Now, let's make it really complex (complicated): A systematic review of the complexities of projects

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Now, let's make it really complex (complicated):

A systematic review of the complexities of projects

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Abstract

Purpose: The purpose of this paper is to contribute to OM Practice Contingency Research by describing the complexity of projects. Complexity is recognised as a key independent (contingent) variable that impacts on many subsequent decisions in the practice of managing projects.

Methodology: This paper presents a systematic review of relevant literature and synthesises an integrated framework for assessing the complexities of managing projects.

Findings: This framework comprises five categories of complexity – structural, uncertainty, dynamics, pace and socio-political complexity. These five complexities present individuals and organisations with choices about how they respond to each type of complexity, in terms of business case, strategic choice, process choice, managerial capacity and competencies.

Originality and contributions: The contribution of this work is to provide a clarification to the epistemology of complexity, to demonstrate complexity as a lived experience for project managers, and offer a common language for both practitioners and future empirical studies considering the individual or organisational response to project complexities. The work also demonstrates an application of systematic review in OM research.

Keywords: complexity; complexities; uncertainty; pace; socio-political complexity; structural complexity; typology; lived experience; project management; systematic review.

Article classification: literature review

Background

We live in a *projectified* world, where change, revenue earning and many other activities take place through project-based processes; processes that are core to most organisations, be they governments or industries. Such importance is reflected in the increasing formalisation of projects, including the spread of the project form of organisation. This gives legitimacy, structure and, for most organisations, a recognisable business process for anything termed 'a project.'

The practice of project management (PM) is widespread and differs from other areas of operations management (OM). It is dominated by the professional associations. These associations have their *Bodies of Knowledge* (e.g. PMI, 2008; APM, 2006), statements of 'best practice' which provide a baseline for organisational practice and individual competence or knowledge assessment. The largest, the Project Management Institute (PMI), has over half a million certified Project Management Professionals globally. Its Body of Knowledge is an American National Standard, and its use is mandated in US. The UK's Office of Government Commerce standard, PRINCE2, has had over 300,000 practitioner-level certifications in the past five years alone, predominantly in Europe. There is clearly an appetite on the part of both individuals and organisations for improved performance – performance that is currently poor for most projects. The professional associations promote their 'best practices' as remedies for poor performance. However, performance improvement is illusive.

In OM terms, with the exception of New Product Development (NPD), project processes attract scarcely more coverage than a single chapter in OM texts. Moreover, this coverage is highly mechanical in nature. As will be expanded in this paper, better understanding of the context in which work is carried out moves the discussion of these key processes from a mechanical one-size-fits-all approach (which has been shown to be ineffective), to a contingency domain. It is this improved understanding of context that we are seeking because of the need to understand the nature of the organisational response to the context, and its subsequent impact on success.

This paper contributes to the development of OM Practice Contingency Research (OM PCR), (Sousa and Voss, 2008). In common with other areas of OM, PM has a strong normative element, based on the assumption that good performance will result from the application of best practices. In this case, a high level of dissemination of best practices (as exemplified by certifications to various bodies of knowledge), has not been accompanied by improved performance (e.g. as evidenced by continued performance problems – Standish Group, 2009). This does question the universality of the best practices and indicates that there is an independent contingency variable that impacts on practice and thence performance. In this paper, we identify an independent variable as being the complexity of the project being undertaken. The 'practices' on which this will impact include formulation of the project business case, strategic choice, process choice, managerial capacity and managerial competencies.

Introduction to project complexity

Understanding project complexity is of interest to both practitioners and academics. For practitioners, there is a need to 'deal with complexity', to determine how an individual or organisation responds to complexity (Thomas and Mengel, 2008; Augustine*, et al.*, 2005; Austin*, et al.*, 2002; Brown and Eisenhardt, 1997). In the academy, research has focused on two streams

of work: 'complexity *in* projects' and 'complexity *of* projects' (Cooke-Davies, *et al.*, 2007). The first stream studies projects through the lenses of various complexity theories (Manson, 2001). Examples of research in this stream are those of Benbya and McKelvey (2006), Cicmil (2003), Cicmil and Marshall (2005), Cooke-Davies *et al.* (2007) and Ivory and Alderman (2005). The second stream is practitioner-driven and aims to identify the characteristics of complex projects and how individuals and organisations respond to this complexity (e.g. Geraldi and Adlbrecht, 2007; Jaafari, 2003; Maylor*, et al.*, 2008; Shenhar and Dvir, 2007; Malach-Pines, *et al.*, 2009; Williams, 2005). This paper focuses on the second stream. However, some of the lessons from the first stream, about emergent behaviour and the production of non-linearity and dynamics within complex systems, give particular motivation to the need for the second stream of work to help practice.

Theoretical and empirical studies conducted in a range of industries, proposed forms of defining and characterising the complexity of projects. The literature is dispersed across project management (Cooke-Davies*, et al.*, 2007; Geraldi and Adlbrecht, 2007; Williams, 1999), IT (Xia and Lee, 2004), NPD (e.g. Chapman and Hyland, 2004; Hobday, 1998; Shenhar and Dvir, 1996), and general management (Pich, *et al.*, 2002), among others.

The objective of this paper is to integrate the findings and frameworks of complexity of projects into an umbrella typology, taking up a challenge identified by Williams (2005). Williams' (2005) challenge was to understand what makes projects complex to manage and to provide a common understanding of the complexities of the 'lived experience' of managing in a project context. This will provide both academics and practitioners with a shared language to name and make sense of what is making projects complex to manage and how to both shape and respond to this complexity. Such a common language will allow us to connect

findings, experiences and knowledge accumulated in different environments, e.g. NPD, engineering, IT, etc., as well as different phases and parts of projects.

It is claimed that there is little building on previous studies and there is no unified understanding of complexity in the PM community (Vidal and Marle, 2008). However, we show in this paper that the work that has been done can be synthesised into an overarching schema in five dimensions. As well as answering Williams' challenge, we also provide a classification that is more general and better grounded than those used in recent, more normative (and perhaps more simplistic) textbooks on the subject such as those of Remington and Pollack (2007) and Haas (2009).

