The Contribution of Earned Value Management to Project Success on Contracted Efforts

Project managers need effective tools and techniques to meet the challenges of their profession. One such method believed to be effective is earned value management (EVM). This article presents a quantitative statistics approach within a population of experienced practitioners.

BY ROBERT A. MARSHALL

Abstract

Earned value management (EVM) is believed to be an effective project management methodology on external projects under contract. A number of qualitative case studies crossing multiple project management processes have validated its positive contribution. This research departs from, as well as complements, existing case analyses by taking a quantitative statistical approach. Utilizing Pearson's product moment correlation, bivariate linear regression analysis, and canonical discriminant analysis, this research (1) investigates the direct relationship of the principles of EVM to project success on contracted efforts; (2) investigates the moderating effect contract type may have on the relationship; and (3) investigates between-group differences (fixed-price versus cost-plus contract arrangements) with respect to the contribution of EVM mechanics to project procurement management items. Quantitative techniques are used to analyze data from a cross sectional survey of 145 experienced earned value practitioners. The findings suggest that stronger implementations of the principles of EVM result in greater levels of project success on contracted efforts, with contract type having a moderating affect. The results further suggest that EVM mechanics positively contribute to project contract development and administration and are not dependent on contract type.

Introduction

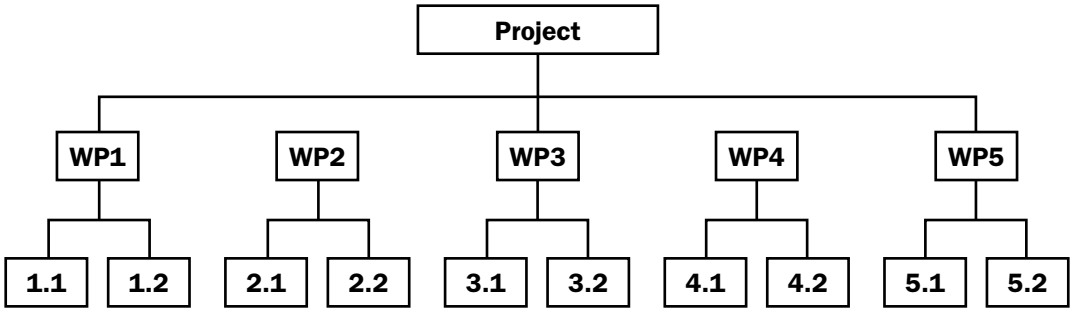
Project management is challenging. Whether in construction, information technology, or software development, odds are high that project success will be jeopardized. Consider that cost overruns of 25–33 percent are not unusual in the construction industry (Thelen Reid & Priest, 2004). The same industry also has seen substantial growth in projects ending in either dispute or litigation (Levin, 1998). In the information technology industry, "at-risk" projects have been commonplace in the public sector (GAO, 2006). Moreover, 18 percent of projects in the software industry are prematurely canceled (Standish Group, 2004). Further still, 53 percent of software projects will

About the Author

ROBERT A. MARSHALL, MBA, MSci.PM, PMP, is chair of the Association for the Advancement of Cost Engineering (AACE) earned value management special interest group, and a program manager with the Federal Acquisition Service of the General Service Administration. Send comments about this article to **cm@ncmahq.org**.

Development of EVM Metrics

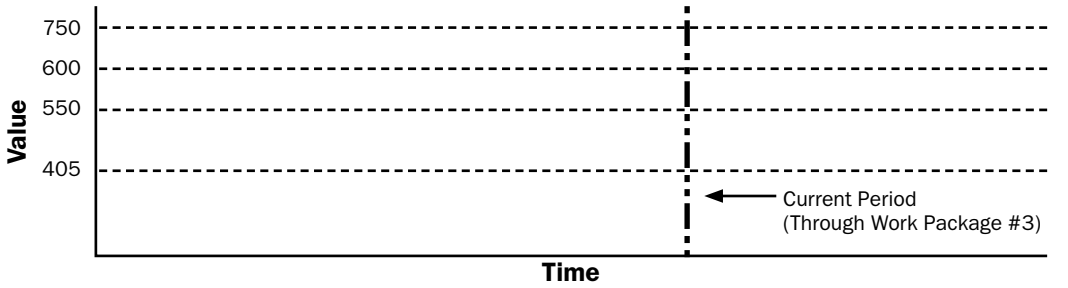
Work Breakdown Structure (graphical)



Work Breakdown Structure (tabular)

