# Systems Approach to Engineering Contracts[1]

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## Abstract

*Engineering Contracts are crucial to delivering Large Infrastructure Projects (LIPs) successfully. These megaprojects significantly impact national economies and are characterised by complexity, scale, and long durations, often involving multiple stakeholders, vast resources, and fast-evolving requirements. Alas, traditional Contract Management approaches have struggled to cope with such complexity, leading to widespread issues such as cost overruns, delays, disputes, and even project failures—billions spent, but nothing to show. Examples abound of fiascos due to deficient contracts.*

*This article proposes a systems approach to Engineering Contracts, grounded in systems thinking and systems engineering. The systems approach views contracts not merely as legal documents but as dynamic instruments that govern interactions, responsibilities, and the expectations of all parties involved. This perspective is particularly relevant for LIPs, where complex stakeholder interactions, interconnectedness, risk-sharing, and adaptive management are essential for success.*

## Significance of Large Infrastructure Projects

The upsurge in project complexity severely challenges many organisations to achieve project success —to deliver the quality and *operability* expected by the acquirer and stakeholders on time and within the established budget. In response to this challenge, governments and the infrastructure industry have fostered the application of the systems engineering (SE) discipline to enhance project delivery.

> "Infrastructure represents the largest portion of capital investment in any country, and when one considers that on a typical infrastructure project, the construction costs represent about 85% of the total costs, it is reasonable to put some effort into extending the benefits that SE has brought in its traditional domain [of aerospace, defence industry, electronics, etc] to the construction industry and, in particular, to Large Infrastructure Projects." (INCOSE, 2012)

In her seminal book titled "Economic Theory and Construction Industry," Hillebrandt submits that construction makes up to 10% of GDP worldwide and, for example, is the largest industry in the United Kingdom (UK) and the second largest, after public health, in Sweden (Hillebrandt, 2000). LIPs contribute to the national economy during construction and through their positive outcomes, viz., job creation, GDP growth, increased wealth, and enhanced standard of living (US DoS, 2012). Recent studies suggest that every dollar spent on infrastructure yields an estimated GDP increase of US$0.05 to US$0.25—generating a socio-economic return of between 5% and 25% (GI Hub, 2019). Thus, South Africa relies on infrastructure investments to realise its socio-economic development.

> "Infrastructure investment is a key priority of both the National Development Plan and the New Growth Path. We are transforming the [SA] economy, directing national growth and driving job creation by implementing a long-term, government-led infrastructure investment programme […] builds social capital; and raises living standards as people have access to […]" (PICC, 2012)

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"The National Infrastructure Plan is made up of eighteen Strategic Integrated Projects (SIPs), each of which consists of a large number of projects drawn from a wide range of economic sectors and stretching across all […] provinces of the country" (SIPs and Skills, 2014). Medupi is a key element of the National Infrastructure Plan; however, years of delay and ±150% cost overrun at this project could spell disaster for Eskom and South Africa (SA). Yet, this debacle is no isolated incident; indeed, infrastructure projects worldwide suffer similar predicaments that could be synopsised as follows:

(1) Challenges facing project management—Despite its apparent maturity as a discipline with a host of registered professionals, traditional project management has proven inadequate in the face of increasing complexity in project scope and environment. Only ~26% of projects executed are generally deemed successful; therefore, a need to propose an alternative model.

(2) Implications of project failure—Large Infrastructure Projects (LIPs) are prone to failure and, therefore, have the potential to cause financial failure (to the company) and fiscal failure (to the country), reinforcing the need for an alternative approach, particularly for megaprojects.

(3) Inadequacies of traditional approaches—The inability of project management approaches (not necessarily tools or techniques) to cope with complexity often results in delays, massive cost overruns, and failure to meet the owner's requirements. A systems approach is needed.

A need thus arises to consider why and how contractual risks make LIPs particularly vulnerable to cost and schedule overruns (or utter failure) and then propose a remedial or alternative approach to managing Large Infrastructure Projects, as J.B. Porter has noted in his foreword to (Merrow, 2011). Moreover, in discussing "*Governance of Relationship Risks in Megaprojects*," Xie maintains that:

> "Delivery of megaprojects [i.e., LIPs] involves various stakeholders and usually requires […] cooperation. These stakeholders play different roles and undertake different responsibilities and obligations [per agreements], forming a complex social network […]" (Xie et al, 2019)
>
> "The social attributes of megaprojects, as a result, lead to significant relationship risks, which is the product of dynamic interaction between stakeholders. The project stakeholders' position in the project social network and their interaction have an important influence on the realization of the expected yields; this 'influence' is defined as the relationship risk." (Xie et al, 2019)

Risks associated with roles, responsibilities, and obligations of primary stakeholders may influence or determine outcomes of megaprojects; contracts and agreements shall govern such risks. One thinks of roles (e.g., contract manager) not allocated, responsibilities not fulfilled, and obligations not met.

## Shortcomings of Traditional Contract Management

Traditional Contract Management is largely transaction-based, focusing on "*getting the job done*." This approach has long been rooted in a transactional paradigm—treating contracts as static legal instruments whose primary purpose is to enforce compliance and administer payments (essentially emphasising documentation), and after-the-fact dispute resolution (i.e., reactive conflict resolution). While legally sound, such an approach can be rigid, focusing primarily on enforcing terms and clauses rather than enabling project success. Such rigidity, nonetheless, is problematic in the context of Large Infrastructure Projects and is increasingly viewed as inadequate for the delivery of LIPs, where complexity, stakeholder interdependence, and uncertainty dominate owing to the following:

- Stakeholder Diversity: Government agencies, partners, contractors, subcontractors, financiers, regulators, and affected communities often exhibit "changing" expectations and/or interests.

- Complex Interfaces: Projects involve multiple phases (e.g., design, construction, operations, and maintenance), each with lifecycle-specific and evolving requirements and challenges.
- Dynamic Environments: Changes in context, scope, specifications, or stakeholder priorities can arise, making rigid contracts a liability; not only is each project unique, but it may also be changed. For instance, the configuration of the product will change across the lifecycle.

It is not only about *uncertainty*; many other aspects of project contracts are non-conducive to success. In recent years, the traditional Contract Management has been confronted with criticisms as follows:

(1) Reactive, not Proactive
*Traditional models focus on post-issue resolution rather than anticipating and mitigating risks, often leading to disputes, delays, and cost overruns before any collaborative solution is sought.*

(2) Siloed Stakeholder Interactions
*With an emphasis on separate roles and responsibilities rather than relationships and systems, transactional models reinforce adversarial postures. Stakeholders may withhold information to protect themselves rather than collaborate to achieve shared goals—the project will suffer.*

(3) Focus on Inputs, Not Outcomes
*Traditional contracts are often activity-based, defining scope and deliverables but lacking mechanisms to drive system-level performance outcomes such as reliability, lifecycle value, or social impacts. It is not rare to find teams or stakeholders thriving at the expense of others.*

(4) Inflexibility to Change
*Fixed-price and rigid contractual mechanisms can become counterproductive in dynamic environments, where design evolves, technologies shift, and stakeholder expectations change.*

(5) Disjointed Lifecycle Governance
*Traditional approaches generally fail to integrate the contractual and project lifecycles. This leads to misalignment between phases (e.g., design and operations) and weak feedback loops, impairing long-term value and operational readiness—The oxen are not yoked to pull the cart!*

These fatal shortcomings are widespread in Large Infrastructure Projects, particularly in Africa. A few examples illustrate how “inadvertences” in contractual arrangements usually ruin projects:

- The Kusile Power Project, a flagship project in South Africa, faced delays and cost overruns; complex stakeholder interactions and “fragile” contract governance were its primary issues.
- The Gautrain Rapid Rail Link was delivered through a public-private partnership (PPP) with a mix of FIDIC contract forms and achieved “partial” success. It faced disputes in land acquisition and operational standards, which resulted in delays, cost overruns, and litigation.
- The Medupi Power Project was developed under a FIDIC Silver Book (Turnkey) approach; it faces major delays, cost overruns, weak stakeholder alignment and poor risk management.
- The Lesotho Highlands Water Project, a cross-border infrastructure project between South Africa and Lesotho, is implemented through a mix of FIDIC Red and Yellow Book contracts. At this stage, the project is almost 10 years late and facing massive cost overruns and protests.

Notably, the Medupi and Kusile megaprojects—both structured under traditional, compliance-heavy FIDIC contracts—have suffered from disputes, scope creep, and timeline slippage due to poor early-phase alignment and rigid implementation, resulting in operational failures. Regarding the Lesotho Highlands Water Project, it is on record that it has faced disputes over proposed water tariffs and environmental impacts, necessitating strong stakeholder management, like that of Medupi or Kusile.

Although this megaproject is critical to the socio-economic context of both South Africa and Lesotho (i.e., providing vital water to one and revenue to the latter), it has suffered from (and may exacerbate) several consequences of issues bordering on contractual inadvertences, including those listed below:

- Broader implications of contract failure
- Financial losses for contractors and clients
- Disputes and litigation, which consume time and resources
- Economic impacts on national GDP growth and job creation
- Reputational damage for organisations and countries involved

Furthermore, global entities like the Standish Group and the World Bank have provided supporting evidence based on data collected from infrastructure projects across continents, over many decades:

- The CHAOS Report states that 66% of large projects are challenged or fail, often due to unclear requirements, weak stakeholder engagement, or scope misalignment (Standish Group, 2020).
- In "*Megaprojects and Risk*," Flyvbjerg identifies "lock-in" and "optimism bias" as recurring systemic failures in mega-infrastructures—in the transportation sector (Flyvbjerg et al, 2003).
- The PPP Reference Guide indicates that lifecycle integration, performance alignment, and adaptability of key contracts are essential to sustainable project delivery (World Bank, 2018).

The consequences of such contractual inadvertences are too high to bear, ranging from expensive rework to steep litigation bills to commercial and reputational liabilities. Forfeited socio-economic returns (e.g., missed GDP growth) and opportunity costs of failed investments make the matter worse. The industry ought to heed this crucial call: "*Consider why and how contractual risks make LIPs particularly vulnerable to cost overrun and schedule slippage (or utter failure) and then propose a remedial or alternative approach to managing Large Infrastructure Projects*"—There is no choice! Indeed, let one be guided by "*Fiat voluntas systematis*" [Latin]—Let the will of the system be done.

