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Analyzing Cost Estimating and Analysis Organizations within the United States Government

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Analyzing Cost Estimating and Analysis Organizations within the United States Government

Abstract

An emerging research area in cost estimating and analysis organizations has gained attention as the general body of knowledge on cost estimating, analysis, and management has matured via a myriad of research efforts. Yet, multiple research studies have shown an equivocal overlapping area commonly shared by the disciplines of systems engineering and project management. The overlapping area may encompass subjects and fields of cost estimating, analysis and management not well studied by scholars and researchers.

The goal of the research study is to comprehend and characterize the organizational structure, resources composition, and functional capabilities of seven major cost estimating and analysis organizations existing in the United States (US) government body through a series of scientific research methods. The study is also aimed to observe, discern, analyze and document commonly established organizational structures, departmental roles and responsibilities, and fundamental functions of these selected cost estimating and analysis organizations. This manuscript reviews the wealth of literature on definitions of cost infrastructure, estimating, analysis, analytics, and management through various refereed journals, professional societies and government publications, as well as the general mission statements, structures, and functional areas of cost and analytics communities. Through an application design of case study, the research further validates and verifies a set of preliminary findings by applying and examining the intersections of organizational mission, structure, maturity, functions, technical capabilities, roles and responsibilities of a cost estimating and analysis organization in another US government department focusing on a different mission and purpose.

Furthermore, the research study contains a series of interviews with subject matter experts (SME), experienced practitioners in the field of systems engineering cost estimating and analysis, as well as senior leadership of cost estimating and analysis organizations to support its data collection, validation and verification effort and findings. The analysis and results contained herein may be useful to various government agencies and programs, private contractors, and national laboratories.

Introduction

Senator of Virginia, Mark Warner, once said in an interview with Senator of Maine, Angus King (2013), that the largest enterprise in the world is the federal government of the United States of America, which based on its governing size of budgeting and spending makes the nation the front leader of the world (Madsen, 2014). In recent years, topics related to systems acquisition cost, budget and affordability have been a critical emphasis across different government agencies, and the Government Accountability Office (GAO) has identified various areas and programs that require management attention and further improvement (GAO, 2014, 2015, 2016, 2017). In general, several areas that shall be improved include cost estimation, analysis, infrastructure, and management, which may well contain governance, policy, procedure, etc. Professionally, practitioners who work in these particular areas have shown a strong interest of continuing improvement, for example, the National Nuclear Security Agency (NNSA) hosted a first annual Cost Estimating Community of Practice (CECOP) symposium in March, 2017 (NNSA, 2017).

In the realm of research and development, many scholars and researchers have conducted various studies on different types of topics, systems and industries related to cost estimation and analysis. Their research efforts and results have been published through different publications. Examples include cost risk analysis (Smart, 2015), systems engineering cost modeling (Valerdi, 2005), expert judgement and historical data (Valerdi, 2016), railway infrastructure system life cost analysis (Rama and Andrews, 2016), and cost estimation challenges and uncertainties within oil and gas industry (Hall and Delille, 2012).

As the general body of knowledge on cost estimating, analysis, infrastructure, and management has matured via a myriad of research efforts, an emerging research area in developing organizational cost estimating and analysis capabilities has gained attention (DeReus, 2017; Patel et al., 2017; Samuels and Brown, 2017; Geier et al, 2012). Establishing cost estimating and analysis capabilities for an organization is a complex subject matter as its cross-functions are attributed and contributed by several departments and personnel within an enterprise network, and strategizing and sustaining these capabilities require a large sum of organizational investments including time and resources, but leadership vision, skills and commitment are critical success factors (Fitch, 2017).

Furthermore, multiple recent research studies have focused on an equivocal overlapping area commonly shared by the disciplines of systems engineering, project management, business and financial management (Kossiakoff et al., 2011; Seymour and Luman, 2011). Yet, the overlapping area may encompass subjects and fields of cost estimating, analysis and management, but it has not been well studied by scholars and researchers. Hence, this research manuscript helps organizations comprehend and identify the fundamental characteristics of a cost estimating and analysis entity as such a need of institutional establishment arises, as well as contributes to the general body of knowledge on cost estimating, analysis, infrastructure and management.

Background

The research study has reviewed the wealth of literature on definitions of cost infrastructure, estimating, analysis, analytics, and management through various refereed journals, professional societies and government publications, as well as the general mission statements, structures, and functional areas of cost estimation and analysis from different organizations and agencies. The research study has found that there is a limited amount of literature regarding cost estimating and analysis organizations as it is an emerging and novel area of research. This research effort may be the first to collect and analyze data pertaining to various cost estimating and analysis organizations within the US government.

Further, among these available literature, very few publication studies were conducted by federally funded research and development centers (FFRDC). Hence, our primary scope of literature review within this manuscript is only pertinent to publications and studies conducted by researchers and scholars at FFRDC, government funded agencies, facilities and laboratories, including University-Affiliated Research Centers (UARC).

In the area of cost and schedule growth for systems engineering (SE) and project management (PM), the researchers at the Johns Hopkins University Applied Physics Laboratory (APL) built cost models to identify trends in PM and SE effort based on several sets of space mission program

data (Shinn, Wolfarth, and Whitley, 2011; Shinn, Wolfarth, and Hahn, 2010). Although a cost estimating and analysis organization was not directly involved in the scope of the research, Shinn et al. stated the impact of these two influential, technical and non-technical managements in the manuscripts. Other practitioners and researchers at the APL also shared their lessons learned from different organizational establishment designs and infrastructural impact on mission center and integration and test facility (Liggett et al., 2011 and 2014).

