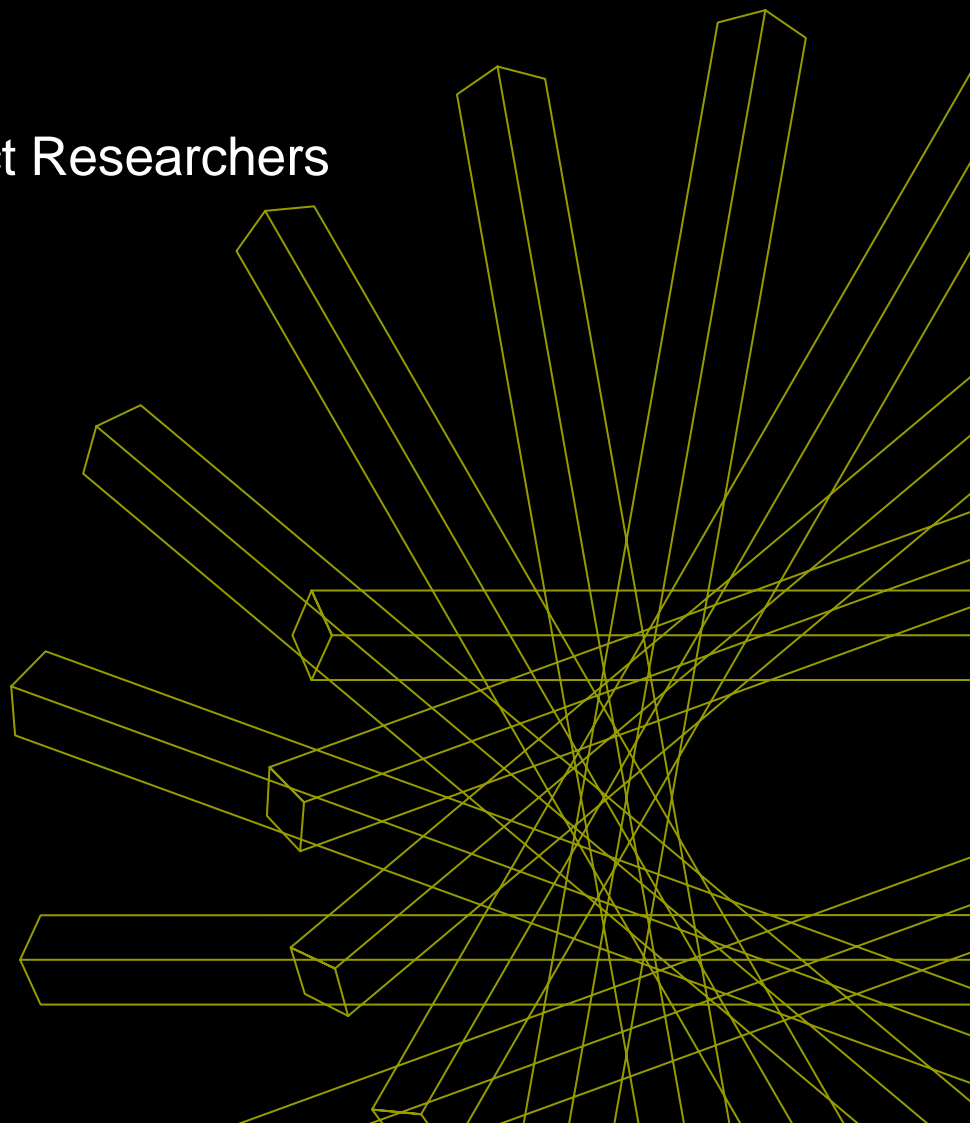


# A Megaproject Research Framework

A Guide for Megaproject Researchers

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**COST – European Cooperation in Science and Technology is an intergovernmental framework aimed at facilitating the collaboration and networking of scientists and researchers at European level. It was established in 1971 by 19 member countries and currently includes 35 member countries across Europe, and Israel as a cooperating state.**

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- + Providing networking opportunities for early career investigators;
- + Increasing the impact of research on policy makers, regulatory bodies and national decision makers as well as the private sector.

Through its inclusiveness, COST supports the integration of research communities, leverages national research investments and addresses issues of global relevance.

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## About this guide

### Who should read this guide?

This guide is aimed at members of the megaproject research community who are seeking to develop further understanding of these complex and societally impactful phenomena.

### What is the background to this guide?

This guide brings together the many and diverse research findings of the MEGAPROJECT COST Action funded by the European Commission's COST Programme. MEGAPROJECT comprises a network of over 80 individual researchers from 25 countries. The main objective of MEGAPROJECT is as follows:

*“to understand how megaprojects can be designed and delivered more effectively to ensure their effective commissioning within Europe.”*

The work of MEGAPROJECT has been undertaken through working groups (sectoral and thematically based), training schools, whole action workshops and individual short-term scientific missions. The thematic working groups acted as coordinators for these activities and their areas of focus are given in Table 1:

MEGAPROJECT Working Group	Area
The 'Risk in the Front End' Working Group (RFE)	Risk identification and management at the 'front-end' of megaprojects
The 'Special Purpose Entity' Working Group (SPE)	The use of special-purpose-entities (SPE) in megaprojects
The 'Innovative Methodologies' Working Group (INNOMET)	Novel and empirically based methodologies for researching megaprojects
The 'Managing Stakeholders' Working Group	Identification and engagement of stakeholders in megaprojects

**Table 1: Areas of Focus of MEGAPROJECT Working Groups**

The area of focus for working groups emerged following a meta-thematic analysis by the MEGAPROJECT Action of issues that were most impact on megaproject design and delivery within Europe. The Action based this analysis on its MEGAPROJECT Portfolio which brought together 30 megaproject cross-sectoral cases from across Europe.

Each of the working groups has developed a report on their findings as follows:

- Delivering European Megaprojects
- Learning Across Megaprojects ( INNOMET)

- Risk in the Front-End of Megaprojects (RFE)
- Managing Stakeholders in Megaprojects (MS)
- Special Purpose Entities in Megaprojects (SPES)

This guide does not repeat the contents of these reports and the reader is directed to these for the substantive detail of the research methodologies employed and the research outcomes created by each of the working groups. This guide brings these experiences together into a framework to give overview findings and recommendations to other megaproject researchers.

