Project Portfolio Earned Value Management Using Treemaps

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1   Introduction

Project portfolio management deals with organizing and managing a set of projects in an organization. Each organization has its own way of managing the portfolio that meets its business goals. One of the main challenges is to track project performance across the entire portfolio in a timely and effective manner. It allows managers to diagnose performance trends and identify projects in need of attention, giving them the opportunity to take management action in a timely fashion.

In this paper, we investigate the use of Earned Value Management (EVM) for tracking project performance across the portfolio, and explore the benefits of an interactive visualization technique called Treemaps to display project performance metrics for the entire portfolio on a single screen.

1.1 Project Portfolio Management (PPM)

Project portfolio management (PPM) is the art and science of applying a set of knowledge, skills, tools, and techniques to a collection of projects, in order to meet or exceed needs and expectations of an organization's investment strategy (Pennypacker et al., 2002). Project portfolio management can be thought of as having three main objectives:1) portfolio value maximization, 2) balance within the portfolio, and 3) strategic alignment. *Value maximization* deals with the resource allocation to maximize the value of the portfolio in terms of company objectives such as profitability. At the same time, there should be a *balance* of projects in terms of parameters, such as risk versus reward or breakdown by project type. It is equally important that the final portfolio of projects truly *aligns* with the business' strategy and that all projects are "on strategy" (Cooper et al., 1998).

We stipulate that a portfolio of projects in any given organization should meet the above mentioned objectives. Each of these objectives has to do with the project selection process and criteria that an organization uses. Once project selection is completed, however, the issue rapidly becomes how to manage the portfolio of projects effectively. Fundamental to efficient project management at all organizational levels is the timeliness and effectiveness of project reporting. Project management information that is timely, accurate and actionable results in successful projects and project portfolios.

Typical portfolio reporting methods include extensive narrative, bar charts of project metrics, project risk versus reward graphs, project progress charts, and tables showing the established project metrics. Program and portfolio managers are routinely expected in the execution of their responsibilities to absorb large amounts of project data compiled into progress reporting books. The problem is twofold: progress reporting "books" with one or more pages of data for each project does not equal information, and secondly, with the well documented manager's scarcity of attention (time), it is not reasonable to expect them to

devour the data, synthesize it, and draw conclusions that lead promptly to management decisions, resource allocations, and other management actions.

Many commercial tools are available for managing portfolios; however, recently, there has been an increasing concern about managing project portfolios in a more efficient way, and to bring the expected and desired benefits to the stakeholders. Most organizations are not completely satisfied with their project portfolio management methods (Cooper et al., 1998).

The Center for Business Practices conducted a benchmark study of the current practices of PPM that shows that a considerable percentage of the organizations practicing PPM are at level 1 of maturity which is defined as ad hoc processes only (Pennypacker et al., 2002). Exhibit 1 shows the different levels of PPM maturity among the organizations.
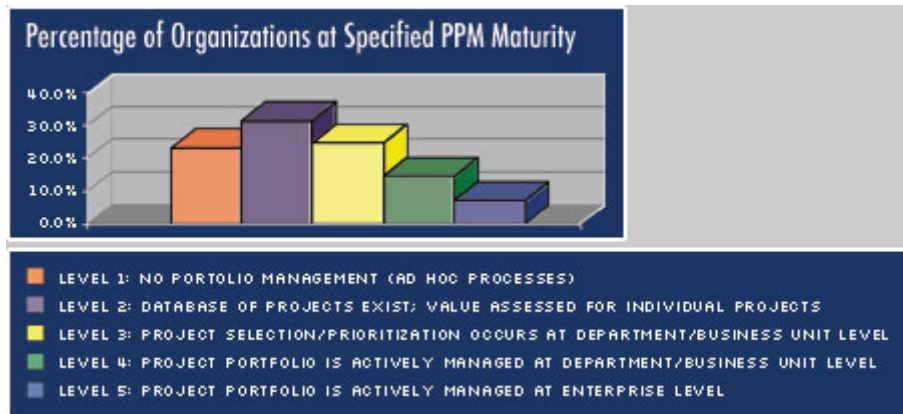

Exhibit 1 Percentage of Organizations at Specified PPM Maturity

Source: "State of the Industry", Center for Business Practices (CBP)

The statistics in Exhibit 1 clearly show the room for improvement in project portfolio management for a number of organizations.