In cost management, Liggett et al. (2012) documented a history of implementing cost management, organizational and cultural resistance, and deployment challenges at APL. The authors also provided a list of essential elements that supported their program success. Similar to the conclusion of a study conducted in 2012, the researchers at APL re-emphasized the importance of organizational communication and leadership support as part of their findings in their latest publication (Liggett et al., 2017).

In a subfield of cost management, the National Aeronautics and Space Administration (NASA) documented their organizational initiatives on new cost policies and programmatic challenges faced within their cost community during the implementation and deployment phases of an organizational requirements streamlining effort (Hardash and McGurk, 2008). Furthermore, in a project landscape of multiple national institutions and nations, Oak Ridge National Laboratory (ORNL) documented an experience from a large and complex international project management implementation effort (Strawbridge, 2005). ORNL's lessons learned from the international collaboration effort were similar to NASA's experience by Hardash and McGurk.

Specifically, in cost estimating and analysis organizations, Patel et al. (2017) discussed the evolution of the cost estimating processes from 2012 to 2016 in the Missile Defense Agency (MDA) and their lessons learned from establishing and implementing cost estimating standards across the agency over an extended period of time. Patel et al. concluded that MDA's cost estimating capabilities have become more mature enabling the agency to generate more accurate program estimates, affirm best cost estimating and analysis practices, improve credibility and empower contract negotiation. The Cost Estimating, Modeling & Analysis Office (CEMA) of Goddard Space Flight Center of NASA documented the institutional practices of cost estimation and analysis, programmatic challenges, and current technical limitations, as well as their perspective and lessons learned since its organizational establishment in 2012 (Samuels and Brown, 2017). Additionally, the Department of Homeland Security (DHS) has published its progress and current results of establishing a cost analysis division (CAD). DHS describes CAD as a long-term joint effort assisted by a commercial contractor (Geier et al, 2012), and an overall transformation of a cost estimating and analysis organization that took 7 to 8 years to reach its current state (DeReus, 2017).

Evidently, these literature and manuscripts demonstrate that establishing a cost estimating and analysis organization is a complex effort, which requires a vast amount of management support, time, and resources to develop.

Research Framework and Methodology

The goal of the research study is to comprehend and characterize the organizational structure, resources composition, and functional capabilities of seven major cost estimating and analysis organizations existing in the United States (US) government through a series of scientific research methods. The study is aimed to observe, discern, analyze and document commonly established organizational characteristics, structures, departmental roles and responsibilities, and fundamental functions of these selected cost estimating and analysis organizations.

The research study has incorporated the fundamental research approach and methods to serve as the foundation of the research which is shown in Exhibit 1. As part of the research steps, literature regarding cost infrastructure, estimating, analysis, analytics, and management published through various refereed cost estimating and analysis journals, professional societies and government publications were reviewed.

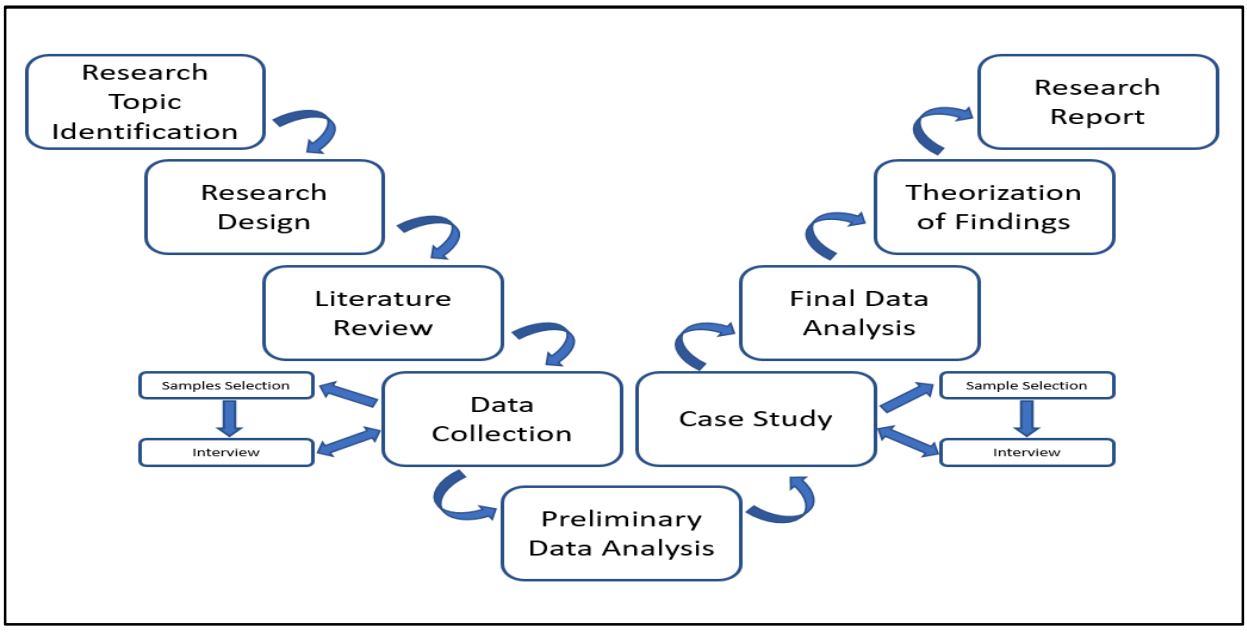

Exhibit 1. Research Framework

The research study selected the major US government cost estimating and analysis organizations that are known in several professional associations and societies. The study collected and analyzed the general mission statements, organizational structures, team composition, and functional areas of cost estimating, analysis, analytics, policy, standards and procedures within these organizations and communities.

