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Acquisition Risks in a World of Joint Capabilities: A Study of Interdependency Complexity

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Preface & Acknowledgements

Welcome to our Ninth Annual Acquisition Research Symposium! This event is the highlight of the year for the Acquisition Research Program (ARP) here at the Naval Postgraduate School (NPS) because it showcases the findings of recently completed research projects—and that research activity has been prolific! Since the ARP's founding in 2003, over 800 original research reports have been added to the acquisition body of knowledge. We continue to add to that library, located online at www.acquisitionresearch.net, at a rate of roughly 140 reports per year. This activity has engaged researchers at over 60 universities and other institutions, greatly enhancing the diversity of thought brought to bear on the business activities of the DoD.

We generate this level of activity in three ways. First, we solicit research topics from academia and other institutions through an annual Broad Agency Announcement, sponsored by the USD(AT&L). Second, we issue an annual internal call for proposals to seek NPS faculty research supporting the interests of our program sponsors. Finally, we serve as a "broker" to market specific research topics identified by our sponsors to NPS graduate students. This three-pronged approach provides for a rich and broad diversity of scholarly rigor mixed with a good blend of practitioner experience in the field of acquisition. We are grateful to those of you who have contributed to our research program in the past and hope this symposium will spark even more participation.

We encourage you to be active participants at the symposium. Indeed, active participation has been the hallmark of previous symposia. We purposely limit attendance to 350 people to encourage just that. In addition, this forum is unique in its effort to bring scholars and practitioners together around acquisition research that is both relevant in application and rigorous in method. Seldom will you get the opportunity to interact with so many top DoD acquisition officials and acquisition researchers. We encourage dialogue both in the formal panel sessions and in the many opportunities we make available at meals, breaks, and the day-ending socials. Many of our researchers use these occasions to establish new teaming arrangements for future research work. In the words of one senior government official, "I would not miss this symposium for the world as it is the best forum I've found for catching up on acquisition issues and learning from the great presenters."

We expect affordability to be a major focus at this year's event. It is a central tenet of the DoD's Better Buying Power initiatives, and budget projections indicate it will continue to be important as the nation works its way out of the recession. This suggests that research with a focus on affordability will be of great interest to the DoD leadership in the year to come. Whether you're a practitioner or scholar, we invite you to participate in that research.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the ARP:

- Office of the Under Secretary of Defense (Acquisition, Technology, & Logistics)
- Director, Acquisition Career Management, ASN (RD&A)
- Program Executive Officer, SHIPS
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- Program Executive Officer, Littoral Combat Ships

We also thank the Naval Postgraduate School Foundation and acknowledge its generous contributions in support of this symposium.

James B. Greene Jr.	Keith F. Snider, PhD
Rear Admiral, U.S. Navy (Ret.)	Associate Professor

Panel 15. Major Defense Acquisition Programs: Assessment and Challenges to Successful Management Outcomes

Thursday, May 17, 2012	
9:30 a.m. – 11:00 p.m.	**Chair: Dr. Nancy Spruill,** Director, Acquisition Resources and Analysis, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics ***A GAO Assessment of the DoD's Major Weapon Systems Acquisition Program Portfolio*** Michael Sullivan, *Government Accountability Office* ***Schedule-Driven Costs in Major Defense Programs*** Roy Wood, *Defense Acquisition University* ***Acquisition Risks in a World of Joint Capabilities: A Study of Interdependency Complexity*** Mary Maureen Brown and Graham Owen *University of North Carolina at Charlotte*

Nancy Spruill—Dr. Spruill is the director of Acquisition Resources & Analysis at the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. Dr. Spruill received her Bachelor of Science degree in mathematics in 1971. From 1971 to 1983 she held a variety of positions with the Center for Naval Analyses, including technical staff analyst, professional staff analyst and project director. She earned her Master of Arts in mathematical statistics in 1975, followed by her doctorate in 1980.

Dr. Spruill served on the staff of the Office of the Secretary of Defense from 1983 to 1993. Initially, she was the senior planning, programming, and budget analyst in the Manpower, Reserve Affairs and Logistics Secretariat. Later, she served as the director for support and liaison for the Assistant Secretary of Defense for Force Management and Personnel. Then she served as the senior operations research analyst in the Office of the Assistant Secretary of Defense for Program Analysis and Evaluation.