### What is the Structure of the Guide?

The structure of this guide comprises the following sections:

- **Researching Megaprojects: Coping with Complexity** This section reviews the particular challenges that are faced in researching megaproject phenomena and explained how MEGAPROJECT faced these challenges
- **Research Outcomes** This section collates the research outcomes generated by the working groups
- **Methodological Developments** This section collates the innovations in research methodologies generated by the working groups
- **A Dynamic Framework of Megaproject Development** This section derives a dynamic framework of megaproject development to capture MEGAPROJECT's findings and to guide further megaproject research endeavours

### The European Context

All of the data from which MEGAPROJECT has derived its findings has been obtained from European megaprojects. It is important that the limitations of this context are understood. For example, whilst the power of external stakeholders to influence megaproject performance may be immense in Western democracies, that power may be much greatly diminished in more autocratic political systems. The research outcomes collated in this document are derived singularly from European megaprojects and therefore their extendibility should be limited accordingly. However findings that pertain to research methodologies are not similarly contextualized and will be more widely applicable.

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# Researching Megaprojects: Coping with Complexity

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## Dealing with Megaproject Complexity

Research into megaproject performance has been ongoing now for over forty years. One of the seminal books in megaproject research, 'Megaprojects and Risk: An Anatomy of Ambition' is now over ten years old. Despite this, research into megaprojects is still not as well developed a field as other aspects of project management research. There is still a dearth of extensive empirically based investigations: shared understandings of the way that megaprojects work are still to emerge. The MEGAPROJECT COST Action has made substantive progress in satisfying these gaps.

Part of the difficulty of researching megaprojects lies in the inherent nature of the phenomena. Megaprojects are extremely complex by almost any dimension by which complexity can be measured. They involve a multitude of actors engaged in a dense web of interrelationships. They are physically huge and command resources that are equivalent in size to the gross domestic product of small nations. They involve a high degree of technological complexity combining multiple layers of electro-mechanical and civil engineering systems. Their lifecycle is extremely long, running into decades and they have implications that can have national and even global dimensions. The complexity of the megaproject phenomena makes peculiar demands on the research methodologies that can be adopted to investigate them

Firstly, the complexity of megaprojects almost demands multi-disciplinary approaches with multi-disciplinary researchers. MEGAPROJECT working groups contained researchers with backgrounds in finance, civil engineering, construction management, operations and project management, law experts, legal researchers and social science. Whilst multi-disciplinary research teams were able to better comprehend the complex interactions at play in megaprojects, they did face considerable challenges. Communication across disciplines could be difficult. Particular research methodological approaches dominate in certain disciplines ( and are non-existent in others.) From a pragmatic perspective, it was very difficult to locate multi-disciplinary research in single discipline publications.

Secondly, gathering data on the holistic totality of these complex megaprojects was, by its nature, impossible: any attempt to do this would be reductionist. In this investigation MEGAPROJECT wanted to adopt an approach that maintained as holistic viewpoint as possible and we therefore turned to systems thinking (and by implication modelling) as an approach that would enable us to maintain holistic considerations. General systems theory has at one of its fundamental tenets an idea of a system comprising actor elements related in some sort of network of relationships and connecting links which accrete into some form of transformational

processes. Both actors and activities are taking place within a defined boundary that forms the 'edge' of the system. The system exists within a wider environment with which it interacts and the transformational processes that it undertakes have some element of performativity. MEGAPROJECT translated these ideas in the context of megaprojects as follows:

- 'Basic information' about the project was captured which formed the statement of the megaproject system's scope. Furthermore MEGAPROJECT constrained the activities mapped within the megaproject systems as those pertaining to activities that could be considered as managing the megaproject.
- Actors within the megaproject system were identified as 'external' and 'internal' stakeholders using Winch's<sup>1</sup> definition of these and his 'template' as a way of categorising these actors. (Interestingly, the act of identifying stakeholders became a way of discerning the boundaries of the megaproject in consideration.)
- The relationships between the actors were mapped using a simple graphical representation of their social network
- The tasks and processes were captured within the megaproject system that pertained to its project management. We used the PMI's PMBOK's delineation of the 9 aspects of project management knowledge to stimulate the capture of these activities and processes
- Any substantive changes in the legal and regulatory, economic and political environment that resulted in a change in the megaproject system's configuration were noted
- MEGAPROJECT attempted to ascertain how far the transformation processes that existed within the megaproject system had resulted in outcomes that were in-line with actors' expectations
- Actors, processes, outcomes and environmental changes were linked temporally in a 'time-line' for the megaproject's development.

Thirdly, a significant problem in gathering data in the context of complex megaprojects is the scale of the activity. Construction of a large dataset of large phenomenon in a timely fashion demands the cooperation of a large number of researchers. In the case of the MEGAPROJECT investigation, over 80 individuals from 24 countries were involved in the investigation's activities which meant that we encountered not only issues of scale but of cross-cultural understanding. This brings the importance of Yin's<sup>2</sup> ideas of case protocols in cross-case research to the fore as a mechanism to increase the reliability of a multi-case investigation. To this end MEGAPROJECT converted the systemic list of constructs derived in the previous paragraph to a template which formed part of a larger case protocol which MEGAPROJECT investigators followed. This protocol was trialed until an approach was established that could be followed and understood by all investigators. The template at the heart of the protocol then formed the basis of the dataset on which

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<sup>1</sup> Winch, G. M. (2010). *Managing construction projects*, John Wiley & Sons.

<sup>2</sup> Yin, R. K. (2009). *Case study research: Design and methods*, sage.

the subsequent inductive analysis was carried out. The template is given in Appendix A.

Another significant challenge relating to the scale of megaproject data collection is the resource required to gather it. Thus, to gain data a timely fashion<sup>3</sup>, the compilation of case template was mostly derived from secondary data. Secondary data is defined as pre-existing data not gathered for the purposes of the current research. The problems of using secondary data relate to the inability to control the data collection process. In this instance, MEGAPROJECT asked its investigators to give footnotes for each data item that they added to the portfolio giving source in terms of publically available information or ,where data had been collected through an internal interview process, details of internal reports on that activity.

