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Factors Influencing the Selection of the Systems Integration Organizational Model Type for Planning & Implementing Government High-Technology Programs

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Abstract

While there has been extensive research in defining project organizational structures for traditional projects, little research exists to support high-technology government project's organizational structure definition. High-Technology Government projects differ from traditional projects in that they are non-profit, span across Government-Industry organizations, typically require significant integration effort, and are strongly susceptible to a volatile external environment. Systems Integration implementation has been identified as a major contributor to both project success and failure.

The literature research bridges program management organizational planning, systems integration, organizational theory, and independent project reports, in order to assess Systems Integration (SI) organizational structure selection for improving the high-technology government project's probability of success.

This paper will describe the methodology used to 1) Identify and assess SI organizational structures and their success rate, and 2) Identify key factors to be used in the selection of these SI organizational structures during the acquisition strategy process.

Key Words: Systems Integration, Organizational Structures, Government Project Management, Government Acquisition Strategy

Introduction

Eisner (2002) observed that although systems integration is widely discussed, it has not been very well defined and offered the following definition (2002, 357): "The process of bringing together a variety of (possibly separate) functional elements, subsystems, and components into a larger (meta)system, or system of systems, to provide a highly interoperable and cost-effective solution that satisfies a customer's needs and requirements, while at the same time managing the overall process and delivery of products in a highly effective and efficient manner." He further noted that systems integration appeared to be the "optimal synthesis of systems engineering and program/project management." This observation resonates with Kerzner's (1998) emphasis on the project manager's key role as the project's integrator.

The systems integration role is required throughout all project life cycle phases, beginning with deriving and decomposing system technical requirements, ensuring interoperability (including management of interfaces and standards), coordinating across Government, contractors and subcontractor organizations, maintaining the customer interface, and evaluation of technology insertion (as program matures) (Dombrowski, Ross, Gholz, 2003).

The systems integration function has been a major contributor of successful, high technology government programs, and is becoming increasingly important as technology is driving programs towards more integrated systems. And, with trends towards more system-of-systems approach for high technology Government programs, systems integration has been identified as crucial in the ongoing major military transformation process (Dombrowski, Ross, Gholz, 2003).

Significant issues relating the systems integration implementation for high technology Government programs/projects were identified as part of this study:

- Organizational structures to support systems integration for high technology Government programs (Crisp (1998), Freidman & Sage (2003), Dombrowski, Ross, Gholz, (2003))
- Strong potential for organizational conflict. The General Accounting Office (GAO, 2003) identified organizational conflict as a major cross-cutting factor associated with military space program issues. GAO found diverse organizations with competing interests and no "honest broker" at the senior level of management.
- Unclear roles and responsibilities and inadequate communication across multiple Government/contractor organizations. (Johnson).
- Inadequate systems engineering processes across multiple Government/contractor organizations.
- These programs are often subject to volatile external environments due to government funding processes, multi-decade program implementation, and changes in Government prioritizations.

These issues emphasize the need for a strong systems integration implementation strategy for high technology Government programs/projects.

Based on the above, it is understandable that systems integration issues have been identified as a major contributor to the failure, termination, and significant cost and schedule growth for high technology Government projects. However, as stated earlier, there have also been several high technology Government programs that have been either highly successful (met major objectives, cost, schedule) or successful (met major objectives).

Which leads to the question, how can a high technology Government program manager increase the probability of success, from the systems integration perspective? Several areas of research were required to address this question. Major areas included past studies and reports relating to factors associated with program/project outcomes, organizational theory. These studies provided the formation of this research.

Several studies relating to program success and failure factors associated with program/project outcomes were also reviewed as part of this study. Merrow, McDonwell, Arguden (1988) evaluated 52 civilian project size versus the project outcome and found most projects met their performance and schedule goals, but few met their cost goals. Large projects and megaprojects appeared to have more cost growth than smaller projects. They also found that technological innovation (doing things even slightly different) played a role in project outcomes. Bearden (2000) developed a system complexity index and demonstrated a relationship between a program/project's complexity, resource availability, and project outcome. Parsons (2003) categorized variables affecting program/project outcomes. This research provided a framework for tailoring project controls and management techniques to address these four categories. Honour (2004) focused on the systems engineering perspective concerning program/project outcome. This study examined NASA program/project outcomes in relationship to systems engineering funding. Delano (1998) identified key factors that contribute to program success and were ranked as follows: Program manager's ability to communicate, type and quality of people associated with program, program manager's ability to lead, good relationship with the user organization, resources: people, facilities, money, product requirements and design stability, funding stability, good relationship with prime contractor, program's acquisition strategy, program manager's acquisition experience, program personnel continuity, program manager's continuity, degree of technical difficulty, program manager's technical ability, and total quality management program.