In March 1995, she was selected as the deputy director for acquisition resources for the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]). In February 1999, she was appointed the director of acquisition resources and analysis (ARA) for the USD(AT&L). In this capacity, she is responsible for all aspects of AT&L'S participation in the Planning, Programming and Budgeting System (PPBS); the congressional process; and the Defense Acquisition System. She serves as the executive secretary to the Defense Acquisition Board and is responsible for the timely and accurate submission to Congress of Selected Acquisition Reports and Unit Cost Reports for Major Defense Acquisition Programs. She manages the Defense Acquisition Execution Summary monthly review of programs; monitors cost and schedule status of high interest programs; and conducts analyses of contract and program cost performance including analysis of the effective use of integrated program management principles through the use of earned value management. She leads the Department in developing plans to manage property, plant and equipment, inventory, operating materials and supplies/deferred maintenance and environmental liabilities. She proposes modifications to, or acquisition of, new DoD feeder systems, in support of achieving an unqualified audit opinion on DoD financial statements as mandated by the Chief Financial Officers (CFO) Act. She also manages the studies program for the OSD, oversees the USD(AT&L)'s office automation system and manages its information system network. She serves as the focal point for DoD-wide software-intensive systems program initiatives to improve mechanisms for the management of defense acquisition programs; manages software intensive systems assessment initiatives; performs systemic analysis from independent expert program reviews to improve acquisition policy and education, and conducts special analyses for the under secretary.

Dr. Spruill has been a member of the Senior Executive Service since 1995. She is a certified acquisition professional and an active member of the American Statistical Association. Her many honors and awards include the Defense Medal for Exceptional Civilian Service, the Defense Medal for Meritorious Civilian Service, the Hammer Award, and the Presidential Rank Award. She has contributed papers in publications of the statistics and defense analyses communities and authored articles in the general press on how politicians use—and abuse—statistics.

Acquisition Risks in a World of Joint Capabilities: A Study of Interdependency Complexity

Mary Maureen Brown—Brown is a professor of public administration at The University of North Carolina at Charlotte, a senior fellow at the Center for Excellence in Municipal Management at George Washington University; and a visiting scientist at Software Engineering Institute at Carnegie Mellon University (2007–2008). Dr. Brown has extensive experience in cross-organizational information systems integration in government and in researching the development and design of a program methodology for the acquisition of joint information systems. Her research interests center on participatory design, knowledge management, and joint problem solving and program planning. Dr. Brown received her PhD from the University of Georgia. [marbrown@uncc.edu]

Graham Owen—Owen is a research assistant at the University of North Carolina at Charlotte and a law student at the University of North Carolina. His interests lie in the areas of research methodology, statistics, and organizational performance. He is especially interested in contract law and its influence on program performance.

Abstract

Environmental uncertainty has particular ramifications for programs that seek the benefits of interdependent coordinated action. This research examined the influence of a number of interdependencies on major defense acquisition program (MDAP) performance. The analysis found that interdependencies, when defined by *joint status*, *number of program elements*, or *number of data connections* do not appear to exhibit any ill-toward effects.

However, the results illustrated that programs exert cascading influences on neighboring programs. The examination of whether MDAPs that share a program element influence each other was supported for both program acquisition unit cost (PAUC) growth and estimation cost variance. Moreover, upstream program PAUC growth appeared to influence both downstream PAUC growth and downstream estimation cost variance. The upstream programs' estimation cost variance also demonstrated a positive effect on the downstream programs' estimation cost variance. The findings illustrate that the performance of interdependent organizations are susceptible to the performance shortfalls of their partners.

Introduction

In a world of insurgent and asymmetrical warfare, no defense organization is an island. While the Services have engaged in a host of coordinated efforts in the past, the need for situational awareness and rapid response rates demand the synergistic benefits that only wide-scale cross-integration and interoperability affords. Never in the history of the DoD has the rapid fielding of flexible and adaptive technology for countering unconventional and time-sensitive threats been more important.

This research examines DoD acquisition from the context of a network of interrelated programs that exchange and share resources for the purpose of establishing joint capabilities. The research focuses on the joint space of MDAP programs—the space where transactions form interdependencies among major defense acquisition programs (MDAPs). The research is especially salient because, to date, little is known about the risks associated with interdependent activities.

Unfortunately, by and large, the literature on interdependent activities is steeped in contradictory findings. For example, some argue that tight-knit arrangements are more likely to have the social traction needed to overcome environmental difficulties (Sosa, 2011), whereas others argue that loose coupling, or weak ties, may be a better solution (Granovetter, 1973). Some claim that more information is the key to benefit attainment (Comfort, 1994); whereas others claim that more information leads to a false sense of security (Hall, Ariss, & Todorov, 2007). Yet despite the absence of consistent sage advice, resource limitations and a demand for comprehensive solutions continue to push organizations toward complex structures for the delivery of products and services.

For this research, jointness, interdependency, exchange, and partnerships all refer to a similar concept: the notion that autonomous organizations build relationships to provide capabilities that, when looked at in totality, form network structures. While it is true that at the individual pair-wise level, these exchanges exist as explicit transactions for the transfer of data, labor, capital, or materials, it is also true that the totality of the various dimensions, coupled with the turbulence of perturbations, influences the cost, schedule, and performance of the acquisition effort.

This research examines the role that interdependent activities play in delivering products on time and on budget. In short, it seeks to identify the role that environmental turbulence plays in the pursuit of coordinated activities. The study of environmental uncertainty and turbulence is especially pivotal because organizations often seek to forego the benefits of partnerships, or coordinated activities, to eliminate the risk of environmental uncertainty. The following section provides a short overview of environmental uncertainty as related to organizational theory. It then extends the dialogue to the arena of interdependent structures. In doing so, several questions, and potential challenges, are revealed. The research methodology follows, and the findings of the empirical analyses are presented. While much is left to be learned, the research provides important insights on the nature of interdependent activities.

