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Revisiting Project Complexity: Towards a Comprehensive Model of Project Complexity

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Abstract. Project complexity is a hotly debated area addressed in numerous books and papers. Developments in project complexity are classifiable as contributing to either *complexity of projects* or *complexity in projects* streams. Unfortunately, much of the work in the *complexity of projects* steam relies on a model of project complexity that is far from complete and is in dire need to be revisited. Building upon earlier work this paper presents a revised and more comprehensive model of project complexity.

Keywords: Project complexity, complexity model, complexity in projects

1. Introduction

The birth of project management resides in the interstice of the 1930s, in the chemical industry [1]. While 'project management' as a practitioners discipline, emanated in the post-WWII developments of technology and infrastructure [2]. In the years following the publication of the first academic article on project management by Gaddis [3], the discipline has made significant strides and contended with various issues. In recent years the discipline has focused on a critical examination of it self through the lens of complexity. Complexity literature is apportioned as either debating the issues of *complexity of projects* or *complexity in projects*; where the former relies on pragmatic concerns stemming from project complexity, while the latter borrows heavily from developments in the natural and physical sciences and provide esoteric discussions of less practical concern. In this paper we concern ourselves with the *complexity of projects* stream and contend that the classical model of project complexity, upon which most of its literature is based, is itself lacking and needs re-examination.

2. Background Discussion on Complexity

Etymology of the word 'complexity' has been traced back to 1721 and it conveys the idea of compositeness and intricacy [4]. The term 'complexity' comes from the Latin word *complexus* [which comes from *complecti*], which translated means to twine, ply, or braid [5]. In general, complexity refers to the difficulty of understanding a phenomenon in a given context or environment. In more specific terms its usage signifies complicated interactions between many parts. Complexity is defined in various ways across a diverse set of disciplines and in relation to various systems, there is however, little consensus regarding the precise meaning of the term [6].

Complexity is defined variously depending on the field in which it is applied, literature at one point identifies at least 31 definitions of complexity [7], attributed to a list compiled by Seth Lloyd.From a sociological perspective it is considered to be a natural consequence of our society, where the entire complex of structural elements in our society contribute to what can be viewed as a 'instrumental complex', which is comprised of certain fundamental dimensions, such as: occupation, exchange, and property; these are considered to be inextricably interdependent[8] and it is due to the interactions between these that specific implementations of complexity arise within this macro societal level complex and it is one of these micro level complexities that concerns us i.e. the complexity of projects.

A working definition of complexity is provided by Mikulecky[9] who defines it as '*the property of a real word system that is manifest in the inability of any one formalism being adequate to capture all its properties. It requires that we find distinctly different ways of interacting with systems. Distinctly different in the sense that when we make successful models, the formal systems needed to describe each distinct aspect are NOT derivable from each other*'. However, further discussion on the granularity underlying complexity is necessary before we move our discussion forward. The terms complex and complicated are often used interchangeably in common dictum however, each has specific connotations therefore it would be pertinent here to differentiate between them. Additionally, the word 'interesting' has also been used as a synonym for complexity [7], however as its not in prevalent usage we do not discuss it further. According to Eriksson [10], who in elaborating Le Moigne's Systemic Theory defines complicated systems as having characteristics of reducibility and complex systems as those exhibiting surprising behaviour and any attempts to simplify a complex system increases the complexity of the problem and will not yield a solution. Therefore, instead of relying on simplification, intelligence is needed to understand and explain a complex system; this requires a focus on the processes of actions and outcomes (consisting of three functions: temporal, morphologic, and spatial transfer) comprising the system *(ibid)*. Thus, transitioning from an understanding of complicated systems to complex systems requires a paradigm shift. Comparatively, a simpler dichotomy between complex systems and simple systems is provided by Mikulecky[9], who defines a simple system as a formal system that provide a linear functional (yet approximate) model of the real.

It begs a discussion then, what are chaotic systems? A possible answer is that chaotic systems are not complicated, complex or simple systems, however this does not clarify precisely what we mean when we use the term a 'chaotic system'. From the descriptions provided above it could be inferred that chaotic systems are those that are non-linear, completely unknowable, and thus fully unpredictable. As chaotic systems are beyond the scope of this study they will not be discussed any further.