Work Package Number	BCWS/PV	BCWS/PV	BCWS/PV
1	100	80	90
2	200	175	185
3	300	150	275
4	100	TBD	TBD
5	50	TBD	TBD
Period Total	600	405	550
Project Total	750	TBD	TBD

S-Curves



Performance Metrics

Metrics Definition	Value this Period
BCWS=PV=Planned Value	600
BCWP=EV=Earned Value	405
ACWP=AC=Actual Cost	550
BCWP - ACWP=CV=Cost Variance	-145
BCWP (EV) - BCWS (PV)=SV=Schedule Variance	-195
BCWP (EV) / ACWP (AC)=CPI=Cost Performance Index	.74
BCWP (EV) / BCWP (PV)=SPI=Scheduled Performance Index	.67
BAC=ΣBCWS (PV)	750
EAC=BAC/CPI	1013
VAC=BAC - EAC	-263
TCPI=BAC - BCWP (EV) / BAC	1.72

FIGURE 1.

exceed their cost, schedule, or scope constraints (Ibid). There is no shortage of data about under-performing projects, and even more frequent stories in the workplace about troubled and—worse still—failed projects. Therefore, project managers need effective tools and techniques to meet the challenges of their profession. One such method believed to be effective is earned value management (EVM).

EVM is a comprehensive methodology used to manage projectized efforts. The methodology addresses many project management areas, including project organization, planning, scheduling and budgeting, accounting, analysis, reporting, and change control (Fleming and Koppelman, 1996). EVM also incorporates specific mechanics to include the use of the work breakdown structure (WBS), performance curves (S-curves), as well as a defined set of performance metrics. EVM is among the first project management methodologies to be codified by national standards setting organizations (ANSI/EIA, 1998; ASI, 2003).

A distinguishing characteristic of EVM is its unique metrics. EVM integrates a project's scope, schedule, and cost into a unified set of prescribed metrics for the purpose of monitoring and forecasting project performance. The building blocks of all EVM metrics are the following three elements:

1. Budgeted cost of work performed (BCWP or EV[1])=Earned Value

2. Actual cost of work performed (ACWP or AC)=Actual Cost

3. Budgeted cost of work scheduled (BCWS or PV)=Planned Value

FIGURE 1 (on page 22) depicts a simplified project in demonstrating the sequence of EVM implementation. The methodology begins with planning the entire project scope in the form of a WBS. Each of the work packages contained in the WBS is cost-estimated, scheduled, and rolled up to the next higher-level WBS element. An S-curve, bounded by zero and total cumulative cost as end-points, is created next using BCWS (PV) data to form a visual baseline. Values for BCWP (EV) and ACWP (AC) are calculated as work progresses, forming their own unique S-curves to compare against the baseline. Higher-level EVM metrics are derived from the three primary values, and are used to monitor and control the project, as well as to provide performance information to stakeholders.

Putting EVM aside and relying on the traditional accounting viewpoint of this sample project, one might erroneously conclude that the project is performing well. Given that 550 have been expended against the total project budget of 750, it appears the project is 73 percent complete. Or more optimistically, given that 550 have been expended against a budget to date of 600, the project appears to be performing below cost.

Closer examination using EVM metrics, however, reveals the opposite. Not only is the project behind in scheduled scope completion [schedule variance (SV)=-195], the project is also over-running costs [cost variance (CV)=-145]. Only 405 worth of scope have been completed despite that 550 have been spent. Moreover, the estimate at completion (EAC) for this project at the current rate of performance is 1,013—a cost overrun of 263. To end on time and on schedule, the project would have to perform at a rate of 1.72 times that originally planned [to complete performance index (TCPI)=1.72].

FIGURE 1 offers a simple yet illustrative example of EVM's unique and effective integration of scope, schedule, and cost data into a unified set of metrics based on a thoroughly planned project WBS.

Literature Review

A review of literature uncovered three categories of knowledge regarding the contribution of earned value management to project success. Ample literature offers rational support for EVM's positive contribution (Presutti, 1993; Fleming and Koppelman, 1996, 2002; Christenson, 1998; Abba, 2001; Antvik et al, 2001; Anbari, 2003). Works of this type suggest the benefit of EVM across major project management processes including planning, executing, monitoring, and controlling (PMBOK, 2004). While logical and meaningful, these works are sources of propositional knowledge and, in and of themselves, limited to providing theoretical beliefs and assertions. They do not provide evidence, per se, of EVM's contribution to project success.