Environmental Uncertainty

Over half a century ago scholars noted that organizations were not immune to the uncertainty of shifting environmental conditions. Thompson, Simon, and March all wrote extensively about the role of the environment on organizational performance. The general concern was the inability to accurately predict resource shifts. Others identified that it was not necessarily the rate of change, or the degree of the change, as much as it was the unpredictability of change that creates the greatest turmoil (Lawrence & Lorsch, 1973; Miles, Snow, & Pfeffer, 1974; Milliken, 1987).

Milliken’s (1987) work illustrates that there are at least three different types of uncertainty: state, response, and effect. He defines state uncertainty as “the situation that occurs when managers do not feel confident that they understand what the major events or trends in an environment are or feel unable to accurately assign probabilities to the likelihood that particular events or changes will occur.” Conversely, response uncertainty characterizes an inability to predict the likely consequences of a response choice. Effect uncertainty is characterized by an inability to predict the nature of the effect on the organization’s future state.

Most of the research suggests that organizations take deliberate, intentional, and rational steps to eliminate environmental flux and to regain equilibrium. In 1969, Herbert Simon identified that organizations rely on three different modes to regain stability: passive insulation, reactive negative feedback, and predictive adaptation. He claimed that organizational policies and the division of work constrained behavior to the degree that it could isolate the organization from environmental turbulence.

Thompson (1967) argued that organizations used “buffering” techniques such as rational planning, standard operating procedures, industry standards and contracts to minimize flux. All of these behaviors seek to absorb environmental uncertainty. Thompson’s (1967) research found that organizations attempt to buffer the technical core from outside disturbances, and, if it fails, they try to make adjustments to the technical core to regain equilibrium. Where buffering seeks to absorb environmental fluctuation, smoothing or leveling seeks to reduce fluctuations in the environment. Smoothing involves active intervention by the organization to stabilize the environment, and Cyert and March (1963) called attention to the importance of slack resources in protecting the organization from environmental flux.

Milliken (1987) argues that the most effective strategies for dealing with environmental turbulence depend on the type of uncertainty. Whether the uncertainty is rooted in state, effects, or response may mandate different approaches to buffering and the type of slack resources required to maintain stability in the face of turbulence.

For an organization that wishes to maintain stability, Miles and Snow (1978) recommended an organizational structure that focused on functional divisions, centralized control, long-looped vertical information systems, and conflict resolution via hierarchical channels. For organizations that wish to promote flexibility, they recommended low division of labor, decentralized control, short-looped horizontal information systems, and resolution through integrators.

More recently, scholars have called attention to the ill-toward effects of isolationary strategies. They claim that isolating the organization from the environment can lead to diminished capacities. With this realization came the knowledge that agencies that were capable of improving performance by leveraging external resources, while also protecting themselves from the turbulence of uncertainty, realized substantial performance gains.

Others found that organizations actually interacted with the environment in a manner to gain power, manipulate, and control the environment. In other words, they anticipated flux and reacted prior to its occurrence. In this way, they attempted to head off the uncertainty; thus, the finding that anticipatory organizations often create their own future state.

Despite all the research, the question that Ansoff posed in 1979 remains valid: “How do we configure the resources of the firm for effective response to unanticipated surprises?” He pointed out that the “strategy of structure” had largely been ignored. In many ways, his question, while not ignored, remains unanswered.

The Rise in Interdependent Activities or Complex Structures

Whereas organizations in the past sought to limit interdependencies to maintain control over the environment, more recently organizations have sought to leverage the benefits that interdependencies, or partnerships, can provide. Thus, discussions of the nature of structure and how to best organize in the face of increasing needs for holistic comprehensive solutions have taken center stage. The key question seems to be whether organizations can benefit from interdependence while minimizing the negative influences of environmental turbulence. The question thus becomes, “what structural arrangements and behavioral practices are conducive to achieving the benefits of coordinated actions?”

Where organizations in the past had the opportunity to buffer key processes from exposure to environmental stimuli, the desire for joint capabilities is an attempt to open up the organization to allow leveraging the capabilities of other organizations in the environment. Purportedly, partnerships provide the benefits of economies of scale. And the use of coordinated operations often results in productivity gains. Moreover, coordination allows for a wider and richer information source that is capable of providing insights on how to shape services.

The use of partnerships and coordination gave rise to complex networks of organizations that are intricately interdependent on outside sources to meet production and service delivery objectives. Scholars and practitioners alike quickly identified that the complexity associated with a given objective rested in the actual links that tied the organizations together. They also discovered that as individual organizations sought to change their procedures to circumvent environmental flux, they actually created instability for others.