Several studies and independent Government reports cited significant issues with systems integration for High-Technology Government programs/projects.

Organizational planning for High-Technology Government projects research included previous studies that demonstrated the relationship between organizational structures and architecture type alignment (Brady, Sosa) and SIOM types. More specifically, various Systems Integration Organizational Models have been defined for high technology Government programs to address the Government/Industry organizational structure, roles and responsibilities, and acquisition strategy. However, there are limited assessments associated with the selection and implementation of these SI Organizational Models.

Kerzner (1998) defined factors and analyses to support the selection of a traditional project organizational structure.

As mentioned earlier, significant issues have been identified relating to the systems integration function/organizational structure. Kerzner's factors for organizational structure selection, appeared to capture most of the relevant factors associated with High-Technology Government project outcomes. This study will evaluate the application of Kerzner's factors and analyses as a framework to support SI organizational model selection for high technology government programs/projects.

By defining a general class of SIOMs for high technology Government programs, determining the influential factors associated with these models, it is anticipated that a decision tool can be developed to support the Government Program/project planning. This study will attempt to address the following questions:

1) Is there a relationship between SI Organizational Models and project success/failure?

2) Are Kerzner's derived factors/analyses applicable to selecting SI Organizational Models to improve the probability of success?

3) What are the advantages/disadvantages associate with implementing each SI Organizational Model?

This paper is organized in the following manner: Key definitions will be identified, followed by a discussion of the proposed three phases of the methodology approach, and conclusion.

Key Definitions

Accountability: "The acceptance of success or failure." (Kerzner, 1998, 236)

Authority: "The right of an individual to make the necessary decisions required to achieve his objectives or responsibilities." (Kerzner, 1998, 236)

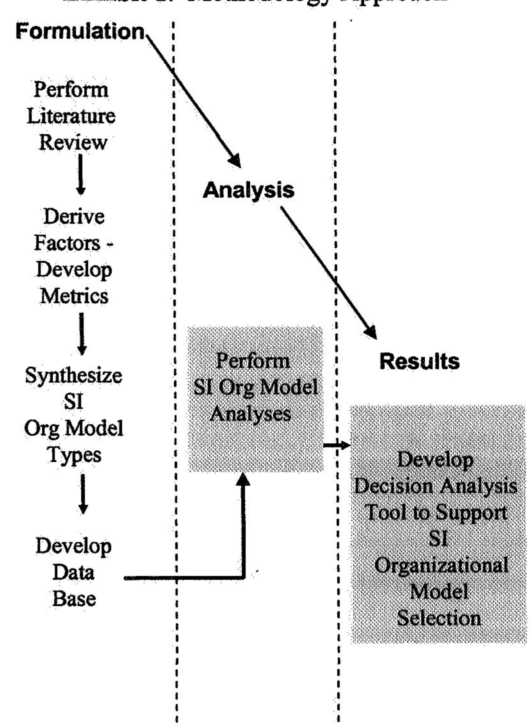
Federally Funded Research Center (FFRDC): "Federally Funded Research and Development Centers (FFRDCs) conduct research for the United States Government. They are administered in accordance with U.S Code of Federal Regulations,