Another source of knowledge is from the experiential accounts of project practitioners (Mukho and Lisanti, 1982; Adamczyk, 1989; Chen, 1991; Yu, 1996; Antvik, 2001; Kauffman, Keating, and Considine, 2002). These works are important in that, unlike theory, they offer empirical evidence based on

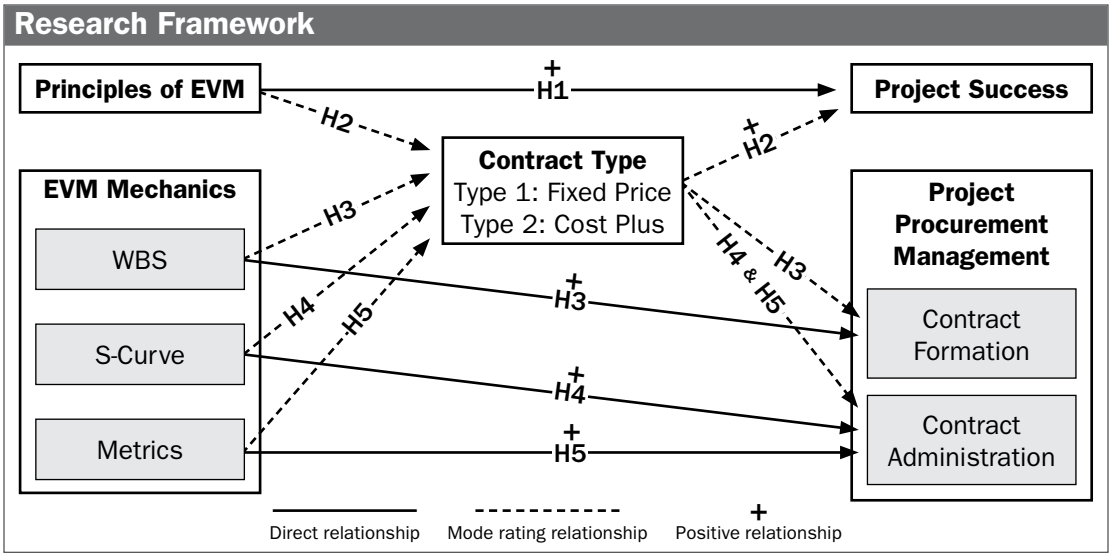


FIGURE 2.

personal experience and observations. They generally illustrate EVM's contribution in one or more project management processes. To the extent the author's projects were successful, a contribution to project success can be concluded from these experiential accounts.

A third source of knowledge about EVM's contribution to project success blends both theory and experience (Marrella, 1973; Kim, 2000; Vargas, 2003). These works offer the highest level of precision in both their methodology and findings and can be said to offer scientific knowledge. Works in this category are research-oriented, and to date rely on qualitative methods to make relevant points. All emphasize EVM's contribution to project control (Marrella, 1973; Kim, 2000; Vargas, 2003). Additionally, two of the three have emphasized EVM's contribution to project planning along with project control, yet differed on the relative strength of each (Marrella, 1973; Vargas, 2003). In Marrella's work, the author found that "...C/SCSC (EVM's predecessor) have affected a significant improvement in planning and a positive but less significant improvement in control." In Vargas's, the author concluded EVM to be effective in the control of projects, yet dependent on a project's first having established effective plans. What we know collectively from these research works is (1) EVM contributes to project planning; (2) EVM contributes to project control, but perhaps more or less so than planning; and (3) since EVM contributes to these project management processes, and these processes are believed to positively influence project performance, it can be inferred that EVM contributes to project success.

Among all of the available sources of knowledge, only certain works specifically address contract type with respect to EVM. Theoretical as well as research works support EVM's contribution to projects under cost-plus contract arrangements (Fleming and Koppelman, 1996; Marrella, 1973; Kim, 2000). Similarly, propositional, empirical, as well as research works, exist in support of EVM's contribution to projects under fixed-price arrangements (Fleming and Koppelman, 1996; Yu, 1996; Antvik, 2001; Kauffman, Keating, and Considine, 2002; Vargas, 2003). Qualitative justification is available in support of the belief that EVM contributes to project success generally, and under alternative contract types, in particular. Conspicuously missing from the literature is a quantitative approach. The research at hand fills the gap.

Framework and Hypotheses

The theoretical framework for this research is the belief that EVM directly contributes to project success; and contract type may moderate EVM's overall contribution as well as the contribution of EVM's mechanics to contract formation and administration items. FIGURE 2 depicts the theoretical framework for this research.

The following hypotheses (H) are tested:

H1: *Principles of EVM* are significant positive predictors of *project success*.

H2: There will be no significant difference between fixed-price and cost-plus contracts when relating *principles of EVM* to *project success*, separately.