Under stable conditions, organizations can establish mutually acceptable arrangements. But when environmental flux occurs, it typically causes organizations to adapt to the stimuli. Oftentimes these adaptations perturb external relationships that then demand some form of accommodation. As an example, program managers establish multi-year financial forecasts of how much money they will receive from Congress for their programs. When an unexpected shortfall occurs, the program must scale back. Not only does the scale-back influence the individual program, but it could influence all of the program’s partners, causing them to have to accommodate for their partner’s shortfall. In the acquisition arena where programs are interdependent, the inability to accurately predict future state, effect, and response needs can manifest in cost, schedule, and performance fluctuations.

Apparently, an organization’s capacity to address environmental uncertainty depends on the absorptive capacity of its members (Cohen & Levinthal, p. 131). By 1990, Cohen and Levinthal had refined some of their thinking and argued that an organization’s absorptive capacity is not resident in any single individual but depends on the link across a mosaic of individual capabilities that are often internalized via routines, histories and stories, documentation, procedures, and know-how (Grant, 1996). Long-term survival is contingent on adapting to uncertainty and environmental change by taking deliberate, intentional, and rational steps to regain equilibrium. Highly successful organizations are able to sustain creative, innovative, continually changing behavior. Stacey calls for the need to establish spontaneous changeability—downward and upward spirals where feedback loops act to amplify existing behaviors.

Comfort’s (1994) work also indicated that organizations were capable of rearranging and reforming configurations of operation in mutual adaptation to the changing needs and capacities of their environmental components. She found that they were also capable of mutually adapting to the changing demands and opportunities imposed by the environment. The distinguishing characteristic of this process is that it occurs as a result of communication, selection, and adaptation processes within the system itself and between the evolving system and its environment (Comfort, 1994; Kaufmann, 1993).

In considering interdependent organizations, Levinthal (1997) argued that each individual’s payoff function depends on choices that other external actors make, so each individual’s adaptive landscape—the mapping of behavior to realized outcomes—is constantly shifting. In this way, interdependencies form complex adaptive systems that evolve over time through the entry, exit, and transformation of other actors. Because the linkages evolve over time, the configuration and strength of the interconnections are in constant flux. Closely tied to the concept of bounded rationality (March & Simon, 1958), because the actors are unable to forecast the system level consequences of their individual choices, they optimize according to their own fitness, not that of the collective whole. Kauffman’s adaptive landscape metaphor (borrowed from Wright, 1931) suggests that organizations co-evolve on a fitness landscape to a state poised between order and chaos. The landscape on which actors adapt continually shifts, because the payoffs of individual agents depend on the choices that other actors make (Levinthal, 1997; McPherson & Ranger-Moore, 1991).

Complex adaptive systems, when defined by interdependent relationship structures, are often examined in terms of their ability to adapt to changes in the environment. The adaptation can take a variety of forms, from immobility on one extreme to chaos on the other. A static or immobile state reflects the inability of the relationship to adapt the necessary policies, procedures, or activities required to address environmental perturbations. Conversely, the chaotic state represents a hyper-turbulent response to environmental flux. An understanding of the adaptation configurations of these complex relationships carries important implications for management. Goals and objectives, as well as capital and opportunity costs, are inherently tied to potential activities of adaptation. Unfortunately, previous research has also illustrated that adaptive behaviors can cascade in unexpected ways and, thus, can have a tremendous impact on the achievement of critical goals and the final costs associated with any organizational activity. Despite Cohen and Levinthal's seminal article some twenty years ago on absorptive capacity, scholars argue that the "emergence of absorptive capacity from the actions and interactions of individual, organizational, and interorganizational antecedents remain unclear" (Volberda et al., 2010).

Theoretically, joint capabilities should provide significant defense advantages. From the battlefield perspective, joint capabilities should promote greater situational awareness and thus reduce the risk of fratricide (i.e., "friendly fire"). An improved understanding of the location of various Service resources should also allow battlefield commanders to tap a wider range of arsenal assets. From a support perspective, joint capabilities should allow support agencies to improve their understanding of where various resources are located and how to leverage them to assist battlefield operations. Furthermore, from a command perspective, joint capabilities should improve understanding of the available resources that can be leveraged and enable a greater understanding of how to mitigate enemy threats.

Yet, little is known about the risk that organizations encounter in these highly interdependent complex structures. This research seeks to examine the influence of interdependencies on program performance. In short, it seeks to address Ansoff's question.

The Research Methods

The sample for the research was all active major defense acquisition programs between the 2005–2010 time period. The data for the analysis was derived from Select Acquisition Reports and Defense Acquisition Executive Summary Reports.

Two major analyses were performed. First, the research tested to see whether interdependent activities influenced an MDAP's cost or schedule. Second, the data were organized to reflect the network structure of two different types of interdependencies. The programs were then tested to determine whether cascading effects were witnessed. In short, it is not uncommon for a program to have a number of different types of interdependencies and, thus, be involved in several different network structures simultaneously, hence, the need for this multi-dimensional approach.