At the outset, we encountered the issue of nomenclature. Whilst practitioners routinely use the term 'complex' to describe aspects of their context, this can be discounted by academics as 'merely complicated' (Baccarini, 1996; Remington and Pollack, 2007). The argument is made that complexity, as propagated within complexity theories, is about the emergence, dynamics, non-linearity and other behaviours present in systems of interrelated elements. Such a conceptualisation is narrower than the common usage of the term 'complexity'. We are not going to argue this particular point here, as neither is an objectively definable construct (Klir, 1991). For the purposes of this discussion, the term 'complexity' will follow common usage, and therefore include both 'complicatedness' and theoretical complexity.

Methodology and data analysis

In order to construct a typology of existing work, a systematic review was conducted. A systematic review *"provide[s] collective insights through theoretical synthesis"* (Tranfield*, et al.*, 2003, p. 220). Traditionally, a systematic review was used to summarise findings based on positivistic and quantitative research, which *"sees knowledge as accumulating"* (Noblit and

Hare, 1988, p. 12,), in areas such as medicine. However, management research is eclectic (Bryman, 1995) and has a different logic (Tranfield, *et al.,* 2003), and hence the quantitative study of a heterogeneous sample of publications can lead to epistemological and ontological problems, as well as mislead and lose the richness of qualitative studies (Petticrew, 2001). This is especially true in the study of complexity. The approach known as 'systematic review' has "*methodologies that are more flexible*" (Petticrew, 2001, p. 98), which account for the different epistemologies and conceptualisations, and uses a qualitative reasoning of the studies reviewed. In the management field, there have been a number of articles in top ranking journals using such systematic reviews (Farashahi*, et al.*, 2005; Knoben and Oerlemans, 2006; Pittaway*, et al.*, 2004). This review follows such an approach.

Two databases were used as a starting point of the search: Web of Science and Scopus. The overlap between sources of publications considered in Web of Science and Scopus is not large, and consequently these sources can be used in combination to provide a wider view of the subject area. The keywords used were 'complexity' OR 'complex' AND 'project management'. The first journal article in these databases to meet these keyword criteria was published in 1996 (Baccarini, 1996) and hence the time span of the search was from 1996 to June 2010. In addition, the two key project management journals: International Journal of Project Management (IJPM, from January 1996 to June 2010) and Project Management Journal (PMJ, from January 1996 to June 2010) were included in the analysis. In press articles were not considered. The initial sample was subsequently refined through six steps (adapted from Farashahi, *et al.,* 2005; Petticrew, 2001) described below and summarised in Table 1.

Sample selection

- **Step 1:** Identification of publications. This phase consisted of the keyword search in Web of Science and Scopus, and a more detailed scan of PMJ and IJPM.

- **Step 2:** Focus on academic papers. Both Web of Science and Scopus provide this option automatically by defining the article type. Citation information, abstract and keywords of all papers were downloaded to EndNote ©, and publications that appeared more than once were deleted.
- **Step 3:** Focus on project management and on complexity (or complex). Based on an analysis of the abstracts of the articles, the sample was refined to publications explicitly related to 'project management' AND complexity, OR 'complexity of projects'. Articles that clearly did not aim at contributing to the development of the management of projects at least in a broad sense were disregarded, for example papers that were clearly focused on different knowledge areas such as medicine and biology. As this paper focuses on the managerial and organisational understanding of complexity, papers focused on mathematical scheduling techniques were also excluded from the sample. The sample was significantly reduced in this step.
- **Step 4:** Checking completeness. A good systematic review is characterised by the search of all relevant publications in the subject (Petticrew, 2001, p. 99). In order to minimise the chances of not considering relevant studies, especially books, which were not in the search engines, the references of the resulting articles were examined for further relevant publications that would also comply with the criteria used in steps 1 to 3. Academic conference papers were included, and working papers and non-academic conference papers excluded. Where a journal article was published based on a conference paper, the conference version was discounted. This contributed a further 25 sources to the pool of analysis.
- **Step 5:** Focus on 'complexity of projects'. The papers selected were from both 'complexity in projects' and 'complexity of projects' streams. The sample was reduced to papers focusing on the second. Table 2 provides an overview of the demography of the sample.
- **Step 6:** Final filter. This identified the articles that provided a framework or explicit definition of complexities, reducing the sample to 25 publications. The typology constructed

was based on these studies. The papers eliminated at this stage were used to identify indicators for each of the types and in the conceptualisation of each type of complexity.

Results of sample selection

Table 1 provides an overview of the number of publications by each refining step.

Table 1: Number of Publications by each Refining Step

	Search options	*Step 1*	*Step 2*	*Step 3*	*Step 4*	*Step 5*	*Step 6*
Web of Science	"Complex" or "complexity" and "project management" in topics, SSCI only, published after 1996	202	168				
Scopus	"Complex" or "complexity" and "project management" in title, abstract or key-words, excluding non-managerial or organisational topics such as mathemat-ics, physics, medicine, published after 1996	878	499				
IJPM	"Complex" or "complexity" and "project management" in abstract, published after 1996	101	101	48	72	47	25
PMJ	"Complex" or "complexity" and "project management" in abstract, published after 1996	32	32				

Table 2: Overview of the Sample of 47 Papers (Step 5)

Type of Paper	
Theoretical	21
Qualitative	15
Quantitative	6
Qual & Quant	5

Publication Year	
1996-1998	6
1999-2001	7
2002-2004	14
2005-2008	15
2009-2010	5

Industry	
General	21
IS	9
Construction and engineering	5
CoPS (Complex Products and Systems)	6
R&D	5
Organisational projects	1

Analysis of the 25 papers

Analysis of the publications followed five steps. In the first three, we identified a framework of five types of complexity that emerged from previous works. The last two steps explored suitable indicators for each of these complexities.