H3: There will be no significant difference between fixed-price and cost-plus contracts on the contributions of *EVM's work breakdown structure* during *contract formation*.

H4: There will be no significant difference between fixed-price and cost-plus contracts on the contribution of *EVM's S-curve* during *contract administration*.

H5: There will be no significant difference between fixed-price and cost-plus contracts on the use of *EVM's performance metrics* during *contract administration*.

Research Variables

There are three variables to the analysis, each comprised of multiple items. The first variable is *principles of EVM* and is made up of the seven principles of earned value management specified in ANSI/EIA-748-A-1998. The second variable is *project procurement management* and consists of 18 items divided into two groups—*contract formation* (seven elements) and *contract administration* (11 elements). The third variable is *project success* and is made up of the four project success factors developed by Shenhar, Levy, and Dvir in 1997. Both the EVM standard, as well as Shenhar et al's framework, were selected using the same rationale—each offers parsimony as well as breadth. In the case of ANSI/EIA-748-A-1998, it consists of four fewer principles as compared to ASI-4817-2003, yet as industry standard offers construct validity (Kline, 2000). Similarly, Shenhar's framework is comprised of only four success factors, yet is appropriate in that it addresses a wider set of objectives (Turner and Muller, 2004), consistent with the emerging and broadening understanding of project success (Jugdev and Muller, 2005). Shenhar et al's model includes organizational dimensions of success in addition to traditional success factors centered on meeting cost, schedule, and scope parameters. The elements of the *project procurement management* variable represent common contract development and administration functions where EVM mechanics are utilized. Each variable and its elemental items are outlined below.

Variable #1: Principles of EVM

1. Plan all work scope for the project to completion;
2. Decompose the scope into finite pieces that can be assigned to a responsible person or organization to control;
3. Integrate program work scope, schedule, and cost objective into a performance measurement baseline plan against which accomplishments may be measured. Control changes to the baseline;
4. Use actual costs incurred and recorded in accomplishing the work performed;
5. Objectively assess accomplishments at the work performance level;
6. Analyze significant variances from the plan, forecast impacts, and prepare an estimate at completion based on performance to date and work to be performed; and
7. Use EVMS (earned value management system) information in the company's management processes.

Variable #2: Project Procurement Management

1. WBS with respect to *contract formation* items.
   - Scope development (wbs1),
   - Risk assessment (wbs2),
   - Should cost-estimates (wbs3),
   - Schedule planning (wbs4),
   - Payment planning (wbs5),
   - Evaluating bids and negotiating with bidders (wbs6), and
   - Ensuring fairness and equity to contract (wbs7).

Industries Represented in Sample Population					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Heavy Construction	3	2.1	2.1	2.1
	Light Construction (Residential and Commercial)	2	1.4	1.4	3.4
	Government/Public Works	19	13.1	13.1	16.6
	Military/Defense	67	46.2	46.2	62.8
	Information Technology	16	11.0	11.0	73.8
	Professional Services (Banking, Consulting, Management., etc)	10	6.9	6.9	80.7
	Aerospace	15	10.3	10.3	91.0
	Software	7	4.8	4.8	95.9
	Other	6	4.1	4.1	100.0
Total		154	100	100	

TABLE 1.

2. S-curves with respect to a single *contract administration* item.
   - Monitoring work (s-curve)

3. Performance metrics—(earned values, schedule variance, cost variance, schedule performance index, cost performance index, estimate at completion, to complete performance index (TCPI)—with respect to multiple *contract administration* items.
   - Controlling schedule (metric1),
   - Controlling scope (metric2),
   - Controlling cost (metric3),
   - Evaluating and processing change orders (metric4),
   - Evaluating and processing payment requests (metric5),
   - Evaluation and analyzing delays (metric6),
   - Evaluating and analyzing claims (metric7),
   - Acceptance of completed work (metric8),
   - Contract close-out (release of claims) (metric9), and
   - Post-project audits (metric10).

Variable #3: Project Success

1. **Meeting schedule and budget goals**—how well the project satisfied the resource constraints of schedule and budget.

2. **Benefit to customer**—how well the project satisfied the functional requirements and technical specifications of the organization that benefit from the project's realization.

3. **Commercial success**—how well the project satisfies the desired business results (includes return on investment for performing organization; or enhancing the profits of the benefiting organization).

4. **Preparing for the future**—the contribution the project made to the performing organization in developing new business opportunities; technologies or increasing core competencies.