For each MDAP, programmatic interdependency was measured by the following: the number of program elements, the number of external data sharing connections, and whether the program was designated as officially *joint*.

The number of program elements an MDAP shares is used as a proxy for funding interdependency. The number of external data sharing connections is a reflection of data interdependencies. And, whether a given program is considered *joint* is an indication of organizational interdependencies. These three types of interdependencies are examined below for their influence on programs as well as whether they act as triggers for cascading effects.

Several control variables were incorporated into the analysis: program manager turnover, development estimate, program stage, the previous year's growth rate, and the year of the observation. These variables were included in the models as they were seen as potentially influencing cost or schedule growth.

Four dependent variables were tested: annual percent per acquisition unit cost growth, annual percent engineering cost variance, annual percent estimation cost variance, and annual percent schedule cost variance. The results of the analyses are presented in the Findings section.

Findings

Individual Effects

The first analysis sought to determine the extent to which interdependent activities influenced a given MDAP's annual percent PAUC (program acquisition unit cost) growth or annual percent engineering, estimation, or schedule variance. The relationships were tested employing the multiple regression procedure. Per Table 1, for annual percent PAUC growth, the MDAP's previous year's growth rate demonstrated the greatest predictive power. Whether the program manager changed was also a significant predictor. None of the interdependency variables achieved statistical significance. For the *annual percent estimating cost variance*, the previous year's *estimating cost variance* was the only variable in the model that achieved statistical significance. None of the variables in the *annual percent engineering cost variance* or *annual percent schedule cost variance* were significant.

Table 1. Individual Effects

Dependent Variable: PAUC Pct Growth				
R square: .599	B	Beta	t	Sig.
(Constant)	-1.275		-.052	.959
Joint	-35.393	-.167	-1.178	.244
Stage	3.963	.022	.227	.821
Last Year's PAUC Pct Growth	.518	.722	7.066	.000
Pct Engineering Cost Variance	-.187	-.012	-.130	.897
Pct Estimation Cost Variance	.157	.068	.715	.478
Pct Schedule Cost Variance	.157	.003	.028	.977
Development Estimate	-.002	-.059	-.590	.557
Number of Data Connections	.375	.050	.538	.593
Number of Shared Program Elements	-4.658	-.116	-1.021	.312
PM Turnover	77.608	.360	2.188	.033
Year 2006	46.893	.222	2.074	.043
Year 2007	-9.468	-.048	-.455	.651
Year 2010	-42.776	-.142	-1.013	.316
Dependent Variable: Pct Estimation Cost Variance				
R square: .65	B	Beta	t	Sig.
(Constant)	4.428		.558	.579
Joint	-3.609	-.046	-.439	.662

Stage	-10.228	-.144	-1.916	.059
Last Year's Pct Estimation Cost Variance	-1.656	-.771	-9.911	.000
Pct Engineering Cost Variance	.706	.109	1.493	.140
PAUC Pct Growth	.007	.085	1.105	.273
Pct Schedule Cost Variance	-.264	-.010	-.135	.893
Development Estimate	.000	-.010	-.137	.892
Number of Data Connections	.048	.016	.220	.826
Number of Shared Program Elements	.858	.051	.632	.529
PM Turnover	4.415	.054	.423	.673
Year 2005	11.236	.122	1.416	.161
Year 2006	1.225	.014	.160	.873
Year 2007	-2.621	-.032	-.368	.714
Year 2010	-7.342	-.056	-.529	.598
Dependent Variable: Pct Engineering Cost Variance				
R square: .147	B	Beta	t	Sig.
(Constant)	1.150		.602	.549
Joint	.996	.083	.505	.615
Stage	-.152	-.014	-.115	.909
Last Year's Pct Engineering Cost Variance	.072	.141	1.237	.220
PAUC Pct Growth	.000	-.023	-.191	.849
Pct Estimation Cost Variance	.022	.145	1.229	.223
Pct Schedule Cost Variance	-.071	-.017	-.151	.880
Development Estimate	.000	-.004	-.033	.973
Number of Data Connections	.022	.048	.409	.684
Number of Shared Program Elements	-.154	-.060	-.469	.640
PM Turnover	-1.994	-.158	-.800	.426
Year 2005	-1.090	-.077	-.556	.580
Year 2006	.514	.038	.280	.780
Year 2007	-.814	-.065	-.475	.636
Year 2010	8.332	.411	2.619	.011
Dependent Variable: Pct Schedule Cost Variance				
R square: .078	B	Beta	t	Sig.
(Constant)	1.162		2.569	.012
Joint	.031	.011	.063	.950
Stage	-.286	-.110	-.886	.378
Last Year's Pct Schedule Cost Variance	.000	.001	.007	.994
PAUC Pct Growth	.000	.002	.019	.985
Pct Engineering Cost Variance	-.004	-.016	-.132	.895
Pct Estimation Cost Variance	.000	-.009	-.073	.942
Development Estimate	.000	-.021	-.173	.863
Number of Data Connections	-.005	-.043	-.351	.727

Number of Shared Program Elements	-.075	-.123	-.934	.353
PM Turnover	-.344	-.115	-.553	.582
Year 2005	-.590	-.175	-1.255	.213
Year 2006	-.397	-.123	-.880	.382
Year 2007	-.693	-.234	-1.663	.100
Year 2010	-.434	-.090	-.530	.598

Cascades

The second set of models sought to isolate the extent to which interdependent MDAP programs influence each other's growth rate. The first set of tests examines MDAPs that share a program element. The second set examines data interdependencies to determine whether upstream programs exhibit influences on downstream nearest neighbors.