MEGAPROJECT's response to dealing with megaproject complexity in its research was, hence, founded upon:

- A systemic consideration of megaprojects
- The use of templates and protocols to ease capture and communication of that complexity
- The use of secondary data to ease the burden of data gathering

These approaches crystallized in the creation of the MEGAPROJECT Portfolio ([www.mega-project.eu/portfolio](http://www.mega-project.eu/portfolio)) which is a collection of 30 megaproject cases that is freely available to all megaproject researchers. The Portfolio allows the downloading of individual cases and is searchable by a variety of categories. The MEGAPROJECT Portfolio acted as the basis for the identification of meta-themes vital to megaproject performance and as data that was used by each of the MEGAPROJECT thematic working groups.

### The MEGAPROJECT Findings

Given the methodological challenges in researching megaprojects, it is not surprising that many of the contributions that the thematic working groups made lay in the field of methodological innovation. Invariably they needed to first develop new methodological approaches to their task before they could go on to identify substantive research findings.

Table 2 gives an overview framework of the findings of the MEGAPROJECT COST Action Working Groups both in terms of their research outcomes and their methodological developments.

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<sup>3</sup> The use of secondary data was also necessary because the COST funding mechanism does not provide resource for research, it only provides resource for researchers to collaborate.



Working Group	Dataset	Research Outcomes	Methodological Developments
SPE	<ul style="list-style-type: none"> <li>The MEGAPROJECT Portfolio</li> <li>Literature review of SPEs in megaprojects</li> <li>An Italian metro megaproject case</li> </ul>	<ul style="list-style-type: none"> <li>A taxonomy of SPEs and their functionality</li> <li>A lifecycle approach to megaproject development</li> <li>The identification of the phenomena of 'temporal flipping' and 'enduring projects'</li> </ul>	<ul style="list-style-type: none"> <li>Ontological approaches to reviewing existing literature</li> <li>Use of Systems Dynamics</li> <li>Use of Cross-case analysis</li> </ul>
INNOMET	<ul style="list-style-type: none"> <li>The MEGAPROJECT Portfolio</li> <li>20 additional Coded cases from UCL's OMEGA Centre</li> </ul>	<ul style="list-style-type: none"> <li>The identification of the critical characteristics associated with megaproject delivery performance</li> </ul>	<ul style="list-style-type: none"> <li>Use of Cross-Case analysis</li> <li>Use of the Fisher Exact Test</li> <li>Use of Machine Learning</li> </ul>
MS	<ul style="list-style-type: none"> <li>The MEGAPROJECT Portfolio</li> <li>52 survey responses based on 4 additional megaprojects</li> </ul>	<ul style="list-style-type: none"> <li>A framework for Relating Stakeholder Impact and Project Sustainability</li> <li>A framework for understanding stakeholder impact in terms of success, execution and sustainability</li> <li>An identification of the most impactful stakeholders on megaproject performance</li> </ul>	<ul style="list-style-type: none"> <li>Use of Social Network Analysis</li> <li>Use of Systems Dynamics</li> </ul>
RFE	<ul style="list-style-type: none"> <li>The MEGAPROJECT Portfolio</li> <li>9 further megaproject cases</li> </ul>	<ul style="list-style-type: none"> <li>A greater understanding of the differentiation in terms of risk and uncertainty in megaprojects</li> <li>An identification of the greater and lesser areas of uncertainty in megaproject development</li> </ul>	

**Table 2 Outcomes and Methodological Developments of the MEGAPROJECT Thematic Working Groups**

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## Research Outcomes

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This section outlines the major research outcomes produced by the MEGAPROJECT thematic working groups.

### The SPE Working Group

The major outcomes of the SPE working group relate to the following areas and are discussed in the section below:

- A taxonomy of SPE functionality in megaprojects
- The identification of idiosyncratic organizational phenomena

One of the aims of the SPE Working Group, given the lack of investigation of SPEs in the context of megaproject governance, was to create a taxonomy of functionality adopted by SPEs in megaprojects. Figure 1 gives an outline representation of this taxonomy. (Further detail can be garnered from the ‘SPEs in Megaprojects’<sup>4</sup> report.) The taxonomy demonstrates the far-reaching effects of SPE structuring have on megaproject behavior particularly in terms of the impact that the introduction of an SPE has on the governance of a megaproject. The SPE establishes the context not only for the financing of the megaproject, but for the way in which decisions will be made throughout its lifecycle. The importance of SPEs in establishing the governance framework for a megaproject is a unique contribution of the SPE Working Group.

The SPE Working Group also identified organizational phenomena that were either peculiar to megaprojects or had a particularly contextualized interpretation in megaprojects. Firstly SPEs in megaprojects appeared to act in a way that confounds much of the theorization as projects (and by implication megaprojects) as temporary organizational structures. The SPE often seemed to outlive the so called ‘permanent’ organization from which it was spawned. MEGAPROJECT labeled this SPE phenomenon as an ‘**Enduring Project:**’

- Enduring Projects organizations are SPEs (i.e. legally separate structures associated with and centred around a particular project, they are legally constrained by specific objectives, they are legally separate independent organizations but they are owned by other external organizations)
- Their lifespan is time-limited by the nature of the project with which they are associated but it is not temporary as it can run into decades (and tens of decades if the Enduring Project organization also is responsible for operating the megaproject)

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<sup>4</sup> ‘Special Purpose Entities in Megaprojects’ ed Corrado Lo Dorto, April 2015, University of Leeds ISBN 978-0-9576805-3-1

In much of the literature to date, a project organization has been conceptualized as a temporary group of people drawn from across an organization or group of allied organizations to undertake a project. In contrast, Enduring Projects have a



**Figure 1: An Ontological Taxonomy of SPE Functionality in Megaprojects**

formally constructed organizational structure, the governance of which has a defined (and legally based) separation from the organizations that own them. Enduring Projects have considerable resources and command the efforts of a large number of individuals (albeit these efforts may be subsumed in a 'supply chain' of separate sub-projects). Enduring Projects continue years or decades. Their design and construction alone can take at least a decade and they are associated with infrastructure provision that will have an operational lifespan of several decades if not centuries. These lifecycles are likely to extend beyond the corporate existence of the other organizations interacting with the Enduring Project organization and in many cases will surpass the length of an individual's entire working life. Thus Enduring Projects exhibit a phenomenon the MEGAPROJECT has labeled as 'temporal flipping.' The temporary-permanent paradigm that underpins much of the existing research work in project management can be 'flipped' in the case of an Enduring Project in a megaproject. The Enduring Project organization becomes 'permanent' (through outliving its association organizations) and the other organizations associated with the Enduring Project are 'temporary' (by ceasing to exist).

