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Mapping risk and complexity for construction projects

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Abstract
A project is the organised undertaking of pre-determined tasks or activities, using specific technologies and resources, in order to fulfil desired objectives. Project complexity arises from the differentiation, interdependency and uncertainty associated with any or all of these elements in the procurement, operational or disposal environments of a project. The presence of uncertainty, and the implicit and explicit decision making involved in projects, exposes project stakeholders to risks. Complexity increases the level of risk. A technique is proposed for identifying and mapping risks against the project elements and their complexity characteristics. Mapping projects in this way should better inform stakeholders about the nature, type and intensity of the complexities and risks associated with their projects, and should lead to better ways of dealing with them.

Keywords: Project complexity; risk management; risk/complexity identification and mapping tool.

Introduction
The aim of this paper is to explore the use of a mapping technique for investigating complexity and risk in projects; the objective being to develop a risk/complexity mapping tool that project stakeholders can use to assess the nature and level of complexity, expose uncertainty, audit their decision making and identify the associated risks.

The paper commences with a brief review of the nature of projects, project stakeholders, complexity, uncertainty, risk and risk management. This provides the necessary underpinning for the design of a risk/complexity mapping tool. Feedback from postgraduate student critique of the tool is presented, and refinements are suggested. The implications for communication processes and organisational structure are also considered.

While much of the paper uses construction projects as vehicles for examples, the proposed mapping technique is intended to be generic in principle but customisable for application.

Projects
According to the Project Management Institute (PMI, 2004: 5), a project is a “temporary endeavour undertaken to create a unique product, service or result”. It is therefore a deliberate undertaking that comprises the planned and organized achievement of pre-determined objectives, usually within a given timeframe.

Projects incorporate three elements: tasks, technologies and resources, brought together through a fourth element – organisation, and constrained by time (Edwards and Bowen, 2005). Tasks are what
need to be done. Technologies are the technical processes involved (how it is to be done). Resources are the means for carrying out the tasks, applying the technologies and staffing the endeavour. Organisation integrates and controls the other three. It determines who and/or what will be involved, when, and where. Decisions are made about each of these elements, and the decision making gives rise to risk – largely because the decisions are focussed on the future rather than the present and thus uncertainty is encountered. In projects, therefore, the essential contexts for risk and risk management lie in the decision-making associated with any or all of the project elements. This is shown diagrammatically in Figure 1.

![Figure 1. Project elements and environments (Source: Edwards and Bowen, 2005).](image)

Initially, decision-making takes place within the environment of project procurement – the process of designing and delivering the project to an operational state where it will function as intended. Beyond this, decision making – and thus risk and risk management - may also be involved in the project’s operational environment. Beyond that, yet more decisions may concern the eventual disposal or termination environment of the project. Decision making about matters relating to any or all of these environments may occur at the inception of a project, or at appropriate points along its time continuum.

An open-cast mine is a good example of a long-term project where decisions about the disposal environment (and, more importantly, its pre-planning in the procurement phase) may be as important as any required for the procurement and operational environments. Events projects, such as conferences, expositions, exhibitions, parades and sporting competitions, demonstrate the need for consideration of all three environments on a relatively short-term basis. With a life-cycle approach, the impacts of procurement decisions upon the operational and disposal environments can be assessed. Designing for buildability, but with eventual disassembly in mind, is an example of this.

**Project stakeholders**
Many of the decisions about project tasks, technologies, resources and organisation affect other stakeholders (participants or actors) involved in the project. Essentially, each stakeholder must deal with the risks he or she faces on a project. A universal risk management system for a multi-
stakeholder project is therefore impracticable, and this paper assumes the perspective of a project stakeholder organisation managing its own risks. A similar approach is taken towards project complexity, since perceptions of complexity may differ between stakeholders. However, differences in perception must not preclude interaction and communication between the various stakeholders on matters of complexity and risk.

