Reinventing Gantt's Chart

Daniel Brandon, Christian Brothers University, 650 East Parkway South, Memphis, TN 38104; E-mail: dbrandon@cbu.edu

INTRODUCTION

The "Gantt Chart" has been a key tool in project management and industrial engineering since the early twentieth century. Even today the Gantt chart along with the relatively modern "spreadsheet" are still the most commonly used and well understood tools for analyzing and presenting project schedules and progress thereon. However today's Gantt, while similar in basic concept to the original Gantt chart, has evolved considerably in terms of appearance and functionality.

This article researches the Gantt chart both looking back and forward. It is appropriate to present this research at this time on the one hundredth anniversary of the original Gantt chart. The article follows the Gantt chart's evolution, and then looks forward to hyperlinked web based "earned value enabled" Gantt charts emerging in the twenty first century.

THE ORIGINAL GANTT CHART

Henry Laurence Gantt (1861-1919) was a mechanical engineer and management consultant. He formulated his Gantt charts early in 20th century, about 100 years ago. The charts were used as a visual tool to show scheduled and actual progress of tasks, types of work, and individuals. Now a commonplace project management tool, it was an innovation of great importance then. Gantt studied in great detail the order and types of tasks in industrial work, and his studies initially focused on Navy ship construction during WWI. He formulated "The Task Idea", and a couple years later presented it in Chapter VII of his book (Gantt, 1910). His "task" had a well defined procedure for carrying out the steps thereof, metrics to ensure proper completion of the task, metrics for approximate resources used to perform that type of task, and bonuses or some other type of motivation for a worker to complete the task in a timely and quality manner. Even today some of these components of tasks are not quantified in our construction of schedules. His definition of a schedule was a series of ordered tasks charted on a calendar.

Gantt charts had visual task bars and they outlined the sequence and duration of project tasks. His original charts were organized by person, and also showed work type ("piece" or "day" work), absence, termination, promotion, and bonus situations. One of Gantt's main areas of study was worker motivation, hence the inclusion of that additional type of information on his charts. An original chart from his book (Gantt, 1910 and 1919) is shown in Figure 1, which compares the same time period in 1909 and 1910. Gantt charts were later used on large U.S. domestic construction projects like the Hoover Dam started in 1931.

With the advent of WWII, the growing complexities of projects and a shrinking war-time labor supply demanded new organizational structures. Complex network diagrams called PERT charts and the critical path method were introduced and combined with Gantt charts, giving managers greater control over very large and extremely complex projects (such as military weapon systems) where tasks were highly interdependent. Later his charts were used on large peace time projects such as the U.S. interstate highway system started in 1956.

A typical Gantt chart of this era is shown in Figure 2. Here each task is represented as a horizontal bar and is a time-line view of the tasks. Now each task may have one or more resources assigned thereto. This chart is a bar graph where the length of each bar designates the start and finish dates for each task. Each task is typically labeled with its ID (or WBS code) and description.

