) | Determines whether the project is under or over budget | CV=EV-AC |
| Cost performance index (CPI) | Indicates the cumulative cost efficiency of the project | CPI=EV/AC |

Sources: Adapted from [11] and [5].

The work breakdown structure (WBS) was utilized to create the activity list for the soybean harvesting project (see table 3). For each task listed on table 3, it was estimated its time and cost. Time for each task execution was elaborated either using agronomic techniques or by asking the farmer his opinion. The budget at completion was estimated using the total cost method using the information of the farmer's loan project, which was elaborated on May 2012. The actual costs were elaborated using receipts and personal notes of expenses during the harvesting operation that occurred in April, 2013.

### *3.2. Quality Earned Value (QEV)*

The objective of Quality Earned Value (QEV) is to measure the project ability to deliver the quality requirements defined by the project's stakeholder, throughout the project execution. It focuses on providing a snapshot of the project efficiency to deliver the project quality requirements based on the used time and spent money (actual costs). Additionally, the methodology seeks to link the quality management process to the earned value management. Therefore, the processes and formulas follow similar logic existent in the EVM. Table 2 presents the Quality Earned Value components.

Table 2. Description of EVM definitions and formulas.

| Name | Description | Formula |
|---|---|---|
| Quality Requirements (QR) | It is the quality requirements for a given task. The unit may vary according to the QR | |
| Quality Performance Index (QPI) | Indicates how efficient the project is conducted to meet the task's QR. It is used when a task has one quality requirement or as part of the Quality Index Number (QIN) when a task has more than one QR | QPI = 1 (when the quality requirements are met<br><br>QPI= 0 (when the quality requirements are NOT met) |
| Quality Index Number (QIN) | The ratio between the Sum of Quality Performance Index (QPI) for a given task, divided by the sum of the number of Quality Requirements (NQR) for a given task. It is used when a task has more than one quality requirement | QIN= ∑QPI/∑NQR<br><br>1 QR = 1NQR |
| Quality Earned Value (QEV) | The earned value of the work that met QR of the performed work. It is estimated by multiplying the QPI (or QIN) by the Actual Costs (AC) expressed in monetary units. | QEV= QPI*AC (one QR per task)<br><br>QEV= QIN*AC (More than one QR per task) |
| Quality Variance (QV) | Indicates the cumulative quality efficiency of the project | QV=QEV-AC |

In order to elaborate the Quality Earned Value (QEV), we took five steps as following:

*3.2.1. Step 1*

The first step was to identify quality indicators for each activity listed on the WBS. A table was elaborated having a column for the project WBS and their quality requirements (see table 3). The WBS are as following: 1. Soybean Harvesting, 1.1. Pre harvesting, 1.1.1. Freight: Harvester, 1.1.2. Freight: Tractor + Loader, 1.1.3. Freight: Trunk 1, 1.2. Harvesting, 1.2.1. Harvester machine, 1.2.2. Grain transfer: (tractor + loader), 1.2.3. Quality control, 1.2.4. Freight 1 (own Trunk), 1.2.5. Freight 2 (contractor), 1.2.6. Freight 3 (contractor) and 1.3. Project Management.

Then, a quality management plan was elaborated following recommendations the PMBOK® *Guide* 4th. In this case study, it was defined and measured only quality requirements in the task 1.2.1.

Table 3. Quality indicator list per activity listed on the WBS.

| WBS | Name | Quality Requirements |
|---|---|---|
| **1** | **Soybean Harvesting** | |
| **1.1** | **Pre harvesting** | |
| **1.2** | **Harvesting** | |
| 1.2.1 | Harvester machine | Pre-harvest grain losses + Pos-harvest grain losses: 1.5 sc/ha<br>Worked hours:7 hours per day<br>Grain moisture: 14 %<br>Impurities: 3% |
| **1.3** | **Project Management** | |

*3.2.3. Step 2*

The next step was to draw a table the limits of specification for each quality requirement listed on table 3. In order to facilitate the next steps, the Quality Performance Index was also added to the table.