Academic and sector data consistently attribute failures not to unforeseen events but to governance weaknesses, locked-in decisions, and contract-system misalignment (Standish Group, 2020). Yet, it is anticipated that a systems-based model of Contract Management transcends these limitations by:

- Emphasising interactions over transactions
- Supporting adaptive, not disjointed governance
- Aligning contractual logic with lifecycle thinking
- Driving continuous value through feedback, integration, and stakeholder cohesion

Nevertheless, the effective application of these systemic provisions is beyond traditional Contract Management and, thus, necessitates the adoption of the systems approach to Engineering Contracts.

## Systems Thinking and Contract Management

The Large Infrastructure Projects industry is facing unprecedented challenges, which perhaps only our forefathers might have tasted when evolving from huts to designing and building the pyramids:

- Increased complexity of products and processes owing to fast-changing customer demand;
- Large number of different interfaces between or among components, sub-components, etc.;
- Evolution of global competitive markets or Time to Market (i.e., heightened Competition);
- Exponential expansion of knowledge and technology (i.e., more information than ever); and
- Necessity of multi-disciplinary or eclectic teams where each member contributes a specific expertise and interacts with many others to achieve a common goal (i.e. *a successful system*).

Moreover, Wood contends that "It is a common statement that the construction industry process is one of the most complex and risky businesses undertaken, however is has also been suggested that the construction industry [or LIPs] has developed great difficulty in coping with the increasing complexity of major construction projects" (Wood *et al*, 2010). Indeed, while *project complexity* as such is but one dimension of attaining project success, both Baccarini and Senge maintain that:

> "The significance of project complexity to project success or otherwise [i.e., failure] cannot be underestimated, hence the compelling need to allow for a thorough understanding of the inherent complexities in an infrastructure delivery system [for success]." (Baccarini, 1996)

> "Systems Thinking is a discipline for seeing wholes [i.e., holistic]. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static 'snapshots' [...] Systems Thinking is needed more than ever because we are becoming overwhelmed by complexity. Perhaps for the first time in history, humankind has the capacity to create far more information than anyone can absorb, to foster far greater interdependency than anyone can manage, and to accelerate change far faster than anyone's ability to keep pace." (Senge, 2006)

It took twenty years for this "plea" to seek a *"thorough understanding*" of complexity in large infrastructure projects to be heeded, for a project delivery methodology that sorts out complexity to be proposed (Mabelo, 2016). Indeed, effectively applying systems thinking to project lifecycle methodologies enhances project delivery and accommodates an approach that defeats complexity. No wonder, systems engineering, which derives from systems thinking, allows "*the realization of successful systems*"—successful Large Infrastructure Projects with no systems thinking are scarce!

> "Systems Engineering is […] an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining Acquirer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem." (INCOSE, 2015)

Systems Acquisition, as a phase, entails appointing contractors and suppliers under a set of contracts. The acquisition and supply processes are two sides of the same coin. Each process establishes the contractual context and constraints under which the other system lifecycle processes are performed.

> "The Supply Process is invoked to establish an agreement between two enterprises under which one party supplies products or services to the other. Within the supplier enterprise, a project is conducted according to the recommendations of this handbook with the objective to provide a product or service that meets the contracted requirements." (INCOSE, 2015)

However, the ISO/IEC 15288 Standard (on system lifecycle) marked a pivotal shift in how project agreements—especially Engineering Contracts—should be approached. It formally acknowledged systems engineering not merely as a technical discipline, but as a structured and integrative means of establishing and managing agreements between parties, typically an acquirer and a contractor. This systems-based view transcends transactional interactions and resulting obligations; instead, it promotes alignment across the lifecycle of product or service delivery (ISO/IEC 15288, 2008).

Furthermore, real-world project environments often involve a complex web of partners, designers, contractors, and subcontractors, which can be described as a "system of systems." In such contexts, the traditional, linear understanding of contracts becomes insufficient. Agreements and contracts must now be understood as dynamic interfaces between interdependent systems, requiring active coordination, assumption management, and feedback control—the hallmarks of systems thinking.

The systems approach would perceive an "Engineering Contract" as an *interconnected* system of obligations, responsibilities, and relationships—an approach grounded in the following principles:

(1) Holistic Perspective:
*Appreciate that contracts exist within broader economic, social, and regulatory environments.*

(2) Lifecycle Management:
*Address the contract's full lifecycle—from conception, negotiation, and execution to closure.*

(3) Stakeholder Integration:
*Actively involve all stakeholders and ensure that roles and responsibilities are clearly defined.*

(4) Dynamic Risk Management:
*Identify, assess, and manage relationship risks, particularly around stakeholder interactions.*

(5) Continuous Validation and Improvement:
*Regularly assess the contract's effectiveness in meeting the project goals and/or objectives.*

The notion of systems thinking relies on the concept of "system," which is introduced here through its definitions and scope of application—viz, how should any set of connected systems be treated?

The INCOSE Systems Engineering Handbook (INCOSE, 2015) defines a *system* as "A combination of interacting elements organised to achieve one or more stated purposes." Putting it more simply, a system is interpreted as "A set of related components that contribute to a joint goal in an organised way." Further, a system can be part of yet another system; thus, the notion of "Systems-of-Systems."

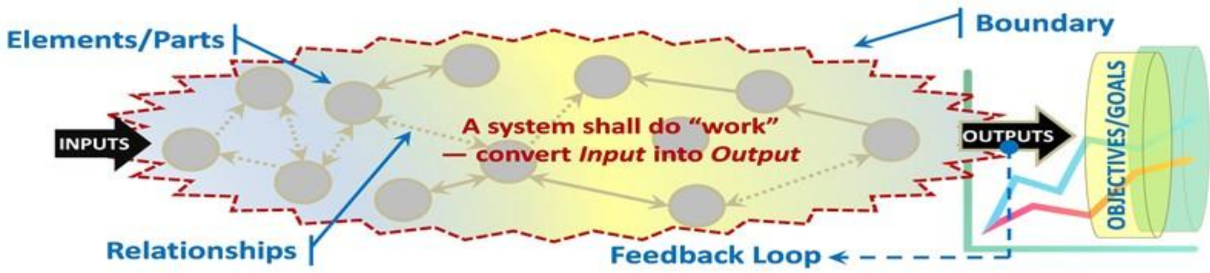


*Figure 1— Components of a Generic System*

A system is more comprehensively defined as "A construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents [e.g., contracts and other related artefacts]; that is, all things required to produce system-level results […]" (INCOSE, 2019).

Yet, the basic INCOSE definition of system reads: "A combination of interacting elements organised to achieve one or more stated purposes [or goals]" (SE for ITS, 2007). The keywords here are "*interacting elements*", without which this '*combination*' is reduced to a mere '*grouping of things*' and, therefore, would not necessarily lead or contribute to achieving a common purpose or a set of objectives. In the case of megaprojects, the common purpose or objective is "*a successful system*."

A system shall do "work", meaning, it gets involved in "*converting input into output*." This work relies on the various elements or parts of the systems and their relationships. However, it is argued that those *relationships* bear a greater influence on system performance compared to their *parts*. Further, a *feedback loop* is crucial in adjusting the work (of the system) and tracking its contribution to goals and objectives over time; no wonder, without this loop, the system may drift out of control.

The "world of projects" is replete with systems, and infrastructure is a technological system *nested* in a socio-economic environment. These dynamics manifest themselves in the realisation-system (the system established to deliver the project), the solution-system (the product of the project), and the context-system (the environment where the created product will be deployed)—because systems come in 3's (Scott, 2012). In terms of this article, one could expand on the realisation-system, which indeed consists of a social network working together towards a successful project.

> "The [infrastructure] project, which is a network formed by various stakeholders and their interactions, has the characteristics of a social network. The success of the project stems not only from the optimum plan, efficient allocation of resources, and utilization of control functions but also from a high-performance team, where the project participants communicate, exchange information, cooperate, etc. to complete the whole project efficiently and effectively. Moreover, megaprojects' social networks [i.e., realisation-system] are highly complex because of the large number of participants involved and great impact on society [...]" (Xie et al, 2019)

The individuals and entities involved in the realisation-system or the social network appointed to deliver the infrastructure project must cooperate (i.e., interact and share information). Further, the various roles they may play in the project's social network, the responsibilities they might undertake, and the obligations placed on them may entail relationship risks with influence on project success.

The complexity of this social network stems from its components and impact on segments of society. Therefore, "contracts" are usually needed to govern any *interactions* and *responsibilities* between or among parties in that social network. In infrastructure projects, contracts reflect the "system's workings." As shown in Figure 2, the working of the system aligns with '*goals and expectations'* from the relevant meta-systems (upper systems), but with '*capabilities and vulnerabilities'* of the sub-systems (lower systems)—and both determine the *overall performance* of the 'target-system'.

It follows that any delivery agent should accurately appreciate "*where*" the project at hand rests on the Hitchins-Kasser-Massie-Mabelo (HKM$^2$) Framework (below), lest one misconstrue which operational layers might constitute the respective 'upper' and 'lower' systems of their project.

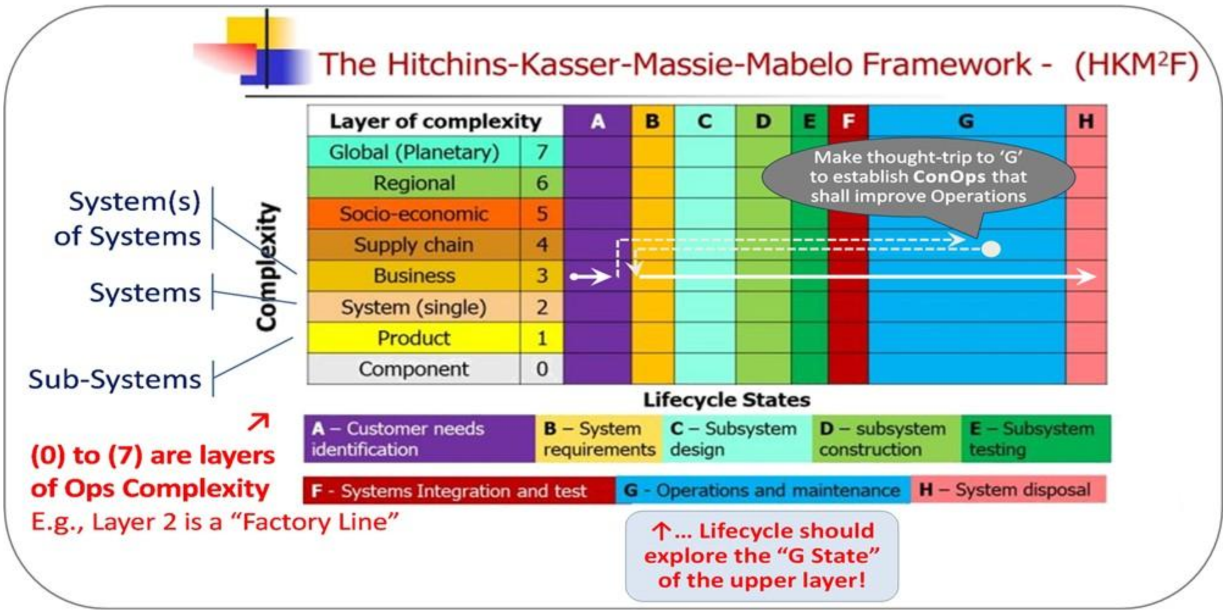


*Figure 2 — HKM$^2$ Framework (Systems Hierarchy and Lifecycle)*

The HKM[2] Framework describes, on the one hand, a hierarchy of operational systems (per level of complexity) and, on the other, the generic lifecycle (through its phases) for any system development. At the lowest level of complexity is the component or part; components are combined to produce a product—and interacting products combined to constitute a (singular) system to achieve a purpose. Therefore, components are classified as level 0, products as level 1, and (singular) systems as level 2.