In the early 1990s link lines (as shown in Figure 2) were added to these task bars depicting dependencies between tasks. Today there are many variations of the basic Gantt chart where more information is added in task ID area or in the graphic area with the bars. In the graphic area there may be: use of color, precedence
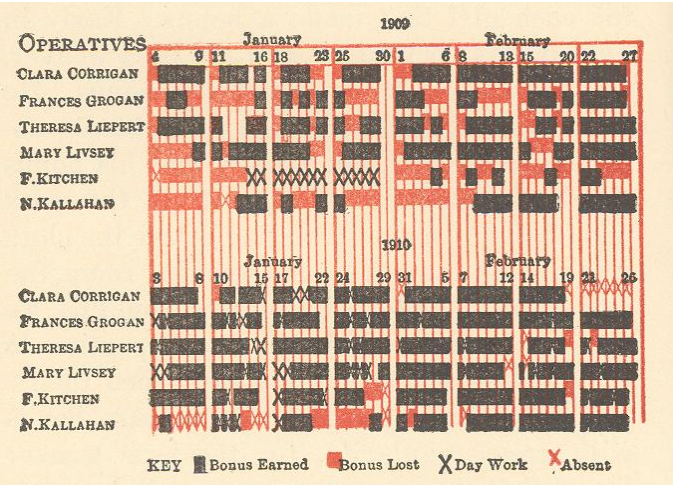
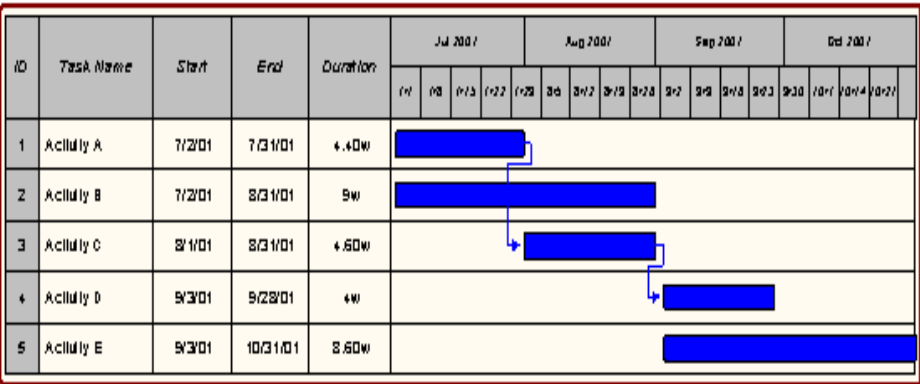*Figure 1. Original Gantt chart*
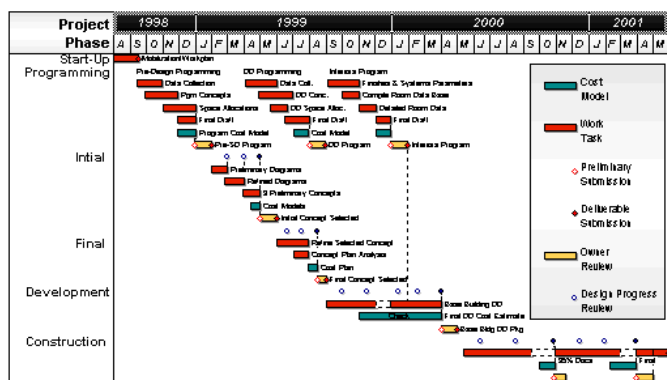

Figure 2. Classical Gantt chart

Figure 3. Modern Gantt chart (Kidasa Software, www.kidasa.com)

Figure 4. Project info in spreadsheet

Project Plan and Progress - Week 30

Task	Start Week	Weeks	% Complete	Weeks Complete	Weeks Remaining
Planning & Staffing	0	8	100	8	0
Prototype Design	4	8	100	8	0
Construct Prototype	8	8	100	8	0
Test/Evaluate Prototype	13	8	80	6.4	1.6
Full Design Specs	17	12	50	6	6
Documentation	21	27	12	3.24	23.76
Site Preparation	21	14	36	5.04	8.96
Construction	25	18	15	2.7	15.3
Test/Certification	35	13	0	0	13
Finishing	43	9	0	0	9
Maintenance Training	48	4	0	0	4

Figure 5. Gantt chart from spreadsheet

relations, shading in the bars to show percent completions of the tasks; coloring or other notation of the bars to show tasks on the critical path, and milestones (zero length event markers). In the task ID area there may be a WBS hierarchy, phasing, envelopes, or other information about the tasks in additional columns. Figure 3 is an example of a Gantt chart with other such information.

However even the modern Gantt chart is not without some problems in regard to the representation of a project schedule and the progress thereon:

- It portrays an even distribution of both planned and actual effort from the start of a task to the end of that task (particularly when per-cent complete shading of the bars is used).
- It is not generally interactive, and does not respond to user actions (i.e. mouse clicks) to change the content, level of detail, or perspective of the information displayed
- It is not immediately apparent what tasks may be in trouble in regard to schedule or cost parameters
- It does not show true schedule variances (i.e. EVA schedule metrics)
- It does not show cost information (planned, actual, and EVA variances)

MANAGEMENT AND TECHNOLOGY ADVANCES
In the last twenty years or so a number of management and technology advances have occurred many of which have been applied to the basic Gantt chart. These advances remove some of the problems previously itemized and also provide other utility. Such management and technology advances include electronic spreadsheets, relational database management systems (RDBMS), earned value analysis (EVA), management by exception, management "dashboards", client/server computing, hypertext, and the Internet/WWW.

The most commonly used computer software for project management (and business in general) is the spreadsheet program. Spreadsheets are easy to learn, easy to use, inexpensive, generally available, and adaptable to most project management tasks. Consider the project planning and progress information shown in the spreadsheet of Figure 4; the last two columns are calculated columns. A graphical representation in the form of a classical Gantt Chart can also be created from the spreadsheet data in the first three columns using the "charting" capability in most modern spreadsheet programs (such as Microsoft Excel). In addition one can also use the columns for "weeks completed" and "weeks remaining" to draw a Gantt Chart showing progress as illustrated in Figure 5.