The phenomenon of Enduring Projects has important implications for much of the theory devised to understand temporary organizations such as projects. The implications for 'flipping' the temporality between permanent and temporary organizations as exemplified in Enduring Projects holds important implications for risk, knowledge transfer and management and the embedded nature of organizational processes within the Enduring Project . This is a very important contribution of MEGAPROJECT to the theoretical basis of projects as temporary organizational systems.

### The INNOMET Working Group

In additions to its contribution to novel methodological approaches (which was the substantive part of its rationale) INNOMET also succeeded in using these approaches to identify in a rigorous and a statistically significant way the key characteristics of a megaproject that are correlated with its delivery performance. This is a unique contribution in the context of academic megaproject research.

By triangulating:

- the results obtained from the application of the Fisher Exact Test (a non-parametric test that uses 2x2 contingency tables) to an enlarged MEGAPROJECT Portfolio
- the results of applying machine learning techniques to the same dataset

INNOMET produced the outcome reported in Table 3. These findings indicate that:

- the engagement of external stakeholders
- the presence of SPE s

represent the characteristics that are most correlated with aspects of megaproject delivery performance. This is a very important finding not only for megaproject researchers but also for practitioners who are seeking to improve megaproject delivery

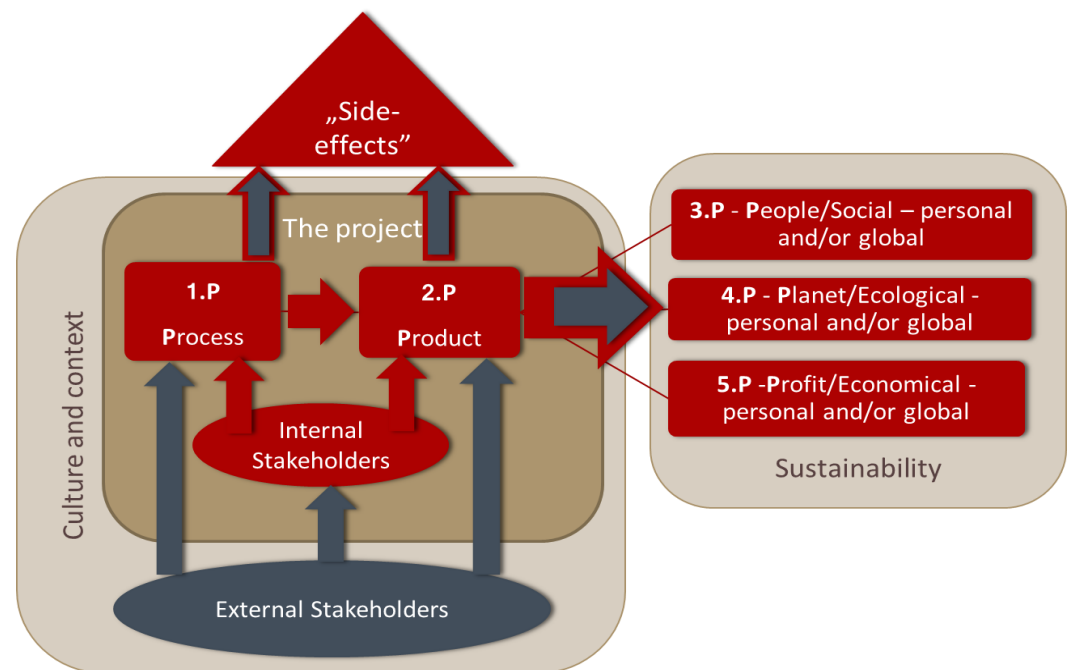
Megaproject Characteristic	Fisher Exact Test Analysis			Machine Learning Analysis		
	BUDGET	PLAN. SCHED.	COSTR. SHCED.	BUDGET	PLAN. SCHED.	COSTR. SHCED.
<b>SHARED CHARACTERISTICS:</b>						
An SPE is present in the megaproject	X	X	X		X	X
Public acceptability for the megaproject at national level			X			X
Environmentalists engaged ex-ante	X			X		
A regulator fined an actor in the megaproject	X		X	X		
A regulator delayed an activity in the megaproject		X			X	
<b>UN-SHARED CHARACTERISTICS:</b>						
Client and EPC have the same nationality	X					
Pre-existing environmental group objected			X			
The megaproject was supported by local government			X			
Local compensation is >0,1% of the total budget			X			
The megaproject is a renewable energy project			X			
The megaproject encompasses bridges			X			
The megaproject encompasses other underground structures	X					
The megaproject encompasses highways			X			
There is planned a long term stability in usage and value of the megaproject				X		X
Financial Support from the national government was received by the megaproject				X		
The megaproject is composed of more than 1 identical independent unit					X	
The project is modular with dependent modules						X
First-of-a-kind megaproject: wide definition					X	
The megaproject is nuclear				X		X
Project physically connects two countries				X		

**Table 2 Megaproject Characteristics that are Associated with Megaproject Performance**

### The MS Working Group

One of the primary research outcomes that the MS Working Group produced were a group of theoretical frameworks that could be used to express the interactions and impact of stakeholders with megaprojects.

The first framework was derived to delineate the relationship between stakeholders and a megaproject's sustainability and is given in Figure 2. This was articulated through the '5Ps' model whereby external stakeholders can affect both the governance process of a megaproject and its encapsulation in project form and, through these mechanisms, the sustainability of the megaproject from the perspective of the people involved, the ecological perspective and through its profitable longevity.