Table 4. Soybean harvesting quality requirements.

| Description | Impurities (%) | Grain moisture (%) | Worked hours (hours) | Grain loss (Bags/ha) | **Quality Performance Index** |
|---|---|---|---|---|---|
| Lower Specification Limit | 0 | 10 | 6.5 | 0.0 | **1.0** |
| Target | 2 | 13 | 7.0 | 1.0 | **1.0** |
| Upper Specification Limit | 3 | 14 | 7.5 | 1.5 | **1.0** |
| Out of specification | >3 | >14 | >7.5 | >1.5 | **0.0** |

*3.2.3. Step 3*

The quality management team monitored and controlled the project quality in parallel with the schedule and cost management team. The quality data was collected during the execution of each task or at the end of it, following the quality management plan. In order to collect data on field, it was taken 50 samples before harvesting for quality control of pre-harvesting grain loss, and other 50 samples post- harvesting for quality control of the remainder quality requirement item on task number 1.2.1 (Harvester machine).

The researchers used a GPS to mark the data collecting points on the field in order to collect data at the same points pre and post-harvesting. The post-harvesting data collection accompanied the harvester machine work. The findings were grouped in worked days. Then, it was calculated the percent of samples that were between the Lower Specification Limit (LSL) and the Upper Specification Limit (USL).

### *3.2.4. Step 4*

The final step was to calculate the Quality Earned Value (QEV) for task 1.2.1 (see table 5). Every day, the quality requirements data was collected along with the schedule and cost data. Table 5 grouped the quality requirements (QR), the Quality Performance Index (QPI), the Quality Index Number (QIN), the work day actual cost, the Quality Earned Value (QEV), and the Quality Variance (QV).

### *3.2.5. Step 5*

In order to make easier the interpretation of the EVM and QEV performance measures, it was elaborated the table 6 that shows all possible combination between schedule, cost, and quality. This table is and adaptation of original table found in the ([12], p. 16).

Table 5. Interpretations of EVM considering the Quality Variance (adapted from PMI, 2005)

| Performance Measures | | Schedule | | | Performance Measures | |
|---|---|---|---|---|---|---|
| | | SV > 0 & SPI > 1.0 | SV = 0 & SPI = 1.0 | SV < 0 & SPI < 1.0 | | |
| Cost | CV > 0 & CPI > 1.0 | Under specification<br>Ahead of Schedule<br>Under Budget | Under specification<br>On Schedule<br>Under Budget | Under specification<br>Behind Schedule<br>Under Budget | QV = 0 & QPI = 1.0 | Quality |
| | CV > 0 & CPI > 1.0 | Out of Specification<br>Ahead of Schedule<br>Under Budget | Out of Specification<br>On Schedule<br>Under Budget | Out of Specification<br>Behind Schedule<br>Under Budget | QV > 0 & QPI = 0 | |
| | CV = 0 & CPI = 1.0 | Under specification<br>Ahead of Schedule<br>On Budget | Under specification<br>On Schedule<br>On Budget | Under specification<br>Behind Schedule<br>On Budget | QV = 0 & QPI = 1.0 | |
| | CV = 0 & CPI = 1.0 | Out of Specification<br>Ahead of Schedule<br>On Budget | Out of Specification<br>On Schedule<br>On Budget | Out of Specification<br>Behind Schedule<br>On Budget | QV > 0 & QPI = 0 | |
| | CV < 0 & CPI < 1.0 | Under specification<br>Ahead of Schedule<br>Over Budget | Under specification<br>On Schedule<br>Over Budget | Under specification<br>Behind Schedule<br>Over Budget | QV = 0 & QPI = 1.0 | |
| | CV < 0 & CPI < 1.0 | Out of Specification<br>Ahead of Schedule<br>Over Budget | Out of Specification<br>On Schedule<br>Over Budget | Out of Specification<br>Behind Schedule<br>Over Budget | QV > 0 & QPI = 0 | |

## 4. Results

### *4.1. Time management*

The harvest was planned to take place from April 6th to 13, 2013. However, it rained between April 6th and 7th 2013, postponing the starting of the harvest to April 9. The farmer carried his machines to field on April 9, starting the soybean harvesting in the afternoon. It rained again on the night of April 10, forcing the farmer to stop harvesting in the area of study and transport his machinery to another field. He returned to the area of study on April 19, spending four working days to finish the harvesting on April 22nd, 2013. The rains on April 6th and 7th caused a delay of 3 days at the beginning of the project resulting in a negative schedule variation on April 9 and 10 as R$ 162.06 and R$ 538.17, respectively. The schedule performance index (SPII) as 0.30 and 0.59, respectively. The project was expected to be close on April 13, however, the project extended until the April 22nd, which resulted in overall SPI equals 0.07. (see Table 7). Figure 1 shows the project's "S" curve of the Soybean Harvesting Project.