Further, practical experience and recent theories suggest that singular systems are often integrated to constitute systems-of-systems; hence, the central notion of systems-of-systems alluded to earlier. Thus, HKM[2] refers to a singular system-of-systems as "business" (or more accurately, "enterprise"), and it is commonly accepted that most WETWITS (Water, Energy, Transport, Waste Treatment, Information Technology, and Social) infrastructure constitutes a business or enterprise at level 3. For instance, a power plant may consist of 'systems' such as coal piles, conveyors, boilers, turbines, generators, and transformers; these systems interact to generate electricity—the purpose of the plant.

Similarly, a set of interacting businesses or enterprises shall constitute a "supply chain" at level 4. In the case of the power plant, the national electricity grid represents one of such supply chains. Thus, an interacting combination of "supply chains" will constitute the "macro-economy" at level 5, and an integration of "macro-economies"—a web of socio-economic systems—will form a "regional economy" and, ultimately, an overlap of "regional economies" will constitute the "global economy".

Therefore, since infrastructure (e.g., power plant) resides at level 3 (enterprise), its upper systems (from which its *goals and expectations* shall derive) should be at level 4 (supply chain) and higher, as relevant. Likewise, its lower systems (from which its *capabilities and vulnerabilities* shall arise) should be at level 2 (singular sub-systems) and lower. On that note, agreements and contracts governing the delivery of the power plant ought to reflect and address any risks about the roles, responsibilities, and obligations among and between parties involved in supplying and integrating the plant's sub-systems (e.g., boilers, turbines) "*for the purpose of*" generating power into the grid.

It should follow that a project to build or expand the national electricity grid will entail a different set of purposes (from the macro-economy) and a level 3 sub-systems (i.e., interacting enterprises). However, no matter at what level one pitches such contracts, lawyers must understand that the whole process is mainly about identifying and allocating '*interactions and responsibilities*' risks and how to resolve disputes that may arise during the project—it is not about mere legal arguments! Hence, the following "minimum" legal principles should apply to every clause and in their totality:

(1) Offer: A clear proposal made by one party to another; however, a tacit offer is acceptable.

(2) Consideration: Something of "value" (e.g., cash, goods, services, duties) to be exchanged between the parties—this alludes to the "*quid pro quo*" (something for something) principle.

(3) Intention to create legal relations: Parties must intend the agreement to be enforceable in a court of law or similar courts; hence, a valid contract should include "legally binding" clauses.

(4) Acceptance: Unconditional agreement to the terms of the offer. The "*meeting of the minds*" (i.e., same perceptions of expectations) is essential for an offer and acceptance to be valid.

(5) Capacity: The "legal ability" of the parties or representatives to enter a contract or similar agreements; this generally refers to age, mental aptitude, sober mind, or not under coercion.

(6) Legality: The purpose of the agreement must be "lawful" (i.e., per the law) and not against public policy. It must also remain *physically or morally* possible, feasible, and unharmful.

## Contract Formation and Project Lifecycle

The previous section only discussed the transversal or layer dimension of the HKM$^2$ Framework; the longitudinal or lifecycle dimension is equally crucial, particularly in Contract Management. Project delivery proceeds through several phases, each with a specific purpose, aim, artefacts, deliverables (and minimum requirements thereof) and the activities needed for their development.

Furthermore, a well-documented project lifecycle model is required to apply systems thinking to managing project delivery; thus, such a *lifecycle* is also essential in Project Contract Management:

> "A well-documented project lifecycle model enables us to apply systems thinking to creating, planning, scheduling, and managing the project through all of its phases, and to evaluating both the success and the value of both the project and results that the project has produced […] This is of greatest benefit to the project owner, key stakeholders, the ultimate user of the project results, and the social beneficiaries of those results—whether it is a new process plant, a highway, a new business processor system, or a new product […]" (Archibald et al, 2012)

Concerning contracts, what is good for the project manager is also good for the contract manager. Effective Contract Management entails managing the '*interactions and responsibilities*' risks not only within each phase, but more importantly, across the successive phases of the project lifecycle. Figure 2 (above) illustrates that no matter the operational layer considered, system development must follow the same lifecycle with A to H consecutive phases, with some overlap when needed:

A - Customer Needs Identification:
*Understanding the end-users' or stakeholders' expectations and constraints to define value.*

B - System Requirements:
*Translating customer needs into measurable, verifiable technical/functional specifications.*

C - Sub-System Design:
*Structuring the system into components, defining interfaces, and allocating requirements.*

D - Sub-System Construction:
*Building and assembling components according to the design and applicable standards.*

E - Sub-System Testing:
*Verifying that individual components function as intended under "controlled" conditions.*

F - Systems Integration and Testing:
*Combining sub-systems and validating performance against global system requirements.*

G - Operations and Maintenance:
*Deploying the system into service, while managing reliability, availability, and support.*

H - System Disposal:
*Retiring the system responsibly, managing environmental/contractual closure obligations.*

It is worth mentioning that transitioning from Phase A (Needs Identification) to Phase B (System Requirements) is not as straightforward as it might appear. A closer look at Figure 2 suggests that a "*trip in thought*" to Phase G (Operations and Maintenance) of the upper level is required to grasp the *goals and expectations*. This exploration of the operational workings of the system at hand shall provide the Concept of Operations (ConOps), indicating how the community of users in the upper system exploit the system in a manner that adds value and improves operations at that level.

For instance, in a power plant project, the ConOps is derived from exploring the supply chain. Moreover, two critical issues must be noted on the transfer of responsibilities across the lifecycle:

(1) **Owner's Responsibilities:**

The owner or client is de facto responsible for the "*works of the project*" (i.e., creating the solution-system); however, they may elect to transfer this responsibility to any suitable entity or parties. Without delving into the details, Figure 3 (below) suggests that when the owner chooses to execute steps 1 and 2, but transfers step 3 onwards to a contractor or third party, they must issue an Owner Requirements Specification (ORS)—the basis of the *approved* delegation—at the handover point.

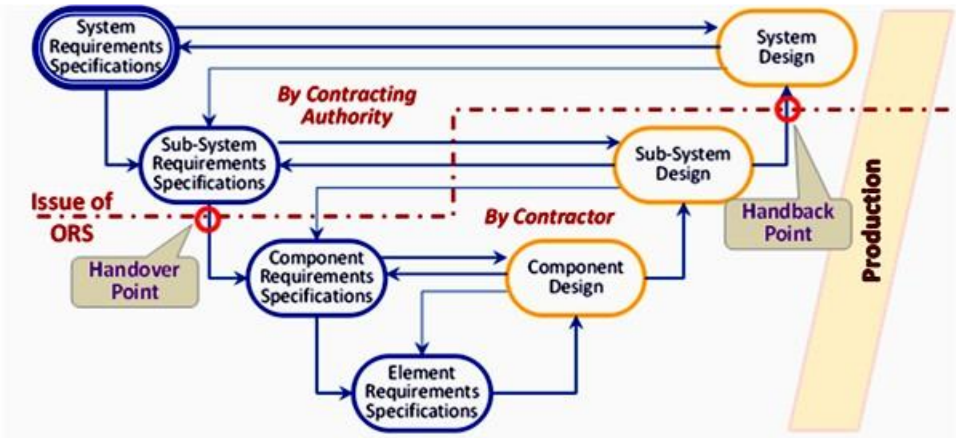


*Figure 3 — Transfer of Responsibility from Employer to Contractor (Adapted: ProRail, 2013)*

"*Imperium tenet dominus, sed ministerium traditor*" [Latin]—The command remains with the master, but the task is entrusted, delegated. This captures the essence of the owner's ultimate accountability while allowing for *temporary* transfer of responsibilities (for works to be executed) to contractors.

Figure 3 illustrates the mechanics involved in determining which portions and under what conditions the owner's responsibilities are transferred to the contractor. This outlook explains why the ORS should prominently feature in contractual arrangements with the contractor to secure project success.

Assuming the owner has the capabilities required to safely and effectively execute steps 1 and 2, the ORS should specify the conditions under which, and what elements of responsibilities are to be transferred; also, what the handback point might be, and any acceptance conditions and criteria.

This arrangement may suggest that everything up to the issuing of ORS falls in the owner's hands and, thus, everything beyond the issuing of ORS will be in the contractor's hands. The contractor, accordingly, is responsible for the consequences of decisions taken throughout the implementation of the ORS, right up to handback (of the work-in-progress) to the owner in line with the ORS. This scenario implies the owner has what it takes to execute any remaining steps towards success.

(2) **Transfer Requirements**

To discuss the requirements of an effective transfer of responsibility, one may take a trip to ancient Greece to evoke the "Myth of Sisyphus"—the man was doomed to a vain and ungrateful pursuit. For having upset the gods, Sisyphus was condemned to rolling a boulder to the summit of a hill; sadly, an insidious curse was inflicted on the boulder: it shall escape Sisyphus' hands every time it gets close to the summit. Sisyphus would follow the boulder down the valley—and then try again.

"And I saw Sisyphus in violent torment, seeking to raise a monstrous stone with both his hands. With hands and feet he struggled to roll it to the top of the hill, but just as he was about to heave it over the crest, the force of gravity turned it back, and the cruel stone rolled down again to the plain. Then he toiled again, sweating, and the dust rose over his head." (Homer, ~700 BC)

It would seem Sisyphus ought to handle two boulders: the physical one he had to roll up to the summit, and the subliminal one that always dragged him down the valley every time it escaped his sore hands. Hence, infrastructure delivery, when left to its own devices, would resemble this *perpetual* difficulty.

