Modelling Risks in IS/IT Projects through Causal and Cognitive Mapping

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Software systems development and implementation have become more difficult with the rapid introduction of new technology and the increasing complexity of the marketplace. This paper proposes an evaluation framework for identifying the causes of shortfalls in implemented information system projects. This framework has been developed during a longitudinal case study of a problematic project, which is described.

Keywords: causal and cognitive mapping, project evaluation, information systems project risk

1. Introduction

IT projects have been notorious for their proneness to fail for some time (see, for example, Flowers 1996). In the United Kingdom, recently reported problems include delays to an online hospital booking application in September 2004 (Arnott 2004a), to the national firearms database in October 2004 (Nash 2004) and to the implementation of a secure national radio system for ambulance and fire services in November 2004 (Arnott 2004b). A very well known supermarket chain reported a write-off of £260 millions associated with IT and supply chain systems (Knights 2004). The United Kingdom is not alone in suffering from these setbacks. One survey of over 13,000 IT Projects (Standish Group 2003) estimated that US corporations spent more than $255 billion per year on software development projects of which $55 billion was wasted on failed projects. The project success rate was just 34%, while the project failure rate was 15%, with 51% of projects suffering from cost overruns, time overruns, or a reduction in the features and functions delivered.

One reason that has been put forward for the prevalence of these failures is that information systems/information technology (IS/IT) applications are not constrained by physical laws (Brooks 1995). “Software is largely free of constraints and its potential is therefore unlimited”, according to the Royal Academy of Engineering (2004). Thus it is easy to embark on over-ambitious and ill-advised projects. This is perhaps exemplified by the supermarket project mentioned earlier: in that report (Knights 2004) an analyst is quoted as suggesting that the organization “was too ambitious on the business side, trying to over-segment its customer base which meant that it, in turn, created an overly complex IT system that wouldn’t scale.”

This paper proposes a method of presenting in a visual fashion the factors that have a bearing on project failure and their interrelationships. This allows the different stakeholders in a project to use the diagram to collaborate in the creation of risk models that can simulate the propagation and evolution of risks throughout the project life cycle.

2. Risk management

One textbook definition of risk management is “the identification of the hazards and possible problems, the evaluation of their importance and the drawing up of plans to monitor and deal with those problems” (Hughes & Cotterell 2002, p.134). Thus good risk management should be able to assist the reduction of the likelihood of project failures. There are numerous risk management paradigms, for example: Boehm 1991, Charette 1997, Dorofee et al 1996, McManus 2004, Robin et al 2002 and Yardley 2002.

The elements of risk management are summarised by Boehm (1991) as follows:

- Risk Assessment.
  - Risk identification
  - Risk analysis
  - Risk prioritisation
- Risk Control.
  - Risk-management planning
  - Risk resolution
  - Risk monitoring

Risk management paradigms tend to have a similar content, and most place an emphasis

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on adding details of identified risks and their resolution to the lessons learned from previously implemented projects. The maintenance of historical records of risks and issues as they are closed allows an organisation to effectively learn from experience (Boehm 1991, Dorofee et al 1996, Charette 1997).

The definition of risks needs to be conducted with care. There are conditions that might cause loss, such as the inexperience of staff. Methods such as Riskit (Kontio et al 1998) identify these possible causes of risk as risk factors. However, a risk factor by itself does not identity a risk. There must, for example, be many projects where some staff are inexperienced in some way but where the project outcomes are successful. It also follows that the risk factor of inexperience could lead to several different unfortunate outcomes. For example, it could be that productivity is reduced in some cases, and in other cases the quality of the end products is reduced. On the other hand, a risk outcome like ‘delayed project completion’ by itself is incomplete because in this case a risk outcome has been identified, but not the risk factors. Thus Riskit also identifies risk events which, when triggered in an environment where certain risk factors are relevant, will cause certain risk outcomes.

3. Learning in the risk management process

It has been suggested above that an effective organizational learning cycle can increase the capability and maturity levels of the team, project and organisation. However, although risk management is focussed on identifying future problems, it is usually difficult for people to foresee future events and problems (Wiegers 1998). The study of past projects, however, can help to ‘sensitise’ project participants to the potential obstacles to a new project’s success. Top management should therefore support and sponsor the evaluation of implemented projects in a ‘no-blame’ culture. After the implementation stage it is time to learn from the collective experience of the project team and to retain that knowledge, (McConnell 1997). Pitagorsky (2000) sums this up neatly: “The most important step to improve the quality of decision making is the Post-Implementation Review.”