The research study performed a series of interviews via telephone and in-person with subject matter experts (SME) and experienced practitioners in the field of systems engineering cost estimating and analysis, as well as senior leadership of cost estimating and analysis organizations to support its data collection, validation and verification effort and findings.

Through an application design of case study, the research further validates and verifies a set of preliminary findings by applying and examining the intersections of organizational mission, structure, maturity, functions, technical capabilities, roles and responsibilities of a cost estimating

and analysis organization in another US government department focusing on a different mission and purpose. A case study is an intensive description and analysis of a single individual, group, or organization, which offers several research benefits summarized below (Stake, 1995; Yin, 2013):

- Supports answering research questions regarding the how and why
- Serves as a source of ideas, behaviors, and contemporary phenomena in real-life context
- Serves as a method to challenge theoretical assumptions
- Serves as an alternative or complement to the focus group

Research Results

Upon selection of the major US government cost estimating and analysis organizations, the research study collected information regarding these organizations via the internet, email requests and organizational publications. Furthermore, the research study received various organizational and programmatic artifacts, such as internal and external briefing presentations, handbooks, informational program brochures, etc. The study team used these artifacts along with public information to analyze general mission statements, organizational structures, team composition, and functional areas of cost estimating, analysis, analytics, policy, standards and procedures within these organizations and communities. Exhibit 2 depicts a generalized cost estimating and analysis organization within an enterprise structure based on the sampled organizations.

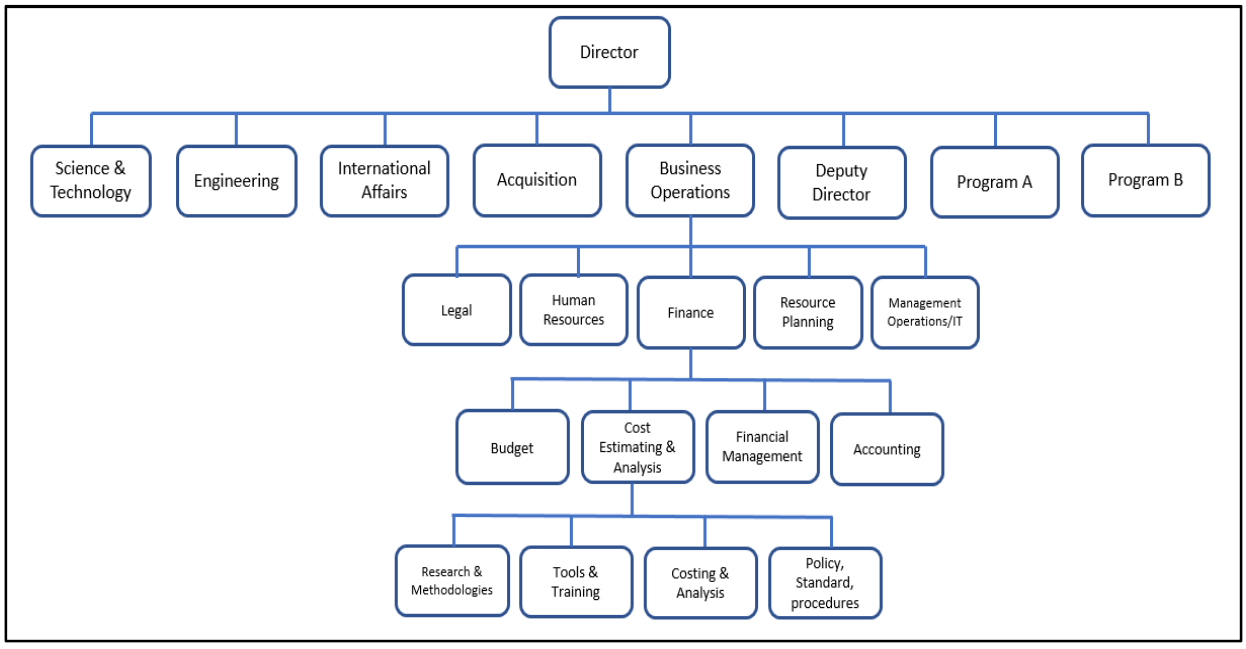

Exhibit 2. Depiction of a Generalized Cost Estimating and Analysis Organization Structure

After reviewing and analyzing the preliminary data, the research study performed a series of interviews via telephone and in-person with subject matter experts (SMEs) and experienced practitioners in the field of systems engineering cost estimating and analysis, as well as senior leaders of these cost estimating and analysis organizations. The research team focused on 5 major topic questions with subtopic questions for the interview process:

1. How was the cost estimating and analysis organization established in their organization?
    - What was the mission of your cost estimating and analysis organization?
    - Why was there a need for the initiative?

- How did your organization plan and execute the initiative?