Title 48, Part 35, Section 35.017 by universities and corporations." (Wikipedia).
Heritage: "Heritage can be from a previous flight system architecture, actual hardware/software, or driven by technology assessment and validation." (Freeman, I1-9)
High Technology: "Technology that involves highly advanced or specialized systems or devices." (The American Heritage Dictionary)
Individual Project: "Short-duration projects normally assigned to a single individual who may be acting as both a project manager and a functional manager." (Kerzner, 1998, 71)
Non-Profit Organization: "A non-profit organization is an organization whose primary objective is something other than the generation of profit." (wikipedia)
Project: "A project is within a program as an undertaking with a scheduled beginning and end, and which normally involves some primary purpose." (Kerzner, 1998, 70)
Project Success: Completion within allocated time period; within budgeted cost; at the proper performance level; with acceptance by the customer/user (Kerzner, 1998)
Project Failure: Project does not meet major objectives.
Project Termination: Unplanned project stop work order (Kerzner)
Project Traditional Organizational Structures: Functional, Product, Matrix (Kerzner, 1998, 99, 110)
Program: "Programs can be construed as the necessary first-level elements of a system." (Kerzner, 1998, 70)
Staff Projects: "These are projects that can be accomplished by one organizational unit, say a department. A staff or task force is developed from each section involved. This works best if only one functional unit is involved." (Kerzner, 1998, 71)
Special Projects: "...Special project occur that require certain primary functions and/or authority to be assigned temporarily to other individuals or units. This works best for short-duration projects. Long term projects can lead to severe conflicts under this arrangement." (Kerzner, 1998, 71)
Matrix or Aggregate Projects: "These require input from a large number of functional units and usually control vast resources." (Kerzner, 1998, 71)
Responsibility: "The assignment for completion of a specific event or activity." (Kerzner, 1998, 236).
System: Set of inter-related which interact with each other in an organized fashion toward a common purpose. The hierarchical system terminology (NASA Systems Engineering Handbook):
System, Segment, Element, Subsystem, Assembly, Subassembly, and Part.
System-of-Systems: "A system of systems is a set or arrangement of interdependent systems that are related or connected to provide a given capability. The loss of any part of the system will significantly degrade the performance or capabilities of the whole." (Defense Acquisition Guidebook, 4.2.6).
Systems Engineering: "Systems engineering is the overarching process that a program team applies to transition from a stated capability need to an operationally effective and suitable system. SE ... *is intended to be the integrating mechanism for balanced solutions addressing capability needs...*" (Defense Acquisition Guidebook, 4.1)

Methodology

This study was partitioned into three phases: formulation, analysis, and results, as shown in exhibit 1.

Exhibit 1. Methodology Approach

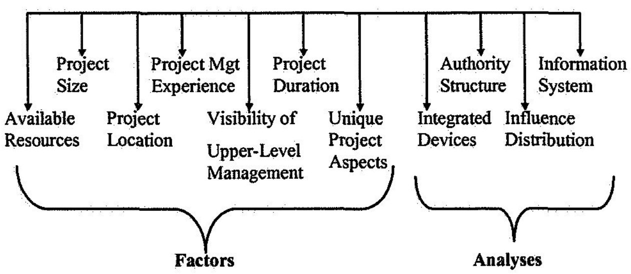


Perform literature review. An extensive literature review was performed, as discussed in the previous sections, to identify factors associated with Government project outcomes, systems integration implementation, and organizational planning for both traditional and High-Technology Government projects.

Derive factors and develop metrics. As stated earlier, Kerzner's factors for organizational structure selection, appeared to capture most of the relevant factors associated with High-Technology Government project outcomes. Research included studies and independent Government reports to extend this framework and to develop the metrics associated with these factors.

Kerzner (1998, 129), defined seven factors and 4 parameters that influence the traditional project's organizational form definition, as shown in Exhibit 2. These organizational forms include individual, staff, special, and matrix or aggregate project types. The factors are project size, length, project management organization experience, upper management visibility, project location, available resources, and unique project aspects. The integrating devices, authority structure, influence distribution, and information system parameters were identified by Kerzner (1998, 130).

Exhibit 2. Kerzner's Factors for Traditional Project Organizational Structure Considerations.