The processes by which an organisation can learn from past experiences are core elements of the concept of the ‘learning organization’ (Argyris 1999). As Argyris points out in his survey of the literature on learning organizations, some writers have identified obstacles that prevent organizations using past lessons as a basis for improving future performance. Leavitt and March (1988) for example point out that organizations often adopt strategies that have worked in the past but which do not work in new situations. The lessons may be based on a small number of cases that might not in fact be typical. The links between cause and effect in past projects may not in fact be obvious or can be subject to controversy. What exactly happened in a past project may not be clear, and judgements about the relative success or failure of a project may depend on the viewpoint of individual stakeholders.

These obstacles to effective organizational learning do not in themselves invalidate the argument that organizations need to learn from past experience. In fact it is argued that they underline the need to make the nature of the lessons learnt and the basis upon planning is based more explicit.

4. Project risk evaluation and documentation

Post-Project Reviews, Post-Mortems or Project Post-Evaluations all have one ultimate purpose: to learn from past projects, be they successful, challenged or failed. However, the terms used in such retrospective processes must be chosen with care. For example some people have a particular perception of the term ‘Post-Mortems’ where Spafford (2003) argues that “a failed project is one thing, but to have a post-mortem meeting after a great project just doesn’t sound good”. Even with acceptable shared perceptions that are intended to emphasise the positive aspects of learning, the actual processes involved need to be carefully designed. Dalcher (2003) states that:

> *“Information about each failure and the circumstances surrounding the failure are difficult to obtain, but there is also a general lack of knowledge about the ways, methods and approaches for doing so”* (Dalcher 2003).

This author goes further in calling for new ways of “studying the failure phenomenon” supported by empirical validation (Dalcher 2003). Ikram (2000) observes that risk management itself has not benefited from rigorous research. In fact, the author is quite critical about the claims made: “The current literature provides useful knowledge and guidelines on Risk Management, but many of the claims made in the literature have no empirical validation. According to the empirical findings, the application of Risk Management to Information Systems Development is not a common practice. “(Ikram 2000).

DeMarco and Lister (2003) suggest that by applying post mortems to half a dozen past projects we could have enough data as input for future risk management process.

5. Longitudinal case study in IS project failure

The proposed framework was developed as the result of a longitudinal study of a problematic system development and implementation project. An advantage of the case study approach was that it added richness to the detailed information collected. It was able to capture causal influences and interaction effects which would not have been detected by a more statistical approach (Garson 2004).

The longitudinal case studies (LCS) method requires that quantitative/qualitative data are collected a number of times from the area of study (Jensen and Rodgers 2001). In this instance, the case study, which was embedded in a government organization in Kuwait, was documented during several field trips/visits. The project started in 1998-1999 and raised many failure issues at the beginning of 2000. The project suffered from various setbacks during the following two years. At one point the project was stopped for a period of time, and many stakeholders thought that the project had failed and been abandoned. The project was reinitiated and went through much revision of the project design and management approaches. Many problems and issues remain with the project up to the current time.

5.1 First phase

The aim of the first phase of the study was to document the a) background for the project and, b) the shortfalls that led to project failure (Al-Shehab et al 2004). Data gathering was done through semi-structured interviewing (Kane & Brun 2001) of the stakeholders using a taxonomy-based questionnaire (Dorofee et al 1996).The analysis of the data collected in this way used a grounded theory approach (Dick 2003). This was used to identify qualitatively the concept variables relating to the relative success or failure of the project mentioned in the interviews. These concept variables were thus candidate risk factors.

The list of concept variables identified by the stakeholders is shown below

- High level description
- Unclear project scope
- Insufficient budget estimation
- Poor performance contractor
- Unclear evaluation criteria
- Contractor has no previous experience in developing such projects
- Unrealistic schedule estimation
- Delays in project.
- Contract milestones were not clear towards payment
- Poor partnership relation between customer and contractor.
- Undefined user role
- No user involvement in the project
- All-in-one project
- Technical staff not appropriately skilled to tackle technical activities required
- No tech-team member involvement
- Wrong design
- Undefined project objective
- Lack of project management skills
- Lack of project control
- New technology introduced
- Poor database structure design.
- Lack of leadership
- lack of communication
- Lack of control over contractor
- Poor product outcome
- Unfrozen requirement
- Poor design
- Poor documentation
- Unstructured design
- Project plan was not followed
- Lack of top management support
- Lack of project guide and objective
- Lack of user commitment
- Delays in acceptance testing.