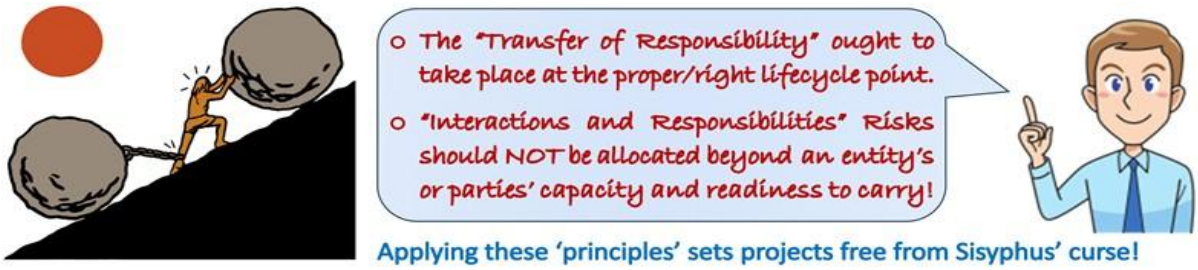


*Figure 4 — Representation of Sisyphus Dealing With Two Boulders Under the Sun*

Unless one is committed to achieving a meaningful set of objectives (i.e., improve operations, in line with strategy), the contract manager would feel like Sisyphus, the ultimate absurd hero, an individual working tirelessly with no final resolution and striving for meaning in a "universe" that offers none. To prove effective in infrastructure delivery, project professionals (e.g., contract managers) must learn from Sisyphus that the physical and the subliminal boulders should be addressed differently:

(i) From the *physical* boulder, one understands that the "*transfer of responsibility*" must happen at the proper/right points in the project lifecycle—between two "Front-End-Loading" phases.

(ii) From the *subliminal* boulder, one could learn that "*interactions and responsibilities*" risks should not be allocated beyond the contractor's capacity and readiness to carry them properly. This "*elusive*" boulder forever lurks, although not always perceived, and can easily escalate. Alas, traditional Contract Management has not made it obvious or addressed this *tricky* burden.

Owners' responsibility in Large Infrastructure Projects (LIPs) should be transferred at the right point of the lifecycle and only to entities with the capacity and readiness to execute them effectively. These Sisyphus principles shall remain a crucial recommendation to project and contract managers. For example, transferring project responsibilities *within* a phase may prove imprudent or ill-advised.

However, the Sisyphus principles would necessitate the application of a holistic lifecycle that not only reflects every phase of infrastructure delivery but also indicates "contract appointment" points with their preferred mode of funding (e.g., BOT, public-private partnership, bank loan, etc).

"It will not be of similar interest to a project [or contract] manager or an organization that only holds responsibility for one phase, or one aspect of one phase, of the entire project. Unless a well-documented, integrated, understandable picture of the overall lifecycle process—the model—for each project category/sub-category exists, it will be difficult to achieve the full benefits of modern, systematic project management" (Archibald et al, 2012) [*Underline added*]

On this note, the client may elect to transfer specific portions to a suitable party or contractors, or apply whole or portions of Engineering-Procurement-Construction or Engineering-Procurement-Construction Management activities (EPC or EPCM, respectively), giving rise to five alternatives:


*Figure 5 — Project Lifecycle, Showing Delivery and Operational Stages, and Funding Avenue*

(1) BOT – where a private entity is granted a concession from the private/public sector to finance, design, construct, own, and operate (and handback) a facility stated in the concession contract.

(2) PPP – involving a government agency collaborating with a private-sector entity or consortium that can finance, build, and operate a facility for some time, and hand it back in due course.

(3) Private Equity – where private capital is directly invested in commercial or project schemes.

(4) Bank Loan – providing medium or long-term finance to a project, with a fixed period over which the loan/debt is offered, the interest rate, and the timing and amount of loan repayments.

(5) Private Operator – involving a private entity for a fixed fee by the awarding authority for performing specific operations-related tasks; e.g., managing and maintaining an infrastructure.

Irrespective of the mode of Responsibility Transfer (and funding avenues), the realisation-system would produce "*emergent behaviours or properties*" (like effective project governance) owing to the complex *interactions* between and among the various 'agents' involved in project delivery. Hence, such "interactions" ought to be governed by a suite of contracts, or else there will be chaos.

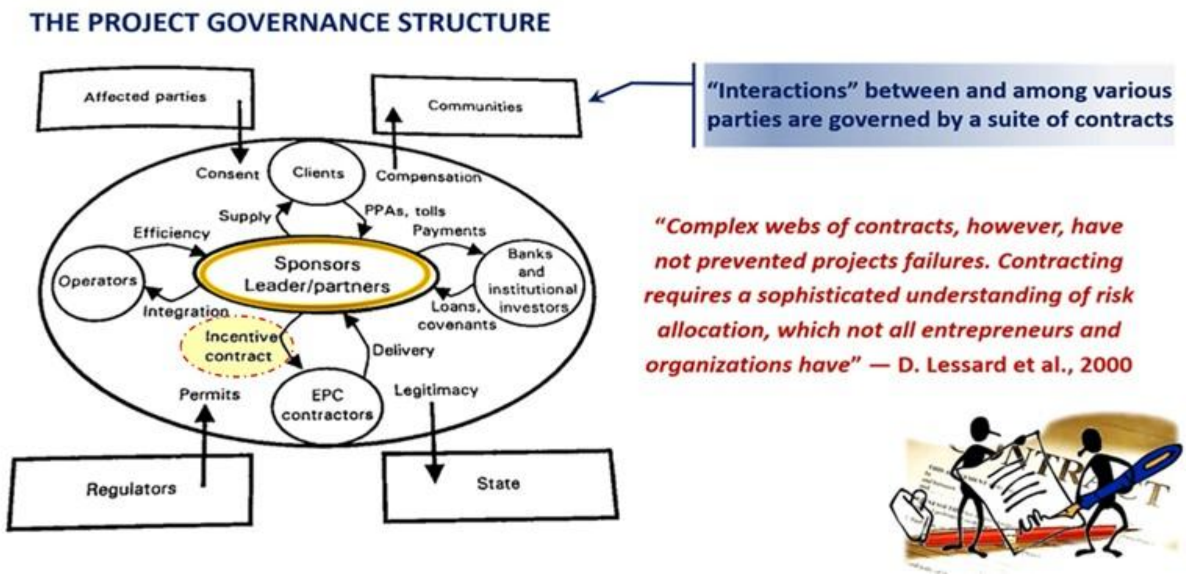


*Figure 6 — Project Governance Ecology (Adapted: Lessard et al, 2001)*

One must appreciate that "Incentive Contracts" should reflect other project agreements (i.e., arrows in Figure 6) with banks, regulators, affected parties, and communities in the governance ecology. For instance, penalties for contractors' late completion must align with those for late payments to banks. Equally, a promise to forward disused furnishings (e.g., doors, bathtubs) to the community should be reflected in the contract; thus, the contractor may adjust their reverse logistics accordingly. Refer to the Annexure for clause-stakeholder leverage points diagrams and more concrete examples.

## Contract Management Revisited

Contract Management (CM) is the process of overseeing legally binding agreements from their creation to their eventual termination. It involves managing the entire contract lifecycle, including drafting, negotiation, execution, performance monitoring, and renewal or termination. Effective CM ensures compliance, reduces risks, maximises value for all parties, and ultimately contributes to project success. Indeed, Contract Management is crucial to *successful* project delivery as follows:

- A significant portion of the project scope is outsourced (i.e., executed or provided by others);
- Significant and complex scope transfer between or among the parties involved in the project;
- Low margins and high competition prompt or exacerbate commercial disputes among parties;
- Projects are unique undertakings in scope/content and context, but are susceptible to change.

Contract Management is the process of managing contracts, deliverables, deadlines, contract terms and conditions while ensuring customer satisfaction. CM is about appreciating the '*rules of the game*':

- Managing contracts to achieve project and/or business objectives.
- Facilitating collaboration (i.e., interactions) between and among the parties.
- Ensuring contractual obligations are fulfilled and all parties receive due entitlements.

Contract Management is like conducting an orchestra: each musician (party) must know their part (obligations), follow the score (contract), and stay in harmony with others (collaboration). The goal is not just to play the notes correctly, but to deliver a *symphony* that resonates—on time, in tune, with shared purpose. Sadly, many of our flagship infrastructure projects—Medupi, Kusile, Gautrain, and Lesotho Highlands—sound less like orchestras and more like discordant ensembles, where poor alignment, lack of coordination, and conflicting *rhythms* result in cacophony rather than coherence.

To play this game effectively, contract managers shall learn, nurture, and master a blend of hard and soft skills. As shown in Table 1, effective Contract Management requires capabilities across a broad competency base, including risk management, financial acumen, and a good measure of contract law.

*Table 1 — Skills Required for Effective Contract Management (Adapted: Linton, 2001)*

| Skills | | % |
|---|---|---|
| 1. Understand contract terms and conditions | | 85 |
| 2. Negotiation tactics and planning | Soft Skills | 82 |
| 3. Soft skills (influencing, persuasion, etc) [i.e., Leadership] | Soft Skills | 76 |
| 4. Risk management | | 73 |
| 5. Financial analysis | | 70 |
| 6. Handling conflict situations and dispute resolution | Soft Skills | 66 |
| 7. Managing internal stakeholders | Soft Skills | 65 |
| 8. Understand the fundamental principles of contract law | | 60 |
| 9. Creating a performance framework for suppliers | | 56 |
| 10. Relationship management | Soft Skills | 55 |

The survey findings reveal a telling emphasis on "*understanding contract terms and conditions*," with less focus on "*identifying and allocating the interdependencies, responsibilities, and risks*" that underpin a systems-oriented perspective; this reflects a lingering transactional mindset. However, an Engineering Contract, when viewed through the lens of systems thinking, is not merely a legal instrument but an interconnected web of relationships, obligations, and performance interfaces. In a nutshell, it is about a paradigm shift, "*Beyond Clauses: Engineering Contracts as Living Systems*."