Program Element Cascades

MDAP interdependency with other MDAPs due to a shared program element is on the rise. Per Figure 1, the growth rate over the past six years identifies substantial interdependence. As a consequence, the first examination of cascades sought to test whether MDAPs that share a program element influence each other's growth rate. Because MDAPs are nested within program elements (i.e., a given program element can support more than one MDAP), cross-classified multilevel modeling was employed. The multilevel modeling technique allowed the ability to test whether programs that experience PAUC growth or engineering or estimation cost variance "hang together." Meaning, to what extent did the programs that share a program element influence each other?

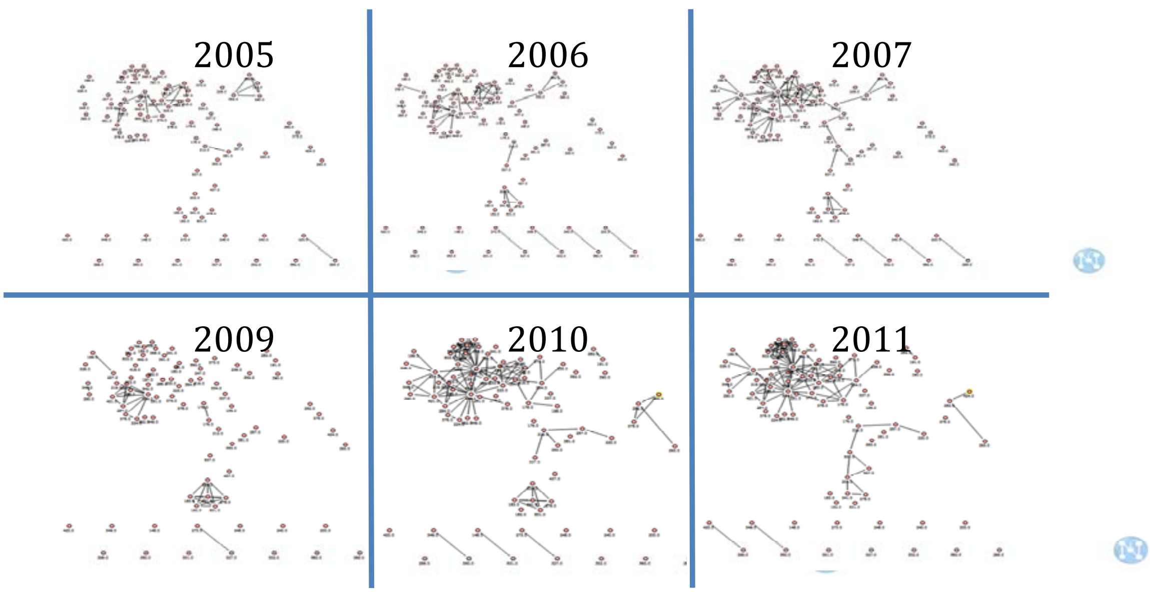

Figure 1. Program Element Interdependencies Over Time

Table 2 provides the results of the analysis. Both development estimate and year were employed as controls because of their potential influence on growth. When considering an individual MDAP's *pct PAUC growth*, member PAUC growth mattered. Alternatively, group member *pct PAUC growth* did not appear to influence *pct engineering cost variance*. But it did influence *pct estimation cost variance*. Thus, group members appear to move together on both PAUC growth and estimation cost variance. The dataset had too few cases to test percent schedule cost variance. The next section examines the influence of performance cascades in data interdependency networks.

Table 2. Program Element Interdependency

Dependent Variable: Pct PAUC Growth			
Parameter	Estimate	t	Sig.
Intercept	26437.752419	2.480	.014
Development Estimate	-.001777	-.671	.503
Year	-13.153862	-2.478	.014
Member Pct PAUC Growth	.319423	7.025	.000

Dependent Variable: Pct Engineering Cost Variance			
Parameter	Estimate	t	Sig.
Intercept	-1338.794270	-3.761	.000
Development Estimate	-.000112	-1.227	.221
Year	.667622	3.767	.000
Member Pct Engineering Cost Variance	-.041699	-.917	.361

Dependent Variable: Pct Estimating Cost Variance			
Parameter	Estimate	t	Sig.
Intercept	-1525.533399	-2.194	.029
Development Estimate	-.000247	-.685	.494
Year	.760167	2.196	.029
Member Pct Estimating Cost Variance	.142229	2.873	.004

Data Cascades

This set of tests sought to isolate the influence of data interdependencies (see Figure 2). The following results test whether upstream programs influence their downstream counterparts. The examination considered the influence of the upstream programs: percent annual PAUC growth, percent engineering cost variance, percent estimation cost variance, and percent schedule cost variance.