1.2 Measuring Project Performance

To manage a portfolio, portfolio managers need an overview of the current state of the portfolio and to identify the problem areas quickly, so as to allocate management attention and resources immediately.

In project management, we routinely make trade-offs among cost, schedule, and technical performance. When the project achieves the right balance among the three, the project is successful. Project performance measurement consists of determining, organizing and presenting cost, schedule and performance information in a way that provides project managers with better and more reliable information to analyze these trade-offs in a timely manner.

Project performance measurement involves progress monitoring, which has two processes and outcomes. The first part of the process is to look at actual performance data as it is compiled. Even with real time compilation, this view is looking backwards at where the project has been and the outcome is historical data. The second part of the process involves looking forward and projecting where the project is going in terms of compliance with plan.

An important characteristic of project performance measurement is that it should provide timely information for decision-making and detecting the necessary corrective measures.

Reporting the outcomes of the performance measurement system involves collecting and disseminating performance information. The process of performance reporting typically includes: status reporting, progress reporting and forecasting. The status report describes where the project stands now, the progress report describes what the project team has accomplished, and the forecast report predicts future project status and progress. Performance reporting should generally provide information on scope, schedule, cost, and quality. Many projects also require information on risk and procurement (PMBOK, 2000).

This complex and dynamic information reporting past, present, and future results must be assimilated quickly and accurately by project portfolio managers. Treemap is a visualization that provides in a single screen an overview of the status of all projects status (Exhibit 2). Users can at a glance judge the overall health of the portfolio and identify areas of concern.

2   Earned Value Management

The Project Management Book of Knowledge (®*Guide, 2000)* defines Earned Value Management (EVM) as a method that integrates scope, schedule, and resources for measuring project performance. It compares the amount of work that was planned with what has been spent and with what has been accomplished to determine cost and schedule performance. The International Council for Project Management Advancement (ICPMA) defines Earned Value Performance Measurement as a method for measuring and reporting project performance based on planned expenditure, actual expenditure and technical performance achieved to date. The EVM method provides values for variances and performance indices that can be used to assess current project status and performance, and predict future project performance based on past project performance and new information.

The analysis for computing Earned Value involves calculating three key values for each activity:

- Earned Value (EV) is the value of the work actually completed during a given period.
- The Planned Value (PV) is that portion planned to be spent on the activity during a given period.
- The Actual Cost (AC) is the total of costs incurred in accomplishing work on the activity during a given period. This Actual Cost must correspond to whatever was budgeted for the PV and the EV.

These three values are used in combination to provide measures of whether or not work is being accomplished as planned. The most commonly used measures are the cost variance (CV) and the schedule variance (SV). These two values can be computed as $CV = EV - AC$ and $SV = EV - PV$ and they can be converted to efficiency indicators to reflect the cost and schedule performance of any project. The cost performance index ($CPI = EV/AC$) is the most commonly used cost-efficiency indicator. The cumulative CPI (the sum of all individual EV budgets divided by the sum of all individual AC's) is widely used to forecast project costs at completion. Also, the schedule performance index ($SPI = EV/PV$) is sometimes used in conjunction with the CPI to forecast the project completion estimates. (PMBOK®*Guide,*