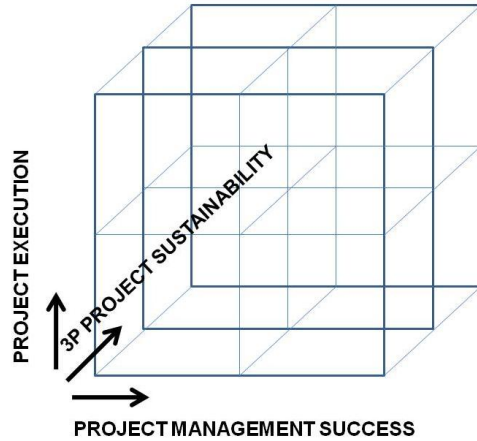


**Figure 2: The Impact of Stakeholders on Sustainability**

The second theoretical framework derived by the MS Working Group was used to characterize the impact of stakeholders on a triad of aspects of a megaproject and is given in Figure 3. Most existing work on assessing stakeholder impact only uses two dimension so the inclusion of an additional dimension to move from a stakeholder impact 'matrix' to a stakeholder impact 'cube' is highly novel. The dimensions captured in the cube were 'project management success,' 'project execution' and '3P sustainability.' Stakeholders that occupied the bottom left hand corner of the cube were judged as having little impact and those stakeholders that occupied the top right corner of the cube were judged as most impactful.

Having created these frameworks, the MS Working Group went on to apply these to an empirical investigation of a further group of megaprojects to identify which of the

types of stakeholders within megaprojects can be judged as having the greatest impact on the megaproject.



**Figure 3: The Stakeholder Impact ‘Cube’**

The results of the investigation are given in Table 3. This indicates that some ‘internal stakeholders’ (such as principle contractors and local governments) can influence megaprojects both positively and negatively whereas the impact of ‘external stakeholders’ is almost entirely inimical to the megaproject. This is a novel finding in megaproject research and has profound implications also for practitioners.

Stakeholder groupings having a positive influence on megaprojects	Stakeholder groupings having a negative effect on megaprojects
<ul style="list-style-type: none"> <li>• principal contractors</li> <li>• national government</li> <li>• client/owner</li> <li>• financiers</li> <li>• project team</li> <li>• local government</li> </ul>	<ul style="list-style-type: none"> <li>• principal contractors</li> <li>• <b>local residents</b></li> <li>• <b>environmentalists</b></li> <li>• <b>regulatory agencies</b></li> <li>• suppliers</li> <li>• local government</li> </ul>

**Table 3: The Most Influential Stakeholders in Megaprojects**

**The RFE Working Group**

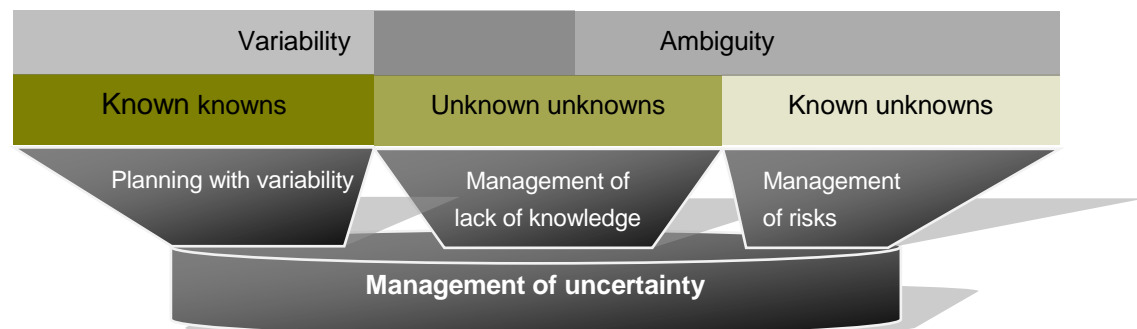
The RFE Working Group identified that the existing work in risks in project management had not focused on megaprojects: there was a very limited body of work that pertained to megaprojects alone. Furthermore, the RFE Working Group also identified a confusion in understanding between managing ‘risk’ and managing ‘uncertainty’ in the front-end of megaprojects. One of the first outcomes of the RFE working group is a series of further areas that require more investigation including cross-sectoral aspects or risk and comparisons of approaches to risks in

megaprojects and in smaller less complex projects. Other areas which merit further investigation include:

- Risk and stakeholders (their objectives and relationships)
- Governance and its relationship with risk management
- Structural complexity and its interactions with uncertainty
- Sustainability and risk ( especially in terms of Environmental Impact Analysis)

The empirical studies of the RFE Working Group revealed a lack of maturity in the management of risks in megaprojects. The most mature areas were found in the way that organizations dealt with barriers to implementation of the megaproject. The areas of least maturity were associated with the utilization of early warning indicators.

The RFE working group determined the following framework in the consideration of risk and uncertainty in megaprojects:



**Figure 4: Managing Uncertainty in Megaprojects**

The empirical studies of the RFE working group also identified that the areas of greatest uncertainty in megaprojects related to:

- The complex nature of megaprojects especially in terms of relationships between factors.
- The wide possibility and impact of external events
- The uncertain capabilities of actors involved in the projects

Areas of less uncertainty were identified as those related to:

- Objectives and priorities
- Formal contractual conditions



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## Methodological Developments

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In addition to research outcomes, the Working Groups also contributed a series of methodological developments in researching megaprojects that would be useful to other investigators in this field

### Ontological Approaches

The SPE Working Group was faced with the situation of a lack of clarity on the nature of SPEs in existing literature and a particular lack of understanding of the context of SPEs in the delivery of megaprojects. It was viewed as important to identify a way to bring a systematic clarity to INNOMET's review of SPEs beyond that normally produced by a conventional literature reviews: an 'ontological' approach was identified as having the systemic clarity demanded in this situation.