What is noticeable with this list is that some are clearly risk outcomes, that is, the effects or consequences of preceding problems, as in the case of ‘delays in project’. It is also noticeable that the precise meaning of terms and expressions used by various stakeholders may not be obvious, and that problems associated with the lack of a shared and explicit ontology may be quite important. Other identified variables do not themselves necessarily point to the probability of project failure, but might contribute to failure in conjunction with other factors, for example, 'new technology introduced'. These would be identified as risk factors. What is required is the identification of cause and effect relationships between the risk factors and risk outcomes. Below is a list of the relationships between risk factors and risk outcomes that were identified by the stakeholders.

- High level design led to unclear project scope
- Insufficient budget estimation led to use of unqualified contractor.
- Unclear evaluation criteria led to not making sure the contractor has previous experience in developing such projects.
- Unrealistic schedule estimation led to delays in project.
- Contract milestones were not clear towards payment, which led to poor partnership relation between customer and contractor.
- Undefined user role led to no involvement in the project
- An all-in-one application design led to large number of technical tasks needing to be completed compared with a small number of unskilled technical staff.
- No user involvement led to wrong design
- Undefined project objectives led to wrong design
- Lack of project management skills led to lack of project control
- New technology introduced led to poor structure design.
- Lack of leadership led to lack of communication
- Lack of control over contractor led to poor product outcome
- Unfrozen requirement led to unstructured design
- Poor documentation led to unstructured design
- Project plan not being followed led to lack of control over project.
- Lack of top management support led to unclear project scope
- Lack of user commitment led to delays in acceptance testing.

In this list it can be seen that one risk outcome could be linked to several risk factors. For example, 'wrong design' is caused by a combination of 'no team member involvement' and 'undefined project objectives'. In other cases, the outcome from one risk becomes a factor that contributes to some other. For instance, 'undefined user role led to no involvement in the project' which in turn means 'lack of user commitment led to delays in acceptance testing'. The relationships between the factors that lead to unsatisfactory project outcomes therefore seem to be more complex than what the simple list of cause and effect relationships above implies. In the next section the possibility of using causal maps to create a richer picture of these relations will be explored.

5.2 Second phase

Experience during data collection and subsequent analysis suggested the need for a method that could capture the often complex interactions between concept variables in a project environment. Causal cognitive maps (CCM) suggested themselves as such a method. The second phase of the case study therefore focussed on adopting CCM as a tool for, a) documenting the past experience of the project, and b) forecasting the outcome of the project.

CCMs were drawn individually by project team members in assisted sessions. These were then combined to produce a consolidated map that was presented to and further analysed in a group session. The participants were asked to provide their views on the map and whether they agreed or disagreed with any of the sub/individual maps. A large amount of data was collected, which is currently being analysed as part of a subsequent investigation into the application of quantitative model building. Currently a commercial tool, Decision Explorer by Banxia, is being assessed for the use in this case study.

5.3 Experimentation with and evaluation of relevant techniques

A particular aspiration of this work is to reach agreement on a common ontology of project risk factors and outcomes that could be applied to future projects. The project team members who are involved in the study can be clustered into a management group and a staff group, and the differences between the two need to be assessed. An intriguing research question is whether CCMs produced by the two groups will be different but complementary, that is focussing on different factors but not actually contradicting each other. An alternative is that there is actual contradiction where one group for example perceives a positive influence between two factors when the other does not.

Elements of this part of the study are:

- Refinement of project maps in terms of the cause and effect chains that lead to undesirable project outcomes.
- Production of a consolidated map by the management group in a collaborative session.
- Production of a consolidated staff map.
- A comparison of the resulting management and staff maps.
- An investigation of limitations of the tool and techniques.

6. Causal and Cognitive Maps (CCM)

A causal map is a network diagram representing causes and effects (Bryson et al 2004). The diagram contains two basic elements: concepts, which are the nodes in the network and causal relationships, represented by the arcs between the nodes. Concepts are considered as the variables of the system and in some notations carry either a positive or negative sign implying the type of the causal relationship and effect (Tsadiras 1997). Cognitive maps use the concept to elicit and represent perceptions.

CCMs have been used frequently in the operations management discipline (Axelord 1976, Brown 1992, Bryson et al 2004, Eden 1988, Scavarda et al 2004, Williams 1995),, commonly using them to support empirical research for building and communicating theory. The areas where the causal maps have been used include:

- Risk mitigation: anticipating unintended consequences.
- Diagnosis: identifying the possible causes of a problem.

Huff (1990) suggests that an advantage of causal maps is that they can portray information about a system more succinctly than a corresponding textual description.