From the discussion above it is conferred that complicated systems are those that are not simple (rather it could be argued that they are a collection of simple systems), but still knowable; conversely complex systems are those that are not fully knowable, but are reasonably predictable. These four systems could be placed on a continuum ranging from the simple to chaotic, see figure 1. Another way to understand a complex system is from a reductionist perspective i.e. a complex system can be broken down and examined where each of its pieces can be understood in its own right, however how all the pieces interact and function is a mystery, however such a reduction destroys important system characteristics irreversibly (this is explained in terms of set theory in Mikulecky[9]); or in other words, permitting the use of an aphorism, the whole is greater than the sum of its parts. Interestingly, its been noted that complex behaviour may be found in the simplest of systems as well [1].

Predictable Unpredictable

Figure 1: The system continuum, from the knowable to the unpredictable

Flood [11]andFlood and Carson [12] disassemble complexity into two parts *people* and *things*; where the former contribute to complexity via abstract thought and the latter suggests concreteness and tangibility. Thus it could be argued that even the most concrete of situations may present itself differently due to the different possible perspectives of the people involved. In examining common definitions of complexity Flood [11]goes on to present a simple model of complexity, reproduced in figure 2.

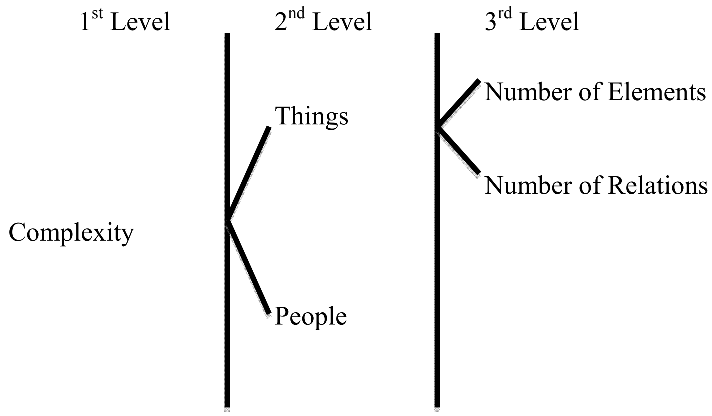

Figure 2: Disassembly of Complexity [11]

The role of people in complexity is further elaborated by Stacey et al. [13] who in presenting a collection of arguments proposes that people's role in complexity is composed of two elements. The first element, which we term 'Social Interactions', is first presented by Langton [14] who argues that the logical structure of the interactions rather than the properties of the agents involved is of import; Wheatley [15] attests to the importance of these interactions, suggesting that individuals cannot exist without such relationships. While, Kauffman [16, 17] argues that these interactions are driven by self-interest and a need for survival. The second element of people complexity, what we term 'Rules', are derived from 'schemas' [18] that describe or predict others behaviour, and 'strategies' [19] that suggest to an individual what to do as the game unfolds. Thus we are able to derive an extended model of complexity from the preceding discussion, this is presented in figure 3.

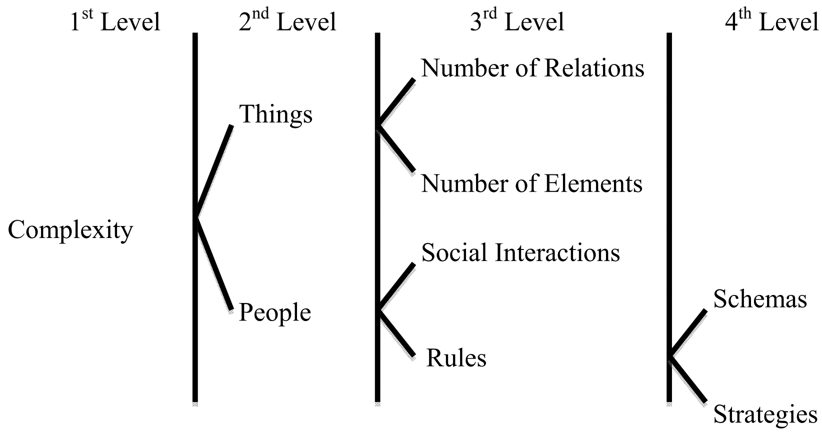

Figure 3: Disassembly of Complexity an Extended Model

Most writings on complexity in organizations are concerned with task complexity. Campbell [20] proposes that task complexity increases when out of many possible paths only one leads to goal attainment, multiple outcomes are required, there is conflicting interdependence among paths, and goal attainment is uncertain. Wood [21] establishes three types of task complexity: component, coordinative, and dynamic. Component complexity relates to the number of actions and information exchanges during a task; coordinative complexity relates to the relationships underlying actions and information exchanges; and dynamic complexity relates to the changing state of the task environment.