2000) The measure that considers both indexes is called Critical Ratio (CR). The Critical Ratio is obtained by CR = CPI * SPI and represents the overall status of the project.
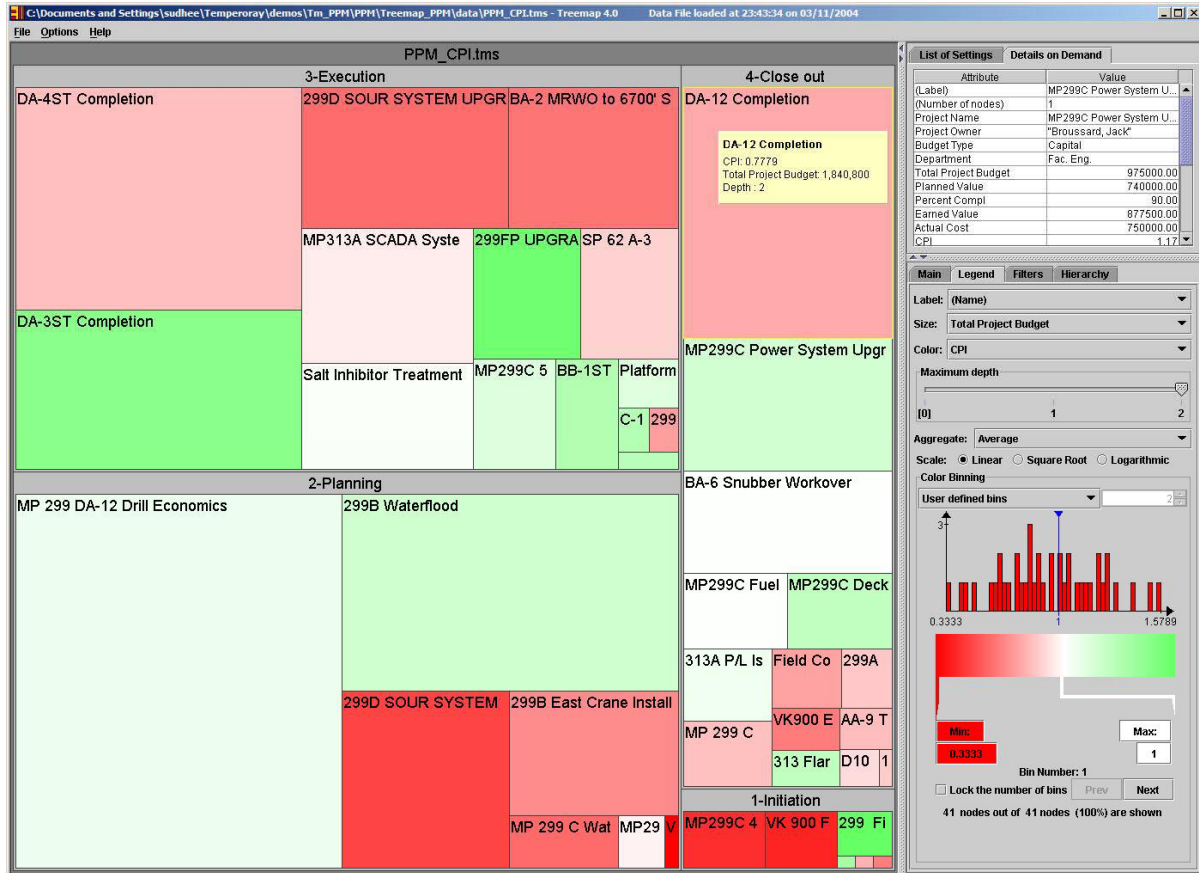

Exhibit 2: A treemap showing a project portfolio with 41 projects grouped by project life cycle phase. Each rectangle represents a project, the size of the rectangle is proportional to the budget, and color is mapped to any available performance metric, here the Cost Performance Index. Users can quickly spot the large red rectangles representing the major underperforming projects.

2.1 Experience with Earned Value Management

The International Council for Project Management Advancement obtained the following results based on surveys (ICPMA, 2002) where 75.3% of the respondents felt that EVM was suitable as a Standard for project performance measurement (Exhibit 3).

Earned Value	Sometimes	Yes	No	Affirmative (Sometimes +Yes)
Have you ever used Earned Value on your projects?	27.71 %	30.12 %	42.17 %	57.83 %
Do you currently use Earned Value on your projects?	23.17 %	21.95 %	54.88 %	45.12 %
Does your organization require the use of Earned Value?	25.30 %	24.10 %	50.60 %	49.40 %
Do your clients require the use of Earned Value?	37.97 %	13.92 %	48.10 %	51.90 %
Do you plan to use Earned Value in the future?	16.67 %	78.57 %	4.76 %	95.24 %

Exhibit 3: Respondent Experience with Earned Value

Source: ICPMA Response to Standards Australia on: Draft Standard for Project Performance Measurement Using Earned Value V5.6, International Council for Project Management Advancement.

In the same way the respondents identified the type of project to which they believed Earned Value is most suited to.

Type of Project	*Proportion of Respondents*
Construction	80.00%
Engineering	76.47%
I.T.	56.47%
Defense	51.76%
Finance	32.94%
Process	31.76%
HR	17.65%
All Types of Projects	8.24%
Government Projects	1.18%
Invested Industrial Assets	1.18%
Production Improvement	1.18%
Research Project	1.18%

Exhibit 4 Proportion Project Types Suitable for Earned Value

Source: ICPMA Response to Standards Australia on: Draft Standard for
Project Performance Measurement Using Earned Value V5.6, International Council for
Project Management Advancement.