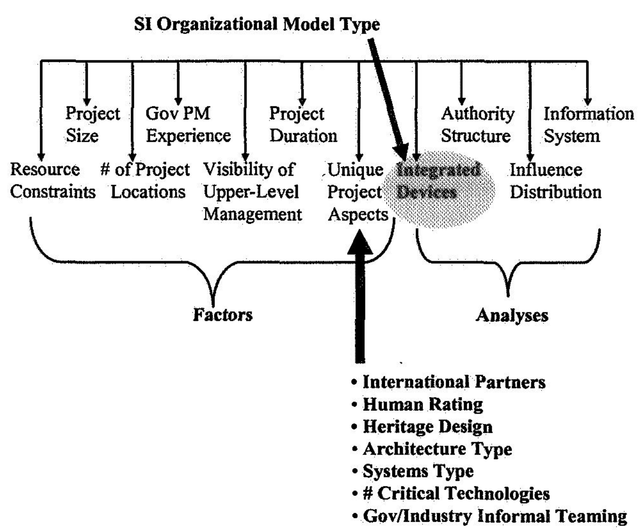


Kerzner emphasized the project's integration function: "Project management is the means of integrating all company efforts, especially research and development, by selecting an appropriate organizational form." Clear lines of authority and formal integrating positions must be established to support the project's integrating function, particularly for large projects, or where there is potential for "intense conflict" within the project. Management must also decide if the authority structure for controlling the integration mechanism, ranging from functional, product, and dual authority. The project's integration can also be affected by influence across functional boundaries, examples include participation in budget process, design changes, office space, and salaries. Finally, the information system's ability to move information through the project for effective decision making must be defined.

Once these factors were identified and defined, a spreadsheet was developed to categorize lessons learned for both successful and failed or terminated high technology Government projects. This spreadsheet leveraged off of the GAO table summary for cross-cutting issues across military space operations projects. (United States Government General Accounting Office, 2003, 3). This overall process resulted in some derivations to the Kerzner factors and analyses, as defined for traditional projects, and identified additional High-Technology Government project-specific factors.

Exhibit 3 reflects the factors and analyses that resulted from this assessment. Available resources were defined as resource constraints. Project size was defined by the initial estimated cost through the first product validation (Honour, 2004) and initial planned production rate. Production rate was included due to the significant differences between NASA, which is typically develops single units, and the development and mass production of DoD helicopters and missiles. Initial cost estimates were based on then-year dollars. The project location factor was defined as the number of project locations, since the emphasis is on the systems integration aspects of the project. Project manager's experience factor was defined as the Government's project manager's experience. Upper management visibility factor remained the same. Project duration was defined as the time from project definition through validation of the first product (Honour, 2004). The unique project factors were identified through extensive review of independent project reports and relevant studies, which included International Partner involvement, human-rated requirement, heritage design, architecture type, Systems type, number of critical technologies, and Government/industry informal teaming.

Exhibit 3. Kerzner-Derived Organizational Structure Factors and Analyses



The integrated devices analysis was defined as the Systems Integration Organizational Model type. The authority structure, influence distribution, and information system analyses, as defined by Kerzner, were limited to formal review processes.

Exhibit 4 defines the metrics used to assess these derived factors and Exhibit 5 defines the metrics used to assess the analyses section.

Exhibit 4. Metric Definition for Derived Factors

Resource Constraints	**Cost/Schedule, Cost/Schedule/Technical, Other**
Project Size-Initial Estimated Cost	**Continuous**
Project Size-Production Rate	**Integer**
# Government Project Locations	**Integer**
Experienced Gov PM?	**Yes, No, Multiple PMs**
Upper Mgt Visibility?	**Yes, No**
Project Duration-DDT&E	**Continuous**
Unique Aspect-International Partners?	**Yes, No**
Unique Aspect-Critical Technologies?	**≤3, >3**
Unique Aspect-Human Rating?*	**Yes, No**
Unique Aspect-Architecture Type	**System of System, System, Element**
Unique Aspect-System Type	**Aerospace, Aeronautic, Air-To-Ground, Launch Vehicle, Submarine**
Unique Aspect-Heritage Design	**High, Low, Evolutionary**

Exhibit 5. Metric Definition for Derived Analyses

Authority Structure	**1. Government** **2. Contractor** **3. Government/contractor** **4. Govt/FFRDC/Non-profit** **5. FFRDC/Non-Profit**
Influence Distribution	**1. Government** **2. Contractor** **3. Govt/contractor** **4. Govt/FFRDC/Non-profit** **5. FFRDC/Non-profit**
Information System	**1. Government** **2. Contractor** **3. FFRDC/Non-Profit**

Synthesize Systems Integration Organizational Model (SIOM) types. As stated earlier, several authors have identified SIOM types for High Technology Government Projects. The SI organizations defined by the National Academies Aeronautics and Space (NAA&S) Board – National Research Council, , Freidman, Smiley, and Dombrowski et al., were mapped into the following eight specific SIOM types: 1. Lead Systems Integrator, 2. Shared SI, 3. Project Management and SoSI, 4. Joint Venture, 5. Government In-House Development SI, 6. Government Project Management and SI, (with Contracted Support), 7. Industry-Led PM and SI, and 8. FFRDC or Non-profit PM and SI. Exhibit 6 illustrates this mapping process. The author(s) are identified in the first column, followed by their organizational definition summary, which were then mapped to the eight specific SIOM types.