The Excel chart wizard was used to create Figure 5 with the columns for "task", "start week", "weeks complete", and "weeks remaining"; the first part of each bar was made the same color as the chart background (the chart may be shown in black and white here, but the "completed' and "remaining" parts of each bar are a different color).

There are also spreadsheet "add-ons" available from a number of vendors to facilitate Gantt chart creation; one such add on is illustrated in Figure 6.

Today internet based Gantt charts are starting to be used. These are typically created using hypertext markup language (HTML) tables and cascading style sheets (CSS) as is the example in Figure 7 from the FiveAndDime system. This variation of the basic Gantt chart is a "Cost Based Gantt Chart" where "bars" are
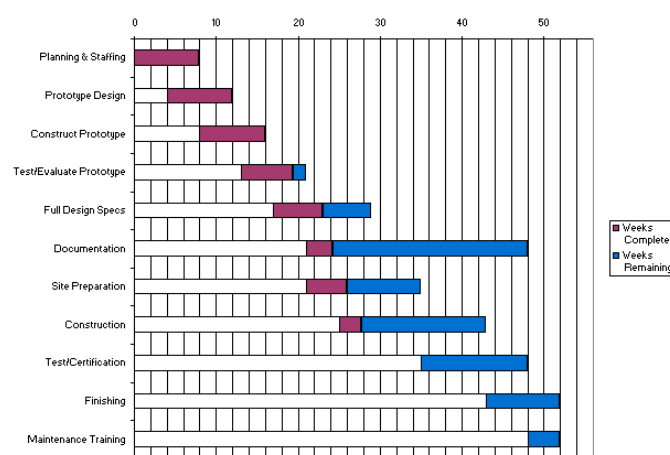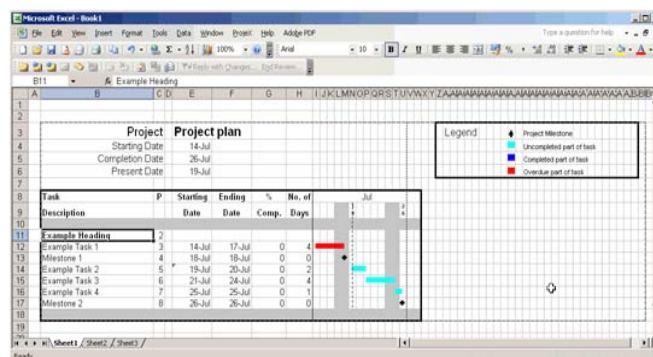
*Figure 6. Gantt chart using an Excel add-on*

represented as a series of cost numbers for each time period of each task. This provides for a non-linear distribution of cost (and resources) across the time span for the task and allows one to quickly see at a glance both the time for a task and the cost distribution (cash flow).

EARNED VALUE ANALYSIS
"Earned Value" (EV) is a value (usually expressed in currency) of the work accomplished up to a point in time based upon the planned (or budgeted) value for that work. The original U.S. government's term for earned value is "Budgeted Cost of Work Performed" (BCWP). Earned value terminology was originally

Figure 7. Cost-based Gantt chart as Web table (www.fiveanddime.biz)

Figure 8. Graphical EV analysis
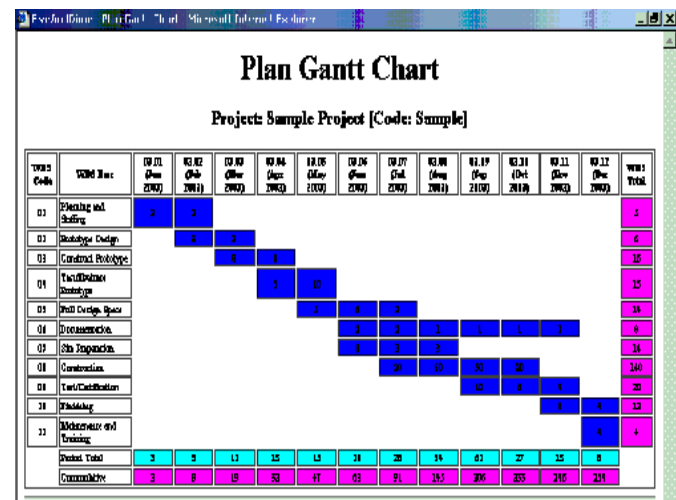
formalized in US DoD (Department of Defense) standard 7000.2. The ANSI standard (ANSI/EIA-748-1998) on Earned Value Management Systems (EVMS) was approved in May of 1998 and later adopted by the DoD. Other governments and organizations have adopted similar standards for earned value such as the Canadian General Standards Board (CGSB 187.1-93 November1993).