Since infrastructure is classified as business (or enterprise) at level 3 of the HKM[2] Framework, it is safe to assume that every system consists of components that are "viable systems" in themselves. Different contract types may exist on the same infrastructure project to reflect its various aspects:

> "Systems are made up of sub-systems that have the same generic organisational characteristics. In other words, viable systems [e.g., LIPs] are made up of [level 2] viable systems that are themselves made of viable systems. At every fractal level […] the same systemic laws apply. This means that you can use the same set of rules to model any organized system from a team right up to the socio-economic system of a country or an industry sector." (Hoverstadt, 2011)

> "A contract type needs to be suited to the specific environment, so within one project it can be wise to have several different contract types [i.e., to suit the different system "elements"], depending on scale, complexity and risk—thus, contract managers should have adequate technical expertise of the physical elements [and aspects] of the project." (NETLIPSE, 2008)

Contract Management is essentially concerned with the formation and administration of incentive-based contracts between the sponsor (on behalf of the owner or client) and EPC/EPCM contractors. Contract formation and contract administration are distinct yet complementary processes as follows:

- Contract Formation: The process through which a contract is created between various parties.
- Contract Administration: The process of monitoring and facilitating smooth performance of a contract to ensure a party fulfil its obligations and receives entitlements at the appropriate time.

Contract Formation includes the Pre-Award and Award stages, while Contract Administration covers the Management and Development and End of Contract Lifecycle stages. Figure 7 (below) depicts this four-phase process, each offering different degrees of leverage for value creation and extraction:

(1) **Pre-Award:**
*Planning, engaging stakeholders, selecting an approach, and establishing key documentation. Early decisions ripple through the system; misalignment creates downstream rework/disputes.*

(2) **Award:**
*Making the contract legally binding, assuming delivery risks, and activating administration. Formal system initiation; terms must reflect deliverables, interdependencies, and assumptions.*

(3) **Management and Development:**
*Monitoring progress, tracking changes, settling conflicts, and developing supplier/contractor. Real-time interaction is key, success defined by feedback loops and collaborative governance.*

(4) **End of Contract Lifecycle:**
*Reviewing contracts for termination or renewal, ending roles, responsibilities, and liabilities. Closure supports exit logic, sustainability obligations, legacy expectations, and future systems.*

True to the "feedback loop" concept as per systems thinking, thorough development work carried out during the Pre-Award phase (e.g., stakeholder engagements) would prevent costly disputes and legal woes at the End of Contract phase. "Downstream troubles, however, are symptoms of upstream shortcomings […] Upstream activities must be held responsible for issues they cause in downstream activities" (Oehmen et al, 2012) and "Attempting to quick-fix a *seemingly isolated* faulty element of the system may have negative impact on other areas of the system, not necessarily in close proximity of time or location […]"—usually making the problem worse (Mabelo, 2016).


*Figure 7 – Four Phases of Contract Management Cycle.*

This all-important Pre-Award phase entails selecting the right approach to Contract Management. Based on Kraljic (1983), Linton (2021) argues that the two key factors of value and risk involved in the agreements or contractual arrangements should be considered when choosing the approach:

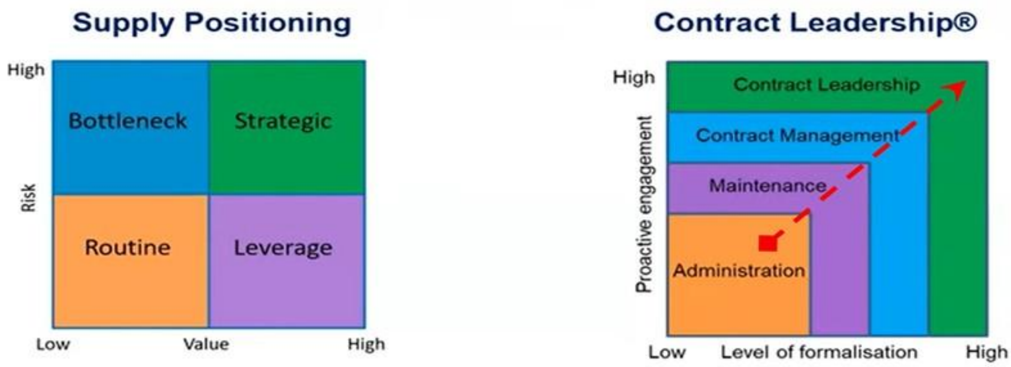


*Figure 8 — Contract Management Complexity Levels (Adapted: Linton, 2021)*

When appropriately combined, these dimensions of value and risk provide a four-quadrant grid as illustrated in Figure 8 (above, left-hand side)—with four different degrees of leverage as follows:

- Low Value—Low Risk entails a "Routine" in supply position.
- High Value—Low Risk implies "Leverage" in supply position.
- Low Value—High Risk creates a "Bottleneck" in supply position.
- High Value—High Risk necessitates a "Strategic" supply position.

Hence, Linton presents two dimensions of "Level of Formalisation" and "Proactive Engagement." The more important the contract, the higher the level of formalisation and "Contract Leadership." The Contract Leadership level would entail strategic stakeholder engagement to a greater extent:

(1) The lowest level of supply position is "Routine" and corresponds to the "Administrative" approach, relying on contractual paperwork to drive the infrastructure project to success. For instance, "*Work has been done; here are the invoices, please proceed with payments*."

(2) The second level of supply position is classified as the "Maintenance" approach. It relies on the contract terms and conditions to enforce governance and steer the project to success. For instance, "*What clauses should be revisited to derive the highest level/amount of value?*"

(3) The next level of supply position corresponds to the "Contract Management" approach. It relies on formalisation and engagement to manage higher and emergent project risks. For instance, "*What interactions risks can cause the project to lose value, fail altogether?*"

(4) The highest level of supply position corresponds to the "Strategic" approach, where, again, formalisation and engagements are used to manage critical risks and preserve project value. For example, "*What 'interactions' risks are likely to impair the highest value on the project?*"

## Contracts and Project Requirements

Under ISO 9001 (Quality Management Standard), the Quality Management System (QMS) applies to a wide range of organisations, including, but not limited to, production, testing, research, and inspection activities. QMS can be used for contractual or certification purposes; thus, in the case of large infrastructure projects, Quality Management Systems would be used in Engineering Contracts.

For example, in FIDIC contracts (devised by the International Federation of Consulting Engineers), it is recommended that the contractor and the Engineer take due regard of the FIDIC publication "*Improving the Quality of Construction*." However, the performance of the contractor's obligations under FIDIC Sub-Clause 4.9.1 includes, inter alia, "*preparing and implementing a QM System [QMS] to demonstrate compliance with the requirements of the Contract*" (FIDIC Red Book, 2017).

Accordingly, the contractor is mandated to fully implement a Quality Management System (QMS) —how the project *works* should be carried out and controlled. Such a Quality Management System, duly reflecting the Owner's Requirements Specifications (ORS), should ensure at least the following:

- Traceability: All construction processes and materials used are documented.
- Coordination: Interfaces within and between project stages are managed efficiently.
- Compliance: Project deliverables align with technical specifications (i.e., ORS) and timelines.

The QMS involves preparing method statements (i.e., work methods), inspection protocols, and maintaining comprehensive records. The appointed Engineer shall verify compliance by conducting site inspections, reviewing reports, and issuing corrective notices when necessary. For instance, the FIDIC framework's detailed compliance requirements ensure that quality standards are consistently met, minimising defects and disputes, and, thus, preventing or eradicating massive project overruns.

The contractor shall prepare and implement the project-specific QMS to demonstrate compliance with the contract's requirements. Such compliance is most effectively achieved through verification (confirming that requirements are met) and validation (per systems approach, attesting that the needs of clients/users are met). While the QMS shall be specifically prepared for the works and submitted to the Engineer within a prescribed period, its updates or revisions must be submitted without delay.

Particularly concerning requirements, Table 2 (below) describes the successive and increasing levels of elaboration of Owner's Requirements Specifications as per the project phases in the lifecycle. It is counterproductive to expect a detailed design level of requirements at the onset; "A common *malpractice* […] entails expecting *detailed* requirements from the project onset" (Mabelo, 2025).

*Table 2 — Level of Details of Owner's Requirements Over the Lifecycle*

| Project Phase | Requirements (i.e., ORS) Level | Description |
|---|---|---|
| ***Conceptual (FEL-1)*** | ▪ Business Needs/Requirements | What "organisation" seeks |
| ***Pre-Feasibility (FEL-2)*** | ▪ Overall System Requirements | What "system" provides |
| ***Feasibility (FEL-3)*** | ▪ System (Functional) Behaviours<br>▪ System Architecture (e.g., BIM) | What "elements, interfaces" will make "system" function |
| ***Execution/Construction*** | ▪ Detailed Design/Measurements<br>▪ V&V Plans (fitted in Contracts) | What "shape, size, physical, etc, performance" criteria ... |

In the context of ISO 9001, quality is defined as fitness for purpose or conformance to requirements. It is the totality of features and characteristics of a product, service, or both that bear on its ability to satisfy stated or perceived needs. Particularly for LIPs, one should rely on the "*conformance to requirements*" aspect of quality because it is objectively measurable, not subject to whims and moods.

Hence, the appointed Engineer ensures that "*project progress aligns with and meets requirements*" by monitoring compliance with technical specifications and quality of workmanship—and seeks to address any deviations. Through inspections and reviews, they enforce the QMS, provide feedback, and minimise risks of non-conformance and disputes. Such a function is of paramount importance:

> "You can't manage cost [or money] and schedule [or time] without managing the 'technical content.' It's where the time and money go [when doing project work]" (Forsberg et al, 2005)

The QMS is positioned as a critical link within this system, providing real-time or periodic feedback. Yet, many contract managers are desperately trying to control the budget and/or schedule (e.g., by tightening processing of invoices and payments) long after the Engineer has lost control of technical works. Thus, the project QMS must ensure clarity and unambiguity in the drafting of conditions of contracts (e.g., Particular Conditions in FIDIC forms or Z-Clauses in NEC forms) to avoid disputes:

- Ensure all records are traceable to the relevant works, goods, or tests.
- Ensure coordination and management of interfaces between work stages and Subcontractors.
- Intended and prepared for submission of the contractor's documents to the engineer for review.

For instance, FIDIC Sub-Clauses 5.4, 8.4, 8.5, and 20.1 may result in the following QMS cautions:

(1) Instead of stipulating that, "*The Contractor shall complete the works in accordance with all applicable standards*," specify instead that, "*The Contractor shall complete the works in accordance with the [specific list of standards, or clauses, or sub-clauses], as published on [date], including any amendments effective as of the Contract Date*."