2. Which direct reporting division does the cost estimating and analysis organization reside in an enterprise?
   - Why under a certain direct reporting division?
     - Why not reside under a different division?
   - What is the organization structure of your cost estimating and analysis organization?
     - What is the staff supporting structure? Functional support, matrixed support, or both?
   - What are the core capabilities of your cost estimating and analysis organization?
     - If appropriate, what is the general percent ratio workload between technical cost estimating and analysis and non-technical, such as policy, guidelines, procedures, and documentation?
3. What is the general background of the staff members of your cost estimating and analysis organization?
   - Why these specific background and skills?
4. If an organization would require to establish a cost estimating and analysis organization, based on your experience, where would you recommend this cost estimating and analysis organization to reside in an enterprise design?
   - What organizational architecture, core functions and capabilities, team composition and hiring, would you recommend?
5. Additional comments and suggestions for other organizations that may pursue establishing a cost estimating and analysis organization?

The interviews with senior leadership of these cost estimating and analysis organizations provided further insight on establishing a costing organization. The leaders of government defense and homeland security cost organizations stated that the executive leaders of their respective organizations were military trained. Additionally, with external political pressure for cost improvement, the top-down executive order supported execution of the initiative of establishing a cost estimating and analysis organization.

All selected samples of cost organizations have a direct organizational reporting structure under finance, which is typical for a cost estimating and analysis organization. Yet, based on an on-going research effort, it has been a traditional dilemma that organizations often have a difficult time to determine an ideal organizational design of a cost estimating and analysis office (Young and Josserand, working-paper). Based on a survey result, most cost estimating and analysis professionals and practitioners have identified other business areas other than finance as suitable enterprise-wide locations for a cost estimating and analysis organization, such as an engineering operations division (Young and Josserand, working-paper). However, these selected samples of organizations chose to design a cost estimating and analysis organization under a financial division due to military influence of design and organizational mission to inform and support financial decision makers.

It was a wide consensus by various senior leaders that their cost organization mission is to inform and support financial decision makers of their respective organizations, but cost estimating

and analysis is integrated and multi-disciplinary, including engineering, technology, economics, statistics, mathematics, logistics, science, business and accounting, etc.

The senior leaders have identified that executive commitment and leadership support is an important factor to the success of implementing a cost estimating and analysis organization. It is nearly inevitable to encounter organizational and cultural resistance while establishing a cost estimating and analysis organization, and these internal challenges would require understanding, commitment, and support from its organizational leaders throughout the establishment effort. This finding of executive commitment and leadership support corresponds with the findings and lessons learned published by Liggett et al. (2012, 2017) at the Johns Hopkins University Applied Physics Laboratory (APL).

The senior leaders also identified the most critical key for a cost estimating and analysis organization is the autonomy of independence. The maintenance of independence is crucial, as it enables the reduction of bias amongst cost estimators and analysts. The organizations decision to structure themselves towards the goal of independence enables the creation of objective cost estimates and analyses to inform financial decision-makers.

The senior leaders also agreed that cost estimation and analysis is unique in nature. Cost estimation and analysis is functionally different than finance, accounting, budgeting, and project management, it requires specific skills, education background, interdisciplinary knowledge, and in-depth technical experience to perform cost estimating and analysis tasks.

Cost Estimating & Analysis Organization	Mission Area	Focused Discipline	Direct Divisional Management Structure	Mission Statement, Goal, Objectives, Roles & Responsibilities	Division of Cost Estimating & Analysis Function	Team Support Structure	Team Background	Team Size	Non-Technical Function of Cost Estimating and Analysis Organization	Proportion of Technical Work vs Non-Technical Work
A	Defense	Engineering & Technology	Finance	Very Identical	System-Centric	Functionally Support	STEM	Large	Yes	Very Technical
B	Defense	Engineering & Technology	Finance	Very Identical	System-Centric	Matrixed Support	STEM	Large	Yes	75% Technical Work
C	Defense	Engineering & Technology	Finance	Very Identical	Program-Centric	Functionally Support	STEM	Large	Yes	50% Technical Work
D	Defense	Engineering & Technology	Finance	Identical	Program-Centric	Matrixed Support	STEM	Large	Yes	80% Technical Work
E	Security	IT & Engineering & Technology Integration	Finance	Similar	Agency-Centric	Mixed Support	STEM	Large (30)	Yes	70% Technical Work
F	Space	Engineering & Technology	Finance	Identical	Program-Centric	Matrixed Support	STEM	Medium (11)	Yes	75% Technical Work

Exhibit 3. Samples of Cost Estimating and Analysis Organizations

The selected samples illustrated in Exhibit 3 were similar in nature. This similarity allowed the research team to make general observations and comparisons; however, the research recognized and acknowledged that this similarity may also create elements of bias due to homogeneity of data.

Exhibit 4 illustrates a simplified set of resultant attributes and characteristics based on the selected samples of cost estimating and analysis organizations. Exhibit 4 serves as a reference for the selected case study in the following section. The research study has acknowledged and recognized a research shortfall of excluding a consideration of organization and process maturity, program budget, size, program and systems complexities, quantity of programs, etc. as part of the

organizational attributes and characteristics. The intent of this introductory research effort followed an approach of incorporating organic methods and simplistic analyses. Hence, these systemic and programmatic characteristics were not included within the scope of the research due to complexity, time and resource constraints. However, these elements are being explored and analyzed as part of a follow up research effort (Young and Josserand, working-paper).