EVA (or EVM – Earned Value Management) is a "progress versus plan" based metric to evaluate the true performance of a project in terms of both cost deviation and schedule deviation. It also provides a quantitative basis for estimating actual completion time and actual cost at completion; EVA can provide an early warning of project time and/or cost problems as early as 15 percent into the project (Fleming, 1998).

In EVA the three key terms and definitions are:

BCWS – budgeted cost of work scheduled (the cumulative planned cost) as of a certain point in time

ACWP – the cumulative actual cost of work done as of a certain point in time

BCWP – this is the "earned value" and is determined from the product of the budgeted cost of each work packet times the percent complete of each work packet as of a certain point in time

Variances between the three values BCWS (planned cost), BCWP (earned value), and actual cost (ACWP) yield the earned value metrics. There are earned value metrics available for both cost and schedule variances. The basic cost metrics are:

Cost Variance (Dollars) = BCWP - ACWP
Cost Variance (%) = (BCWP - ACWP) * 100/BCWP
Cost Performance Index (CPI) = BCWP/ACWP
Estimated Cost at Completion (EAC) = ACWP + (BAC - BCWP)/CPI
Or in its simpler form EAC = BAC/CPI

Where BAC is the budget at completion, ACWP is a "sunk cost", and (BAC - BCWP) is the estimated remaining work. The CPI is also called the "cost efficiency factor"; and values less than one indicate that the project is costing more than planned, or that one is getting CPI of a dollar for each one dollar spent. This is good prediction formula if one expects that future performance will be similar to past performance. There are several other (EAC) formulas, and the most appropriate depends upon project type, whether past performance is a good indicator of future performance, and when in the project the EAC is calculated (Christensen, 1995). For a complete discussion of EVA cost formulas and methods is referred to the following references: Brandon, 2006; Webb, 2003.

The basic schedule metrics are:
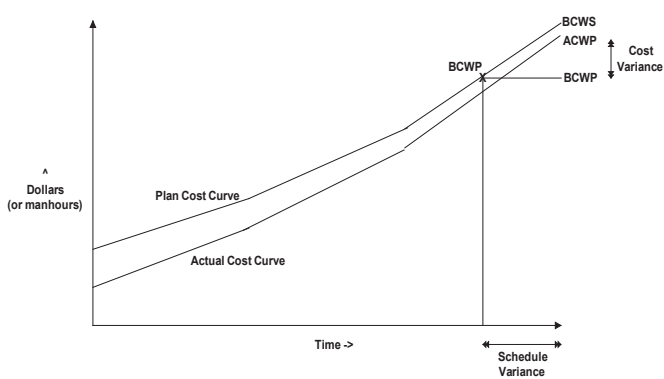
Schedule Variance (Dollars) = BCWP - BCWS
Schedule Variance (Months) = (BCWP - BCWS)/(Planned Cost for Month)
Schedule Variance (%) = (BCWP – BCWS) * 100/BCWS
Schedule Performance Index (SPI) = BCWP/BCWS
Estimated Time to Complete (ETTC) = ATE + ((OD – (ATE * SPI))/SPI
Or in a simpler form ETTC = OD/SPI

Where ATE is the actual calendar time already expended and OD is the original duration. The SPI is also called the "schedule efficiency factor"; and values less than one indicate that the project is taking more time than planned.

The EV can be projected onto the planned cost (BCWS) curve to graphically show deviations. This is illustrated in Figure 8 (Brandon, 2006), which shows the planned cost and actual cost curves for a project analysis for the example here through July. The schedule variance in time is also shown in that figure along the time axis.

There are also other formulas which can be used for ETTC, and some may be better as a project draws closer to completion. In addition there are EAC formulas that use both the CPI and SPI; for a complete discussion of EVA schedule formulas and methods is referred to the following references: Brandon, 2006; Webb, 2003.

EVA uses a percent complete for each work packet to calculate an earned value for each packet. This value requires knowledge of the planned cost and the percent complete; it does not require knowledge of the actual cost. Thus EVA schedule variances can be calculated without any knowledge of actual costs. For some projects or some organizations, the determination of actual costs may not be practical in an accurate and/or timely manner. However, EVA can still be performed partially without any actual cost data including the SPI and estimated time to complete.

