PROJECT MONITORING AND CONTROL USING BURNDOWN CHARTS

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ABSTRACT

The project monitoring and control is performed to measure the actual values of project planning parameters and comparing them to the estimates from the plan identifying the deviations. If the project’s performance deviates significantly from the plan, appropriate corrective actions should be defined. Visual representation of the plan can help project managers to follow easier the progress of the project and take the right decisions. Starting with the 1980s the Gantt became the most common technique for project planning visualization which works well in case of plan-driven project life cycles. For agile project progress visualization the burndown chart was introduced, which can be a powerful tool for any project. This paper presents how to use burndown charts to monitor project progress and presents a method to monitor project performance.

Keywords: project management, cost estimation, earned value management, time delivery, burndown chart

1. Introduction

All projects need to be performed and delivered under certain constraints. Traditionally, these constraints are categorized as scope, time and cost constraints. Later other two were added to this list: quality and risk. The project performance management is the activity which monitors the project, controls it whenever is needed to achieve the preset performance criteria, holds the team accountable and keeps the management team informed. Its purpose is to give answers anytime on question like: How is your project coming along? Preferably, the answer should relay on performance models consisting from measurements and performance indicators built to observe and track the project constrains.

The project performance model described in this paper was defined within Sysgenic Group as a combination of three existing project management techniques: Earned Value Management (EVM), Earned Schedule (ES) and the time-budget burndown charts used for the project status, progress and predictions illustration.

2. The performance model

EVM is a project management technique for measuring project progress. It combines the measurements of scope, schedule, and cost in a single integrated system indicating early any performance problems [1]. The technique was extended in 2003 by Walt Lipke [2] who introduced the ES model to correct EVM’s schedule related measures (Schedule Variance - SV, Schedule Performance Index - SPI) which were indicating incorrect status at the completion of a project with schedule delays. Many researchers studied the correctness and validity of ES, the conclusion [3][10] was that EVM and ES techniques complement each other perfectly and their combination offers a great tool for project performance measurement and control. This way, the performance model defined at Sysgenic Group was built based on the EVM indicators, such as: Cost variance (CV), Cost Performance Index (CPI), To Complete Performance Index (TCPI) and based on the ES indicators, as: Schedule Variance (SV(t)), Schedule Performance Index (SPI(t)), To Complete Schedule Performance Index (TSPI), calculated based on the Earned Schedule (ES), Earned value (EV), Actual Cost (AC), Planned Value (PV) measures, as they were defined in the original models [1][2]. Our biggest challenge while defining the model was how to define and measure the earned value of the work done.

The selected solution was to calculate the Earned Value based on continuous estimation of the remaining work, which means a continuous adjustment of the initial estimation. More exactly the
earned value was defined as the difference between the planned total work and the estimated work remaining:

\[ EV_N = BAC - (EAC_N - EV_{\text{cum}}_{N-1}) \]  \hspace{1cm} (1)

where \( N \) is the number of measurement periods (ex: days, weeks, months), \( EV_N \) is the Earned Value measured at time \( N \), \( BAC \) is the Budget At Completion, the total planned value, \( EAC_N \) - Estimate At Completion, the forecast of total costs that will needed to complete the project - calculated based on past cost performance trends, \( EV_{\text{cum}}_{N-1} \) – the cumulative earned value calculated till that moment. Ideally \( EAC \) should be equal to \( BAC \) during the whole project lifecycle. In real word there is difference between them, which could reflect: incorrect original estimations, development difficulties, scope changes.

3. The steps to follow

Sysgenic Group has a wide range of projects (short, medium and long size, fix cost and/or with fix schedule projects), following different methodologies (Waterfall, Iterative and Incremental Development - IID, Scrum, etc), but the mostly used and preferred ones are the IID and the Scrum models. The performance model described in the previous section can be applied on all projects within the company, based on the assumption that any project can and should be divided in multiple sub-projects/iterations if necessary. These iterations can be the phases of the project in case of Waterfall, the iterations in case of IID, the sprints in case of Scrum software development model usage.

To apply the model the following steps should be followed:
- Identify the project (goal, scope, constraints)
- Divide in subprojects if necessary, (let’s call the project/subproject focus Work Package - WP),
- Create the Work Breakdown Structure (WBS) for the WP, (let’s call the items from the WBS list Tasks),
- Estimate the Tasks one by one, assign them to team members,
- Measure the work progress periodically (\( N \)) per Task,
- Reevaluate (estimate) the remaining work periodically (\( N \)) per Task,
- Monitor the total remaining time of the project,
- Update the model and the charts, generate the report,
- Take corrective actions whenever is necessary.