Focused Discipline	Direct Divisional Management Structure	Mission Statement, Goal, Objectives, Roles & Responsibilities	Division of Cost Estimating & Analysis Function	Team Support Structure	Team Background	Team Size	Non-Technical Function of Cost Estimating and Analysis Organization	Proportion of Technical Work vs Non-Technical Work
Engineering & Technology	Finance	Inform Financial Decision Making, Improve Credibility, Fidelity, Capability, etc.	Program or System Centric	Likely Matrixed Support	STEM	At Least Medium; Size of 10	Yes	Ave 71% of Technical Work

Exhibit 4. Preliminary Findings - Generalized Attributes and Characteristics of a Cost Estimating and Analysis Organization

Case Study

The research study team selected a cost estimating and analysis organization serving in a different mission area as an experimental group, which is not within the disciplines of defense, homeland security or space. The logic of this case study selection is to perform an experiment of the applicability and reliability of the preliminary findings of generalized attributes and characteristics of a cost estimating and analysis organization derived from a control group, i.e. the samples of cost estimating and analysis organizations. The experiment assumption is that if the identified characteristics are applicable to the experimental group, i.e. the case study subject, it may be applicable to other non-defense, homeland security, and space organizations as well (Kothari, 2004). This experimental design is graphically illustrated in Exhibit 5.

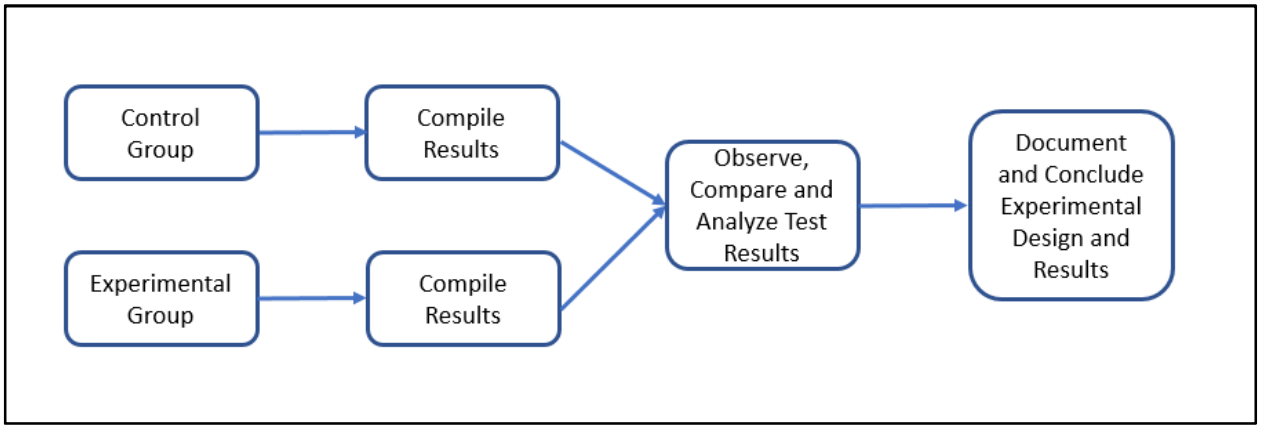

Exhibit 5: Experimental Design

Structurally, the cost estimating and analysis organization of the case study does not have a direct reporting role within a pure finance-driven architecture and does not report directly to a Chief Financial Officer (CFO), which is different than the control group. Instead, as shown in

Exhibit 6, the cost estimating and analysis office is a peer to other business divisions on the same level reporting to a director of business operations. Based on an interview with the senior leaders of the cost estimating and analysis organization, this organizational structure permits a more efficient chain of command with less bureaucracy, and promotes information flow with faster team responsiveness. This organizational structure and reporting chain allowed their cost organization to function and perform independently and objectively. The finding of organizational independence resonates with the preliminary finding, which is critical to the mission and purpose of a cost estimating and analysis organization.

Functionally, the cost estimating and analysis organization of the case study subject is comparable to the attributes and characteristics of the control group. The organization divides focus areas and practices of cost estimating and analysis into 2 departments. One department focuses on non-technical aspects of cost estimating and analysis including policy, standards, guidelines, procedures, and training. The other department focuses on technical aspects of generating cost estimates and performs cost analysis work for various construction, civil engineering and environmental engineering related programs. The general ratio of scope between technical and non-technical cost estimating and analysis is approximately 70% and 30% respectively, which is comparative to the control group.