(2) Rather than rely on a vague clause on time extensions, such as "*The Contractor may request additional time for unforeseen issues*," provide a detailed process: "*The Contractor may request an extension of time for completion due to unforeseen issues beyond the Contractor's control, as defined in Clause [X], by submitting a written request within [Y] days of the issue's occurrence, detailing the reason for the delay and the additional time required*."

Once the appointed Engineer has duly accepted the QMS, the contractor must use it to prepare and submit reports to demonstrate and ascertain compliance with the project requirements. For instance, FIDIC Sub-Clause 4.9.2 (Red Book) stipulates a set of provisions applicable to QMS compliance:

- "*The Contractor shall prepare and submit to the Engineer a complete set of compliance verification [or rather Verification and Validation, as per systems approach] documentation for the Works or Section (as the case may be), fully compiled and collated in the manner described in the Specification or, if not so described, in a manner acceptable to the Engineer*."
- "*Compliance with the QM System and/or Compliance Verification System [or rather both Verification and Validation, in line with systems approach] shall not relieve the Contractor from any duty, obligation or responsibility under or in connection with the Contract*."
- "*Unless otherwise stated in the Specification, each progress report shall include: […] copies of quality management [QMS] documents, inspection reports, test results, and compliance verification [and validation] documentation*."

Still, traditional Contract Management isolates requirements from assumptions, causing integration mismatches and disputes. A systems approach views a contract not merely as a legal transaction but as a living interface between expectations (assumptions) and deliverables (promises). As the SAAB study on Contracts-Based Systems Engineering (Herzog and Andersson, 2009) illustrates, capturing, and negotiating assumptions early on—alongside requirements—enhances collaboration, prevents late-stage failures, and accelerates integration. The author reviews the SAAB case in the box below:

**Case Study: Contracts and Requirements — A Systems View**

***Overview:***

Traditional Contract Management often assumes that defining clear and static requirements is sufficient to guarantee delivery. However, complex engineering and infrastructure projects operate in environments of uncertainty, where assumptions evolve, interfaces shift, and system interactions defy linear documentation. A systems approach to contract formulation recognises that project success depends not only on documented deliverables, but also on understanding, sharing, and updating the assumptions that underpin or extend them.

***The SAAB Aerospace Experience:***

In a study on Contract-Based Systems Engineering, SAAB Aerosystems introduced the innovative concept of explicitly modelling both promises (deliverables) and assumptions (contextual dependencies) as part of their contractual and design strategy. This approach enabled concurrent subsystem development without waiting for the complete stabilisation of system-level requirements, which is an essential capability in highly complex or fast-paced projects.

Their experience revealed six critical insights that challenge conventional, transactional contract practices:

1. Over-reliance on Textual Requirements is Problematic
   "*The prevailing industry practice is to focus exclusively on textual requirement statements [...] with little regard placed on the assumptions made on the components and interfaces in the design process*."
2. Hidden Assumptions Are a Major Source of Integration Failures
   "*The lack of system knowledge at the time of requirement formulation makes attempts to achieve completeness impractical—even counterproductive*."
3. Contracts Should Capture Both Promises and Assumptions
   "*A promise coincides with a requirement [...] but assumptions allow engineers to state expected behaviours of the environment in a persistent format*."
4. Systems-Based Contracting Supports Concurrent Engineering
   "*Concurrent subsystem development can be initiated and coordinated before system requirements are stabilised*."
5. Assumption-Promise Contracts Improve Cross-Team Communication
   "*Assumptions have highlighted design problems [...] and served as drivers for harmonising subsystem design solutions"—each member contributes a specific skill or expertise to achieve a common goal.*
6. Contract Inspection Can Begin Early Using Models
   "*Early verification is performed through contract inspection [...] based entirely on model content*."

By embedding assumptions alongside promises in model-based contracts, SAAB's engineers were able to:

- Detect mismatches in design expectations early;
- Coordinate across (eclectic) teams more effectively;
- Resolve integration issues prior to physical assembly;
- Shift from a reactive to a proactive quality assurance process.

***To be continued ...***

***Link to FIDIC and the Quality Management System (QMS):***

FIDIC's Sub-Clause 4.9 mandates the contractor to implement a QMS. Traditionally, QMS documents are treated as mere compliance checklists. From a systems thinking perspective, a QMS is not just about process control—it is also a vehicle for making expectations (i.e., assumptions) visible, measurable, and adjustable.

***An effective QMS under FIDIC:***

- Embeds verification (and validation, per systems approach) mechanisms at all stages;
- Defines inspection and test plans linked to evolving assumptions;
- Helps manage quality through clarity, traceability, and feedback;
- Provides assurance not only of physical outputs, but of systemic integrity.

***Key Takeaways of this case study:***

- Conventional contracts often assume stability of context. A systems view acknowledges uncertainty and seeks to manage it through dynamic, cross-referenced models.
- When developed from a systems perspective, a Quality Management System (QMS) bridges the contract, design logic, and field execution.
- As SAAB illustrated, capturing assumptions as contract artefacts transforms the contract into a living system of expectations, enabling better alignment, risk management, and trust across disciplines.

***Implications for Engineering Contracts:***

(1) Contracts should enable, not constrain, collaboration across uncertain boundaries.
(2) Clearly stated assumptions and verifiable context should accompany Requirements.
(3) The QMS should be treated as a design-support and integration tool, not merely a compliance tool.

***Conclusion:***

Contractual success on large infrastructure projects depends not only on clause enforcement but on systemic coherence. By embracing contracts as interfaces between human intentions, design logic, and operational systems, project stakeholders can foster resilience, clarity, and high-performance delivery.

As the review of the SAAB case suggests, an effective implementation of the systems approach to Engineering Contracts must begin with consideration and accommodation of holistic requirements.

> "The systems approach to engineering contracts involves using systems thinking to identify and allocate interaction risks in managing the entire project lifecycle, from initial requirements to final delivery, with a sustained focus on integrating various project elements and managing interdependencies. Unlike in traditional Contract Management, this approach emphasises risk management, collaboration, trust, and a holistic view of the project as a system-of-systems."

This stance results in a Quality Management System that is not just about process control, but is also a vehicle for making expectations (or assumptions) visible, measurable, and adjustable—effectively bridging the contract, design logic, and field execution to ensure a successful infrastructure delivery. The approach must also allow regular contract validation and improvement, as per systems thinking; in the unfortunate event that the contract itself proves unsatisfactory, amendments should be made.

With a holistic QMS as a yardstick, it is no wonder the "feedback loop" (e.g., inspections and reviews for verification and validation) is comprehensive and, thus, provides a clear and accurate picture of progress (i.e., *that project progress aligns with and meets requirements*), obligations, and risks—monitoring of compliance—and project outcomes contribute to goals and objectives as per strategy. Only on such a basis would inspections, claims, and payments be treated without any apprehensions.

## Inspections and Claims Mechanisms

The effective application of the QMS is generally aligned with the adopted claim regime; the degree of compliance informs the obligations due to the contractor. Payments are essentially moderated to reflect progress. Therefore, standard conditions of contracts (whether FIDIC, NEC, JBCC, or GCC) provide a structured approach to claims, ensuring both parties' rights are "*adequately*" protected:

- Contractor Claims: Common project claims include Extensions of Time (EOT) and additional payments for unforeseen circumstances. Contractors should notify the Engineer promptly and submit substantiated claims within a prescribed period, unless otherwise stipulated in writing.
- Employer Claims: Employers may claim damages for delays, defects, or non-performance. These owners' claims must also follow specified notification and documentation procedures.

A systematic and structured claim process reduces doubt and conflicts by promoting transparency. Further, an effective claim process should distinguish between excusable and compensable delays:

- Excusable Delays: These are delays beyond the contractor's control, including force majeure, adverse weather, or any legal changes. Contractors may request an Extension of Time (EOT) but not financial compensation, giving notice within a specified number of days after an event.
- Compensable Delays: These occur due to omissions or actions by, on behalf of the employer, such as late site access, delayed approvals, or changes to the scope of work. Contractors can claim both EOT and additional costs incurred, providing reasons for such claims.

Applying the most suitable contract and payment system is crucial for the success of infrastructure projects here in Africa and globally. Understanding the implications of each payment structure helps project stakeholders efficiently manage risks, control costs, and enhance infrastructure delivery.

FIDIC allows four Payment Methods. Each FIDIC contract form is associated with specific payment methods aligned with project requirements and risk allocation. The main payment structures include:

- Lump Sum (Fixed Price) Method: The contractor assumes a greater risk as the price is fixed. This method is popular in EPC and Design-Build projects (Silver, Yellow, and Gold Books) where design responsibility rests with the contractor. Payment is based on a percentage of work completed or per milestone; yet, the "*fixed amount*" may be exceeded per approved Variations.
- Measurement (Unit Rate) Method: This approach is common in projects with uncertain scope where adjustments may be needed (per FIDIC Red Book). Thus, payments are made based on actual quantities of work performed, as verified and validated by the Engineer through QMS.
- Cost Plus (Reimbursable) Method: This approach provides flexibility but may lead to higher costs if not properly managed. It is applicable where the contractor is reimbursed for actual costs plus a fixed or percentage-based fee (e.g., in the FIDIC Gold Book for BOT contracts).
- Target Cost Method: In this approach, cost savings/overruns are shared between the employer and contractor, encouraging efficiency and risk-sharing, and providing incentives to "parties" to strive for cost savings. It is adaptable to different books, typically in collaborative contracts.

Just as it was earlier argued that it can be wise to have several different contract types in the same project, it may equally prove wise to apply a judicious combination of the above payment methods in the same contract—so long as viability is maintained at the level of "elements" where they apply.

Most structured payment mechanisms (for contractors) are designed to ensure fairness and financial stability. Such mechanisms must be acceptable to the employer and its financiers, and often include:

- Advance Payments: Initial funding to contractors, secured by an advance payment guarantee.
- Interim Payments: Periodic payments based on work completed and certified by the Engineer.
- Retention Money: A portion of payments withheld to ensure due 'defect rectification' during the Defects Notification Period; however, percentages and limits of retention must be stated.
- Variations: Payments for additional or modified works, subject to agreement and certification.

Construction contracts provide for an independent third party to issue certificates indicating specific events and embody administrative decisions. These types of certificates are a manifestation of the parties' private (not legal) agreement, and their effect is no more than what the parties have agreed.