### *4.2. Cost management*

The estimated budget for the harvesting project was R$ 7,951.35, based on calculations on August 2012, when the farmer got the loan for funding the crop cycle at a Brazilian bank. The rains forced the farmer to spend twice with machinery freight than it was planned. In addition, he planned to deliver the soybean production in the nearest cooperative's Silo. On April 10$^{th}$, the farmer was informed that the deposits was complete load, forcing him to deliver the remaining production in a warehouse 100 km away from the Cooperative's silo, which increased the freight costs. Thus, the soybean crop cost R$ 10,470.60, which represents an cumulative cost of variation (CV) of R$ 3,389.32 and average cost performance index (CPI) 0.46 (see table 7).

### *4.3 Quality Earned Value (QEV)*

In Table 6 shows the Quality Earned Value (QEV) per working day (milestones). On April 21 soybeans had a moisture percentage above the QR limits and grain loss over the specification limits, resulting a QV of R$817.22. QIN was 0.5 meaning that 50 percent of the performed work met the QR. In other words, the farmer wasted R$ 817.22 in work out the specification. The overall lack of quality of the performed work resulted a QIN equals 0.67. It means that R$0.67 of the work performed met the limits of specifications for each Real spent in the project. The farmer spent R$10,470.60 on harvesting soybean in which R$7,074.12 was converted into "correct" deliverables, resulting on R$3,396.47 of performed work out the quality requirements.

Table 6. Quality Earned Value (QEV) for the harvesting activity.

| Day | Impurities | | | Moisture | | | Worked hours | | | Grain loss | | | Index Number | | Quality Earned Value | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | QR | QPI | % | QR | QPI | Hours | QR | QPI | Bags/ha | QR | QPI | Sum (QPI) | QIN | AC (R$) | QEV (R$) | QV ( |
| 9 | 2.54 | | 1.00 | 14.00 | | 1.00 | 6.50 | | 1.00 | 1.94 | | 0.00 | 3.00 | 0.75 | 1,803.11 | 1,352.33 | (45 |
| 10 | 2.52 | | 1.00 | 14.00 | | 1.00 | 7.00 | | 1.00 | 2.77 | | 0.00 | 3.00 | 0.75 | 1,496.78 | 1,122.59 | (37 |
| 19 | 2.25 | 3.00 | 1.00 | 14.00 | 14.00 | 1.00 | 6.80 | 7.00 | 1.00 | 2.27 | 1.50 | 0.00 | 3.00 | 0.75 | 2,846.39 | 2,134.80 | (71 |
| 20 | 3.00 | | 1.00 | 14.00 | | 1.00 | 6.50 | | 1.00 | 3.55 | | 0.00 | 3.00 | 0.75 | 1,209.01 | 906.76 | (30 |
| 21 | 2.06 | | 1.00 | 18.00 | | 0.00 | 7.00 | | 1.00 | 2.28 | | 0.00 | 2.00 | 0.50 | 1,634.45 | 817.22 | (81 |
| 22 | 1.04 | | 1.00 | 14.00 | | 1.00 | 6.00 | | 0.00 | 2.70 | | 0.00 | 2.00 | 0.50 | 1,480.85 | 740.42 | (74 |
| | | | | | | | | | | | | | | 0.67 | 10,470.60 | 7,074.12 | (3,39 |

QR: Quality requirements; QIN: Quality Index Number; QPI: Quality Performance Index; QEV: Quality Earned Value; and QV: Quality Variance

Table 7. Earned Value Management: Schedule and Cost.