The first step in the analysis identified and extracted the frameworks and definitions of complexity from the 25 papers left after step 6. They addressed complexity in different ways, some listed attributes of complexity (e.g. Crawford*, et al.*, 2005; Hobday, 1998; Müller and Turner, 2007; Müller and Turner, 2010), others grouped them around products, processes, technology and customer interface (Chapman and Hyland, 2004), technological or organisation (e.g. Baccarini, 1996; Xia and Lee, 2005), MODeST (mission, organisation, deliver, stakeholders and team) (Maylor*, et al.*, 2008), or concepts, such as pace, structural complexity and uncertainty (e.g. Shenhar and Dvir, 1996; Williams, 1999).

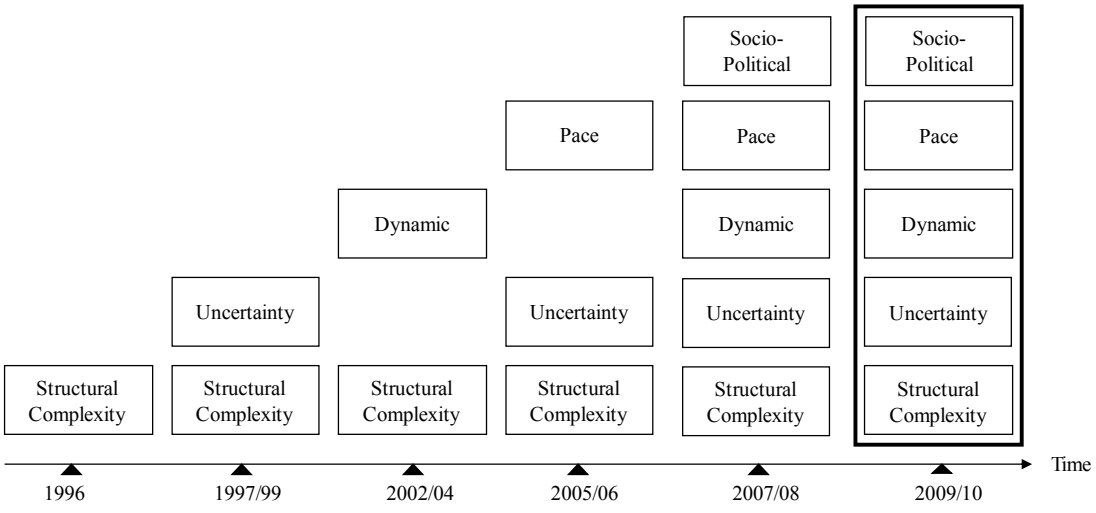
The second step in the analysis consisted of an iterative process of grouping and meta-grouping of the conceptualisations extracted from the 25 articles. The most revealing analysis though was when the publication date was considered and we identified conceptualisations progressing towards a set of five types of complexity: structural complexity, uncertainty, dynamic, pace and socio-political complexity (see Figure 1).

This does not mean that groupings of complexity were not used after the date they were proposed. For example Little (2005) used the uncertainty vs. structural complexity pair to explain complexity in 2005; Maylor *et al.* (2008) demonstrated the dual nature of structural and dynamic complexity in 2008.

The timeline indicated in Figure 1 shows when new understandings of complexity emerged. The earliest conceptions were based on structural complexity (Baccarini, 1996), and this has been considered a feature of complexity since 1996. Uncertainty was the next type to be identified (Williams, 1999). In 2002 and 2004, Ribbers and Schoo (2002), and Xia and Lee (2004) proposed the pairing of structural and dynamic complexity. The next type of complexity emerged in 2005 with Williams adding pace as a relevant aspect of complexity. The com-

bination of pace, structural complexity and uncertainty was also used by Dvir et al. (1998; 2006). Finally, the socio-political dimension of complexity was introduced by Geraldi and Adlbrecht (2007), Remington and Pollack (2007) and indirectly by Maylor et al. (2008).

The development of the concepts shows that types of complexity, on the whole, were not deliberately building on previous work. This confirms our intention of providing a framework expressing the foundations for understanding the complexity of projects. At the same time, the findings and frameworks were similar enough to suggest that a common language to express complexity of projects is possible. It is also interesting to note that the publications in 2009 and 2010 did not identify further types of complexity, reinforcing the face validity of the framework proposed here.



	1996	1997/99	2002/04	2005/06	2007/08	2009/10
First appearance	(Baccarini, 1996)	(Dvir and Shenhar, 1998; Shenhar and Dvir, 1996; Williams, 1997, 1999)	(Ribbers and Schoo, 2002; Xia and Lee, 2005)	(Dvir, *et al.*, 2006; Shenhar and Dvir, 2007; Williams, 2005)	(Geraldi and Adlbrecht, 2007; Remington and Pollack, 2007)	
Later appearance	(Austin, *et al.*, 2002; Clift and Vandenbosch, 1999; Jaafari, 2003)	(Little, 2005; Tatikonda and Rosenthal, 2000)	(Benbya and McKelvey, 2006; Maylor, *et al.*, 2008; Xia and Lee, 2004)		(Haas, 2009)	(Howell, *et al.*, 2010)

Figure 1: Historical Development of Complexity Frameworks

In the third step of the analysis, we revisited the 25 articles to validate the comprehensiveness of the five complexities and the results of this are shown in Table 3.