An ontology can be defined as:

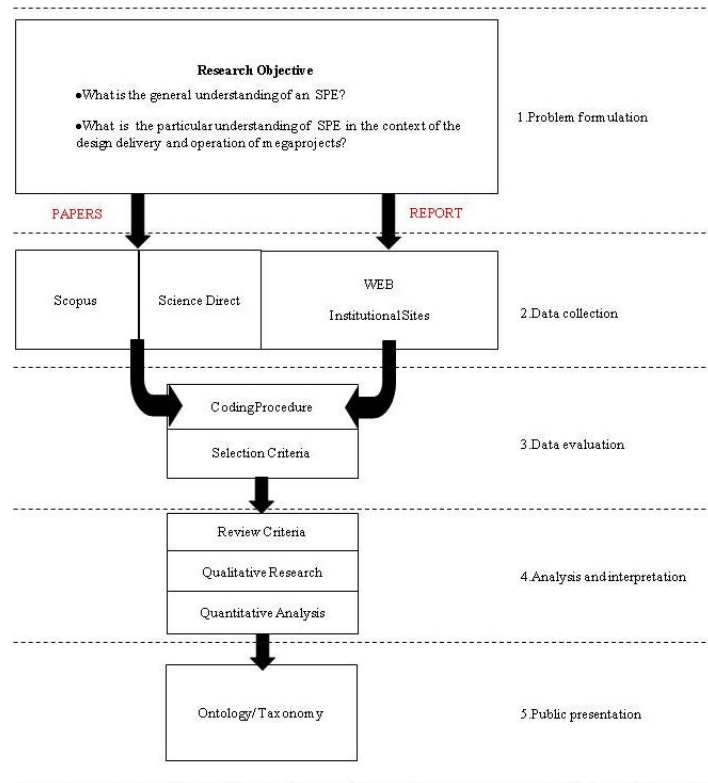
"a formal, explicit specification of a shared conceptualization"

In Information Science, ontologies are used to formally represent knowledge within a domain. An ontology provides a common vocabulary to denote the types, properties and interrelationships of a particular set of concepts and constructs. An ontological perspective is adopted in a wide variety of situations where the precise and linked nature of a phenomenon needs to be explored and described in a systematic and non-ambiguous way. Although widely used in engineering management, ontological approaches to reviewing existing literature have only been used in a limited way in the field of project management<sup>5</sup>.

The development of an ontology demand a series of prescribed phases. These were developed by the INNOMET working group in the way described in Figure 5. This approach provided INNOMET with a systematic and easily communicable taxonomy of SPEs in megaprojects which would prove amenable to use in other similar situations of megaproject research where investigators are trying to 'make sense' of a pre-existing but diffuse literature.

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<sup>5</sup> It is important that we distinguish the our use of the term 'ontology' from other more philosophical conceptualisations prevalent in project management research



**Figure 5: An Ontology Development Process**

### Systems Dynamics

System dynamics (SD) is an approach to understanding the nonlinear behaviour of complex systems over time. It models the linkages or (flows) between activities within a system in order to aggregate an overall understanding of ‘whole system’ characteristics. System dynamics approaches have already been use in the context of megaproject research and the MEGAPROJECT COST Action applied these further.

The SPE Working Group developed a fuzzy cognitive map ( a first stage in developing a SD model) of an Italian metro megaproject. This was used to successfully link attributes of the SPE with its associated megaproject’s performance. The MS Working Group also identified the utility of SD in modeling stakeholder interactions in megaprojects.

The experience of the MEGAPROJECT COST Action suggests that systems dynamics will continue to play a useful role in megaproject research investigations. However, this intent needs to be balance with the vast amount of data required to adequately model many megaproject applications.

### Cross-Case Analysis

One of the research methodologies that was widely employed by the MEGAPROJECT COST Action was ‘inductive cross-case analysis.’ This approach was used by both the INNOMET Working Group and the SPE Working Group. ‘Inductive cross-case analysis’ is a technique that takes similarly constructed cases

and uses a structured process to review the cases to arrive at 'cross-case' patterns. These 'patterns' are the used to generate theoretical propositions. The approach adopted by MEGAPROJECT was based on the seminal work of the US academic, Kathleen Eisenhardt (1989). Eisenhardt derived a process where theoretical generalizations could be generated from reviewing a set of cases of a particular phenomenon.

The MEGAPROJECT Action used the facility of its Training School for early-stage researchers to develop this technique in the context of megaprojects. A key feature of this development was its inductive nature. It is interesting to identify how the emergent meta themes are different than those that would have arisen from considering a singular case. Firstly, their extendibility is greater as they have been found across megaproject sectors in Europe rather than one particular situation in one sector in one country. This gives confidence to the users of the outcomes of the MEGAPROJECT research (many of whom are practice based) that considering these meta-themes in designing and delivering a wide range of European megaprojects is appropriate. Secondly, the evidential support from a wide variety of cases enabled a much richer and nuanced exposition of the meta-theme. This included the ability to both *literally* replicate case situations but also to *theoretically* replicate situations ( c.f. Yin 2003).

The MEGAPROJECT COST Action also provided the opportunity to learn from the operational aspects of multi-case research. Multi-case research is resource intensive ( especially in the context of megaprojects) and, of necessity, may involve many researchers and potentially the use of secondary data. The success of the MEGAPROJECT template in inculcating a uniform approach to case creation was instrumental to the efficacy of a multi-case research approach. The template enabled a highly disparate group of researchers to work together under the auspices of a single investigation. This suggests that a similar approach to multi-case protocol implementation may meet with equal success (assuming that the case template was well-designed.) The use of secondary data did not prove problematic either but it did entail the creation of a very specific 'glossary' for the terminology used in the project to insure a consistent interpretation of the constructs under investigation.

One of the interesting findings of the application of an inductive approach was the difficulty encountered by investigators acting in this fashion. Researchers found it much easier to act deductively i.e. bring pre-defined propositions to the case analysis rather than letting propositions emerge from the case analysis.

### Fisher Exact Test

The rationale for the MEGAPROJECT COST Action lay in its search for systematic and empirically based drivers of megaproject performance to the extent that these relationships could even be described with some degree of statistical significance. Very few attempts had been previously made to undertake the sort of activity and those attempts that had been made lay outside the realm of academic research in

proprietary organizations where it was very difficult to access either the dataset or the methodology. In order to identify a mechanism for a statistically rigorous analysis that linked megaproject performance to megaproject characteristics, compromises had to be made. The rich and complex data that had been gathered in the MEGAPROJECT portfolio had to be converted to constructs that could be operationalised. (This was true for both independent ‘characteristics’ data and dependant ‘performance’ data). The complexity of the data was reduced even further by operationalising constructs such that they were binary. These sacrifices did however enable the use of a statistical analysis technique that could discern relationships between megaproject variables, namely the Fisher Exact test. The Fisher Exact test also had the advantage that it was non-parametric (i.e. it did not depend on the nature of the distribution of the variables). The dramatic reduction in the complexity of the dataset was justified given the power to demonstrate a statistical significance for a relationship between a megaproject characteristic and megaproject performance.