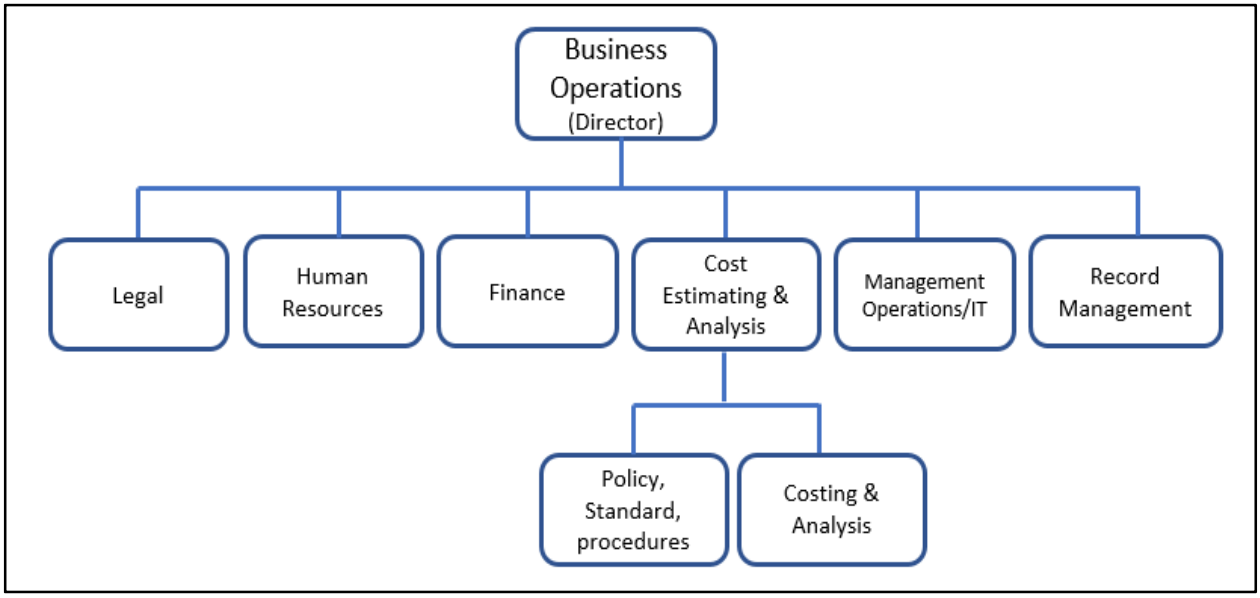

Exhibit 6: General Depiction of a Study Subject's Cost Estimating and Analysis Organization

The cost estimating and analysis team structure also corresponds to the control group where staff members are matrixed to programs to provide support. The team members' educational and professional backgrounds in general science, technology, engineering and mathematics (STEM) also resemble the characteristics of the control group. However, senior leaders expressed that due to the focused discipline and high volume of construction projects, the cost estimating and analysis organizations require a stronger expertise in specialized fields including construction management, civil engineering, and environmental engineering with high relevance to project management experience.

Overall, as illustrated in Exhibit 7, the attributes and characteristics of the experimental group display a corresponding behavior to the control group samples. This indicates that the preliminary findings of organizational attributes and characteristics may inform and be applicable towards efforts of establishing cost estimating and analysis capabilities within an organization. However, further research into the applicability and reliability of this research is warranted.

Mission Area	Focused Discipline	Direct Divisional Management Structure	Mission Statement, Goal, Objectives, Roles & Responsibilities	Division of Cost Estimating & Analysis Function	Team Support Structure	Team Background	Team Size	Non-Technical Function of Cost Estimating and Analysis Organization	Proportion of Technical Work vs Non-Technical Work
Energy	Construction Management, Civil Engineering, Environmental Engineering	Business Operations	Identical	Acquisition Programs and Contracts	Matrixed Support	STEM (Math, Civil, Environmental Engineering, Construction)	12	Yes	70% Technical Work

Exhibit 7. Attributes and Characteristics of a Study Subject's Cost Estimating and Analysis Organization

Conclusion

Establishing a cost estimating and analysis organization under a business oriented hierarchy may be an approach to initiate such effort. This approach may cultivate a culture of utilizing cost estimating and analysis best practices and improve organizational maturity.

Organizational mission and focus on disciplines play a pivotal role that must be considered before designing an architecture for a cost estimating and analysis organization. For example, research and development or engineering driven organizations may need to consider establishing a cost estimating and analysis organization under an engineering division, such as a systems engineering division, and an example is illustrated in Exhibit 8. However, an independent cost estimating and analysis organization with direct reporting responsibility to decision-makers and executive leadership is an ideal and optimal solution of organizational design, and Exhibit 9 illustrates an example of an independent cost estimating and analysis division.