Complexity
General dictionary definitions of complexity provide a starting point: complicated; intricate; involved; difficult to understand or explain. An important aspect of this rather abstract understanding is that complexity contributes to risk in projects (Smith, 1999) and adds to their costs. It contributes to risk because (see later definition of risk) it increases the chance that something will happen to threaten the achievement of project objectives. It adds to costs because of the additional resources required to cope with it. Baccarini (1996) and Williams (1999) have attempted to offer a more concrete understanding. They suggest that the complexity of a project is influenced by two factors relating to its constituent elements and sub-elements, and is exacerbated by the level of uncertainty associated with these factors. The two factors are differentiation and inter-dependency. Project complexity may be present in any or all of its procurement, operational or disposal environments.

Differentiation
The level of differentiation in a project is the extent to which its constituent elements and sub-elements should be considered separately – literally, into how many parts it should be broken down. This is not necessarily the same as the number we could count separately. In a reinforced concrete structure, for example, it might not be necessary to deal separately with the concrete required in suspended slabs and integral beams. On the other hand, it may be important to distinguish between the amounts of concrete of different strengths required, or concrete poured at different heights. Note, too, that differentiation arises in project tasks, technologies, resources and organisationally. High levels of differentiation add to complexity through the sheer number of different things which must be dealt with. Differentiation complexity may also arise from the need to consider the same item occurring in different locations (e.g., spatially distributed projects).

Comparing differentiation complexity in similar types of projects (e.g., hospital projects) cannot be easy. Comparisons between different types of projects (e.g., hospitals and airports) are likely to be far more difficult, and the wisdom of attempting to explore comparative complexity in this way is questionable.

Inter-dependency
Inter-dependency between the differentiated parts of a project contributes significantly to its complexity, and refers to the nature and extent of any relationships among the parts. Dependencies can arise within the task, technology, resource or organizational elements and sub-elements of projects and, to some extent, between them. High levels of inter-dependency complexity are found most often in the task elements of projects, and usually impact on time planning (scheduling, programming). Planning flexibility is usually the only way to mitigate risks arising from this. Inter-dependency can be pooled, sequential, or reciprocal.

Pooled inter-dependency: If the differentiated elements of a project can be dealt with separately and without interference from each others, until the project is complete or a distinct point of integration is reached, then inter-dependency is minimal and the requirements for each element are pooled to represent the whole. In a schedule context, for example, pooled inter-dependency will mean that the time required to complete the project (or to reach a specific mile-stone) can be represented by the time needed to finish the slowest activity. A book project, where different authors are invited to contribute chapters on a common theme, is an example of this. To reach a final compilation point preparatory to publication, the editor has to wait until the slowest author has finished.
**Sequential inter-dependency:** In sequential inter-dependency, the conditional relationships between project elements are important determinants of complexity. One part must follow or precede another (or be undertaken at the same time) in order to effect the whole. Typically this is observed in the logic chains of critical path programming, where the overall time required for the project is represented by the length of the critical path. However, as long as the overall sequence remains unaffected, a change in one part does not necessarily require a concomitant change in any of the inter-dependent elements.

**Reciprocal inter-dependency:** Reciprocal inter-dependency occurs when turbulence or change occurring in one element of a project necessitates change to, or induces turbulence in, one or more of the other parts. Changing the ceiling design in a building, for example, might mean changing the type of light fittings to be fitted in the ceilings.

While this view of complexity appears rational and susceptible to straightforward quantitative assessment, it should be borne in mind that, for any project, it will arise through the subjective perceptions of individuals. The differentiation and inter-dependency complexities of tasks, technologies, resources and organisation relate to project risks and risk management through the uncertainty associated with project decision-making.

**Uncertainty**

Many project decisions are made on the basis of forecasts of outcomes or events occurring at some time in the future, whose occurrence or magnitude cannot be known with precision (certainty) beforehand. Most projects are therefore subject to at least some degree of uncertainty, but uncertainty states are rarely static. The level of uncertainty in a project changes over time, in nature and/or degree. The relationship between project complexity and uncertainty is therefore dynamic. This is indicated in Figure 2 within the context of the constituents of a project. The operational and disposal environments of the project are represented as ‘shadows’ for the purposes of simplicity; and only the organisation element has been expanded to indicate possible sub-elements.