Payment applications must be supported by detailed documentation, including progress reports and invoices. The Engineer evaluates these applications to certify any amounts due, ensuring compliance with contract terms. The function of any certificate is to record events and QMS compliance; such a structured process ensures project outputs meet contractual quality standards and minimise rework. Making payments above *actual* progress or despite non-compliance can breed overruns and disputes. To protect the project from such predicament (i.e., undeserved payments), the contract should ensure rigorous inspection and testing procedures, detailed in specific clauses, must be in place and include:

- Regular inspections by the Engineer.
- Scheduled tests at critical project milestones.
- Documentation of results and corrective actions for non-compliance.

Nevertheless, as one might have alluded to earlier, traditional Contract Management heavily relies on verification in determining compliance. Yet, from the systems thinking perspective, verification alone, while necessary, is not sufficient to establish the extent to which "*project progress aligns with and meets requirements*." Therefore, a more appropriate QMS should involve both verification (i.e., that requirements are met) and validation (i.e., that the client's needs and goals are sufficiently met).

Moreover, in line with the first law of effective systems engineering—"*Systems Come in 3's*"—namely, realisation-systems, solution-system, and context-system (Scott, 2012). Hence, any holistic QMS ought to stretch beyond the realisation-system (system used by the team to design the solution) to involve the solution-system (system being designed) and the context-systems (where the solution will live). This stance departs from traditional Contract Management, in line with systems thinking.

It is worth noting, as Figure 1 illustrates, that indeed the project contract (as a system) should involve a "feedback loop". Therefore, the QMS should function as such a "link" to ascertain the extent and suitability of project delivery in addressing an *undesirable* situation under the *"as-applied"* contract. Should the contract system prove inadequate, changes must be made to render it more effective—in BOT contracts (Gold Book), constructability aspects often remain *vague* until later in the lifecycle. In much the same vein, QMS outcomes should determine whether and to what extent delivery has contributed to project objectives and goals over time. Consistently negative feedback (i.e., delays, overbudgets, non-compliance issues) may indicate "maladies" in the delivery or realisation-system.

Along with the feedback loop, the contract system could be summarised with the following features:

- Inputs: Requirements, clauses and QMS, skills/labour, materials, equipment, budget, time, etc.
- Relationships: Cooperation among stakeholders, interconnections across contract clauses, etc.
- Outputs: Solution-system (i.e., structures and/or facilities) that solve "*undesirable situations*."

Traditional Contract Management primarily focuses on QMS for the realisation-system, with limited consideration for quality compliance within the solution-system and context systems. For instance, FIDIC focuses on "realisation-based" QMS (quality reviews) and has no explicit process to address poor performance during operations—to establish to what extent the project might have "improved" operations. Thus, the contract manager shall resort to *incidental* clauses to gauge quality compliance:

- Clause 11 - Defects Notification Period (DNP): Following Taking-Over, the DNP commences. The contractor is responsible for remedying any "quality" defects and/or damages identified.
- Sub-Clause 14.10 - Statement at Completion: This provision facilitates the early settlement of financial matters, providing a clearer understanding of any outstanding (financial) liabilities.
- Sub-Clause 14.11 - Final Statement: The contractor submits a draft Final Statement to achieve a mutually agreed Final Statement, ensuring all financial aspects are conclusively addressed.

Table 3 (below) recommends basic verification and validation concerns for the realisation, solution, and context systems for a water treatment plant project. Any QMS that ignores the solution-system could create a "wrong" project—it is well-executed, but not fit for purpose. Similarly, the QMS that ignores context exposes the project to the proverbial "dead horse" syndrome—right solution, well-executed project, but the system cannot be used in operations (e.g., crippled by operability failures).

*Table 3 – Example of Verification and Validation (V&V) on Infrastructure Projects*

| Verification & Validation — Example of "Mweene Water Treatment Plant" (MWTP) Project | | | |
|---|---|---|---|
| QMS to "extend" to Solution & Context | ***QMS @ Realisation System*** *(Are the works completed?)* | ***QMS @ Solution System*** *(Is the right solution provided?)* | ***QMS @ Context System*** *(Are the problems addressed?)* |
| ***QMS by Contractor if:*** | *Red/Green or 'other' Book* | *Yellow or Silver or Gold Book* | *Gold Book* |
| ***Verification Focus:*** | *Are the 'components' built and assembled per Design?* | *Is the Plant producing 25 ML of 'drinkable' water per day?* | *Is each 'citizen' receiving 125 L of 'drinkable' water per day?* |
| ***Validation Concern:*** | *Does the 'assembly' form a functioning Water Plant?* | *Is sufficient 'drinkable' water reaching all targeted areas?* | *Are 'communities' becoming more productive (higher GDP)?* |

Since the feedback loop manifests itself through verification and validation, and considering that "*Systems come in 3's*", the holistic QMS should extend to the solution and context systems as well:

- When the contractor is not involved in the design, QMS covers only the realisation-system;
- When the contractor is involved in the design, QMS should also cover the solution-systems;
- When the contractor is involved in operations, QMS should extend up to the context-system.

Adopting the systems approach to Engineering Contracts entails a comprehensive and holistic QMS. Thus, inspections, testing, reviews, and analysis should extend beyond the physical facility to cover the capabilities created and the actual "*improvements in operations*" following system deployment. What a great day it would have been if only these validation provisions had been applied to Medupi!

When the contractor is involved in part of the operations (e.g., in Build-Operate-Transfer contracts), Handback Requirements shall apply in addition to extending QMS provisions to the context system. This is consistent with provisions around the transfer of responsibility and the Sisyphus principles. Yet, the connotation Handback Requirements seems harmless; for instance, under the FIDIC Gold Book, Sub-Clause 8.7 [Delay Damages], the contractor shall ensure that the works comply with the 'handback' requirements specified in the Employer's Requirements (i.e., ORS). Though FIDIC intends to discharge the contractor from post-contractual defects' liability (after Defect Notification Period, DNP), here the exact opposite can be *stated* in the Employer's Requirements by including residual life requirements for the work because of the ensuing handback—examples are as follows:

- There is often a requirement that at least 85% of the road pavement should have a 10-year residual life on handback be included in the agreement, specifically for BOT/DBO contracts.
- Specific handback requirements can be found in bridge projects. Although bridges generally have a design life of 120 years, it is usually considered necessary to demonstrate that most elements (or totality) of these structures have a residual life of at least 30 years on handback.

No wonder FIDIC contracts, to cite them, provide for a joint inspection not less than 2 years before the expiry date of the Operation Service Period to identify maintenance and replacement needs to satisfy the handback requirements and the possible remedial actions that may be required to achieve the specified standards. Consequently, part of the payments to the contractor (i.e., claims based on QMS results) can be withheld and used to remedy defects if handback criteria are not met at expiry. When Building Information Modelling (BIM) is used, the QMS should also include a Digital Twin.

This structured approach, albeit indirectly, ensures that post-completion defects are systematically addressed, maintaining project integrity and quality per QMS, ensuring post-completion ”quality” reviews and defect rectifications are conducted methodically, safeguarding the interests of all parties. Moreover, Post-Implementation Reviews (PIRs)—as a project management tool—are required to establish the extent of “operability” (or lack thereof) during operations. Thus, “operability-based” PIRs are needed (as Particular Conditions) to confirm if the infrastructure is operating at intended levels. However, such PIR provisions are inherent in the FIDIC Silver and Gold Books as follows:

(1) Silver Book (EPC/Turnkey Projects)
Performance Guarantees and Liquidated Damages (Sub-Clauses 4.2 and 8.7): “*If the delivered facility does not meet the guaranteed performance levels [during operations], the Employer may apply liquidated damages for under or poor performance. These damages serve as an incentive to ensure compliance with ‘operational’ expectations*.”

(2) Gold Book (Design, Build, and Operate)
These contract types already maintain the basic provisions of Post-Implementation Reviews. The Gold Book goes further than the Silver Book; it includes an Operation Service Period, meaning, post-implementation performance is duly enforceable as a contractual requirement.

- Continuous Performance Review—Operation Service (Clause 10):
“*The Contractor is fully responsible for ensuring the facility performs as required for the duration of the operation period (often 20 years or more).*”
- Performance Monitoring and Payment Adjustments (Sub-Clause 14.15):
”*Payments to the [BOT/DBO] Contractor are linked to performance during operations. If performance standards (e.g., efficiency, reliability, safety) are not met, the Employer can reduce payments (performance-based penalties) or insist on remedial actions*.”

As the foregoing discussions reflect, the Gold Book is stricter in enforcing post-implementation operability due to its long-term operational component. Meanwhile, the Silver Book relies mostly on upfront testing and defect liability provisions, but does not monitor *long-term* performance once the contract ends upon the Taking-Over. Again, it is all about proving improvements in operations.

“*Dura lex, sed lex*” [Latin]—The law is harsh, but it is the law. This universal adage reminds us that rigid, rule-bound frameworks may offer clarity, yet they often fall short of real-world adaptability. A systems approach does not discard structure but rather recontextualises it—to ensure contracts serve as enablers of performance, not instruments of inertia; and drivers of success, not constraints.

## Conclusion

Across the globe, the construction industry is one of the greatest contributors to the general economy. However, due to the ever-increasing complexity of Large Infrastructure Projects (LIPs), traditional Contract Management approaches have struggled to cope with their intricacies, scale, and fast pace, leading to widespread issues such as cost and schedule overruns, disputes, and even project failures.

This paper argues that traditional Contract Management—focused narrowly on legal enforcement, risk shielding, and transactional compliance—no longer suffices in the complex, high-stakes world of LIPs. While legally sound, such an approach can be rigid, focusing primarily on enforcing terms and clauses rather than enabling project success, which is increasingly inadequate for infrastructure project delivery where complexity, stakeholder interdependence, and uncertainty prevail due to stakeholder diversity, complex interfaces, and dynamic environments. A new approach is required.

As complexity and interdependence rise, a shift is needed: not just in what contracts contain, but in how they function as a living interface between expectations (i.e., assumptions) and deliverables (i.e., promises). The systems approach sees the contract not as a static rulebook but as a living interface—a coordination mechanism, a source of alignment, and a dynamic repository of promises and assumptions. When designed and administered systemically, contracts become infrastructure in their own right: connecting stakeholders, synchronising intent, and promoting continuous learning. Thus, this systemic perspective urges a rethinking of key Contract Management practices as follows:

(1) From oversight (of clauses) to insight (from interactions).
(2) From document control to a holistic system orchestration.
(3) From dispute avoidance to co-creation of enduring value.