3. Discussion: An Extended Model of Project Complexity

Project management literature identifies a number of project dimensions and characteristics that constitute project complexity, these may be found in projects regardless of their size. The term 'a complex project' is elusive to define, however there is a general consensus that it refers to something more than size [1, 22] and uncertainty [22]. Initial attempts at defining project complexity are founded on two key concepts *differentiation* and *interdependency* [22], where differentiation refers to the number of varied elements and interdependency to the degree of interrelatedness amongst those elements [23]; reflecting the underlying themes of complicatedness, involvement, and intricateness (as discussed previously in the discussion on the general meaning of complexity see section 2.6). Differentiation and interdependency according to Baccarini[22] could be examined within the contexts of various project dimensions, such as: organizational complexity and technical complexity; and perhaps other dimensions of complexity e.g. resource complexity [24], and structural complexity [1, 25]. A graphical representation of the complexity model proposed by Baccarini is presented in Figure 4.

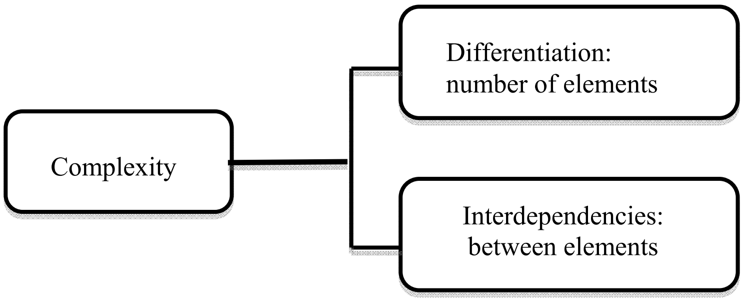

Figure 4: Baccarini's[22] model of project complexity

Surprisingly, Baccarini[22]'s paper ignores the concept of uncertainty despite its reliance on an earlier explanation of technical complexity provided by Jones and Deckro[26], which deployed the concepts of differentiation, interdependency, and instability of assumptions or uncertainty in its explanation building. Uncertainty, according to Turner and Cochrane [25] occurs along two dimensions i.e. goal definition and method design, each contributing to the complexity of a project [1]. Interestingly, Clegg [27] argues that the main objective of all organizations is to absorb or reduce uncertainty arising from the extraneous environment and buffering the technical core from influence, thus reduction of technical uncertainty is the responsibility of technical specialists, achieved via flexibility and adaptability. Turner and Cochrane's uncertainty model is presented in Figure 5.

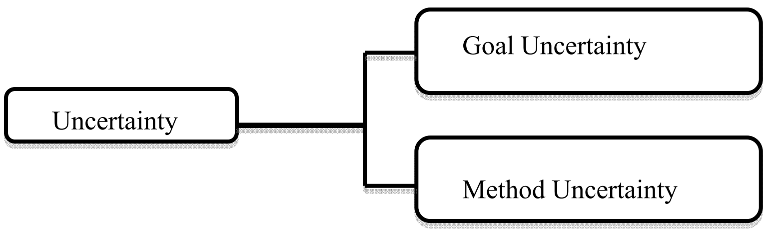

Figure 5: Turner and Cochrane's [25] model of project uncertainty

Gidado[28] defines four types of uncertainties, which he proposes originate from within the task, the environment, and the resources employed. However, of the four uncertainty types proposed the only one not covered by Turner and Cochrane's model is environmental uncertainty; thus, justifying the addition of an added dimension to uncertainty. In a later article Shenhar et al. [29] divide uncertainty into internal and external, where internal uncertainty affects the process of product design while external uncertainty is limited to the accuracy and predictability of customer requirements; however, this too is a rewording of the Turner and Cochrane model.

Williams [1] argues that most of the concerns regarding a project's complexity pertain to its (product) structural complexity – also referred to as structural intricacy [30], thus his model of project complexity is based on structural complexity, which refers to the number of ways in which labour can be divided into distinct tasks and the coordination needed to achieve the task [cf. 31]. Additionally, Williams [1, 32] contends that uncertainty (both *aleotoric*and *epistemic*) adds to the complexity of a project, hence it can be viewed as a constituent dimension of project complexity. Conversely, Tatikonda and Rosenthal [33] propose that complexity contributes to uncertainty. Remington et al. [34] clarify that uncertainty causes technical complexity, while directional (goal) complexity causes uncertainty. De Meyer et al. [35] group uncertainty into four categories: variations, foreseen uncertainty, unforeseen uncertainty, and chaos. Williams' model of complexity is presented in Figure 6.