For many projects most of the cost is labor, and that being the case there are several ways that one can expedite the gathering of actual cost information or approximating cost information. One effective EVA method is to represent cost in terms of person-hours instead of currency (Brandon, 1998). All of the EVA formulas still apply there is just a change to the dimension. This often provides sufficient accuracy for project control purposes, even where there is considerable variation between pay rates on the project team. Even non-labor costs can be converted back into equivalent person-hours using a standard average overall labor rate. This has another advantage for the project manager, since it focuses his attention on the matters that he can control (Brandon, 2006).

EVA AND GANTT CHARTS
Traditional project progress reporting of schedule progress (as represented in classical Gantt charts) cost is neither as accurate or as effective in the early identification of problems, nor in projecting time to complete as is EVA. However EVA can be integrated into modern Gantt charts to overcome these shortfalls. Some modern software programs are capable of such a combination to present a more complete picture of project performance; an example of such a presentation is shown in Figure 9.

Figure 9. EVA on Gantt (Kidasa Software, www.kidasa.com)

Figure 12. Project cost plan graph
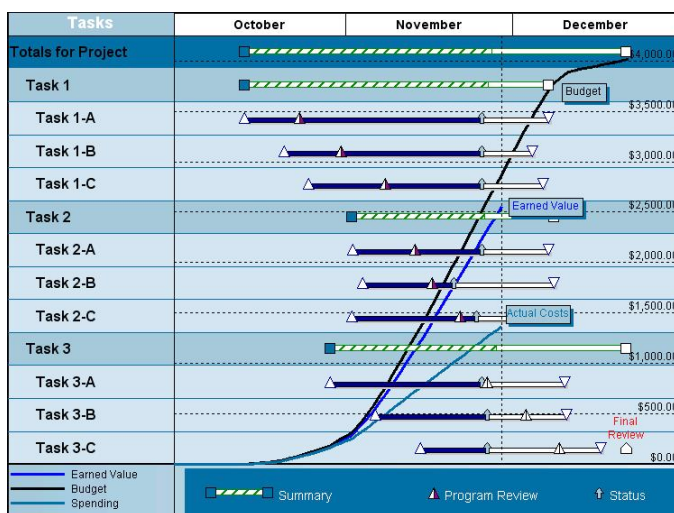
To illustrate how effective a combination of EVA and Gantt analysis can be, we will revisit a brief case study from an earlier publication (Brandon 1998, 1999).

For this example, the WBS consists of two levels, zero and one; and this is shown graphically in Figure 10 for level zero. Each level zero WBS item is further broken down into sub tasks at level 1; for example the breakdown of the "Test Prototype" task is shown in Figure 13.

The "cost plan" is shown in Figure 11 as a spreadsheet rolled up to the top level (level 0) of the WBS; this is also illustrated graphically in Figure 12.

A "bottom-up" estimation method is used to develop the cost plan, where there is another spreadsheet which shows the estimated cost and schedule for associated the level one work packets as shown in Figure 13 (for one of the level zero items – Test/Evaluate Protoype).
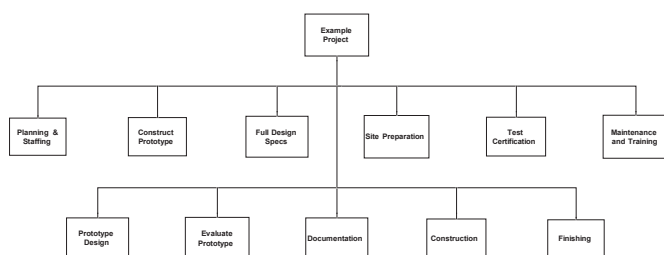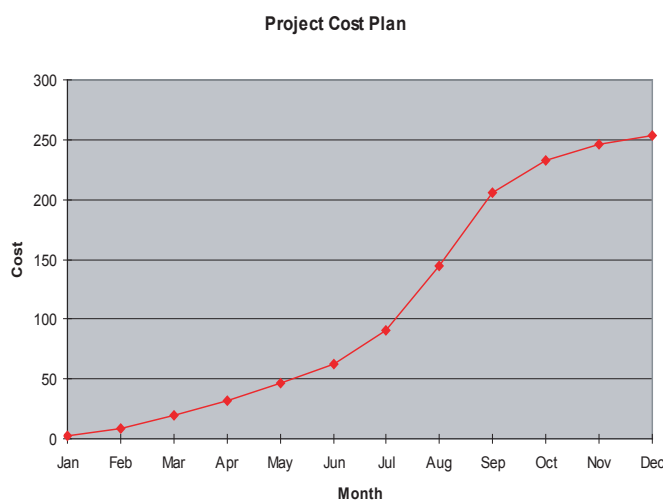
As the project progresses, actual costs are incurred by the effort expended in each work packet. These costs along with the percent complete of each work packet are collected each week work for this case study. This information is typically shown superimposed on the Gantt chart as percent complete numbers inside of the bars or shading a portion of each bar in an amount proportionate to the percent complete value. An example of this Gantt chart is shown in Figure 14. Figure 15 is an example of the planned and actual cost in currency (dollars) thru July for this case study. For most organizations these two types of displays are presented to management to report project performance as of a point in time. In that figure the planned cost curve is marked using the diamond symbols, and the actual cost curve is shown with the triangle symbols.