Research Methodology

The research methodology used is purposive sampling using a structured survey. In that the research is to test actual EVM usage with respect to project success, respondents must have had direct experience using EVM on one or more projects. Four specific groups were targeted because of their unique focus on EVM and high likelihood of having experienced practitioners as members: The Project Management Institute's College of Performance Management, Defense Acquisition University's earned value management community, the Association of Project Management's earned value special interest group, and the Association for the Advancement of Cost Engineering's earned value special interest group.

Each group was solicited on two separate occasions and directed to an online survey. The decision to use the Web for conducting the survey was made because of the ease of administration, its ability to reach a global population, relatively low expense, and fast delivery of results (Sekaran, 2003).

Survey questions were created by presenting affirmative declarations and asking respondents to select an answer that best reflects their level of agreement with the statement as it applies to their specific project. For example, with regard to *principles of EVM*, the first item became, "All work scope was planned for the project to completion." With regard to *project procurement management* items, the first item became "EVM's work breakdown structure contributed to contract scope development." With regard to project success, the first item became, "The project satisfied schedule and budget constraints." Each of these declarations was followed by an identical seven-point Likert scale anchored on the far left end with "strongly disagree," and on the far right with "strongly agree." A neutral point was included in the center of the scale. The seven possible selections were designed to correspond to an interval level measurement scale (one to seven) required for statistical analysis of continuous data.

Bivariate Correlation (Linear Results)

All responses (n=145)

Correlations

		evmcomp	sucesscomp
evmcomp	Persons Correlation	1	.474*
	Sig. (2-tailed)		.000
	N	145	145
sucesscomp	Persons Correlation	.474*	1
	Sig. (2-tailed)	.000	
	N	145	145

*Correlation is significant at the 0.01 level (two-tailed)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	T	Sig
1	(Constant)	2.945	.375		7.849	.000
	evmcomp	.458	.071	.474	6.443	.000

[a]Dependent variable: sucesscomp

TABLE 2.

Statistical Analysis Techniques

The statistical techniques used to test the hypotheses are (1) Pearson's product moment correlation analysis, (2) bivariate linear regression analyses, and (3) canonical discriminant analysis (CDA). The techniques of correlation-regression are used to measure the relationship between dependent and independent variables required to test H1 and H2. In order to perform the bivariate correlation-regression, two single continuous variables are required. Single continuous variables are created by totaling all responses of a single respondent to all questions comprising the variable and dividing by the number of questions. The resulting composites are arithmetic mean scores for each variable. Composites not only facilitate the statistical technique, they have the added value of offering higher measurement reliability (Nunnally, 1967; Biemer et al, 1991) than single elements for a given construct. To investigate differences between groups required for testing H3, H4, and H5, the technique of CDA using a backward stepwise approach based on multiple discriminating variables (independent variables) and a dichotomous criterion variable (fixed-price and cost-plus contract type) is used. The result is a discriminant model that maximizes differences between groups and quantifies the relative importance of each discriminant variable with respect to the criterion variable.

Results

During the period of July 6, 2005, through March 10, 2006, a total of 256 respondents logged on to the survey Web site. Of the total log-ons, 148 completed the entire survey yielding an online completion rate of 57.8 percent. Surveys that were not complete were discarded. Of the 148 responses, three demonstrated extreme outlier characteristics (standardized residual value > 3 σ) when pre-testing H1 with linear regression analysis. These three responses were removed in order to focus on the inferring characteristics of the basic regression model (Barnett and Lewis, 1994). The remaining 145 responses were analyzed using SPSS predictive analytics software.[2]

The majority of respondents worked in the military/defense industry (46.2 percent). The government/public works industry was the second largest group represented (13.1 percent) and information technology was third (11 percent). Nine industries were represented in all, as shown in **TABLE 1** on page 26. Thirty percent of respondents indicated their project was performed under

X–Y Scatterplot of Principles of EVM and Project Success Composite Date

All responses (n=145)

