Conversely, the ability to restore a failed system is dependent on the ease with which a system can be maintained. This is dependent on how the system was designed and built so that failed components can be easily replaced (i.e. has a low mean time to repair) and how often and how well periodic maintenance of the system is carried out to ensure predictable failure is minimized (i.e. an optimized preventative maintenance regime).

Maintainability therefore is a combination of good design and build practice as well as processes and procedures through the operations and maintenance lifecycle that minimize the chance of any failure or manage the risk of failure proactively

Once reliability and maintainability are controlled through good operations and maintenance practice, then the availability (or 'uptime') of a system improves. Balancing the availability of the system with the time required to take the system off-line to carry out essential maintenance can affect how safe the system solution is deemed to be. If operational practice is driven too hard by keeping availability high, then there is a risk that lack of sufficient maintenance will lead to failure and reduce the overall safety of the railway.

In addition, there are significant Human Factors (HF) considerations that need to be taken into account when planning operations and maintenance activities as they have a significant impact on the performance and safety of the railway system.

Specialty engineering disciplines that particularly have expertise and experience in the areas below need to work with the other technical disciplines to develop an integrated approach to the engineering of a railway system:

- Safety, hazard and risk analysis,
- Reliability modelling,
- Operational practices,
- Maintenance procedures,
- Performance modelling,
- Statistical performance analysis, and
- Human factors engineering.

These principles can be equally applied to the engineering of any system to ensure that all aspects of the infrastructure are designed appropriately to deliver a safe, cost-effective solution that meets the specified requirements and is fit for purpose.

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 founded to develop and disseminate the interdisciplinary principles and practices that enable the realization of successful systems.

INCOSE
International Council on Systems Engineering ®

INCOSE
INFRASTRUCTURE
WORKING GROUP

Applying Systems Engineering to Industrial & Infrastructure Projects

Specialty Engineering

What is Specialty Engineering?

Specialty engineering is a component of Systems Engineering that complements the technical activities required to deliver a project. It typically deals with engineering that affects the performance, safety, usability, cost certainty, constructability, deliverability and lifecycle of the product outside of the normal functional aspects of engineering.

Specialty engineering covers activities such as:

- Performance modelling & analysis
- Reliability, Availability and Maintainability (RAM)
- Safety and health hazards
- Quality assurance
- Electromagnetic compatibility and Radio frequency management
- Human factors
- Sustainability and environment
- Constructability
- Whole life cost
- Integrated Logistics Support (ILS)
- System security
- Operability

Engineers that carry out these activities in a project typically have deep domain knowledge in their chosen field and hence provide the specialized advice needed to support the overall systems engineering effort.

Why Use Specialty Engineering?

Systems engineering concentrates on delivering a product according to specific functional, performance and non-functional requirements, often in traditional engineering disciplines such as electrical, civil, mechanical or process.

The resulting product of such engineering has to fit into the environment (or larger system) for which it has been designed. This often involves engineering activities outside those involved in developing the system or product.

Specialized engineering disciplines help answer questions about how the infrastructure system (the product of the project) will be used, whether it will be safe to use and how reliable and easy to maintain it will be over its planned life.

These considerations affect the performance and whole life cost of the product and therefore specialty engineering can have significant benefits for an enterprise developing and delivering the infrastructure system.

It is therefore important that a suitable selection of specialty engineering activities is considered as part of systems engineering activities.

When Do You Use Specialty Engineering?

Specialty engineering, being complementary to the standard engineering disciplines, should be used concurrently in all projects or programs. One of the jobs of the Systems Engineer (SE) is to effectively integrate the traditional engineering disciplines with the specialty disciplines so that project delivers an infrastructure that meets the stakeholder requirements and is fit for purpose.

Specialty engineering activities can occur at all stages of the asset lifecycle from concept development through upgrade and eventually replacement and disposal.

The more effort that is placed on integrating specialty engineering activities as part of the project lifecycle means that there is a greater probability that the system (or its component assets) will meet its requirements within a defined cost over a specified life.

So, for example, if estimations for how easy the infrastructure will be to construct (i.e. its constructability) are included during the development of the conceptual system solution, the more the likelihood that it will be considered all through the project lifecycle and will lead to a satisfactory result from both a delivered system and project cost point of view.

Frameworks for Specialty Engineering

Projects can benefit from the use of specialty engineering practices at all times during the asset lifecycle, from concept development through to disposal. It is important to have a framework that integrates specialty engineering into this lifecycle so that activities can be effectively scoped, staffed, planned and executed.

The framework should:

- Determine which specialty engineering activities apply to which stages of the project,
- Determine the inter-dependencies between specialty engineering and other systems engineering activities,
- Schedule, monitor and control specialty engineering activities so that they provide consistent, effective and timely support to the main engineering activities of the project,
- Define the organizational structure that will support the integration of specialty engineering into the wider project or program of works, and
- Apply appropriate specialty engineering activities to the asset operations and maintenance lifecycle from its first 'putting into use' through to its replacement and disposal.

Some organizations set out specific directives, often in the form of an engineering manual or guide, on how specialty engineering frameworks are to be integrated into projects and how each specialized discipline is to carry out its activities. These directives cover:

- In which project stage a particular activity will be carried out,
- Expected products of a particular activity,
- The roles and responsibilities of the engineers carrying out the activity,
- The inter-relationships between specialty engineering activities,
- Tools to be used, and
- Applicable standards, guidance and governance.

These directives require the co-operation of the project organization, including project managers, chief engineers and systems engineers to ensure effective implementation of specialty engineering activities.

A common approach to managing responsibilities in a project involves the use of a RACI (Responsible, Accountable, Consulted or Informed) or RASCI (Responsible, Accountable, Supporting, Consulted or Informed) matrix. All participants in a project are allocated only one of these categories (unless the accountable person is also responsible for the delivery of a task). This provides all participants in a project a clear view of who is doing what and improves project coordination.

Specialty Engineering Example: Reliability, Availability, Maintainability and Safety (RAMS) in Railways

From European railway standard EN 50126: "RAMS is a characteristic of a system's long term operation and is achieved by the application of established engineering concepts, methods, tools and techniques throughout the lifecycle of the system".

In railway engineering, as in most forms of transport, safety is a paramount. However, it is influenced by, and interlinked to, availability of the system. Availability is influence by operations and maintenance practices as these determine the reliability and maintainability of the system.

Good operations and maintenance practice throughout the life of a railway asset is key to having safe, reliable services that meet passenger demands.

From a specialty engineering perspective, a variety of engineering disciplines are required to assess each aspect of RAMS.

Reliability, for example, is dependent on the probability of various failure modes of a system and the impact they will have on how the system functions.

Hence an assessment of the probability of failure of the individual assets and of the railway system is required to determine the various failure modes and the mean time before failure for the system (or components). This typically requires assessment by subject matter experts who have an in-depth understanding of the railway and all the variety of assets that are part of it.