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**Fig. 2. Project environment and element complexity**
(Source: adapted from Bowen and Edwards, 2005).
Risk and risk management

AS/NZS 4360 (2004: 4) defines risk as “the chance of something happening that will have an impact on objectives” and notes that it is often specified in terms of events and their consequences. Risk management is a systematic approach to dealing with risk, and incorporates processes to:

- Establish the context.
- Identify the risks.
- Analyse the risks.
- Evaluate the risks.
- Treat the risks.

Integrating these should include an emphasis on intra- and inter-organisational communication and consultation, and a continuous process of monitoring and review (AS/NZS 4360, 2004: 13). Additionally, however, since many organisations engage in multiple or serial projects, risk management should also incorporate processes to capture risk knowledge from current projects so as to make it available for risk learning purposes and for application to future projects.

The critical ingredient in risk management is risk identification, since a risk that is not identified cannot be proactively managed. What is needed, therefore, are techniques and tools that an organisation can employ to identify the risks it faces on projects in which it is involved. Several techniques have been devised (event trees, fault trees, decision trees, HAZOPS, etc.) but these are rarely easily applicable to projects. The earlier discussion about projects, project complexity, uncertainty and decision making provides clues about the nature of the tools that are needed. If the appropriate contexts can be established, and the project task, technology, resource and organisational requirements determined, then it should be possible for stakeholders not only to assess the level of complexity presented by a project, but also to proceed in a well-structured manner to identify the risks involved.

The broad context for a stakeholder’s risk management on a project commences with the project objectives (note that these are the objectives the stakeholder has for the project). More specific contexts lie in the stakeholder’s task, technology, resource and organisational elements of the project. The requirements imposed by these elements together determine the level of complexity.

From this point it should be possible to interrogate the project parts systematically to identify risks. For each of the project elements, six questions can be addressed:

1. What decisions are involved?
2. What are the current uncertainties associated with these decisions?
3. What are the threats to successful outcomes?
4. What are the opportunities to improve outcomes?
5. How does project complexity influence these threats?
6. How does project complexity influence these opportunities?

Given these conceptual and process understandings of projects, project complexity, risk and risk management, it is possible to devise a technique which a stakeholder can use to identify and map the perceived complexities and risks of a project.

Mapping project complexity, uncertainty and risk

Figure 2 illustrates project complexity conceptually, if at the cost of some over-simplification. The diagram is useful for understanding the concepts of complexity and uncertainty, and how they are associated, but it does not reveal anything about the risks associated with real-life projects. For that purpose, risk mapping may be a more practical approach, using a spreadsheet matrix to populate cells with appropriate information, assessments or speculations. The information may be derived from
what is already known, or can be assumed, about the project. Assessments and speculations will probably best be obtained from workshop brainstorming, with project staff from the organisation as participants (or, if appropriate, members of the project “team”).

Figure 3 (attached at the end of this paper) shows how the tool can be formatted to permit mapping of project complexity and project risks against the task, technology, resource and organisational elements of a project. These elements are driven by the stakeholder’s objectives for the project. The designed matrix distinguishes between tasks and activities. The former are proposed as aggregations of the latter – in a warehouse construction project, for example, the completion of the structural steel frame might be one task necessary for the contractor to achieve in order to satisfy an objective of delivering the project on time, but this task comprises many related activities such as estimating and ordering the steelwork, taking delivery, hoisting, assembling, fixing in place, painting, etc. The extent of task/activity disaggregation would have to be decided by the mapping workshop team, and the decision would be influenced by the availability of information, the workshop time required, and the cost/benefit implications of using more detailed analysis. The greater the level of detail, the more easily complexity can be assessed and the greater the number of risks likely to be identified, but consequently the longer and more costly will be the mapping workshop.