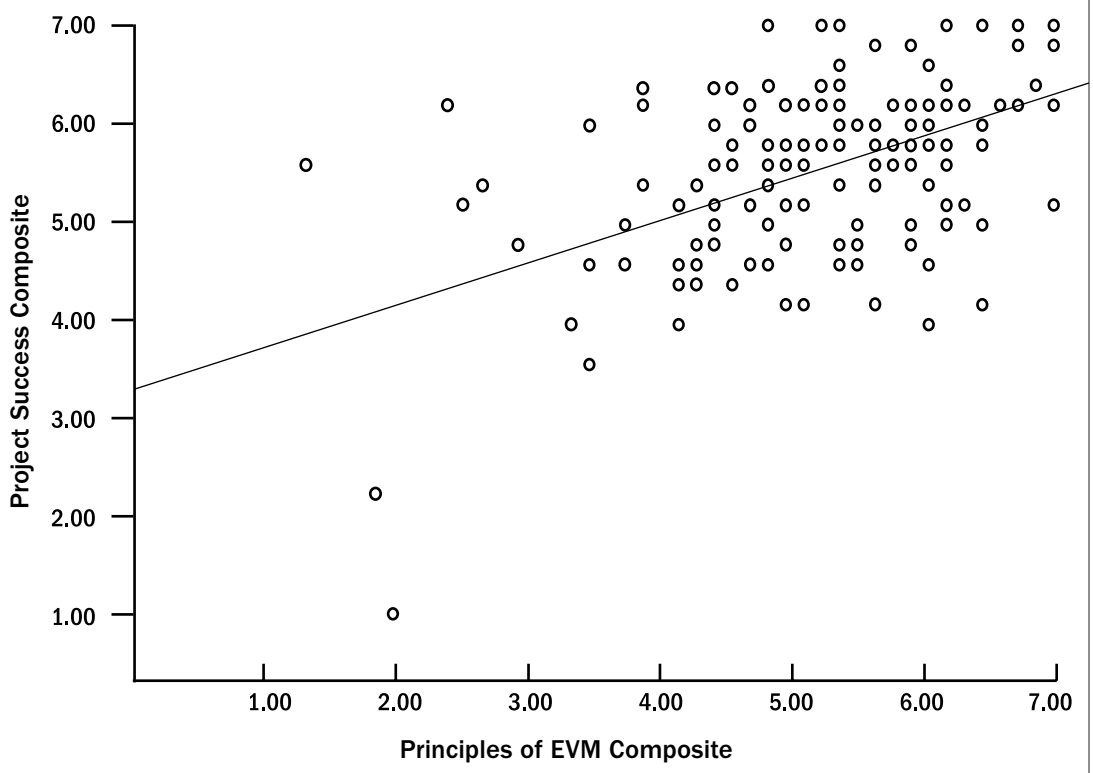


FIGURE 3.

SPSS Bivariate Linear Regression Output (Fixed-Price Contracts)

(contract type=1.00)(n=43)

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig
1	(Constant)	2.183	.714		3.057	.004
	evmcomp	.626	.135	.585	4.622	.000

[a]Dependent variable: sucesscomp
[b]Selecting only cases for which contractype=2.00

TABLE 3.

Bivariate Linear Regression Output (Cost-Plus Contracts)

(contract type=2.00)(n=102)

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig
1	(Constant)	3.385	.434		7.791	.000
	evmcomp	.365	.082	.405	4.432	.000

[a]Dependent variable: sucesscomp
[b]Selecting only cases for which contractype=2.00

TABLE 4.

fixed-price contract arrangements (n=43). Seventy percent indicated using cost-plus contracting (n=102). Fifteen years of project management experience was most frequently reported (15.2 percent). Sixty-five percent of the respondents had 15 or more years of experience. The range of experience was from one year to 40 years. The majority of respondents reported having two to three contractors working on their project (19.3 and 14.5 percent, respectively). Sixty-four percent had between one and five contractors working on their project. An expected project length of five years was most often reported (19.6 percent). Three years and 10 years reported equal frequency (12.8 percent). The majority of respondents reported an expected project length of between four months and five years (69.6 percent). The range of expected project lengths was four months to 20 years.

Results offered support for H1. Linear correlation-regression showed a moderately strong relationship between the independent variable *principles of EVM* and dependent variable *project success* (r=.474; b=.474, t=6.443, n =145). The results were significant setting p at p < .05 (a=.000). The independent variable explains 22.47 percent of the variation in the dependent variable (R^2=.2247). As predicted, *principles of EVM* are significant positive predictors of *project success*, as shown in TABLE 2 and FIGURE 3. A scatter-plot of the response data is shown in FIGURE 3 on page 28. The X-Y plot reflects a positive orientation, as well as the strength of the relationship between *principles of EVM* and *project success*.

Results did not offer support for H2. Contrary to the prediction, a difference exists between fixed-price and cost-plus contracted projects with respect to the contribution of *principles of EVM* to *project success*, measured separately. The results favor fixed-price contracted projects. Linear correlation-regression showed a moderately strong positive relationship between the independent variable *principles of EVM* and the dependent variable *project success* for the cost-plus group (r=.405; b=.405, t=4.432, n=102); and a moderately strong and relatively higher positive relationship for the fixed-price group (r=.585; b=.585, t=4.622, n=43). The independent variable explains 16.40 percent of the variation in the dependent variable in cost-plus contracted projects and 34.22 percent in fixed-price contracted projects. The results are statistically significant setting p at p < .05 (a=.000), separately, as shown in TABLES 3 and 4 on page 28.