4. Visual representation

Inspired and amazed by the power of the chart used in Scrum methodology for its iteration burndown, we chose to use the same charts to visualize all projects progress. The vertical axis of the chart is the unit in which the effort is measured (hours, story points, artifacts), while the horizontal axis is the time (multiple of N). Burn charts have become a favorite way of representing the project progress, because they are simple and are offering a lot of information related the project status and a good base for decision making. Their natural mapping to the earned value makes them even more powerful and 100% applicable for our model. The popular phrase: A picture is worth a thousand words, is so true is case of progress reporting. There are two types of burn charts: the ones which represent the progress based on the work done, having increasing line slopes; and the others which represent the remaining work, with decreasing line slopes. The first one are called simply burn charts, the second one burndown charts. They both are useful, but the burn-down charts are more emotionally powerful because there generate the special feeling about hitting the number zero that helps people get excited about completing their work and pressing forward. Since most of the measures and indicators within the model have the same units, they can be combined and presented in the same chart, offering more complete information about the status.

4.1 Project progress charts

The project progress is illustrated in a burndown chart with three lines (Fig. 1):
- (p) the planned (estimated) progress (PV)
- (s) the remaining work (BAC-EV), reflecting the actual progress
- (c) the cost of the actual work (BAC-AC)

![Fig. 1. Project progress](image)

The estimated work (p) is calculated based on the planned hours of assigned resources, considering their productivity coefficient as well [4][12].

Then (p) is the representation of Relation (2):

\[ PV_N = BAC - (PV_{\text{cum}}_{N-1}) \]  \hspace{1cm} (2)

where \( PV_N \) is the planned value (effort) for that specific period (N). Line (p) will serve as a reference for the other two lines. Line (s) is the representation of Relation (1); it shows the real progress of the team,
the earned value of their work. Ideally this should follow line (p), by starting from the total estimated work, then decreasing towards level 0, reaching it when everything is done. Line (c) represents the remaining budget calculated based on the actual effort spent by the team till that moment:

\[ AC_N = BAC - (AC_{cum_{N-1}}) \] (3)

Adding the cost related information to the burn chart, it will boost its power of providing a wide range of information about the project overall status [5].

4.1.1. Budget usage. The relative position of lines (c) and (p) shows how the budget is spent compared to the planning. If (c) is above line (p) the budget is spent faster than expected. The relative positions between (s) and (c) are even more important, since it shows how the budget is spent compared to the real progress. If line (c) is below line (s) means we’re spending the budget faster than our progress is in the schedule. If we continue like that, we’ll have a cost overrun. (see Fig. 2)

![Fig. 2. Schedule and cost deviation](image)

Conversely, when the schedule is below the cost line, means our real progress is faster than we’re spending the budget, which is good. If we carry on like that, we’ll finish under budget. In other words, the combination of the line (b) and (c) could provide information like: the project is under schedule, because we are spending less than planned, meaning the team isn’t started with full speed yet, or the project is on schedule, but the cost are way more used then planned because of overtimes. In case of budget overruns line (c) will fall below 0 level, while in case of under budget will not reach level 0 at all.

4.1.2. Schedule. The relative position of lines (s) and (p) reflect if the project is on time, is late - (s) is above (p), will be finished earlier – (s) is under (p). The graph could be enhanced with safety risk margins, by adding to the graph a time reference line for the total duration (TD), where TD is \(=\) total + safety duration.

4.1.3. Duration and cost forecast. Based on the project progress (both schedule and cost) the expected finish date and total cost can be predicted. Forecast methods can be based on the average of the previous measures (ex: average of the last three periods), based on historical data [4][11], or by calculating the Independent estimate at completion EVM indicators both for cost (IEAC) and schedule (IEAC(t)) [6]. See line (e) on Fig. 1.

4.1.4. Scope change. Even if the project was divided in subprojects, it happens all the time that new tasks, requirements are added to the task list. This scope changes, if not handled correctly can result project delays. Based on Relation (1), there are scope changes mostly when the result is negative and are visible on the burndown chart as vertical lines (up – added scope, down – decreased scope). Every scope change will influence both schedule and cost estimations of the project. After updating the remaining work, the graph will illustrate if the project is still doable or not within the agreed Total Duration (TD): if the duration forecast line will pass the total duration constraint, the project will have a delay. An example for added cost is marked on Fig. 1.

4.1.5. Project challenges. The inclination angle of the lines (s), (c) provides information about the speed of the progress. If it is decreasing slowly (see Fig. 3) could mean the project has problems like: the team is working on underestimated tasks or on unplanned work (ex: the requirements are not clear, more communication is needed), blocking issues (power failure), the team is not focused, etc. Whatever that is, it is sure: smaller inclination angels then planned needs PM attention and investigation, to find out what the problems are.