Exhibit 6. Systems Integration Organizational Model Mapping

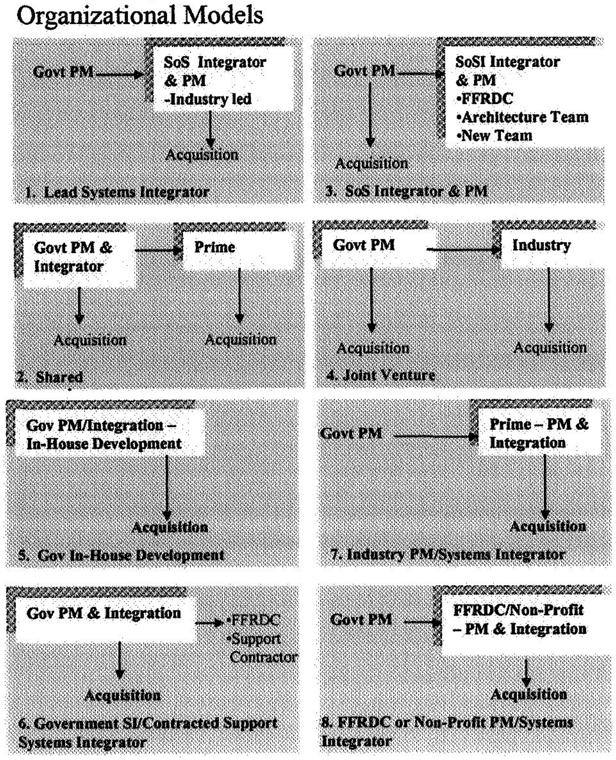
Reference	SIOM Type	Mapped SIOM Type
1.NAA&S 2.Freidman & Sage	• Large Aerospace Company as SoSI • Prime SoS Contract	1. LSI
1.Freidman & Sage	• Shared Government & Contractor SI & Interfaces	2. Shared
1.NAA&S 2.Dombrowski et al 3.Freidman & Sage	• SI/SoSI & PM/No Contract Authority -Non-Aerospace Company as SI/SoSI -New Architecture SI/SoSI -Team of Architecture SI/SoSI -Military Laboratories	3. PM & SoSI
1.Smiley	• Military/Industry Joint Ventures	4. Joint Venture
1.Freidman & Sage	• Government PM & SI	5. Government In-House Development
1.NAA&S 2.Freidman & Sage 3.Dombrowski et al	• NASA as SI/SoSI •Government SI with FFRDC/Contract support (no Contract Authority)	6. Government PM & SI/Contracted Support
1Freidman & Sage	• Contractor SI & Interfaces	7. Industry PM & SI
1.NAA&S 2.Dombrowski et al	• FFRDC/Non-Profit PM & SI	8. FFRDC/Non-Profit PM & SI

Exhibit 7 provides a more detailed description associated with each SIOM type. The highlighted area represents the organization responsible for the project's PM and SI responsibility.

1. Lead Systems Integrator. The Industry-led LSI has Total Systems Performance Responsibility, performing Project Management, Systems Integration, and performs all acquisitions. This type is typically associated with SoS programs or projects.

2. Shared. The Government organization is responsible for PM and is accountable for the overall SI, with the Industry Prime responsible for delivering an end item to the government. Both the Government and Prime perform acquisitions and share responsibility in the overall systems integration.
3. SoSI and PM. The Government organization is responsible for the PM and all acquisition, with the delegated PM and SoSI responsibility to an FFRDC, a cross-cutting Industry team, or a new organization formed specifically for this function. This team can only compete for hardware/software at the subcontractor level.
4. Joint Venture. The Government and Industry share costs, PM, SoSI, and acquisition responsibility.
5. Government In-House Development. The Government organization is responsible for PM, SI and acquisition.
6. The Government organization is responsible for PM, SI, and acquisition, with contracted SI support from either an FFRDC or Industry support contractors.
7. The Government organization is responsible for the overall PM, but delegates PM, SI, and acquisition responsibility to an Industry prime contractor.
8. The Government organization is responsible for the overall PM, but delegates PM, SI, and acquisition responsibility to a FFRDC or Non-Profit organization.