Figure 10. Example WBS (Level Zero)

Figure 13. Cost plan for prototype

Test/Evaluate Prototype

	A	M	J	J	A	S	O	N	D	Plan
Test Screens	3									3
Test Reports	2									2
Test Processing		2								2
Audit Trail Verify		4								4
Destructive Testing		4								4
Monthly Plan	5	10	0	0	0	0	0	0	0	15

Figure 11. Project cost plan in spreadsheet

Project Cost Plan

	Ja	Fe	Ma	Ap	Ma	Jn	Jl	Au	Se	Oc	No	De	Total
Planning & Staffing	3	2											5
Prototype Design		3	3										6
Construct Prototype			8	8									16
Evaluate Prototype				5	10								15
Full Design Specs					5	6	3						14
Documentation						2	2	1	1	1	1		8
Site Preparation						8	3	3					14
Construction							20	50	50	20			140
Test/Certification									10	6	4		20
Finishing											8	4	12
Maintenance Training												4	4
Monthly Cost	3	5	11	13	15	16	28	54	61	27	13	8	254
Cumulative	3	8	19	32	47	63	91	145	206	233	246	254	

Figure 14. Case study Gantt chart
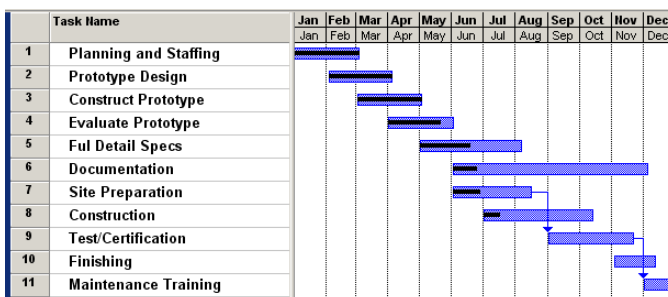
Figure 15. Planned and actual cost plan graph

Plan and Actual Cost

Figure 17. EV calculation for prototype activities

	Ap	Ma	…	Plan	% C	Value
Test Plan Devel.	3			3	100	3
Unit Testing	2			2	100	2
Full Testing		4		4	100	4
Destructive Testing		4		4	50	2
Test Documentation		2		2	50	1
Monthly Plan	5	10	0	15	80	12

Figure 18. EV variance calculations in spreadsheet

Schedule Variances	
Budgeted Cost of Work Scheduled (BCWS)	91
Budgeted Cost of Work Performed (BCWP, EV)	73
Schedule Variance (Dollars)	-18
Schedule Variance (Months)	-0.67
Schedule Efficiency Factor	0.8
Estimated Time to Complete (Months)	15
Cost Variances	
Actual cost of Work Performed (ACWP)	83
Budgeted Cost of Work Performed (BCWP, EV)	73
Cost Variance (Dollars)	-10
Cost Variance (Percent)	-3.9
Cost Efficiency Factor	0.88
Estimated Cost at Completion	289

The problem with these usual methods is that they do not provide a clear quantitative picture of the true project status, nor do they provide a quantitative means for extrapolating project cost to complete or completion date. For the example project here, consider the Gantt chart above (which also shows the task percent complete as dark bars stripes inside the bars) and the actual cost versus budget graph. The project is not over budget (actual cost of $83,000 versus planned cost of $91,000), however it is hard to determine if it is on schedule or not. Actually this project is well behind schedule and is over-spent as the forthcoming earned value analysis will show.

For this case study, Figure 16 shows the EVA calculation through July. Note that the calculation of EV does not involve actual costs, but is simply the product of the percent complete and the planned cost.

Percent complete is determined for each work packet and then EV is calculated for each packet. The total project earned value at a point in time is determined by a WBS rollup of the EV values. A WBS rollup example is shown in Figure 17, for the level one tasks corresponding to the level zero item of "test/evaluate prototype".