![Fig. 3. Project challenge](image)

4.1.6. What if try outs. Due its simplicity, the progress burn down chart can be used also as a tool of try out “what-if”. Some example of this kind of try outs: can we increase the scope without delaying the schedule, or decrease the planned effort without influencing the end dates. In other words, adding new members to the team would help the project, or can people take out free days without affecting the
4.2. Deviation charts

Based on the EV, PV and AC other indicators can be calculated and illustrated offering more detailed information about other area. For schedule and cost deviations the SV (t) and CV, or the SPI(t) and CPI indicators should be illustrated. See Fig. 4 as an example of deviations illustrated for a late project.

Both lines are indicating a deviation from the original plan: the schedule is behind with 40%, while the cost is above the planned budget with 38%. While using the SPI (t) and CPI indicators, based on the company performance expectations, the graph can be enhanced with Red-Amber-Green (RAG) colored reference lines.

CPI relates the physical work accomplished expressed in its budgeted value, against the actual costs incurred to accomplish the performed work. The CPI is reflects the project cost efficiency: are we on target, under-running or overrunning the planned budget?

Value 1.0 for CPI means perfect cost performance, value below 1 is a reflection of excessive costs spent against budget. Project managers should pay attention on this, since initial overruns can be recovered only by under runs, which are rarely happening. The same conditions which caused the current overruns are likely to occur again and again. Values above 1.0 reflect that an under-run cost is occurring. That is good, but make sure you included all the costs related to the project (ex: also work done by purchased labor). The same behavior has SPI (t) which reflects information about the schedule.

5. Conclusions

For successful project management is handy to have a measurement model based on which you can schedule, etc.

4.3 Prediction charts

Knowing about the project status, and the tendency, the question “What will happen?” is justified. Everybody wants to know if in case of deviations, the project will succeed it at the end or not. By calculating the To Complete Performance Index (TCPI) and the To Complete Schedule Performance Index (TSPI) we will have an idea about the probability of the success. They both are used to assess the reasonableness of an estimated final cost (EAC) or the total duration (TD), where the EAC and the TD can be the original estimations, or the predicted ones based on the project progress.

When TCPI, TSPI are equal to or less than 1.00, there is confidence that the EAC, respectively TD can be achieved. Conversely, when they are equal to or greater than 1.10 the project is considered to be “out of control;” the EAC and TD are very likely unachievable. A scope adjustment or a budget and/or schedule negotiation should be started for readjusting the EAC and/or TD values. Between 1.00 and 1.10 the project status is very fragile; the PM’s actions are highly needed for assure the project success. Obviously, when TCPI, TSPI are below 1.00 there is confidence that both cost and schedule estimated are achievable.

As it is visible in Fig. 5, during the project there were several adjustments done on both TD and EAC.

4.3 Other charts

Depending on need, there are many combination possibilities to display different metrics, indicators together in the same graph. Hereby are some examples:

- [SV(t) and IEAC(t)] to have information in the same picture about the deviation and the prediction of how long project will take (the same goes for CV with IEAC);
- [CPI and TCPI], information about the past and the future of the project by illustrating the indicator for past cost performance and the TCPI which indicates the future performance (the same goes for schedule as well: SPI(t) and TSPI)
- The project progress can be illustrated as cumulated or individual progress, where representation of the individual progress will reflect the individual productivity of the team member.

5. Conclusions

For successful project management is handy to have a measurement model based on which you can...
take correct decisions for assuring the project success. Starting from Parkinson's Law: “work expands so as to fill the time available for its completion”, if the project is not measured, monitored, easily can go wrong. Project Managers need to have a close eye on the progress and have a clear periodical communication with the team and project sponsors about the expectations, status and progress.

This work presents a project performance model defined at Sysgenic Group based on the Earned Value Management and the Earned Schedule technique [7]-[9], end date prediction models [4] and the company existing measurement model using the burndown like time and budget charts for progress representation. By applying this model we identified the following benefits:

- It is a single management control system that provides reliable data, integrating work, schedule, and cost using a work breakdown structure,
- Can be applied on any project (big projects should be divide in subprojects)
- Through its performance indexes provides an early warning signal about cost or schedule deviations (CPI, SPI(t)),
- Uses an index-based method to forecast the final cost of the project,
- The “to-complete” performance index allows evaluation of the forecasted final cost,
- Can reduce information overload by its easy, understandable reporting.
- Beside these benefits, there is still room for further improvement. Directions where further studies and work are needed:
  - Find possibilities to incorporate in the model quality related measures as well,
  - Improve and include more sophisticated schedule and cost prediction method which takes into account different other attributes as well (personal productivity, different personal costs, more sophisticated variation trends)
  - Implement more automation for measurement gathering and more flexible report generation.

References