Throughout this paper, case examples—Medupi, Kusile, Lesotho Highlands, and SAAB Aerospace—have illustrated the real costs of treating contracts as detached documents and the potential value of managing them as systems, focusing not only on clause enforcement but on systemic coherence. Not only should the approach to Contract Management align with the lifecycle, but it ought to also consider the level of operational complexity, the skills needed to manage relationships, the domains of requirements, the mechanisms of transfer of responsibility, and the risks involved in steering the project to success—and everything else that significantly contribute to meeting goals and objectives.

As ISO/IEC 15288, INCOSE guidance, and FIDIC's evolving emphasis on the QMS and lifecycle management suggest, the industry is slowly pivoting in the right direction by adopting the systems approach that considers the whole web of interconnected relationships, obligations, and performance interfaces to maximise project value. However, for meaningful change, practitioners must move beyond procedural compliance toward systemic fluency in managing Engineering Contracts (ECs).

A systems approach to ECs is not merely an academic ideal. It is an operational necessity for projects that must face complexity, enable cooperation, and deliver public value. To borrow from the Stoics: "*Quod differtur, non aufertur*" [Latin]—What is delayed is not avoided. If the industry delays this transformation, the consequences—huge overruns, fragmented delivery, broken trust—will persist.

The time has come to recognise that Engineering Contracts are no longer legal artefacts tucked away until disputes arise. In the complexity of LIPs, they are active systems of governance—alive with feedback, dependencies, and intersystem expectations. A contract is not a mere rulebook; it is the DNA of project delivery. Embracing this systems lens is no longer a matter of innovation—it is a matter of survival for high-stakes infrastructure projects; it is about increasing or destroying wealth.

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## Additional Readings

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# Annexure

**Application of a Holistic Quality Management System (QMS) in a Generic Project Ecology:**

As Figure 6 (Project Governance Ecology) in the main text would suggest, any FIDIC contracts governing the relationships between the Project Company and the EPC/EPCM contractors should reflect current/planned agreements among other entities in the project ecology. These nexuses may significantly influence stakeholder roles, contractual interactions, and ultimately, project success. An item not to be ignored is the BIM supply agreements—so crucial to large and complex projects.

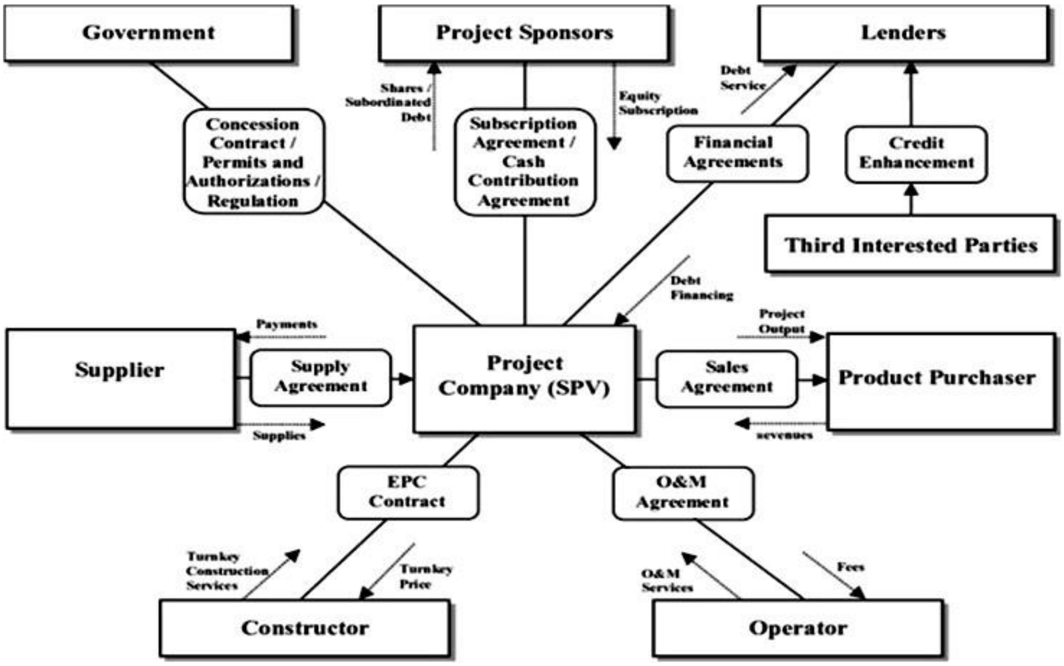


*Figure 9 — Example of a Generic Contract Ecology (Source: Unknown)*

This project ecology could be visualised as a "systemigram" that shows the main stakeholders and their connections to key FIDIC clauses (as sampled for illustration purposes) to highlight leverage points in terms of either delivery agents or clauses. The same information is addressed in Table 4.

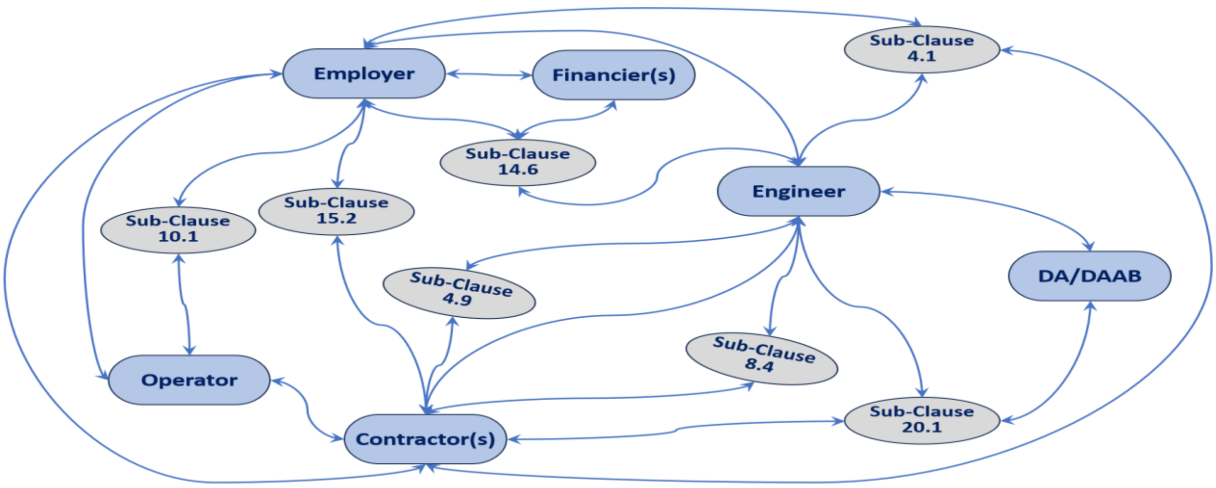


Figure 10 — Contractual Systemigram: Stakeholder Interactions and Clause Interfaces

It is evident from the above systemigram that the highest leverage points can be identified in the roles of Engineer, Contractor, and Employer (with seven to eight arrows), as well as in Sub-Clauses 4.1 [Obligation Definition], 14.6 [Payment Certification], and 20.1 [Claims Procedure]. The project and contract managers would do well to focus on these three roles and three sub-clauses.

Further, the systemic nature of FIDIC may also be summarised in the table below. Since the same roles are involved in many provisions, a single dereliction of duty may propagate across the web of sub-clauses; an inept Engineer may impair sub-clauses 4.1, 4.9, 8.4, 14.6, and 20.1—a ripple effect!

*Table 4 — Examples of Risks Arising from Selected FIDIC Clauses*

| Clause | Stakeholder(s) Involved | Type of Interactions | Risk or Note |
|---|---|---|---|
| 4.1 | Employer, Engineer, Contractor | Obligation Definition | Any ambiguity here can affect scope clarity |
| 4.9 | Contractor, Engineer | Performance/QMS Compliance | Misalignment with operational readiness |
| 8.4 | Contractor, Engineer | Time Entitlement | Requires timely notification, affects the critical path |
| 10.1 | Contractor, Operator, Employer | Operational Interface | Risk of inadequate testing/commissioning |
| 14.6 | Engineer, Employer, Financier | Payment Certification | Delayed payments can trigger cash flow stress |
| 15.2 | Employer, Contractor | Termination Trigger | Escalates risk exposure, often contentious—only as a last resort! |
| 20.1 | Contractor, Engineer, DAB | Claims Procedure | Documentation-heavy, failure leads to forfeiture |
| 21.6 | DAB, Employer, Contractor | Final Dispute Determination | Binding recommendation, high cost if escalated |

Moreover, Table 3 (Example of Verification and Validation on Infrastructure Projects) indicates that the *holistic* Quality Management System (QMS) should address not only the realisation-system, but also the solution-system and context-system to establish compliance with the contract. Thus, one will maintain, in addition to incorporating clauses in the Particular Conditions to reflect the essence of the various agreements manifest in the project ecology, that the *holistic* QMS must accommodate considerations from the realisation, solution, and context systems, as seen in Table 5:

*Table 5 — Examples of QMS Considerations Around Realisation, Solution, and Context Systems*

| Key Stakeholder | Realisation-System | Solution-System | Context-System |
|---|---|---|---|
| Operator | *Is design per ConOps?* | *Is asset capacity suitable?* | *Is operation per ConOps?* |
| Product Purchaser | *Is asset built properly?* | *Is asset sustainable? Safe?* | *Is quality good, cheap?* |
| Supplier | *Are right parts ordered?* | *Do parts perform well?* | *Are warranties in place?* |
| Project Sponsors | *Does asset have value?* | *Is asset fit-for-purpose?* | *Asset help balance sheet?* |
| Government | *Is asset built per permit?* | *Does asset fit concession?* | *Does asset create jobs?* |

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Pascal Bohulu Mabelo *(MBA, MSc Industrial, BSc Civil, Pr. Eng, Pr. CPM, Pr. PMSA, PMP)*, has more than 25 years of professional experience and possesses a wide range of technical and managerial skills in large and complex infrastructure projects. He has worked on large infrastructure projects as a design engineer, project/programme manager, project consultant and project management executive. Pascal was honoured to serve as the national chairman of Project Management South Africa (PMSA), the leading Project Management professional association in Southern Africa.

Pascal has published the book: "*Managing Engineering Processes in Large Infrastructure Projects*" (Cambridge, 2021); he has also published, "*How to Manage Project Stakeholders—Effective Strategies for Large Infrastructure Projects*" (Routledge, 2020) and "*Operational Readiness—How to Achieve Successful System Deployment*" (Routledge, 2020). Through various publications, journal articles, and conference presentations, he assiduously promotes the application of Systems Thinking and/or Systems Engineering principles, concepts, and practices to unravel complexity in Large Infrastructure Projects (LIPs) to address their persistent risks of failure and their massive, even pernicious, cost and schedule overruns.

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