After introducing Project Performance Measurement and the Earned Value Management method, we now describe Treemaps and its application to Project Portfolio Management System.

3   Treemaps

Treemap has been developed at the University of Maryland Human-Computer Interaction Laboratory. Treemap is a space-filling visualization method for representing hierarchical information (Shneiderman, 1992 and 2004). A Treemaps works by dividing the display area into a nested sequence of rectangles whose areas correspond to an attribute of the data set, effectively combining aspects of a Venn diagram and a pie chart. Originally designed to visualize files on a hard drive, treemaps have been applied to a wide variety of domains ranging from financial analysis (Wattenberg, 1999, see also http://www.smartmoney.com/marketmap) to inventory management (Reeve and Williamson, 2004), or petroleum engineering (Plaisant et al. 2003). More recently alternative layout algorithms were devised to reduce the incidence of high aspect-ratio rectangles and to maintain ordering (Bederson, Shneiderman and Wattenberg, 2002). Others have focused on specialized techniques to visualize up to a million items on a treemap without aggregation (Fekete and Plaisant, 2002).

The user interface provides many features to allow users to customize the display to their particular needs. Most importantly, users can specify what data attribute should be mapped to the size or color of the rectangles. In Exhibit 2 users chose to map the size of the rectangle to the budget amount and map the color to a particular index. Interface features also help users focus on areas of interest or get more details about the projects. A window popup shows the long labels that may not fit on the rectangle; clicking on a rectangle displays all the detailed information available about a project in the top right area of the display. Users can zoom on part of the Treemap, for example on projects in the closeout phase, which is useful when the number of managed project becomes very large. They can also filter the display using dynamic query sliders or controls (Ahlberg and Shneiderman, 1992) to show only the projects that have characteristics that fall within specified ranges. Examples of dynamic query sliders are shown at the lower right of Exhibit 5. As users adjust the position of the sliders, the rectangles that fall outside the range are grayed out dynamically (e.g. users could filter out the projects that are internally funded). A click on the "Hide filtered" button removes the gray rectangles and gives more room on the display to the remaining projects. The flexible hierarchy feature of treemap allows users to group the projects as needed. Exhibit 2 shows projects grouped by their life-cycle phase, but they could also be grouped by geographical area or by manager, or any other combination of available attributes.

Treemap is implemented in Java and a demonstration version Treemap can be downloaded at www.cs.umd.edu/hcil/treemap. Several commercial versions of Treemap are also available (see Shneiderman 2004).

4   Using Treemaps for Project Portfolio Management

To illustrate the use of Treemaps in the context of project portfolio management, we have prepared examples that use Earned Value Management project performance metrics. The metrics we display are for illustration purposes only, as users could select any metric that is supported by their organization's internal business processes and visualize the selected metrics using Treemaps.

The following examples show a project portfolio with 41 projects. Although the database can accommodate up to tens of thousands of projects, our experience suggests that users are most comfortable with a number of projects between 50 to 100 displayed at one time. Pre-selection or interactive filtering in the treemap interface becomes useful when the portfolio contains more projects. Exhibit 2 shows a portfolio of 41 projects grouped by the phase of the project life cycle they are in: Initiation, Planning, Execution, and Closeout. Each rectangle represents a project with the size of the rectangle being proportional to the total budget of the project. The color of the rectangle is representative of the level of performance for the selected performance metric (i.e. the cost performance index (CPI) in Exhibit 4).

The CPI is calculated by dividing the Earned Value by the Actual Cost. CPI value equal to 1.0 or higher means that the project is progressing according to plan. If the CPI is less than 1.0 it means that the production is inefficient. Accordingly, we use shades of red to represent a CPI index from 0 to 1, with solid red representing CPI = 0, and white being CPI = 1 and shade of green to represent CPI greater than 1.

From the color of the rectangles/projects, we can identify the problem areas where the CPI < 1 and can infer that the pink or red colored projects require further analysis. The white and light green colored projects have CPI >1 and are on budget. Users can also estimate the budget amount of the projects by the size of the rectangle representing the project. As the mouse cursor hovers over a rectangle, a pop up window displays the full title, CPI value and total project budget of any project. By clicking on a rectangle, detail data is displayed in the detail on demand window (top right area of the display). Custom applications using treemap could launch other detail windows presenting reports about the project.