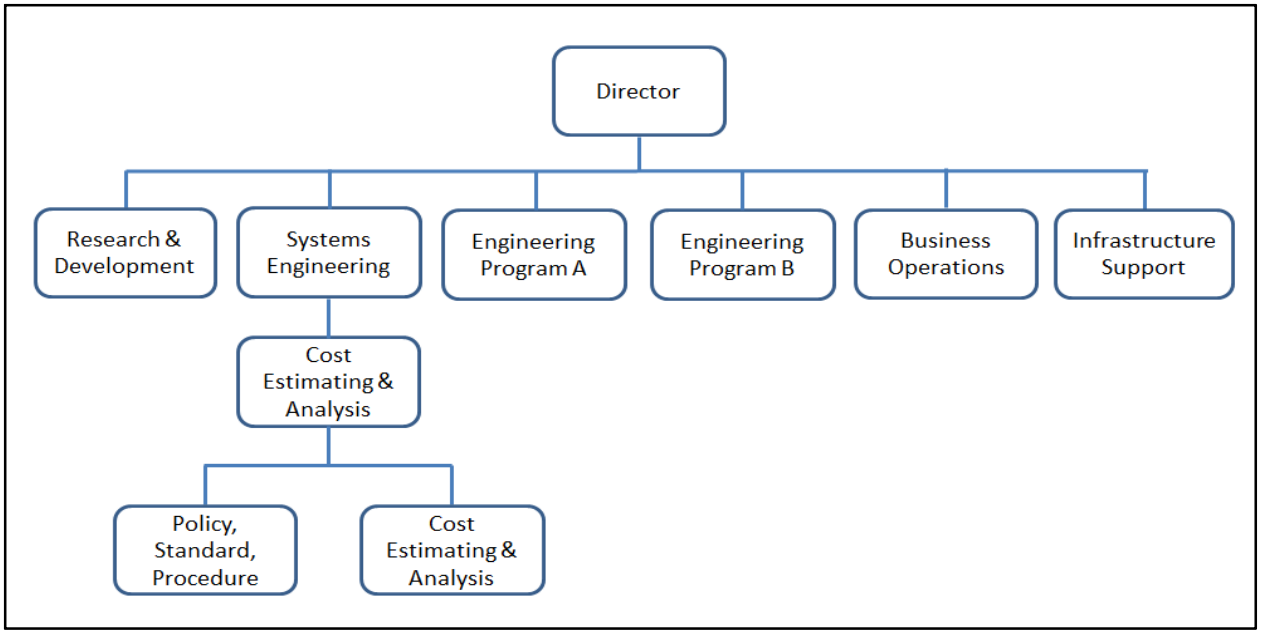

Exhibit 8. Depiction of a Cost Estimating and Analysis Organization for an Engineering Operations Organization

Although organizational design is important, it is not the most critical factor to the success of a cost estimating and analysis organization. It is extremely important to obtain executive commitment and leadership support throughout the organization establishment effort, particularly from the early phase. The research has determined that organizational independence is the most critical factor to the success of a cost estimating and analysis organization. Independence is fundamental, enabling cost estimators and analysts to minimize bias. Without contamination of politics, these objectively and impartially generated cost estimates and analyses inform financial decision-makers and executive leaders with fidelity.

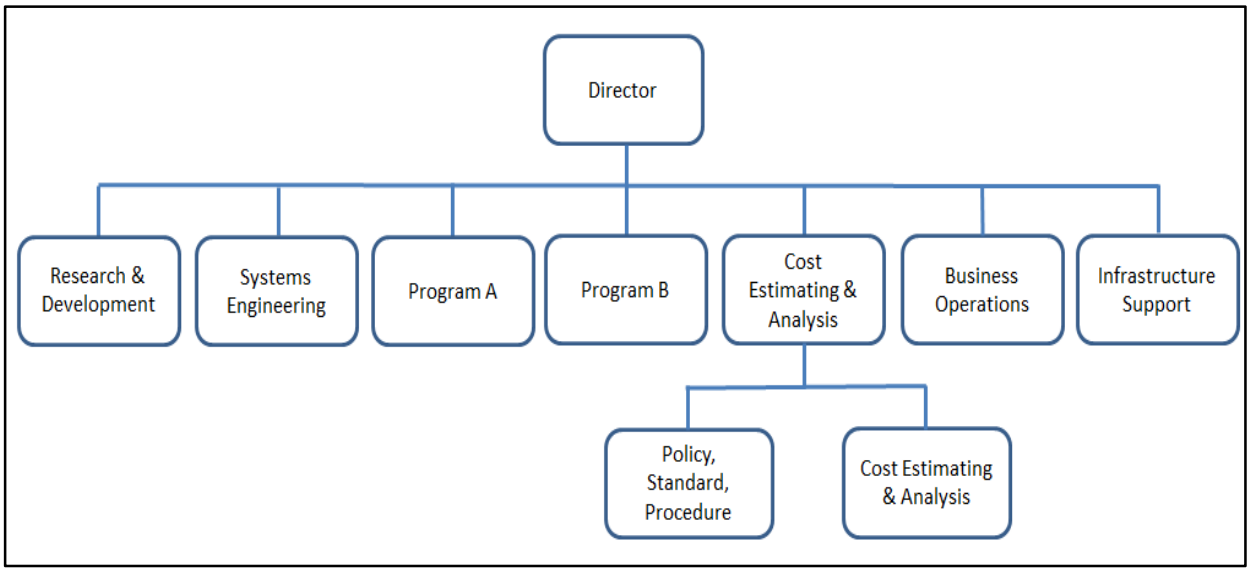

Exhibit 9. Depiction of an Independent Cost Estimating and Analysis Division

Cost estimation and analysis is a unique capability. A cost estimating and analysis organization is multi-disciplinary and highly integrated requiring staff from various divisions and departments within an enterprise network. Cost estimation and analysis is functionally different than finance, accounting, budgeting, and project management, it requires specific skills, education background, interdisciplinary knowledge, and in-depth technical experience to perform cost estimating and analysis tasks.