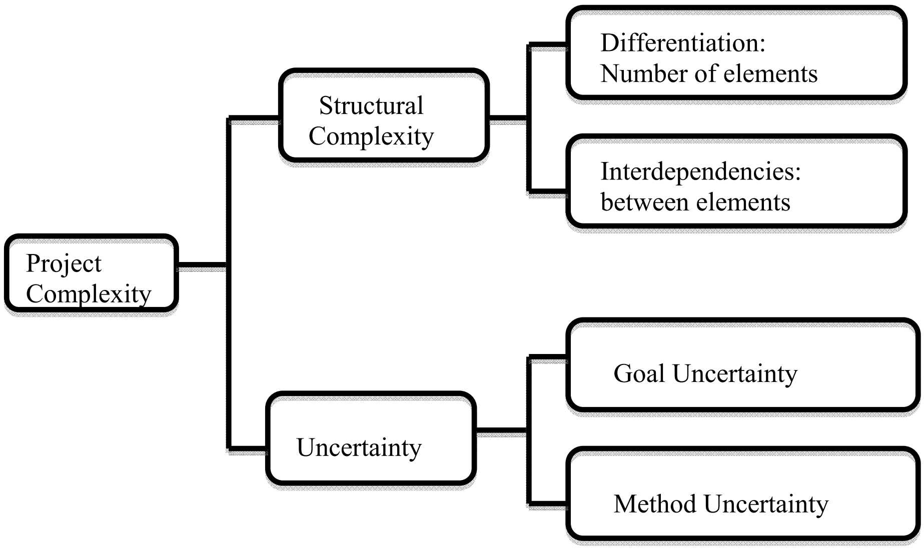

Figure 6: Integrated model of project complexity, adapted from Williams [1, 23]

Interestingly, Remington and Pollack [36] remark that structural complexity is often referred to as complicated rather than complex, the real complexity they argue arises from the difficulty in managing and monitoring the large number of different tasks and activities (the difference between complicated and complex has already been discussed in section 1). Following in the tradition of Baccarini, Williams [1, 23] uses the concepts of differentiation and interdependence to make sense of structural complexity, which according to him is composed of sequential complexity and feedback complexity. Here sequential complexity is used to define the number of elements that are interconnected (differentiation), whereas feedback complexity refers to the nature of these interconnections (interdependence). Work by Scott and Davis [37] argue that technical complexity and structural complexity are directly related, in that greater the technical complexity the greater the structural complexity – where the structural response to technical diversity is organizational differentiation as technical complexity does not invariably give rise to greater complexity of structure, rather it nourishes greater complexity of the performer. Additionally, greater technical uncertainty translates into lesser formalism and centralization but more coordination and information requirements.

Thus, coming to terms with the complexity of a project requires not simply counting the number of interdependencies, but rather to understand their nature as well [1, 22]. Three types of fundamental interdependencies have been identified these are, pooled, sequential, and reciprocal [38]; a pooled interdependency is the simplest interdependency in that each differentiated element contributes a discrete input to the project and is not sequence bound, while the sequentiality of the inputs/outputs is a concern of the sequential interdependency, where the output of one element becomes the input for another. Both Baccarini[22] and Williams [1] confer that reciprocal interdependency, consisting of feedback and loops, represents the highest level of complexity and is a catalyst for project complexity [also see, 39]. Thompson [38] goes on to argue that pooled interdependence is best managed through standardization, sequential interdependence through plans and schedules, and reciprocal interdependence by feedback and mutual adjustment; where each type of coordination will have associated with it certain costs.