Schedule Performance Index (SPI) is another metric in EVM. SPI is positive at 1.0 or higher indicating work started on schedule and negative below 1.0 indicating delayed work. Exhibit 5 shows the SPI values of projects across the entire portfolio. A shade of red to white represents SPI < 1 and the shade of white to green represents SPI >= 1. Users can interpret the pink or red colored projects as problem areas as SPI < 1 and need senior management attention. 299D SOUR SYSTEM UPGRADE (dark rectangle) and 299B EAST CRANE INSTALLATION are two projects in the Planning phase that are behind schedule. Users can see that few projects in Close out phase are behind schedule (pink rectangles).

Users can filter out the uninterested projects using dynamic query filters or controls to show only the projects that fall in the specified range. Users can select the range using the sliders on the right bottom area of Exhibit 5. The rectangles that fall outside the range are grayed   out   and   can   be   removed   from   the   display.

The user interface provides many other options to explore the information interactively through zooming and filtering, customize, and save the display that can be used later.
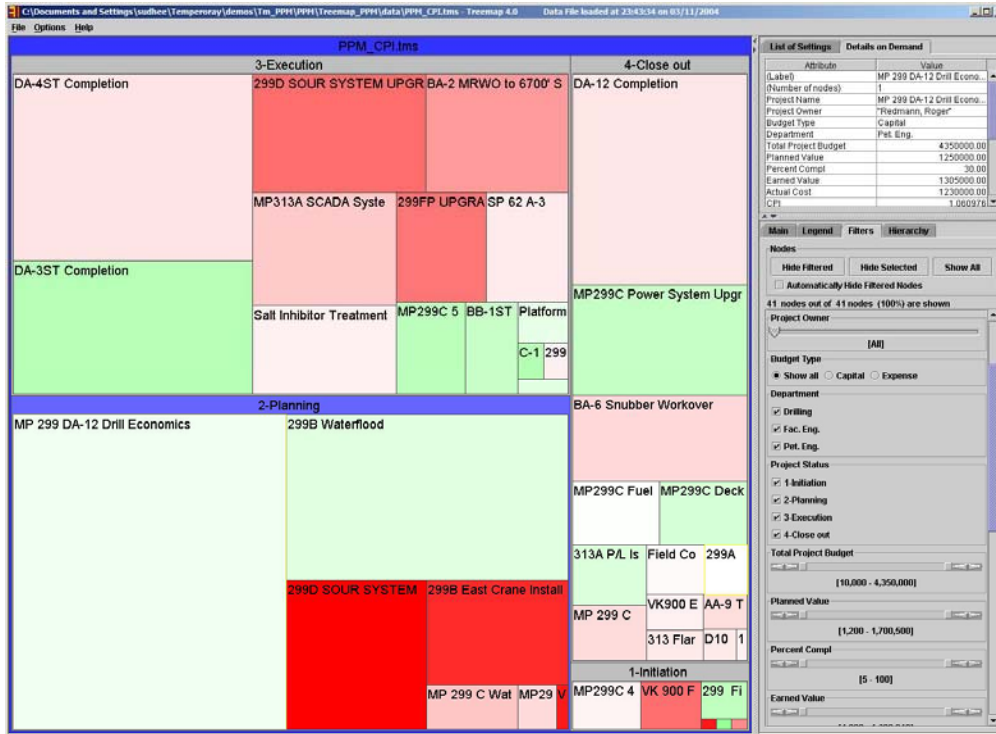