Table 3: Overview of Complexity Typologies focused on Project Management

Key Publication only	Motivation of the Study	Industry	Methodology	Structural Complexity	Uncertainty	Dynamic	Pace	Socio-Political
Baccarini (1996)	To unpack complexity	Construction	Theoretical	Variation and integration				
Shenhar and Dvir (1996)	To develop a typology of projects	Product development	Qualitative (interviews) and Quantitative (survey)	Project scope	Technological uncertainty		Pace (in later publications (Dvir, *et al.,* 1998; 2006; Shenhar and Dvir, 2007))	
Clift and Vandenbosch (1999)	To study approaches to reduce cycle time in projects with different complexities	Product development	Qualitative (20 projects)	Complexity			Short or long project cycle	
Williams (1997; 1999)	To unpack complexity and highlight limitations of traditional project management	General	Theoretical	Structural complexity (number of elements and interdependences)	Uncertainty (in goals and methods)		Pace in later publications (Williams, 2005)	
Tatikonda and Rosenthal (2000)	To investigate the relationship between product characteristics and outcomes	Product development	Survey with 120 projects	Complexity (organisational subtasks and subtask interactions)	Technological novelty			
Ribbers and Schoo (2002)	To identify successful managerial approaches to ERP implementations	ERP implementations	15 case studies	Variety and Interdependence		Variance		
Austin et al. (2002)	To increase repeatability of projects by modelling complexity	Construction	Theoretical	Several aspects of structural complexity				
Xia and Lee (2004; 2005)	To unpack complexity	IS	Qualitative (interviews) and quantitative (survey)	Structural complexity		Dynamic		
Little (2005)	To unpack complexity	IS	Case study in a company	Structural complexity	Uncertainty			

Jaafari (2003)	To investigate the match between complexity and the competence of project managers	General	Theoretical	Project and environmental complexity				
Benbya and McKelvey (2006)	To identify sources of complexity	IS	Literature review		Official (top down) and emergent (bottom up) changes in system[1].			
Remmington and Pollack (2007)	To unpack complexity and its matching management tools	General	Theoretical	Structural Complex (but including dynamic)	Technically complex (ambiguity in technological solution)	Temporally complex (acute dynamism of these projects is acute, especially in their constraints).		Directionally complex (ambiguity in the definition of the objectives together with key stakeholders)
Geraldi and Adlbrecht (2007); Geraldi (2009)	To unpack complexity	Plant engineering	Qualitative	Complexity of Fact (complexity involved in a large number of facts and constraints to bear in mind and orchestrate)	Complexity of Faith (uncertainty and dynamic involved especially at the beginning of projects or in moments of crisis)		Complexity of interaction (complexity emerging in the interaction between people, including transparency, empathy, language, etc)	
Maylor et al. (2008) – similar approach in Whitty and Maylor (2009)	To unpack complexity	General	Qualitative (workshops with over 100 project managers)	Structural complexity	Structural complexity also involves aspects of uncertainty, temporal complexity	Dynamic (changes in any of the elements of structural complexity)		
Howell et al. (2010)	To develop a typology of projects	Literature review	Theoretical	Equivalent to complexity	Uncertainty (focus of the		Urgency	Mentioned (‘team’ and ‘em-

[1] Emergent changes are analysed based on aspects discussed in complexity theory, they focus on adaptive tension, requisite complexity, change rate, modular design, positive feedback, causal intricacy, and coordination rhythm.

					article)			powerment')
Haas (2009)	General book on complexity and project management	General		Number of variables and interfaces, number and types of interaction.	Lack of awareness of events and causality, inability to pre-evaluate actions, and inability to know what will happen	Dynamics as rapid rate of change		

In the fourth step of the analysis, we returned to the larger literature set of 47 articles and extracted the indicators employed. Our intention was to populate each type of complexity with these indicators, and by this means connect the rather abstract concepts with aspects indicating each type of complexity as a 'lived experience', expressed by e.g. empathy, transparency, clarity of outputs, number of people involved, size of the project, etc.. Almost 200 individual indicators were identified, with overlapping items either combined or eliminated. Indicators were assigned to each type based on a best fit between definition of types (from analysis step 3) and the nature of the indicator as described in each paper.

The fifth step involved making sense of the indicators and what they were revealing about each type of complexity. The large number of indicators grouped in uncertainty, structural and socio-political complexities motivated us to develop further sub-categories to help us reflect about what these indicators were signalling. We went through an iterative process as in step three, and developed attributes expressing the characteristics of each complexity. These are summarised in Table 4, and explained in detail in the next sections.

Table 4: Attributes of Complexity Types

Types of Complexity	**Attributes**
Structural Complexity	• size (or number) (e.g. Crawford*, et al.*, 2005; Dvir*, et al.*, 2006; Geraldi and Adlbrecht, 2007; Green, 2004; Hobday, 1998; Maylor*, et al.*, 2008; Müller and Turner, 2007; Shenhar, 2001) • variety (Baccarini, 1996; Eriksson*, et al.*, 2002; Geraldi and Adlbrecht, 2007; Maylor*, et al.*, 2008) • interdependence (Chapman and Hyland, 2004; Hobday, 1998; Little, 2005; Maylor*, et al.*, 2008; Williams, 1999; Xia and Lee, 2005)
Uncertainty	• novelty (e.g. Shenhar, 2001; Tatikonda and Rosenthal, 2000) • experience (e.g. Maylor*, et al.*, 2008; Mykytyn and Green, 1992) • availability of information (e.g. Geraldi and Adlbrecht, 2007; Hobday, 1998; Maylor*, et al.*, 2008)
Dynamic	• change in (Maylor*, et al.*, 2008)
Pace	• pace of (Dvir*, et al.*, 2006; Shenhar and Dvir, 2007; Williams, 2005)
Socio-Political Complexity	• importance of (Maylor*, et al.*, 2008) • support to (project) or from (stakeholders) (Maylor*, et al.*, 2008) • fit/convergence with (Maylor*, et al.*, 2008) • transparency of (hidden agendas) (Maylor*, et al.*, 2008) (Benbya and McKelvey, 2006; Cicmil and Marshall, 2005; Cooke-Davies*, et al.*, 2007)

Structural complexity

Structural complexity, the most mentioned type of complexity in the literature, is related to a large number of distinct and interdependent elements (Williams, 1999).