Stepwise Canonical Discriminant Functions (Work Breakdown Structure to *Contract Formation* Items)

Eigenvalues

Functions	Eigentvalue	% of Variance	Cumulative %	Canonical Correlation
1	.068[a]	100.0	100.0	.253

[a]First 1 canonical discriminant functions were used in the analysis

Wilks' Lambda

Test of Functions	Wilks' Lambda	Chi-square	df	Sig.
1	.936	9.389	2	.009

Standardized Canonical Discriminant Function Coefficients

	Function 1
wbs4	-.710
wbs5	1.022

Structure Matrix

	Function 1
wbs5	-.710
wbs4	-.323
wbs7[a]	.151
wbs3[a]	.136
wbs6[a]	.127
wbs2[a]	.067
wbs1[a]	.041

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions. Variables ordered by absolute size of correlation within function.
[a]This variable not used in analysis.

TABLE 5.

SPSS Summary of Stepwise Canonical Discriminant Function (S-Curve/EVM Metrics to *Contract Administration*)

Eigenvalues

Functions	Eigentvalue	% of Variance	Cumulative %	Canonical Correlation
1	.068[a]	100.0	100.0	.240

[a]First 1 canonical discriminant functions were used in the analysis

Wilks' Lambda

Test of Functions	Wilks' Lambda	Chi-square	df	Sig.
1	.943	8.434	1	,004

Standardized Canonical Discriminant Function Coefficients

	Function 1
metric5	1.00
wbs5	1.022

Structure Matrix

	Function 1
metric5	-.710
metric7[a]	-.323
metric4[a]	.151
metric8[a]	.136
metric2[a]	.127
metric9[a]	.067
metric10[a]	.041
metric6[a]	
scurve[a]	
metric1[a]	
metric3[a]	

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions. Variables ordered by absolute size of correlation within function.
[a]This variable not used in analysis.

TABLE 6.

Results offered support for H3, with exceptions. As predicted, there are no significant differences between fixed-price and cost-plus contracted projects on the contributions of *EVM's WBS* to *contract formation* items, with the exception of wbs4 (schedule planning) and wbs5 (payment planning) (Wilks' λ=.936, χ^2=9.389, df2, p=.009)(eigenvalue=.068; canonical correlation=.253). Five items were removed leaving a single canonical root with two discriminant coefficients (wbs4 and wbs5). No significant differences between fixed-price and cost-plus contracts were observed with respect to the contribution of *EVM's WBS* to *contract formation* items for wbs1, 2, 3, 6, and 7. The analysis results are shown in TABLE 5 on page 29.

Results offered support for H4. As predicted, there is no significant difference between fixed-price and cost-plus contracted projects on the contribution of *EVM's S-curve* to *contract administration* items (single item included in H5 analysis).

Results offered support for H5, with exceptions. The results show no significant difference between fixed-price and cost-plus contracted projects on the contributions of *EVM's performance metrics* to *contract administration* (Wilks' λ=.943, χ^2=8.434, df1, p=.004) (eigenvalue=.061; canonical correlation=.240), with the exception of metric5 (evaluating and processing payment requests). A total of 10 items were removed during the analysis leaving a single canonical root with one discriminant coefficient (metric5). No significant differences between fixed-price and cost-plus contracts were observed with respect to the contribution of *EVM's metrics* to *contract administration* items for s-curve, metric1, 2, 3, 4, 6, 7, 8, 9, and 10. The results are shown in TABLE 6.

Discussion

The purpose of this research was three-fold: (1) to investigate the direct relationship of the principles of earned value management (EVM) to project success on contracted efforts; (2) to investigate any moderating effect contract type may have on the relationship; and (3) to investigate differences between groups using fixed-price versus cost-plus contract types with respect to the contribution of specific EVM mechanics to project procurement management items.

Consistent with the results of previous qualitative research efforts (Marrella, 1973; Kim, 2000; Vargas,

2003), this quantitative research also suggests that EVM is an effective project management methodology. EVM is a significant positive predictor of project success on contracted efforts. EVM also has shown itself to be an even greater positive predictor of project success when using fixed-price versus cost-plus contracts. This finding of the relative strength of EVM favoring fixed-price contracts is unique and previously unasserted. While the results herein are suggestive and do not establish causation, it can be reasoned that to the extent that EVM methodology is effective in driving success on the higher risk projects normally associated with cost-plus contracted efforts, EVM would logically drive success on the less risky efforts associated with fixed-price efforts.