Exhibit 5: This view shows the same grouping of projects, this time using the Schedule Performance Index as the color attribute, highlighting the projects that are behind schedule. The control panel on the right side shows the sliders and controls that can be used to filter the projects to be displayed.
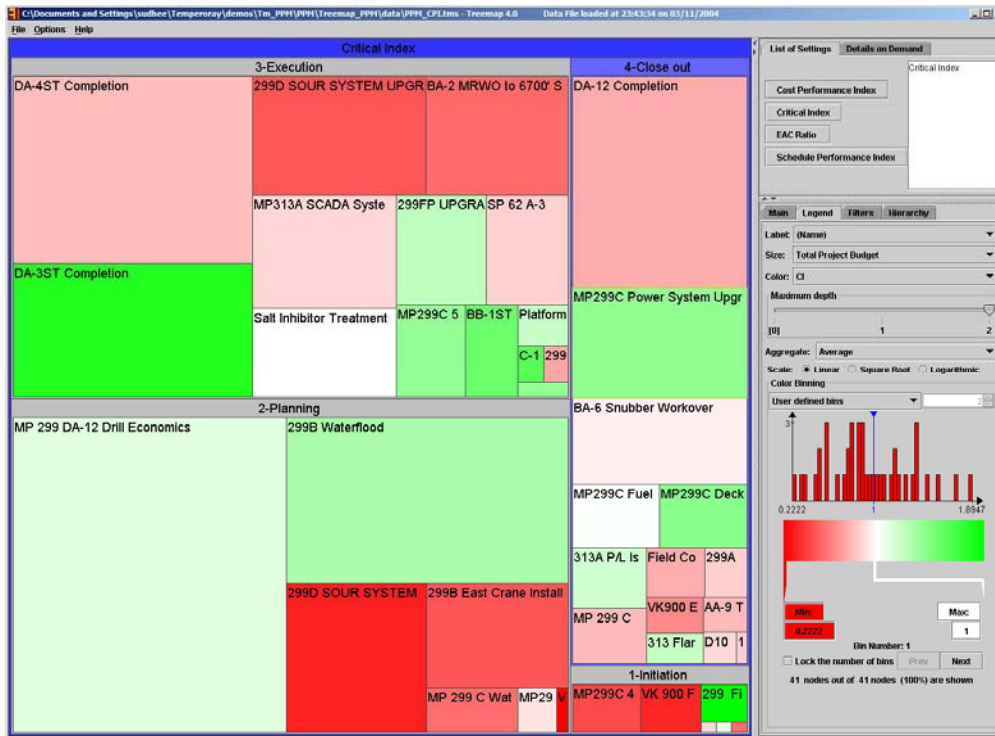
Exhibit 6: This time the display uses Critical Ratio for color. The color legend shows the distribution of critical ratios values in this portfolio. On the top right, one can see a list of 4 available preset views.

Once we have looked at the cost performance index and schedule performance index of the portfolio, we are most likely to want to examine the Critical Ratio (CR). The CR considers both the CPI and SPI, and represents the overall status of the projects in the portfolio. Exhibit 6 illustrates the Critical Ratio for the portfolio of projects. The projects with a shade of red indicate the CR < 1 and are problem areas, and the ones with the shade of white and green – white indicate CR ≥ 1 and are performing well.

Treemaps also allows users to vary the grouping of projects using flexible hierarchy. Users can group projects using any of the attributes available in the data. For example, Exhibit 7 shows the projects organized by Cost Performance Index and Schedule Performance Index. The overall range of attribute values can be split in multiple ranges (here 2). The resulting ranges can be then given meaningful names. For example, the group with CPI less than 1 is named as "over-spent" and the other group with CPI >= 1 is named as "under-spent". The group representing SPI less than 1 is named "behind-schedule" and the one with SPI >= 1 is named "on-schedule". The projects are grouped accordingly. These two groups are again divided into two sub groups: over-spent and under-spent. In this example the size of the rectangles is still proportional to the total budget allocated and color indicates CI values.