Procedurally, the informational content of the project complexity/risk map should first be determined. This would cover the project objectives, tasks, activities, technologies, resources and organisational aspects. The workshop would attempt to assess and map the complexity of the project in terms of the differentiation, inter-dependency and uncertainty associated with these. Brainstorming could then be used to identify the risks involved, using the interrogative approach proposed above. This risk identification process almost certainly needs more guidance, however, and a useful approach might be to incorporate separate risk classifications as triggers to brainstorming. The categories suggested in Fig. 3 are based on the risk source event typology proposed by Edwards and Bowen (2005), but any classification system appropriate to the stakeholder’s business could be adopted. Now, for each of the designated risk categories, the third and fourth questions can be modified to reflect particular types of risk, e.g.:

- What are the political threats to successful outcomes?
- What are the political opportunities to improve outcomes?

Mapping complexity and risks in this way should make it possible for a stakeholder to see more clearly how complexity arises and how risks (and the way in which particular types of risks) are distributed throughout the project. A valuable picture of the “riskiness” of the project is obtained, which can be compared with the risk maps for alternative projects or previously completed projects. The completed map should provide useful information about where complexity is generated and which types of risk may be dominating a project. It will thus act as a pointer towards prioritizing and initiating subsequent risk management action.

There are practical limits to the amount of text material that can be used to populate the cells of a spreadsheet-based mapping tool in a workshop environment, even if secretarial assistance is used for direct cell entry (using a lap-top computer, for example). This can be overcome by assigning codes to replace lengthy descriptions of items in the cells. Fuller explanations for each coded entry can be documented separately, e.g., on individual risk action plans. For handwritten hardcopy workshop use, several A3 size mapping sheets will probably be best. The final cell population entries can be inserted later on a software file version.

Feedback on tool design
The proposed risk/complexity mapping tool was presented to a class of thirty postgraduate students. They were invited to reflect on the usefulness and practicality of the tool and provide feedback in subsequent classes. Most of the students were working in project management positions - some at
relatively senior levels. Other students were undertaking MBA degrees, and were familiar with analytical management techniques generally. Criticisms and suggestions offered included:

a) A workshop would probably benefit from specialist facilitation.
b) Entering known information beforehand would save workshop time.
c) A three-stage sequence could be used (pre-workshop information entry; complexity analysis and mapping workshop; risk identification mapping workshop). This would avoid the fatigue encountered in very long single workshops, and allow cell entry corrections to be made between workshops.
d) Who needs to participate in the mapping process? Workshops with too many participants could be counter-productive.
e) The contextualising process should avoid excessive dis-aggregation of elements (over-elaboration of project detail). This observation supports the view of Grey (1995) who notes that for IT projects it may ineffective to try to deal with risk assessment in too much detail in the early stages.
f) Is it practical to expect workshop participants to assign meaningful scores to complexity factors?
g) Should the identified risks also be scored in terms of severity? This might save some time later in the risk analysis stage of risk management.
h) The matrix display could be amended to show sub-divisions of the organisation, thus indicating different sources and levels of complexity within it. Alternatively it could display the organisational matrix structure of the project.
i) Colour coding some of the various elements of the matrix (e.g., activities, complexity factors, risk types) could enhance its visual communication.
j) First deal with risks that threaten objectives, look at opportunities afterwards.

Generally, students thought that the risk/complexity mapping tool could be useful in managing projects, as long as workshop participants were carefully briefed about how to use it. They perceived strategic and operational project management benefits. Their comments raise issues for project stakeholders in terms of communication processes and organisational structures.

Implications for communication processes and organisational structures

Clearly, the effectiveness of the proposed risk/complexity mapping tool is highly dependent on the fidelity of the communication processes embedded within the mapping process. However, the application of the risk/complexity mapping tool is not performed in isolation; rather, the mapping process is conducted within the context of the project team (either within the stakeholder organisation, or representing several stakeholder organisations). Consequently, the effectiveness of the interpersonal communication processes occurring within the mapping process is itself a function of the quality of intra-project communication. Inadequate internal communication has been identified as a major problem hindering organisations’ new project development endeavours (De Brentani, 1989). Communication and co-operation between the different functional (specialised) project team members is clearly essential considering the divided responsibility for ultimate project delivery. Both individual team members and the group (itself a source of complexity and risk) are the resources that have to be managed towards organisational effectiveness in terms of successfully completing the project.