The majority of the articles define structural complexity based on three attributes: *size* (or number) (e.g. Crawford*, et al.*, 2005; Dvir*, et al.*, 2006; Geraldi and Adlbrecht, 2007; Green, 2004; Hobday, 1998; Maylor*, et al.*, 2008; Müller and Turner, 2007; Shenhar, 2001), *variety* (Baccarini, 1996; Eriksson*, et al.*, 2002; Geraldi and Adlbrecht, 2007; Maylor*, et al.*, 2008) and *interdependence* (Chapman and Hyland, 2004; Hobday, 1998; Little, 2005; Maylor*, et al.*, 2008; Williams, 1999; Xia and Lee, 2005). Table 5 summarises the attributes and indicators.

Table 5: Overview of Attributes and Indicators for Structural Complexity[2]

	Indicators
Number (Size) of… Variety of… Interde-pendence between…	Scope (Crawford*, et al.*, 2005; Dvir*, et al.*, 1998; Geraldi and Adlbrecht, 2007; Müller and Turner, 2007; Shenhar and Dvir, 2007), unit cost/financial scale of project (Hobday, 1998), size/budget of the project (Geraldi and Adlbrecht, 2007; Maylor*, et al.*, 2008; Müller and Turner, 2007), breath of scope (e.g. product for global market) (Maylor*, et al.*, 2008), technologies involved in the product (Chapman and Hyland, 2004; Geraldi and Adlbrecht, 2007), embedded software in product, product volume (Hobday, 1998), systems to be replaced, data misfit, technical and infrastructural integration (Ribbers and Schoo, 2002), number and diversity of inputs and/or outputs (Green, 2004), integration of project elements (Xia and Lee, 2005), technological differentiation and interdependence (Baccarini, 1996), number of separate and different actions or tasks to produce the end product of a project (Green, 2004), process integration (Ribbers and Schoo, 2002), interdependence of distinct processes (Chapman and Hyland, 2004), processes defined and standardised but not over bureaucratic (Maylor*, et al.*, 2008), there are many ways of achieving the solution (Maylor*, et al.*, 2008), key experts are available when needed (Maylor*, et al.*, 2008), variety of distinct knowledge bases, multi-disciplinary (Crawford*, et al.*, 2005; Geraldi and Adlbrecht, 2007; Green, 2004; Hobday, 1998), number of specialities (e.g. subcontractors or trades) involved in a project, number of roles and level of labour specialisation (Baccarini, 1996; Crawford, *et al.,* 2005), variety of skill and engineering inputs (Crawford*, et al.*, 2005; Geraldi and Adlbrecht, 2007; Hobday, 1998), team size (Little, 2005), large number of resources (Maylor*, et al.*, 2008), social integration (Ribbers and Schoo, 2002), empathy and transparency in relationship (Geraldi and Adlbrecht, 2007), number of stakeholders and their interdependency (Maylor*, et al.*, 2008; Müller and Turner, 2007), intensity of involvement and interdependence of stakeholders (regulatory bodies, suppliers and partners, client, user) (Hobday, 1998; Maylor*, et al.*, 2008), number of locations and their differences (Crawford, *et al.,* 2005; Eriksson, *et al.*, 2002; Little, 2005; Müller and Turner, 2007; Ribbers and Schoo, 2002); multi-cultural, multi-language (Eriksson*,*

[2] Two further indicators could also be grouped in the typology proposed here, but these could be considered as possible consequences of projects with high structural complexity: the number of factors taken into account in the decision making process, and the decision/solution space.

	et al., 2002; Geraldi and Adlbrecht, 2007; Maylor*, et al.*, 2008); multiple time zones, collocation of team members (Maylor*, et al.*, 2008), number of concurrent projects, number of linkages from-to projects (Perttu, 2006), level of concurrent similarly complex programmes (Ribbers and Schoo, 2002), competing priorities between projects (Maylor*, et al.*, 2008), organisational vertical differentiation and interdependence – hierarchical structure (Baccarini, 1996), and organisational horizontal differentiation and interdependence – organisational units (Geraldi and Adlbrecht, 2007; Müller and Turner, 2007), number of organisational levels, departments/units involved in project (Green, 2004), client and supplier have effective governance structures (Maylor*, et al.*, 2008), health, safety and security, confidentiality, labour/union, legislative compliance (Maylor*, et al.*, 2008)

Uncertainty

Uncertainty has also emerged as a relevant type of complexity, usually in a two-by-two matrix where it is orthogonal to structural complexity. Such a classification was first proposed by Williams (1999) and subsequently seen in general management (Kirchhof, 2003) and new product development projects. Examples include Tatikonda and Rosenthal (2000)'s article on task uncertainty, and Dvir and Shenhar's (1998) and Shenhar and Dvir's (2001) typology of projects based on technological uncertainty and system scope. Little (2005) applied this combination to IT, and Perttu (2006) to organisational change.

The concept of uncertainty and its intrinsic relationship with risks has been present in the management literature since the 1920s. There are different ways of defining uncertainty. In general management it is common to speak of uncertainty in terms of variety (the probability and chance of an event) or in terms of epistemic uncertainty (lack of information, lack of agreement over current and future situation, or ambiguity). In project management, uncertainty in goals and methods (Turner and Cochrane, 1993) is often considered, as is the level of (un)predictability: variation, foreseen uncertainty, unforeseen uncertainty and chaos (Pich*, et al.*, 2002). Ambiguity in goals (Turner and Cochrane, 1993) is a well-known cause of complexity – "Projects are complex, ambiguous, confusing phenomena wherein the idea of a single, clear goal is at odds with the reality" (Linehan and Kavanagh, 2004).

Uncertainty is involved in the creation of something unique and the solving of new problems. Geraldi and Adlbrecht (2007) termed this complexity as *'complexity of faith'*, as project managers would act as "priests", convincing the team and stakeholders to have faith in the project (Peters and Waterman, 1982), but not necessarily be closed to criticism (March, 2006).