MEGAPROJECT has been able to detect no other use of the Fisher Exact test in the context of project management research ( and very few in the field of wider engineering management.) Data simplification followed by the use of the Fisher Exact test provides a very reliable mechanism for any megaproject researcher who is seeking to establish statistically significant relationships between variables.

### Machine Learning

Machine learning is a scientific discipline that explores algorithms that can learn from data. The conversion of the MEGAPROJECT portfolio into a binary dataset enabled machine learning techniques to be used by the INNOMET Working Group for this investigation. Machine learning techniques were successfully used to identify characteristics of megaprojects that ‘predicted’ megaproject performance. In essence, these could then be used as ‘leading indicators’ when delivering new megaprojects. However, even with a sample size of over 50 megaprojects, the machine learning techniques employed were on the edge of their applicability. To make better use of these techniques, a much greater sample size of megaprojects is required. Machine learning therefore offers advantages to megaproject researchers but they must first generate a much larger dataset than that employed by MEGAPROJECT.

### Social Network Analysis

Social network analysis is an approach to investigating social systems that is based on mapping and analysing the network of relationships that exist between the actors in the system. The MEGAPROJECT COST Action used it in the following contexts:

- The description of the principal stakeholders in a megaproject case and the relationship between them in the form of a social network map used by the MEGAPROJECT template.

- To characterize the relationship between stakeholders in a megaproject and the impact of those relationships particularly in terms of trying to capture the dynamic aspects of those relationships ( dynamic network analysis or DNA)

There is a substantive body of project management research that has employed SNA in its endeavours. The experience of MEGAPROJECT suggests that SNA is also useful in the context of researching megaprojects particularly if it is modified to capture longitudinal changes in the network.

# A Dynamic Framework for Megaproject Development

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## The purpose of the dynamic framework

The purpose of this dynamic framework is threefold:

- To capture graphically the impact of interventions in a megaproject's dynamic lifecycle to the point at which it enters into operation
- To juxtapose and contextualize the separate working group outputs using this graphic in a way that can be used to relate to megaproject performance
- To guide future efforts in researching megaprojects

## Understanding the Dynamic Framework.

Figure 6 presents the dynamic framework for megaproject development.

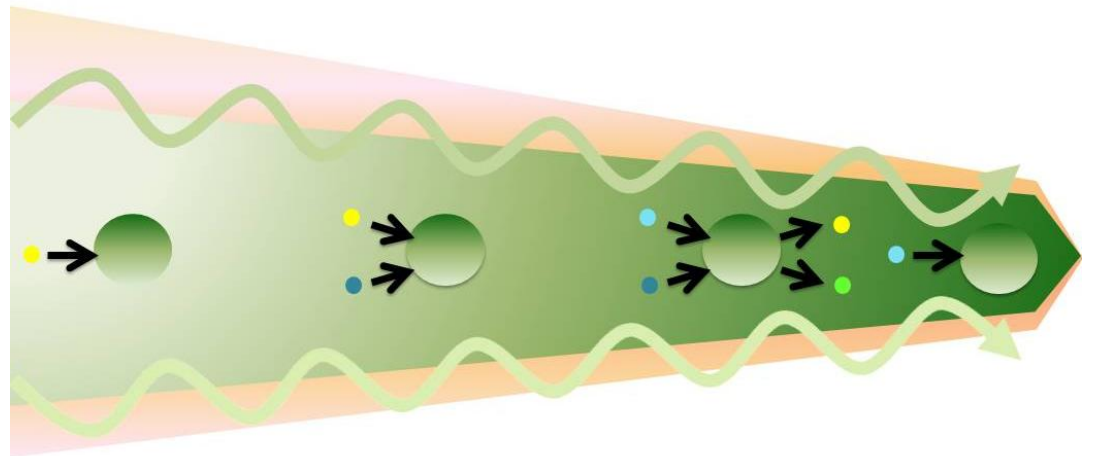
**Time** is represented in the framework by the axis flowing from left to right.

The **megaproject development process** is represented by the green arrow. Its level of opacity represents the degree of resource commitment at each stage of the project phase. (As the megaproject travels along its life cycle, more resources are committed to its development and the density of the 'green' resources increases).

**Uncertainty** is represented by the pink arrow travelling from left to right. As the lifecycle of the megaproject progresses the level of uncertainty reduces.

The megaproject's **stakeholders** are represented by the spiral traversing the development process indicating the interactive flow of stakeholders with megaproject development. The spiral also demonstrates the way in which the stakeholders involved with the megaproject may change over its lifecycle and the role that the same stakeholder plays may also change from 'internal' to 'external'.

The circles represent the **governance** of the megaprojects particularly in terms of ownership (represented by 'arrows' pointing into the circle) and first-tier contractors (represented by 'arrows' pointing out of the circle). The degree of solidity of the circle's border represents the degree of separateness of the governance structure of the megaproject from its owners. A solid line represents a legally separate entity such as an SPE. The series of circles represent the changes in governance during the project lifecycle.



**Figure 6: The dynamic framework for megaproject development**

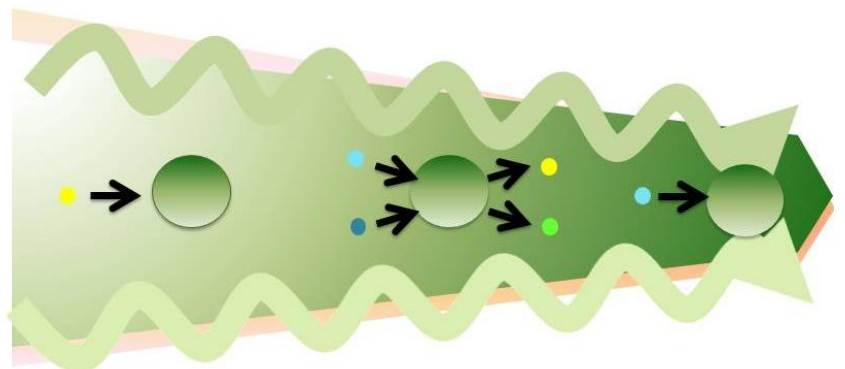
The dynamic framework also shows how the research outcomes from MEGAPROJECT’s thematic Working Groups can be used to improve the delivery performance for a megaproject. Improving the delivery performance for a megaproject comprises two elements:

- reducing the lifecycle leadtime i.e. ‘shortening the arrow’
- reducing the amount of resources required to develop the megaproject i.e. reducing the area and the opacity of the arrow

The thematic working group outcomes indicate that these changes may be effected through:

- Increasing the engagement with **stakeholders** i.e. ‘thickening’ the spiral
- Decreasing the **uncertainty** associated with the megaprojects i.e. reducing the size of the pink arrow
- Improving the **governance** arrangements through more use of SPEs where appropriate i.e. defining the governance circles

Figure 7 shows the impact of these changes on the megaproject’s delivery lifecycle.