In the example project herein, the schedule variance is -0.67 months (behind schedule) and the cost variance is -10,000 dollars (over spent). The estimated time to complete is 15 months instead of the 12 months planned, and the estimated cost to complete is 289,000 instead of 254,000. The calculation of these numbers for our example using the previous formulas is implemented in the spreadsheet of Figure 18.

INTERACTIVE WEB GANTT IMPLEMENTATION

Modern project management methods and modern information technology are now being integrated to produce "super-charged" Gantt charts. Figure 19 shows a display from the web based FiveAndDime system for this case study showing EVA calculations (as well as percent complete and cost data) with a familiar spreadsheet

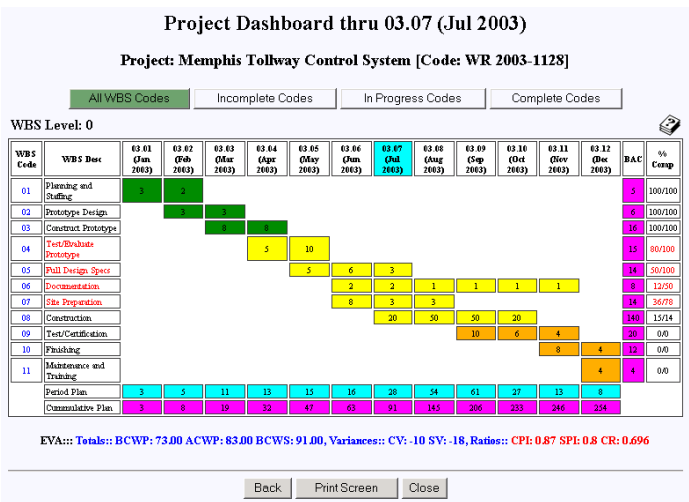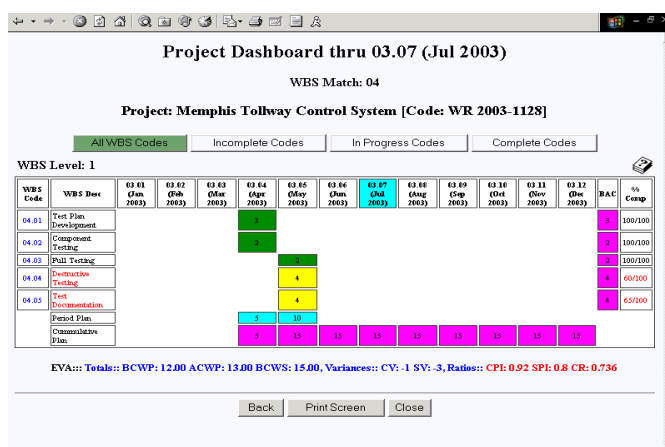Figure 19. EVA display in Gantt table (www.fiveanddime.biz)

Figure 16. EV calculations in spreadsheet

	J	F	M	A	M	J	J	…	Plan	% C	EV
Planning & Staffing	3	2							5	100	5
Prototype Design		3	3						6	100	6
Construct Prototype			8	8					16	100	16
Evaluate Prototype				5	10				15	80	12
Full Design Specs					5	6	3		14	50	7
Documentation						2	2		8	12	0.96
Site Preparation						8	3		14	36	5.04
Construction							20		140	15	21
Test/Certification									20	0	0
Finishing									12	0	0
Maintenance Training									4	0	0
Monthly Plan	3	5	11	13	15	16	28	…	254		73
Cumulative	3	8	19	32	47	63	91	…			
Monthly Actual	4	4	10	11	12	15	27	0	83		
Cum. Actual	4	8	18	29	41	56	83				

Figure 20. EVA drill down (www.fiveanddime.biz)

type Gantt chart format. Such web based systems make project information available anywhere in the world on any device that supports a standard web browser (without any custom client configuration necessity whatsoever) - even on modern PDA's and cell phones. Some emerging 21st century software is also now based on "open source software" to drastically reduce the cost involved with software licenses. For example, FiveAndDime is based on the open source "LAMP" stack (Linux, Apache, MySQL, and PHP).

In figure 19, the color in the Gantt chart bars is green for completed tasks, yellow for tasks in progress, and orange for tasks not yet started. The last column for percent complete shows a ratio where the numerator is the rolled up percent complete and the denominator is the percent complete that should have been obtained as of the reporting date; the value of that ratio is actually the EVA SPI for that task. WBS codes that have either the CPI or SPI below unity are displayed in red.