In the literature reviewed, the indicators expressed attributes of (absolute) *novelty* – technology that is cutting edge, or uncommon contractual framework (e.g. Shenhar, 2001; Tatikonda and Rosenthal, 2000), *experience* – the previous experience of an organisation, manager, team or stakeholder with such a project (e.g. Maylor*, et al.*, 2008; Mykytyn and Green, 1992), and *availability of information* – whether the information needed for decisions is available and its level of ambiguity (e.g. Geraldi and Adlbrecht, 2007; Hobday, 1998; Maylor*, et al.*, 2008).

The same structure that is used for structural complexity is applied to group indicators of uncertainty, see Table 6.

Table 6: Overview of Attributes and Indicators of Uncertainty

	Indicators
Experience with… **Novelty of…** **Ambiguity and availability of information (or knowledge) about…**	Commercial and technological maturity and novelty (Geraldi and Adlbrecht, 2007; Maylor*, et al.*, 2008), clear and well-defined vision, requirements, business case, scope, work packages, goals and success criteria and its measurements, implications of the project are well-understood, benefits are tangible, number of unknowns (Maylor*, et al.*, 2008), realistic expectation of stakeholders (Hobday, 1998), ambiguity of performance measurements (Cicmil and Marshall, 2005; Geraldi and Adlbrecht, 2007), degree to which technological and organisational aspects are new (Turner and Cochrane, 1993),– specifically technological novelty in (Hobday, 1998), or new to the company (Geraldi and Adlbrecht, 2007), degree of customisation of components and of final product (Little, 2005), uncertainty in methods (e.g. Geraldi and Adlbrecht, 2007; Maylor*, et al.*, 2008; Turner and Cochrane, 1993), project data are accurate, timely, complete, easy to understand, credible, available at the right level of detail (Maylor*, et al.*, 2008), maturity level of the organisation with effective change, risk and quality management, experience of project manager, team members are knowledgeable in technical, business and project management issues and understand project management methodology, the team members worked together before, the project team have a shared vision for the project, reliance on key experts (Maylor*, et al.*, 2008), unidentified stakeholders, previous experience of stakeholders in general and with project management, experience to work with stakeholder, stakeholders' understanding of the implications of the project,

	stakeholders are knowledgeable in technical, business and project management issues, the client organisation provides resources in a timely manner (Maylor*, et al.*, 2008), clarity in respect to organisational and technological setting (Geraldi and Adlbrecht, 2007; Hobday, 1998; Maylor*, et al.*, 2008), new organisational structure, the line of responsibility for tasks and deliverables is clear in the client's organisation (Maylor*, et al.*, 2008)

Dynamics

Dynamics refers to changes in projects, such as changes in specifications (or changes in goals due to ambiguity – so are related to "uncertainty" above), management team, suppliers, or the environmental context. These changes may lead the project to high levels of disorder, rework, or inefficiency, when changes are not well-communicated or assimilated by the team and others involved. In dynamic contexts, it is also relevant to make sure that the goals of the projects continue to be aligned with those of the key stakeholders, and new developments in competition (e.g. in NPD). Projects not only change 'outside-in' but also 'inside-out'; team motivation levels may change, internal politics may emerge. Understanding the patterns underlying at least part of this dynamic may be a good strategy to avoid "chaos", for example, by systemising change order processes.

The attributes for dynamic complexity are far less developed and specific than those for structural complexity. Authors tended to be very broad when defining the word dynamic – e.g. variability and dynamism (Maylor*, et al.*, 2008), or quantity and impact of change (Geraldi and Adlbrecht, 2007), or sector specific – e.g. extent of system redesign after pilot (Xia and Lee, 2005).

Maylor et al. (2008) defined dynamic complexity as how each attribute and indicator changed with time. A table, such as in the last two types of complexity, cannot therefore be constructed. The most suitable attribute embracing all indicators related to dynamic is simply *"change in any of the other elements of complexity"*. For instance, dynamic structural complexity

would result from a change in scope, dynamic uncertainty from the emergence of a new or disruptive technology during a project, pace changes from the imposition of a new deadline, and socio-political changes from a period of redundancy (workforce reduction) among key project stakeholders.

Pace

Temporal aspects of complexity were identified in the literature on new product development projects (Brown and Eisenhardt, 1997; Williams, 2005). Shenhar and Dvir (2007) and Dvir *et al* (2006) expanded a framework based on technological uncertainty and structural complexity and proposed the diamond approach, which includes pace. Williams (2005) also added pace to his previous model comprising uncertainty and structural complexity.

Pace is an important type of complexity as urgency and criticality of time goals require different structures and managerial attention (Clift and Vandenbosch, 1999; Remington and Pollack, 2007; Shenhar and Dvir, 2007). Williams (1999) emphasises the need for concurrent engineering to meet tighter project timeframes, which leads to tighter interdependence between elements of the system and therefore intensifies structural complexity. In later publication, the same author goes further and uses arguments of complexity theory and findings in major projects to emphasise issues related to an accelerated pace in projects. He argues that

> *"(...) the systemic modelling work explains how the tightness of the time-constraints strengthens the power of the feedback loops, which means that small problems or uncertainties cause unexpectedly large effects; it thus also shows how the type of under specification identified by Flyvbjerg brings what is sometimes called "double jeopardy"—underestimation (when the estimate is elevated*

to the status of a project control budget) causing feedback which causes much greater overspend than the degree of underestimation." (Williams, 2005, p. 503).

Unlike the other types of complexity, high pace is not an abstract construct with several indicators. It essentially refers to the rate at which projects are (or should be) delivered, and has been summarised as *'speed of'*. However, it is still difficult to operationalise measures since pace refers to the rate at which projects should be delivered *relative to* some reasonable or optimal measure (much as the well-known construction-management concept of "overcrowding" is only defined relative to some standard or optimum value).