In a more recent work Remington and Pollack [36] contend that all projects exhibit attributes, such as: interconnectedness, hierarchy, communication, control, and emergence; and that that most large and many small projects also exhibit certain additional characteristics such as: phase transition, adaptiveness, and sensitivity to initial conditions – which happen to be the characteristics of complex adaptive systems; thus, conjecturing that complex projects are best understood in terms of complex adaptive systems than as simple systems. Where phase transition entails an adaptation in response to a changing environment; adaptiveness is the responsiveness of the complex system to a changing environment, which could take one of two forms, maintaining control or improving: against a single fixed external reference point or against a set of variable external reference points; and sensitivity to initial conditions refers to the unanticipated and often catastrophic effects caused by the miniscule initial conditions in a complex system (perhaps best expressed by Lorenz's 'butterfly effect') [36]. Interestingly, it could be argued that Baccarini's primary criteria of a complex project i.e. differentiation and interdependence are captured by Remington's characteristics of all projects in general, what then is a complex project from Remington and Pollack's perspective is one that exhibits phase transition, adaptivenss, and sensitivity to initial conditions. Whereas, Cicmil et al. [5] propose that in order to classify a project as complex requires focusing on 'the level of non-linearity, evolution, emergence and radical unpredictability in the interaction among, and behaviour of, project participants, and their implications for the management of a project'. They go on to clarify that the existence of certain pertinent concerns within project environments when combined illustrate project complexity, these are: persistent ambiguity and equivocality of project goals and contradictory and conflicting understandings of project success; inherent unpredictability of future events; and complex multi-agency interfaces, social interaction, and processes of relating.

Therefore, it could be argued that Williams' model (see figure 6), although simplistic and helpful, ignores the effects of social interaction and their contribution to project complexity. Thus, an extended model of project conflict is needed; we achieve this by integrating the two models presented in figures 2 & 3 and also extend Turner and Cochrane's model of uncertainty (see figure 5) by adding the component of environmental uncertainty (discussed above), and Williams' original model; this is presented in figure 7.

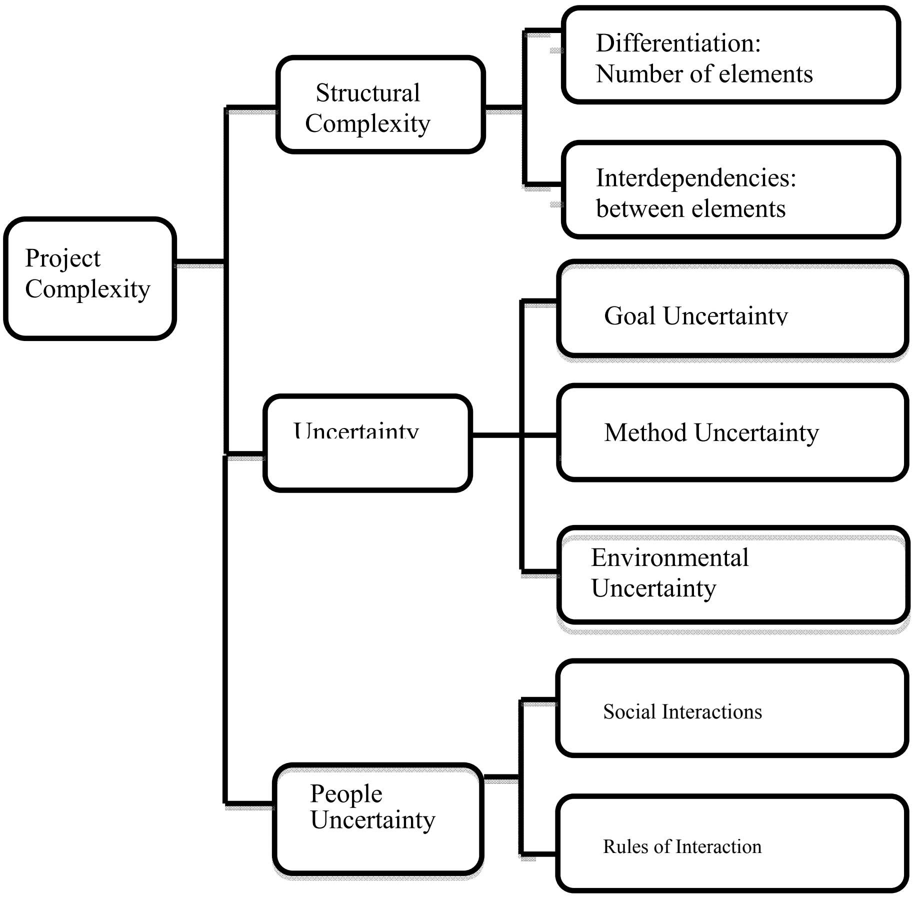

Figure 7: An extended model of project complexity

4. Conclusion

The discussion contained in this paper has established an extended model of project complexity that while retaining elements of the previous model is more rigorous than its predecessor. In addition to extending the body of *complexity of projects* knowledge our model allows for the integration of the social perspectives of projects as valid contributors to project complexity. This model holds further repercussions for the existing measures of project complexity and these measures needs to be updated.

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