EVA greatly facilitates "management by exception". When there is a problem with a project as indicated by CPI and/or SPI less than unity, one can "drill down" in the earned value analysis to lower levels of the WBS. For example if the overall project index(s) is below unity, then one can select the level zero WBS codes that have their index(s) below unity; and then so on to the next level (level one for the case study herein).

Modern Gantt charts can also support this drill down capability and some software systems allow a PM to drill down interactively. Figure 20 is a screen shot from FiveAndDime showing a drill down from level zero to level one. This was accomplished by clicking on a particular WBS code (Evaluate Prototype) on the level zero display (Figure 19, where WBS codes with a CPI or SPI below unity are shown in red).

CONCLUSION

The Gantt chart has undergone many and significant changes since its introduction a century ago. Today's Gantt charts include earned value analysis so that effective performance management can be accomplished. Which of the new presentation formats available may be a matter of personal preference, however the interactive web based products have numerous clear advantages such as "drill down" capability. Even though Henry Gantt may not initially recognize the 21st century web enabled Gantt chart, the basic concepts and visualization he introduced have still been preserved.

REFERENCES

Anbari, F. (2003), "Earned Value Project Management Method and Extensions", Project Management Journal, Vol. 34, No. 4, December

Brandon, D. (2006), Project Management for Modern Information Systems, Idea Group Publishers, Hershey, PA [ISBN: 1-59140-693-5]

Brandon, D. (2004), "Project Performance Measurement", Chapter Thirty Four in The Wiley Guide to Managing Projects, edited by Morris and Pinto, John Wiley & Sons [ISBN: 0-471-23302-1]

Brandon, D. (1999), "Implementing Earned Value Easily and Effectively", Chapter in Essentials of Project Control, Project Management Institute Press, [ISBN: 1-880410-64-8], pp 113 – 124

Brandon, D. (1998), "Implementing Earned Value Easily and Effectively", Project Management Journal, Vol. 29, No. 2, June

Christensen, D. and Ferens, D. (1995), "Using Earned Value for Performance Measurement on Software Projects", Acquisition Review Quarterly, Spring, 155 – 171

Christensen, D., et al. (1995), "A Review of Estimate at Completion Research", Journal of Cost Analysis, Spring

Fleming, Q and Koppelman, J. (1998), "Earned Value Project Management, A Powerful Tool for Software Projects", CROSSTALK, The Journal of Defense Software Engineering, July, 19 – 23

Gantt, H. (1910), Work, Wages and Profit, *The Engineering Magazine*, NY

Gantt, H. (1919), Work, Wages and Profit, 2nd Edition, *The Engineering Magazine*, NY

Webb, A. (2003), Using Earned Value, Gower Publishing, [ISBN: 0-566-08533 X]

Related Content

Metadata Diversity in the Cultural Heritage Repositories

Sumeer Gul, Shahkar Riyaz Trambooand Humma Ahangar (2015). *Encyclopedia of Information Science and Technology, Third Edition (pp. 1843-1854).*

www.irma-international.org/chapter/metadata-diversity-in-the-cultural-heritage-repositories/112590

An Efficient Clustering in MANETs with Minimum Communication and Reclustering Overhead

Mohd Yaseen Mirand Satyabrata Das (2017). *International Journal of Rough Sets and Data Analysis (pp. 101-114).*

www.irma-international.org/article/an-efficient-clustering-in-manets-with-minimum-communication-and-reclustering-overhead/186861

Model-Driven Engineering of Composite Service Oriented Applications

Bill Karakostasand Yannis Zorgios (2011). *International Journal of Information Technologies and Systems Approach (pp. 23-37).*

www.irma-international.org/article/model-driven-engineering-composite-service/51366

Increasing the Trustworthiness of Collaborative Applications

Mamdouh Babiand Wenbing Zhao (2015). *Encyclopedia of Information Science and Technology, Third Edition (pp. 4317-4324).*

www.irma-international.org/chapter/increasing-the-trustworthiness-of-collaborative-applications/112874

Using Fuzzy Logic for Optimizing Business Intelligence Success in Multiple Investment Combinations

Mandana Farzaneh, Iman Raeesi Vananiand Babak Sohrabi (2015). *Encyclopedia of Information Science and Technology, Third Edition (pp. 953-965).*

www.irma-international.org/chapter/using-fuzzy-logic-for-optimizing-business-intelligence-success-in-multiple-investment-combinations/112488