Socio-political complexity

There is a strong stream of research in projects stressing that projects are carried out by human actors, with potentially conflicting interests and difficult personalities (e.g. Clegg and Courpasson, 2004; Goldratt, 1997; Maylor, 2001). Indeed, this is one of the key measures of complexity recognised in all management problems. The classic discussion of complexity was given by Roth and Senge (1996), who define a two-by-two matrix: along one axis is the underlying complexity of the problem situation itself, which they call "dynamic complexity". They further their definition by saying that *"dynamic complexity characterizes the extent to which the relationship between cause and the resulting effects are distant in time and space"; and along the second axis they take the complexity of the human- and/or group-effect, which they call behavioural complexity: "behavioural complexity characterizes the extent to which there is diversity in the aspirations, mental models, and values of decision makers."* (p. 126). Problems high in behaviour complexity they call "wicked"; those also high in dynamic complexity they call "wicked messes" (Roth and Senge, 1996). It was surprising then to find that socio-political complexity, as a measure of project complexity, was identified as such relatively recently (Geraldi and Adlbrecht, 2007; Maylor*, et al.*, 2008; Remington and Pollack,

2007). But having said that, when Cicmil et al. (2009) bring the work of Cooke-Davies et al. (2007) to a conclusion, it is the work of Stacey (2001) on which they focus, looking at the emergent properties of groups of people ("complex responsive processes of relating").

Even more so than the measures described above, socio-political complexity is easy to broadly conceptualise, yet difficult to operationalise. Remington and Pollack (2007) addressed this complexity as 'directionally complex', and stressed the ambiguity in the definition of the objectives together with key stakeholders – which of course compounds the underlying ambiguity of the goals discussed under the "Uncertainty" dimension above. Maylor *et al*. (2008) addressed the topic indirectly and alluded to issues involved when managing stakeholders, such as a lack of commitment of stakeholders and problematic relationships between stakeholders as well as those related to the team. Geraldi and Adlbrecht (2007) grouped some of these aspects in what they termed 'complexity of interaction'. This emerges in the interaction between people and organisations, and involves aspects such as transparency, empathy, variety of languages, cultures, disciplines, etc.

However, it should be said that this is also the area in which there are more theoretical underpinnings available to the OM researcher. For example, Habermas (1984) gives some foundations for the effects of power-relationships between stakeholders and the socio-political complexity produced. Where there is ambiguity in the definition of the objectives, such as in an IT-enabled change project, Weick (1979) gives a good basis for looking at the effects of the group "sense-making" towards a project conclusion.

Abstracting from these descriptions, this type of complexity emerges as a combination of political aspects and emotional aspects involved in projects. This complexity is expected to be

high in situations such as mergers and acquisitions, organisational change, or where a project is required to unite different interests, agendas or opinions.

Looking at the indicators and the concepts related to this complexity, we defined four attributes listed below. The following questions illustrate the kind of aspects involved in each attribute:

- *Importance of*: how much is 'at stake'? Is it a high profile project?
- *Support to (project) or from (stakeholders)*: does the project have the support necessary? Are the stakeholders resistant or helpful?
- *Fit/Convergence with*: are the opinions, interests and requirements aligned or contradicting – and/or ill-defined to allow more divergence? Do they also fit the organisational strategy of client and supplier? Are they realistic or appropriate; are the project methodologies appropriate? Does the client's methodology conflict with that of suppliers?
- *Transparency of* (hidden agendas): how far are there hidden interests in the mission of the project? How transparent is the project process? Are there power relationships between stakeholders that will affect this transparency?

Table 7: Overview of Attributes and Indicators of Socio-Political Complexity

	Indicators
Transparency (hidden agendas) within… Importance of… Support to/ from… Fit/ convergence with …	Senior management support the project, hidden agendas, conflicting requirements, competing priorities, shared understanding of the aims of the project, realistic expectations of timescale and budget (Maylor*, et al.*, 2008), appropriate tools, project management methodology is used 'for real', standardised but not bureaucratic project processes (Maylor*, et al.*, 2008), trust and empathy (Benbya and McKelvey, 2006; Cicmil and Marshall, 2005; Cooke-Davies*, et al.*, 2007), personality clashes, commitment, appropriate authority and accountability (Maylor*, et al.*, 2008), stakeholders' commitment, (un)helpful interference, resistance, ownership, appropriate authority and accountability (Maylor*, et al.*, 2008); conflicts, power struggles and hidden agendas between stakeholders (Maylor*, et al.*, 2008); project information adequately communicated, shared resources across different projects (Maylor*, et al.*, 2008), project information adequately communicated, project manager has control over human resource selection, the project goals are aligned with the organisation's strategy, there is a clear sponsor, the client and supplier organisation accommodates projects well, the client's and supplier's procurement process supports the project's objective (Maylor*, et al.*, 2008)

The framework and the nature of complexity

In identifying these five complexities, we are aware that authors such as Capra (1997) and Malik (2002) would argue that the definition of a delimited set of characteristics of complexity negates the very concept of complexity. Indeed, bounded rationality (Simon, 1982) and the constructed nature of complexity (Klir, 1985) hampers its definition as a complete, general, 'perpetual' and precisely measurable set of characteristics. The complexities identified are broad categories and the associated indicators provide a good, but certainly incomplete, list. Our limited experience beyond this study in testing the indicators in practice has shown that they are reasonably general, though do need minor tailoring for the environment in which they are used. With the emergence of new environments for PM they are unlikely to be perpetual, and precise measurement was not the purpose of this work. However, complexity (or complicatedness) is something that managers experience, and therefore is appropriate to study through such perceptual means. The assessment of the type of complexity is subjective and will be influenced by the project manager. How they perceive and respond to complexities, is a more individual and interactive consideration than is represented by the current literature.

We further recognise that the approach questions whether or not 'complexity of project' is truly an independent variable.

We note the challenges with complexity assessment, but are convinced of the value of continuing to develop the concept of 'a pattern of complexity' (Geraldi and Adlbrecht, 2007). This is undoubtedly a compromise between a paralysing holistic view and an over-simplified atomised view of complexity. Furthermore, the pattern of complexity does not negate the theories of complexity, but rather enables more precise description which will lead to a more informed approach to studying the complexities of projects. Further, for practitioners the complexities can be used as a starting point for a reflection on the challenges a project faces, or will face, and the development of strategies to cope with them (Schön, 1991; Schön and Rein, 1994).