Developing organizational cost capabilities has challenges. As illustrated in Exhibit 10, an organization requires 3 foundational pillars to support, mature, and sustain its cost capabilities and infrastructure over time (Fitch, 2017; Leung, 2017):

- Sound cost policies and proven repeatable cost estimating and analysis processes
- Qualified professionals and experienced practitioners
- Tangible and repeatable tools and assets (e.g., databases, models, cost estimating relationships (CER) repositories, templates)

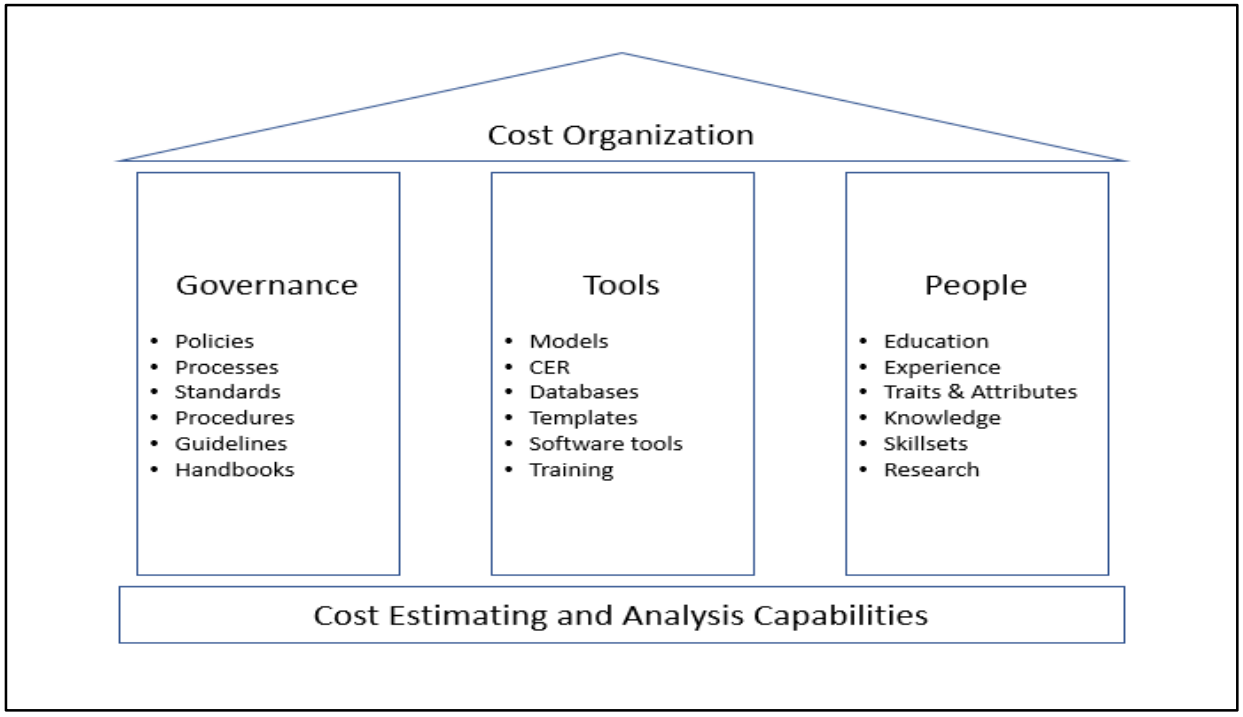

Exhibit 10. Cost Estimating and Analysis Capabilities within a Cost Organization

There are many required criteria to build a cost estimating and analysis capability for an organization and the success requires sustained investment in capabilities and human resources. Importantly, successive leadership must have a strategy, sustained commitment, as well as foster an organizational culture of cost and best practices (Fitch, 2017). It may be arguable that having a systematic cost estimating and analysis infrastructure and process does not promise better production and quality of cost estimates and analyses. However, without continuing improvement, desire to progress and compete with others, an organization would only have the status que and should expect deterioration.

Research Limitations

There are several limitations to this research, which the largest limitation may be imposed by the selected samples.

The first limitation is the availability of literature within this subject matter, which is extremely rare, especially published by FFRDC, UARC, or government funded agencies, facilities and laboratories. The second limitation is the size of sample set. There were only 6 samples available, and these sampled organizations were homogeneous. The case study subject was also very limited as only 1 organization was studied. The limited sample size and case study subject could offer several disadvantages. There could be possible biases in data collection due to a small set of homogeneous samples, which may also cause data interpretation and analyses to be further biased. It is often difficult to generalize and interpret finding from a single case study, which more case studies may be required to support preliminary findings and observations (Kothari, 2004).

Another limitation of this research was the interview process. Since it was an initial interview process, the results are appropriate to the description of this research, but any continuing research will require a more detailed and thorough interview process.

Evidently, due to the data homogeneity in nature, which was majorly collected from defense focused departments under a direct finance-driven reporting organization, this could lead research to be biased as researchers cannot compare the results with other cost estimating and analysis organizations under different types of direct reporting divisions such as engineering or research and development.

Lastly, the samples were collected from government agencies and organizations, which the results may not pertain to commercial and private sectors due to dissimilar goals, objectives, and missions, as well as differences between organizational cultures.

Future Research

There are several subsets for continuing research including:

- Compare current findings with other cost estimating and analysis organizations under a non-finance division
  - Further comparative advantages and disadvantages between financial and engineering organizational designs
- Collect data on length of organizational establishment, organizational maturity assessment, organizational accomplishments and milestones, lessons learned, number of employees, number of programs and project, and budget size. Compare and analyze correlation between these factors and their impact on efficiency and effectiveness.
- Study divisional expertise. Evaluate efficiency and effectiveness on governance (policy, guidelines, process, and procedures), tools and training, methodologies development, research, etc.
- Collect more specific data on staff background (years of experience, level of education, specific skillsets)
- Study and analyze the morale of technical staff members who work under a non-technical structure and team and their career development paths

- Study and analyze organizational evolution and how the transformation is correlated with cost estimating and analysis capabilities and maturity

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