Aside of the project delivery process being considered a process of communication and information processing, it can also be regarded as a process of uncertainty (or risk) reduction (Lievens and Moenaert, 2000). The greater the uncertainty associated with the project, the greater the amount of information that must be processed among decision-makers to achieve a desired level of performance. According to Lievens and Moenaert (2000), acceptance of this view leads to a contingency approach to managing project communication. As the project team has to gather and process information during the project life-cycle, the project team (organisational) structure is therefore a critical determinant of the information processing task and innovation activities in particular.
It has been established that a match between the communication structure and the information requirements is related to higher performance (Tushman, 1979). If the effectiveness of project communication flows is conceptualised by the level of uncertainty reduction, then the better the match between project communication and the level of work-related uncertainty, the more effective communication flows will be in reducing the level of uncertainty. What are the implications of adopting the risk/complexity mapping process on project organisational structures?

The impact of the proposed risk/complexity mapping process on project organisational structures is arguably best examined within the context of the project structures most typically associated with construction projects i.e., matrix organisations. Matrix organisations are claimed to improve efficiency and effectiveness in a time of instability, resource constraints, and tight project deadlines i.e., conditions of risk and uncertainty. Knight (1976) draws attention to the need, within matrix organisation, for more communicating to be done and for more information to be shared between participants. Coupled with these ills are the problems of maintaining the delicate balance of power between the different sorts of project team members, and of power distance (Rowlinson and Root, 1996). Matrix organisation emphasises decentralisation of decision-making and relies on individual members taking responsibility for task production (Rowlinson, 2001) thus creating another complexity perspective to be considered. It is crucial for the client to take ownership for ensuring that appropriate communication structures are created and that the project participants communicate with one another to ensure project success. Clients cannot abdicate responsibility to others for this important function.

It is quite conceivable for the mapping process to form an integral part of project cost planning. Such integration could be either internal or external. Internal integration would mean that the project team would initiate the risk/mapping process to identify the areas of complexity, uncertainty and risk and to incorporate the perceived financial impacts of these into the price forecast. Alternatively, the integration could be external; drawing on techniques utilised in the field of value management. Under of this approach, a risk/complexity modeller could undertake a complexity/risk mapping exercise with a team of specialist consultants employed for the specific purpose (akin to the 40-hour value management workshop). The original project team would brief the risk/complexity consultant team prior to commencing the exercise. Feedback and proposals would be provided by the consultant team at the termination of the exercise. This workshop could occur at any stage during the project, but the earlier the better. Indeed, a form of “Charette” approach could also be applicable. Again, the financial implications could be incorporated into the cost planning process. This approach might even adopt some sort of differentiated mapping process, i.e. the project team map the risks and complexities that are perceived to be ‘minor’, whilst ‘major’ ones are dealt with by the specialist consultant team.

The import of the risk/complexity mapping tool proposed here should not be seen restricted to its usefulness as a modelling tool per se. Rather, the process that participants undergo in the application of the tool should be seen as creating an analytical mapping mindset that will pervade project teams. Ideally, such mindset would serve to minimise the negative impacts of risk and uncertainty and encourage the search for positive opportunities.

Conclusions
Complexity, risk and uncertainty, relating to the decision-making processes which give rise to them, are major contributors to the “messy” nature of many construction projects. In order to understand and deal better with them however, these factors must first be identified. A mapping approach, contextualised by the project objectives and its elements, and conducted through facilitated workshop brainstorming, appears to be a promising way of addressing this problem. Indeed, flexible mapping formats, and the analytical information they are capable of producing for a variety of situations, are a potentially valuable field for exploration and development in project management.
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