A further aspect of the nature of the complexities is that they are transitory – the profile of complexities will change over time. Complexity has a temporal dimension (Geraldi and Adlbrecht, 2007). This temporal dimension is the kind of expected, relatively long-cycle change that would occur over a project life-cycle, and is different from the disruptive influence of dynamic complexity.

In addition, the complexities are interdependent. For instance, high uncertainty may increase the level of dynamic complexity where significant unmitigated risks are realised, and high pace requires high interdependence of tasks leading to high structural complexity. This interdependence challenges the multiple, exclusive clause of typology (McKelvey, 1982).

Making use of the categorisation in practice

We have established this framework as a descriptive tool for both practitioners and academics. For practice, understanding this independent variable can help with:

- *Business case development*: In the concept stage of a project, complexity comes as one of the key themes needing exploration (Williams and Samset, 2010), and in evaluating goals, estimates and the potential effects of turbulence on the business rationale for the project (Haas, 2009). The different complexities could also indicate different success criteria for the project (Shenhar and Dvir, 2007).

- *Strategic choice*: In aligning projects with organisational strategy, there will be a tension between a requirement for diversity of complexities in the project portfolio (do not have all projects high in pace if resources are not going to be available) yet focused on what the organisation has decided are its competitive priorities (for instance by developing the capability to handle socio-political complexity).

- *Process choice*: A key use of the complexity dimensions is in the choice between different PM methods or approaches. This was a key conclusion from Williams (2005), who looked for different PM methodologies when structural complexity, uncertainty/dynamics and pace were all high. Shenhar and Dvir (2007) considered how the PM decisions and concerns should vary as the dimensions of complexity vary. However, they omit socio-political complexity – perhaps the most important dimension which should affect the design of the PM system. The choice of particular tools too can be geared towards helping to understand different complexities. Remington and Pollack (2007) describe 14 tools and the complexities that they are intended to assist in 'managing.' These range from simple (such as mapping) through to advanced techniques such as "Jazz" ("time-linked semi-structures").

- *Managerial capacity*: Just how much time and energy a particular project requires to manage is notoriously difficult to estimate. Understanding the implications of different complexities for managerial input is a major opportunity.
- *Managerial competencies*: The assessment of project complexity should affect both the selection of project managers for particular projects, and project-manager training for an organisation as a whole (a number of organisations have embarked on a complexity-driven approach). While training of project managers traditionally concentrates on the structural-complexity dimension and on the pace dimension, issues of uncertainty, dynamic and socio-political complexity are increasingly being included in management development (Thomas and Mengel, 2008).
- *Problem identification*: Finally, Haas (2009) suggests that considering the complexities of a project would help in understanding causes of problems and also in recovering troubled projects.

Conclusions and Areas for Further Research

Our point of departure was the need to provide a comprehensive description of the independent variable, complexity of project, as a means to develop an understanding of the relationship between practices and outcomes in project-based processes. This paper has systematically reviewed the academic literature on the complexity of projects and has proposed an umbrella typology. Types, attributes and indicators of complexity were identified and regrouped around five complexities: structural, uncertainty, dynamics, pace, and socio-political. The typology also promotes a link from abstract types of complexity to the specific indicators expressing complexity as a lived experience. The link between the complexities and the organisational response to those complexities, in terms of business case, strategic choice, process choice, managerial capacity and competencies has also been identified.

It does appear that the way that uncertainty is managed in projects (through risk and opportunity management) could be broadened to complexity management. Uncertainty is only one type of complexity, and there are well-developed approaches for this. Beyond simply assessing and understanding the complexity of a project, the active management of complexity is worth exploring. An assessment of the complexities could result in some of the indictors being actively managed. For instance, a project with a high socio-political complexity could benefit from more effort being expended on managing the senior stakeholders, or the hiring of a project manager who is skilled in working with such stakeholders. This would be different from a project that had high levels of structural complexity, where the application of systems engineering and computerised tools may help the project manager to deal with such complexity. For further research, the role of agency in developing structures should perhaps also be explored. Complexity can be self-induced (Geraldi, 2009), and therefore studies could also go beyond contingency theory and explore views considering the negotiation of agency and institution when shaping complexity and its organisational response.

Alongside the work presented here on complexity of projects, a preliminary analysis of the application of complexity theory to project management was seen to suffer a particular problem: not one of the publications identified under the heading of 'complexity in projects' provided any evidence or justification that a project **is** a complex system (equivalence). We concur with the view that projects can exhibit many of the characteristics of complex systems (analogy), and there are insights to be gained from viewing projects through the lenses provided by the various complexity theories. However, equivalence has not been established. We believe that the discussion of complexity would benefit from work to clarify whether such equivalence is indeed justified, and under what circumstances.

Finally, we return to the need for a study of the complexities of projects. Even the general study of complexity is criticised for its aseptic way of treating people. The inclusion of socio-political complexity in our typology actively addresses this criticism. With our new understanding of the breadth of the concept of complexity comes the opportunity to study the appropriateness of individual and organisational responses, in particular to non-structural complexity issues. This does open up the possibility for an evaluation of traditional approaches (e.g. through the application of one of the bodies of knowledge), and whether different responses to other types of complexity could be beneficial in practice. Furthermore, it would be worth exploring whether the assessment of complexities could be valuable to strategic choice, process choice and the selection, development, and resourcing of operations managers outside project-based operations.

We are in a moment of paradigm shift in PM (Geraldi*, et al.*, 2008). The study of complexity of projects has emerged in the search for ways to better represent the "realities" of projects, and propose management approaches to 'fit' these realities. The concept of 'fit' is well developed in OM generally but has seen little application to project-based processes. It is vital that this research begins its own paradigm shift, and builds on a common language that moves the debate from defining complexity and its characteristics to developing responses to project complexities. Maybe then, we can help practitioners and their organisations to manage complexity, instead of creating an even more complex (and complicated) reality.

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