The fourth activity arises from the nature of system elements as self-contained units, with defined functionality and external interfaces. Each contract document can be viewed in the same way as one views a software object, and abstracting from its use in a particular project by means of appropriate metadata, it can be incorporated into a corporate contract document database. This standardization, in addition to any industry-wide standardization: NATSPEC in Australia, FIDIC contract templates, DODAF in the U.S., MODAF in the U.K., and TOGAF can be tailored to the business practices of the individual corporation. This Quality Control check on the documentation can benefit both the contractor and customer in cost.

Tailoring

An essential aspect of any application of the systems engineering methodology is to tailor the general processes to the size and complexity of the individual project. The governing principle of this tailoring as it applies to the contracting strategy is that the cost of optimizing the strategy must be less than the expected improvement of project outcome.

General guidelines and useful tips on how to conduct and update the tailoring of business processes are contained in the SE Handbook. Salient points are:

a. Before considering any of the processes, be certain that any mandatory legal requirements on the contracting structure are known. This can assist top level requirements definition. Such requirements are sometimes identified by the legal participants in the development process, but are often due to the customer's interpretation of his or her needs.

b. To the extent possible, determine up front in the development where a purchase order can be substituted for a contract (reflecting a COTS approach). An often observed bad practice is writing a detailed technical specification for a piece of equipment where a suitable off-the-shelf item has already been identified, instead of simply specifying that equipment or equivalent, and putting the onus of proving equivalence on the contractor.

Useful References

International Council On Systems Engineering (2011). *Systems Engineering Handbook: A Guide For System Life Cycle Processes and Activities*.

International Council On Systems Engineering (2012). *Guide for the Application of Systems Engineering in Large Infrastructure Projects.*

This Leaflet

This leaflet is part of a series intended as a brief introduction to the application of systems engineering approaches to infrastructure projects. It was developed by the International Council On Systems Engineering (INCOSE) Infrastructure Working Group in the interest of aiding industry.

For further information about the application of systems engineering in large infrastructure projects, including a Guide applicable to the Construction project stage, go to www.incose.org and look for publications.

INCOSE is a not–for–profit membership organization under 501(C)(6) founded to develop and disseminate the interdisciplinary principles and practices that enable the realization of successful systems.

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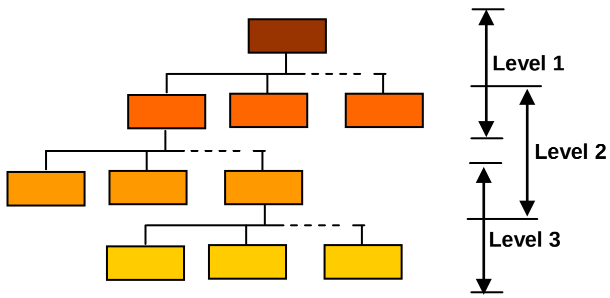
Applying Systems Engineering to Industrial & Infrastructure Projects

Choosing the best Contracting Strategy

The Basics

Infrastructure projects are carried out as defined in a set of contracts. These contracts interact and form a system, and as there is normally a wide range of possible options in designing this system, the question arises as to the best system architecture or, as it is often called, the best contracting strategy. But as infrastructure projects vary greatly in scope and complexity, we first need to describe the particular context in which we will attempt to answer the question.

On any particular project, the set of contracts can be grouped into levels, with a level being identified by the extent of the project the contracts take responsibility for. At any given level, there is an initial structure, in the sense that there is a Principal who issues the contracts, and a set of Contractors: a system of contract parties within a project, structured into levels.



Each contract is between a Principal and a Contractor, and a Contractor on one level may become a Principal on the next lower level.

At any level, determining the set of Contractors basically involves the Principal both dividing the work up into workable contracts, and then selecting down contractors from a pool of candidates. Down selection can be conducted through a competitive bidding process, or sole source if the past performance relationship has proven satisfactory and contract laws allow. The contracting strategy can often be defined by dividing up the scope according to contractor capability and the linkage between chosen contractors in fulfilling the terms of the total contract. Part of the contracting strategy will be the ability of each party to mitigate or assume its portions of the presumed engineering and contractual risks. Effective and well-coordinated Risk Management Plans across the project will help assure that this is accomplished.