| Day | Planned Value (R$) | Actual Cost (R$) | Earned Value | | Schedule Management | | Cost Management | | Quality Earned Value | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (%) | (R$) | SV (R$) | SPI | CV(R$) | CPI | QIN | QEV (R$) | QV (R$) |
| 6 | 5.00 | - | - | - | (5.00) | - | - | - | - | - | - |
| 7 | 729.31 | - | - | - | (729.31) | - | - | - | - | - | - |
| 8 | 778.20 | - | - | - | (778.20) | - | - | - | - | - | - |
| 9 | 896.37 | 1,803.11 | 100.00 | 734.31 | (162.06) | 0.30 | (1,068.80) | 0.41 | 0.75 | 1,352.33 | (450.78) |
| 10 | 1,316.37 | 1,496.78 | 100.00 | 778.20 | (538.17) | 0.59 | (718.58) | 0.52 | 0.75 | 1,122.59 | (374.20) |
| 11 | 1,711.54 | - | - | - | (1,711.54) | - | - | - | - | - | - |
| 12 | 1,316.37 | - | - | - | (1,316.37) | - | - | - | - | - | - |
| 13 | 1,198.20 | - | - | - | (1,198.20) | - | - | - | - | - | - |
| 19 | - | 2,820.11 | 100.00 | - | - | - | (1,503.74) | 0.47 | 0.75 | 2,134.80 | (711.60) |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | - | 1,209.01 | 100.00 | - | - | - | 502.53 | 1.42 | 0.75 | 906.76 | (302.25) |
| 21 | - | 1,634.45 | 100.00 | - | - | - | (318.08) | 0.81 | 0.50 | 817.22 | (817.22) |
| 22 | - | 1,480.85 | 100.00 | - | - | - | (282.65) | 0.81 | 0.50 | 740.42 | (740.42) |
| Total | 7,951.36 | 10,470.60 | | 7,951.35 | (6,438.85) | 0.07 | (3,389.32) | 0.46 | 0.67 | 7,074.12 | (3,396.47) |

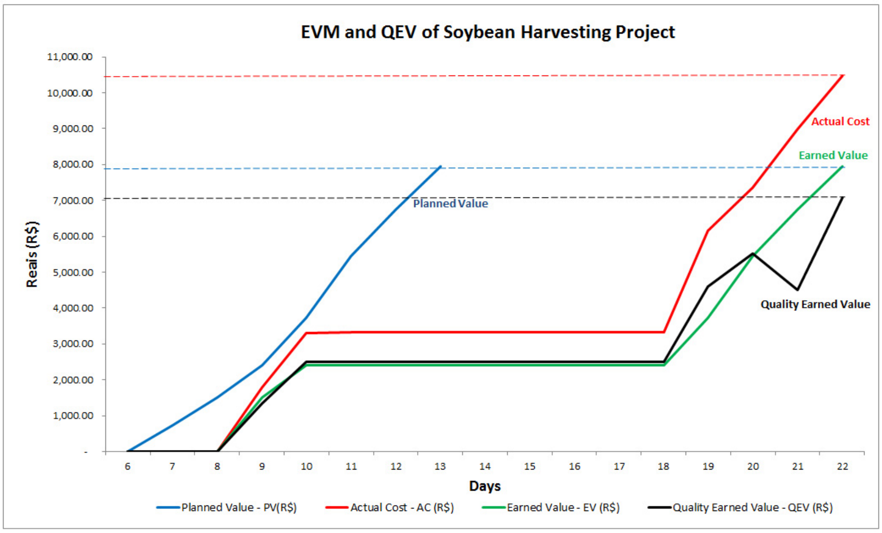


Fig. 1. Cumulative Planned Value, Earned Value, Actual Costs, and Quality Earned Value for the Soybean Harvesting Project.

## 5. Conclusion

This study aimed to contribute to the studies for inclusion the quality component into EVM method. Its secondary purpose was to present the possibility of using EVM to assess the operating performance of agricultural activities. This case study considered as project the soybean harvesting. The results showed that delays in harvest generated a SPI as 0.07 and the cumulative actual costs were R$ 2,519.25 higher than planned value R$7,951.36. The ability of the project to meet the quality requirements was between 50% and 75%. The limitation of this study was the small number of activities evaluated, and the use of five quality requirements, so further studies are recommend, in order to improve or validate the proposed methodology.

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