**Figure 7 Using the Dynamic Framework to Illustrate Improvements in Megaproject Delivery Performance using MEGAPROJECT Research Outcomes**

The same principle can be used to identify further areas of investigation by megaproject researchers. Any approach that can reduce the leadtime (i.e shorten the arrow) or by decrease the amount of resources ( i.e. decrease the area and opacity of the arrow) has the ability to improve megaproject delivery performance. This could be effected

- either by using the mechanisms within the framework namely increasing stakeholder engagement (increasing the thickness or pitch of the spiral); decreasing uncertainty (reducing the size of the pink arrow); and improving governance (increasing the delineation of the circles)
- or by introducing a new graphical element to the framework that has a similar effect on the overall delivery performance.

Thus the dynamic framework can also be used to guide the efforts of future researchers.



# Appendix A: The MEGAPOROJECT Portfolio Template

**MEGAPROJECT Case Study**  
Case complexity: \_\_\_\_\_  
Context details: \_\_\_\_\_

**Basic Project Information**

Project Title	
Location	
Purpose	
Scope	
Total Project Value	
Project Status	
(i.e. - design, planning, construction, operation, decommission)	
Contractual Framework	
(e.g. insurance, retention, etc.)	
Relevant Physical Dimensions (e.g. height, width, volume, length)	

**SECTION 1 - BASIC PROJECT INFORMATION**

**MEGAPROJECT Internal Stakeholder Identification**  
(Stakeholders with a direct legally sanctioned relationship with the project)

Stakeholder Category	Case Study	Comments (e.g. maturity, previous relationships, skills, influence on project)
Project Side	Process	
	Structure	
	Staff/Contractors	
	Staff/Contractors (other categories please specify)	Category: <u>Case Study</u>
External Side	Project/Contractor	
	Third Party Contractors	
	General Public	
	Other Internal Supply and Logistics (please specify)	Category: <u>Case Study</u>

**SECTION 2 - PROJECT STAKEHOLDERS**

**MEGAPROJECT External Stakeholder Identification**  
(Stakeholders with a direct interest in the project but with no legal contract)




Stakeholder Category	Case Study	Comments (e.g. maturity, previous relationships, skills, influence on project)
Public	Regulatory Agencies	
	Local Communities	
	Academic Institutions	
	Other Internal Supply and Logistics (please specify)	Category: _____ Case Study: _____
Private	Local Businesses	
	Local Government	
	Local Media	
	Other Internal Supply and Logistics (please specify)	Category: _____ Case Study: _____

**SECTION 2 - PROJECT STAKEHOLDERS**

**MEGAPROJECT Stakeholder Relationship Maps**

Repeat this map for as many project phases as you require

**Key:**

-  - Project Actor
-  - Project relationship with a contractual basis
-  - Non-contractual project relationship

**SECTION 2 - PROJECT STAKEHOLDERS**

**MEGAPROJECT Project Management**

**Project Organisation**

Client/Project Team Size & Structure	
Contractor Project Team Size and Structure	
Sub-Contractor Project Team Involvement	

**Project Tools and Techniques**  
Please tick present, if absent, tick not known

Life Cycle Coding Approaches  Project Management Software  Lessons Learned Transfer

Stakeholder Involvement  Relationship Management Tools  Team Building Tools

Building Information Modelling (BIM)  Project Knowledge Management Tools  Competency Framework

Other Tools and Techniques or Other Information

**SECTION 3 - PROJECT MANAGEMENT**

**Project Processes**

Site Management Processes	Present (describe below) absent Present or No Information or
HR Management Processes	Present (describe below) absent Present or No Information or
Procurement Management Processes	Present (describe below) absent Present or No Information or
Program Management Processes	Present (describe below) absent Present or No Information or
Scope Management Processes	Present (describe below) absent Present or No Information or
Time Management Processes	Present (describe below) absent Present or No Information or
Cost Management Processes	Present (describe below) absent Present or No Information or
Quality Management Processes	Present (describe below) absent Present or No Information or
Communication Management Processes	Present (describe below) absent Present or No Information or

**SECTION 3 - PROJECT MANAGEMENT**

**MEGAPROJECT Project Performance**

Aspects of Performance Concerned with Doing the Project Right

	Original Targets and changes to targets	Actual Achievements Against Targets
Performance related to <b>time</b>		
Performance related to <b>cost</b>		
Performance related to achieving <b>specification</b>		

**SECTION 4 - PROJECT PERFORMANCE**

Aspects of Performance Concerned with Doing the Right Project

Stakeholder or Stakeholder Grouping	Original Aims of Project Involvement and Changes to these Aims	Achievement of these Aims

**SECTION 4 - PROJECT PERFORMANCE**

**MEGAPROJECT Project Environment**

**Legal and Regulatory Environment**

Legal and Regulatory Project Environment (geography, nationally and Europe-wide)	
Specific Legal and Regulatory events impacting on the project	

**Political Environment**

Political Project Environment	
Specific Political Events impacting on the project	

**SECTION 5 - PROJECT ENVIRONMENT**

**MEGAPROJECT Project Key Events and Activities Timeline**

TIME →

Events and activities relating to project stakeholders																				
Events and activities relating to project management																				
Events and activities relating to project performance																				
Events and activities relating to project environment																				

**SECTION 6 - PROJECT TIMELINE**