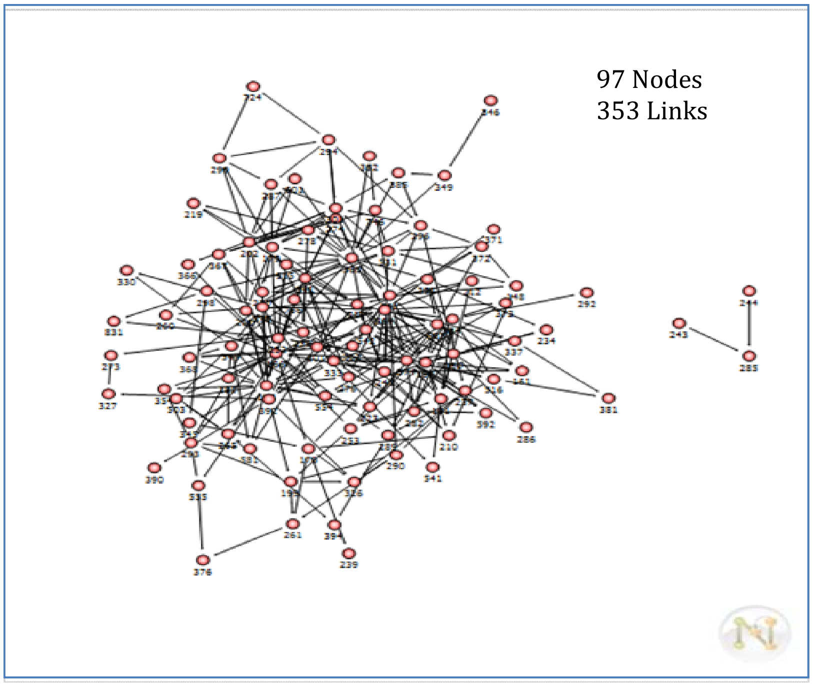

Figure 2. Data Interdependencies

These variables were examined in light of their potential downstream influences on a neighbor's: percent annual PAUC growth, percent engineering cost variance, percent estimation cost variance, and percent schedule cost variance.

To determine the effect of the cascade, several variables were included in the model as controls. Because the goal was to see how upstream programs influence their downstream counterparts, controlling for factors that might influence the downstream program's growth rate became imperative. Consequently, the following controls were added to the model: joint status, stage of development, previous year's PAUC growth, development estimate, number of data connections, number of program element connections, and program manager turnover.

The results of the multiple regression models are displayed in Table 3. In terms of the downstream program's PAUC growth rate, several of the control variables demonstrated statistical significance. In short, joint status, previous year's PAUC growth rate, and program manager turnover all proved important in predicting the downstream program's PAUC growth. In terms of the upstream program influences, upstream program PAUC growth also indicated a statistically significant and positive effect.

Table 3. Data Cascades

Dependent Variable: Downstream Program PAUC Growth				
R square: .74	B	Beta	t	Sig.
(Constant)	-31.535		-1.713	.088
Downstream Program Joint	-106.020	-.311	-5.023	.000
Downstream Program Stage	9.123	.028	.707	.480
Previous Year's Downstream Program PAUC Growth	.491	.672	14.026	.000

Upstream Program PAUC Growth	.031	.075	2.169	.031
Upstream Program Pct Eng Cost Variance	-2.274	-.027	-.779	.437
Upstream Program Pct Est Cost Variance	.120	.016	.456	.649
Upstream Program Pct Sch Cost Variance	-1.354	-.011	-.310	.757
Downstream Program's Development Estimate	-.003	-.041	-1.078	.282
Downstream Program's Number of Data Connections	.711	.049	1.219	.224
Downstream Program's Number of PE Connections	-4.659	-.068	-1.387	.167
Downstream Program's PM Turnover	206.336	.577	9.769	.000
Year 2006	127.056	.335	7.648	.000
Year 2007	5.124	.014	.320	.749
Year 2010	-147.710	-.282	-5.736	.000
Dependent Variable: Downstream Program Pct Est Cost Variance				
R square: .746	B	Beta	t	Sig.
(Constant)	-2.919		-.624	.533
Downstream Program Joint	-11.983	-.120	-2.578	.010
Downstream Program Stage	-16.108	-.163	-4.774	.000
Downstream Program’s Previous year’s Estimation Cost Variance	-1.736	-.778	-21.102	.000
Upstream Program PAUC Growth	.007	.057	1.923	.055
Upstream Program Pct Eng Cost Variance	-.297	-.024	-.691	.490
Upstream Program Pct Est Cost Variance	.294	.116	3.832	.000
Upstream Program Pct Sch Cost Variance	.204	.016	.447	.655
Downstream Program's Development Estimate	.000	-.003	-.107	.915
Downstream Program's Number of Data Connections	.249	.057	1.671	.096
Downstream Program's Number of PE Connections	1.408	.064	1.666	.097
Downstream Program's PM Turnover	17.681	.170	3.397	.001
Year 2005	13.977	.100	2.858	.005
Year 2006	18.829	.160	4.285	.000
Year 2007	.985	.009	.234	.815
Year 2010	-13.273	-.080	-1.845	.066
Dependent Variable: Downstream Program Pct Eng Cost Variance				
R square: 184	B	Beta	t	Sig.
(Constant)	.720		.737	.462
Downstream Program Joint	1.544	.132	1.590	.113
Downstream Program Stage	-.068	-.006	-.098	.922