Exhibit 7. Synthesized Systems Integration Organizational Models



Develop data base. Once the factors, analyses and the associated metrics, and the SIOM types were defined, a database was developed to capture project data to support the analysis process. Public data sources were used to populate this database.

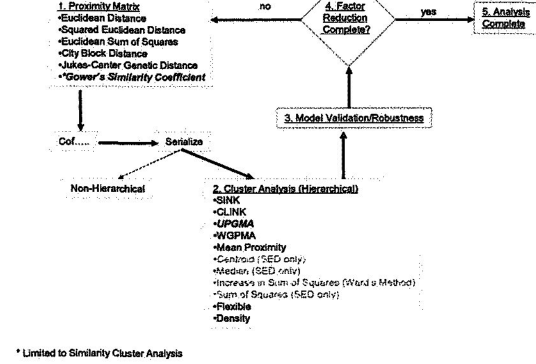
The population included DoD and NASA high technology projects, developed from the 1950's through 2006. The population is represented by a sample size of 82 projects. The sample data was derived from available public data including independent assessment reports, General Accounting Office Reports, and NASA, DoD, and Industry websites. All data has been acquired, and the database is currently being updated to include all 82 projects.

There are limitations and constraints associated with the collected data. First, reliance on public data sources may include inaccuracies. Samples were also selected, based on available data to complete the database entries. Secondly, cost estimate variation was identified due to the following reasons: Source, scope of cost estimate (example: Did DDT&E cost include launch vehicle services and ground operations), and DDT&E phase end/production starts assumptions. More than one source of data was attempted for every project entry to mitigate these risks.

Perform SIOM type analyses. There are two major steps planned for the analysis portion of this study. The first step in the analysis will identify the most frequently used SIOM types, and their associated success or failure/termination percentage. Descriptive statistics for each SIOM type will also be provided.

The second step of the analysis requires a more detailed assessment of the relationships between the different SIOM types, as well as within each SIOM types to support the SIOM type selection process for Government/Industry high technology projects. The cluster analysis process has been selected to assess the SIOM type categories. Exhibit 8 demonstrates this process.

Exhibit 8. Cluster Analysis Process.



Step 1. Proximity Matrix. Several proximity matrixes were evaluated to determine the optimum implementation. Gower's Similarity Matrix was selected since this algorithm supports mixed data types (qualitative and quantitative).

Step 2. Cluster Analysis. The UPGMA hierarchical cluster analysis was selected since it supports the Gowers Similarity Coefficient matrix, and is widely used. It should be noted that the Centroid, Median, Increase in Sum of Squares, and Sum of Squares are not applicable to the selected proximity matrix.

Step 3. Model Validation Robustness. While the UPGMA cluster analysis will be used for the preliminary analysis and evaluated for consistency of data clustering, this step requires the evaluation of other applicable cluster analysis to ensure robustness of the selected cluster analysis tool.

Step 4. Factor Reduction. The application of factor reduction will be evaluated after the cluster analysis is complete, since another level of analysis could add value to the overall findings. This step will be evaluated as part of the overall analysis process.

Develop decision analysis tool. These results will be used to build a decision analysis tool to support SIOM type selection by project managers, to improve the probability of success. Lessons learned associated with each SIOM type will also be included to support the SIOM implementation over the project life cycle.

Conclusion

This paper provided an overview of the research and methodology used to support a Systems Integration Organizational Model selection, for improving a high technology Government program/project's probability of success.

Literature review included four major areas: Systems integration and organizational structure theories, systems integration implementation for high technology Government projects, factors associated with project outcomes, and Systems Integration Organizational Model definition and assessments. This broad span of research provided a systems approach to developing the methodology used for this research.

The methodology to achieve the overall study objectives was partitioned into three major phases: formulation, analyses, and results. Application of Kerzner's organizational structure factors provided the framework for the set of synthesized Systems Integration Organizational Model's selection process. Derivation of Kerzner's factors was defined by use of previous studies and reports. Preliminary analysis of 82 projects is currently underway. It is anticipated that the results of this research can be used to select the appropriate SIOM for increasing the project's overall success.

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