Users can see that many projects are behind-schedule and over-spent have CI < 1 (pink to red rectangles) highlighting the most troublesome projects in bright red. There are few projects that are behind-schedule but under-spent. All the projects that are on-schedule and under-spent are colored green indicating CI >= 1. There are quite a large number of projects that are on-schedule and under-spent. This on-schedule half of the portfolio is doing well.
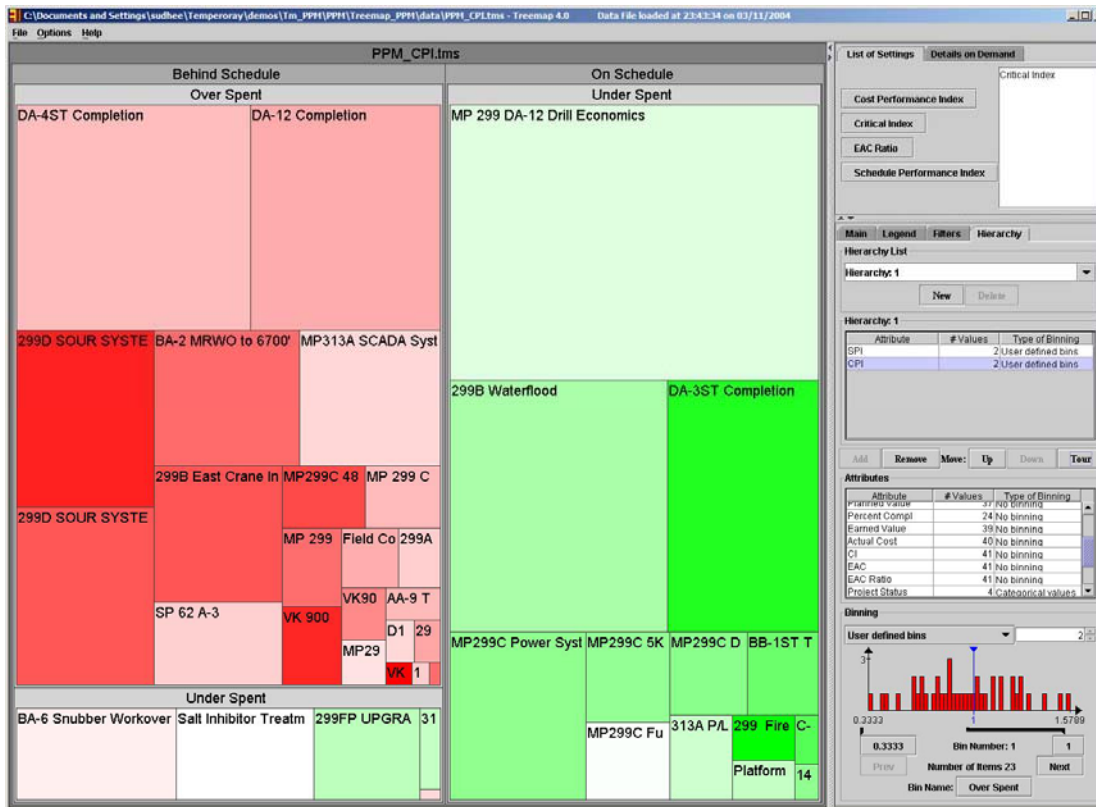
Exhibit 7: Here the 41 projects have been grouped differently, first by Schedule Performance Index (separating behind-schedule projects from on-schedule projects) then by Cost Performance Index (separating over-spent and under-spent projects), showing than nearly half of the projects are over-spent and over budget. Color is mapped to the Critical Index.

The metrics illustrated in Exhibit 1, 4,5, and 6 above are only a few of the measures users can choose to display. In a typical scenario, a single person (a data analyst or a manager) would be responsible for creating a list of pre-set views of interest which could then be made available to a larger number of users. Users can then simply select the view of interest from a list. An example of such list is shown on top right corner of Exhibit 6.

Each of the above visualizations presents an overview of the projects in the portfolio, which will enable the project manager to quickly assess the status of the portfolio. This visualization tool assists in the ongoing drive for continuous improvement because, in addition to understanding how individual projects are performing, senior managers can use the information to look for trends and, consequently, determine if there are systemic issues that need to be addressed.

5   Conclusions

Using Earned Value Management for measuring project performance at portfolio level and Treemaps for visualizing the performance of entire portfolio and tracking project metrics presents a new approach in project portfolio management. Users can group projects according to their needs using flexible hierarchy, and interactively explore the portfolio information through zooming, filtering, and accessing details of projects. Settings of useful views can be saved and re-used anytime with updated information. Treemap displays help project managers quickly compare projects based on their attributes, such as budget. They can spot trends and exceptions in the data.

We believe that Treemaps have the potential to improve project portfolio management. More work needs to be done in integrating Treemaps with existing management accounting and project management scheduling software to improve its usability in project portfolio management. A web-based project management environment can be set up to provide update views. We are currently developing software to allow users to review portfolio changes over time (monthly, quarterly etc), also providing a natural avenue to present forecasting information about the projects. Connecting the Treemaps software with the organization's project database, facilitating the users to add/delete a strategic value to evaluate their portfolio, generating traditional project reports, and monitoring portfolio performance changes over time (monthly, quarterly etc) would be some possible extensions.

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