The Systems Engineering Approach

This description of developing and executing a contracting strategy is, with mainly only a change of language, in many ways similar to the activity identified as the architectural design process in Systems Engineering and described in numerous textbooks (Eberhard Rechter's *Architecting Systems*) and in the INCOSE Systems Engineering Handbook.

The grouping of hardware and software into a system starts with the contractual basis. The system is the group of contracts. The system requirements are the requirements that the Principal has to meet in order to create a functional system out of the customer's interpretation of his or her needs as set out in the contractual documents The system elements are the contracts. The controls and enablers are the legal framework, necessary insurance, company procedures and processes and standards for the documentation. The outputs of the process are the completed set of contractual documents, identification of well–defined risks or possible issues, as well as the appropriate role of Quality Assurance throughout system design and implementation.

Automated tools exist for the Requirements Management process: identification and allocation, configuration control and management, and the assurance of full system integrity through verification and validation. Test strategies must consistently follow necessary changes and maintain traceability to both the design and the design's implementation. Due diligence by and between those maintaining and managing the requirements and the configuration of its allocated functions throughout the life cycle will result in mutual agreement and satisfactory achievement in implementing the system.

The Architecting Process

The process activities and their sequence of application are:

- Define a functional architecture that identifies a satisfactory method for implementing the scope of work for all meaningful stakeholders. The architecture needs to be satisfactory both as a logical structure and a physical reality. Areas this could touch upon would be design, construction, financing, geotechnical investigations, environmental investigations, and community consultation. The level of detail in the definitions of the functions depends on the flexibility of this architecture in allowing system implementation, while maintaining necessary resilience.
- Demonstrate that the requirements placed on the Principal can be fulfilled through allocating functions via an automated tool or if requirements are limited in scope, a Requirements Traceability Matrix.
- Determine the best partitioning of each function into contracts, with "best" being that partitioning that results in the greatest probability of a successful completion of that function, taking into account all relevant influencing factors, such as market structure and ongoing trade studies, capacity, capability, cost and the level of acceptable risk. Of necessity this may be an iterative process.
- For each contract, identify the required documents (conditions of contract, technical specifications, etc.) and the extent to which pre–existing documents with standard formats can be used (the equivalent of COTS). Inadequate attention to this point is often a source of significant unnecessary costs, including the addition of another phase to the contract lifecycle: the time spent in court.
- Identify internal interfaces (between contracts in this group) and external interfaces to other groups within the project as well as to project–external agencies (e.g. for approvals) as well as all sitting requirements and those intended for public safety.
- Produce the contract documents, and perform an adjudication of requirements suitable to the customer needs and satisfactory to create the system in the automated tool of use of in a Requirements Allocation Matrix. This should demonstrate that each of the requirements identified in the first activity is covered by one or more requirement(s) in the contracts.

Optimization

Many of the activities described under "Elaboration" in the Handbook are applicable to the development and optimization of such a system of contracts with an appropriate translation of terms. For example:

Handbook term	Contract development
available technology	available contractors
requirements analysis	analysis of the requirements accepted by the Principal
system performance	the overall outcome of the Principal's contract
architecture views	profit view, risk view, and safety view
COTS	standard contract documents

Four activities are of particular relevance to optimizing a system of contracts: The first is the assessment of the effect of splitting the work into more, smaller contracts. On the one hand, this usually results in lower contact costs due to greater competition and avoiding the contractors' sub-contract management overhead and markup. On the other hand, it increases the Principal's contract management costs, and it requires the Principal to have the necessary detailed knowledge and experience. It is the lack of a critical assessment of the latter that can result in serious problems during project execution, particularly on technologically complex projects.

The second activity is an assessment of the current capacity of the initially selected contractors. The schedule overrun on projects is often due to the fact that one or more of the contractors did not have the capacity to carry out the work in the allotted time due to competing projects. This can be mitigated against by investigating the current workload and the forward pipeline of the contractors.

The third activity is to correctly capture the temporal relationships between the various packages of work and consider the likely effect this will have on different ways of allocating work packages to contracts. A good way of visualizing the temporal relationships is an N-square Chart, and issues to consider include demobilization and remobilization costs and possible interference from other projects.