Downstream Program's Previous year's Engineering Cost Variance	.112	.135	2.438	.015
Upstream Program PAUC Growth	.000	-.012	-.216	.829
Upstream Program Pct Eng Cost Variance	-.114	-.080	-1.282	.201
Upstream Program Pct Est Cost Variance	.010	.034	.632	.528
Upstream Program Pct Sch Cost Variance	.049	.033	.512	.609
Downstream Program's Development Estimate	.000	.019	.344	.731
Downstream Program's Number of Data Connections	.040	.079	1.298	.195
Downstream Program's Number of PE Connections	-.091	-.036	-.527	.599
Downstream Program's PM Turnover	-3.569	-.294	-3.319	.001
Year 2005	-3.410	-.210	-3.275	.001
Year 2006	1.175	.085	1.312	.190
Year 2007	-1.114	-.085	-1.273	.204
Year 2010	7.151	.368	4.988	.000

Dependent Variable: Downstream Program Pct Sch Cost Variance				
R square: .092	B	Beta	t	Sig.
(Constant)	1.233		5.328	.000
Downstream Program Joint	.121	.046	.527	.598
Downstream Program Stage	-.398	-.154	-2.413	.016
Downstream Program's Previous year's Schedule Cost Variance	-.001	-.008	-.112	.911
Upstream Program PAUC Growth	.000	-.006	-.113	.910
Upstream Program Pct Eng Cost Variance	.021	.065	.985	.326
Upstream Program Pct Est Cost Variance	-.001	-.012	-.208	.835
Upstream Program Pct Sch Cost Variance	-.017	-.050	-.741	.459
Downstream Program's Development Estimate	.000	-.024	-.409	.683
Downstream Program's Number of Data Connections	-.001	-.010	-.156	.876
Downstream Program's Number of PE Connections	-.097	-.169	-2.373	.018
Downstream Program's PM Turnover	-.378	-.139	-1.465	.144
Year 2005	-.522	-.143	-1.927	.055
Year 2006	-.549	-.178	-2.597	.010
Year 2007	-.693	-.237	-3.344	.001
Year 2010	-.155	-.036	-.455	.649

In terms of the downstream program's estimation cost variance, again several of the controls demonstrated statistical significance. Joint status, stage of development, previous year's percent estimating cost variance, and program manager turnover were significant predictors of estimation cost variance. Additionally, two upstream program influences were noted. Both the upstream program's PAUC growth, and the upstream program's estimation cost variance were positively related to the downstream estimation cost variance.

Upstream program effects did not prove pivotal to predicting the downstream program's cost variance or their schedule cost variance. The previous year's engineering cost variance and program manager turnover were the only two variables that achieved statistical significance in the engineering cost variance model. The downstream program's stage of development and the number of program elements both illustrated significant relationships with percent schedule cost variance.

Conclusion

This research examined the influence of a number of interdependencies on program performance. The analysis looked at all active MDAPs during the 2005–2010 time frame. It found that interdependencies, when defined by *joint status*, *number of program elements*, or *number of data connections* do not appear to exhibit any ill-toward effects.

The examination of whether MDAPs that share a program element influence each other was supported for both PAUC growth and estimation cost variance. Moreover, for the data networks, interdependency, when measured as a cascade, does appear to influence downstream partners. For this sample, the upstream program's PAUC growth appeared to influence both downstream PAUC growth and downstream estimation cost variance. The upstream program's estimation cost variance also demonstrated a positive effect on the downstream program's estimation cost variance. Interestingly, for *joint status*, both the PAUC cost growth and the estimation cost variance realized a negative effect. In other words, controlling for the other factors, joint programs experienced less PAUC cost growth and estimation cost variance than their non-joint colleagues. Apparently, it is not whether one has a joint status that creates difficulties as much as "who" a program is downstream from.

The findings of this research call attention to the role of environmental uncertainty in interdependent activities. The findings illustrate that the performance of interdependent organizations are susceptible to the performance shortfalls of their partners. While the results demonstrated statistical significance, closer examination of the data revealed that some programs appear to be more susceptible to their upstream partners than others. The examination of why some programs may be more susceptible to their partners was beyond the scope of this research. Given these results, why a given program may be more or less immune is, thus, a topic worthy of analysis.

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