With regard to *EVM's WBS,* the results show that is positively contributes to the formation of project contracts. The relative contribution of the WBS to projects under fixed-price versus cost-plus arrangements was not significantly different with respect to scope development, risk assessment, and the development of should-cost estimates. Moreover, no significant difference was observed for *EVM's WBS* contribution to evaluating bids, negotiating with bidders, and the awarding of a fair contract. However, an important difference between fixed-price and cost-plus contracted projects was observed with respect to the WBS's contribution to schedule planning in cost-plus contracts and payment planning in fixed-price contracts. One possible explanation for the differences is risk management. In contractual arrangements whereby all costs incurred are paid, a carefully planned schedule provides a measure of efficiency and effectiveness during project performance. Following the logic "time is money," the relatively larger contribution of the WBS to schedule planning in cost-plus contracts directly serves to manage costs by planning performance. In contractual arrangements whereby prices are fixed, performance is more at risk. The relatively larger contribution observed for the WBS contribution to payment planning in fixed-price contracted projects serves to both incentivize performance and guarantee work accomplishment. The relative strength of *EVM's WBS* contribution to schedule planning and payment planning reflects the inherent risks associated with cost-plus and fixed-price contracts, respectively.

The EVM S-curve is an important contributor to the administration of project contracts, but not significantly different between fixed-price and cost-plus contracted projects. EVM metrics also are important contributors to the administration of project contracts. The relative contribution of EVM metrics to projects under fixed-price versus cost-plus contracts was not significantly different with respect to controlling schedule, scope, or costs; evaluating and processing change orders; analyzing delays and claims; the acceptance of completed work; contract close-out; or post-project audits.

However, an important difference was observed with respect to the contribution EVM metrics had on evaluating and processing payment requests in fixed-price contracts. One possible explanation for the relatively larger benefit in fixed-price contracts is related to the payment structure, which was previously discussed. Carefully evaluating and processing payment requests is critical to upholding the integrity of the payment structure designed to incentivize performance, guarantee work accomplishment, and mitigation of performance risk associated with fixed-price contracted projects.

These results have important implications for project practitioners, corporate and governmental policy makers, as well as future researchers. EVM should be considered for all projects—not only for its positive contribution to project procurement management, but for its contribution to project success as well, regardless of contract type. Contract type should not be the sole determining factor in the decision whether or not to use EVM. The use of EVM mechanics should be used in all projects. Payment planning should be emphasized in fixed-price contracts using EVM in order to mitigate performance risk. Schedule planning should be emphasized in cost-plus contracts using EVM in order to mitigate financial risk.

Limitations of Research

A primary limitation of the research is in the use of statistical analysis itself. While statistical analysis techniques may serve to either explain or predict the relationship among one or more variables, an exact causal connection can never be absolutely determined. Statistical analysis provides only explanatory or predictive utility. Moreover, the unexplained portion of the relationships between variables is inherently outside the scope of this research. Witness the removal of three outliers—the fact that three data points did not adhere to the model

suggests that the model itself can be improved by further investigating unexplored dimensions of either the *principles of EVM*, *project success*, or both. Lastly, a larger and broader sample population is always preferable. Future studies should attempt to achieve greater levels of project diversity within an even larger sample population.

Directions for Future Research

The findings of this quantitative study point out several possible directions for future research on EVM. As a logical extension of the heretofore unasserted belief that the principles of EVM contribute relatively more to the success of fixed-price contracted projects, an in-depth research case study is warranted in order to uncover the significant characteristics of a fixed-price contracted project environment. A long duration study on the use of EVM in a fixed-price environment would serve to discover new variables and new theories. Another area of future research only touched on in this study is with respect to extreme cases. Like the three outliers that did not fit the model, research aimed at describing extreme cases of both unsuccessful as well as successful EVM implementations would make a contribution to EVM knowledge by way of comparison. Lastly, and more broad in scope, study should be directed at replacing the often-used contract-oriented framework surrounding EVM in favor of a more relevant way of thinking about the methodology, given EVM's beneficial contribution to projects regardless of contract type. Perhaps a more meaningful way to frame EVM would be in the terms and dimensions representative of project risk management. ***JCM***

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ENDNOTES

1. Notation developed by Dr. Cioffi suggests alternatives to EV, AC, and PV: Cb, Ca, and Cs, respectively (Cioffi, 2002).

2. SPSS is a computer program used for statistical analysis and is also the name of the company (SPSS Inc.) that sells it.