Using CCM as the risk identification approach appears to have some advantages:

1. Group discussions guided by CCMs encourage the participation of all relevant stakeholders in the project.
2. CCM-facilitated group discussions tend enhance communication between the project members (Gotterbarn, 2001).
3. Using CCM provides a clear picture of the project situation by creating a diagrammatic representation.
4. The diagram enables identification of the interrelations between risks.

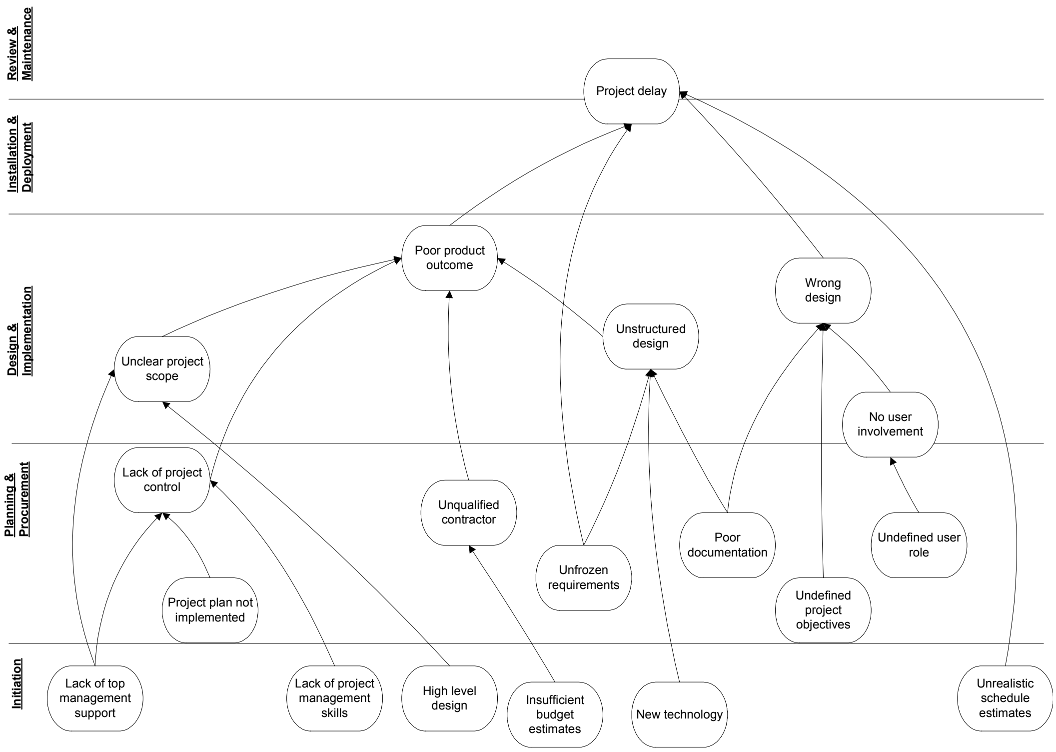

Figure 1: A causal map for the case study in Section 5.1

7. System Development Life Cycle (SDLC)

In conventional project management, a project has to be broken down into physical activities to which resources can be allocated. It is argued by the authors that every IS/IT project follows some kind of life cycle that places structure on the temporal order of the project's activities. Admittedly in some projects this order is not very evident, but there is a generic development cycle that can be applied to most of IS/IT projects. This cycle typically contains the following phases:

- Initiation: system concept, management approval, funding approval.
- Planning/Procurement: identifying stakeholder, top-level project plan, feasibility study, high-level view of the intended system and the determination of its goals.
- Design/Implementation: requirement definition, analysis, design completion & approval, coding/unit test, integration/test, system/acceptance test.
- Installation/Deployment: installation complete, evaluation/acceptance, site preparation, training, business process re-engineering, rollout.
- Completed: review & maintenance.

These stages are reflected in the causal map of Figure 1.

The concept variables relating to risk that have been identified in earlier sections are indicators of some general conditions that could affect more than one activity and these activities could be in more than one project phase. A lack of project management skills could, for example, affect many different activities at many different stages of the project.

However, despite the ubiquity of some of the risk variables, others are specific to particular phases. For example, in the case study, the risk 'lack of user commitment led to delays in acceptance testing' clearly relates to one specific stage in a project. A typical approach to risk management is to maintain a risk register during a project. As the project progresses, some risks will cease to have an impact, while the threat of others may grow. It has been found helpful to produce a template separated into the generic stages of the development life cycle and to locate the occurrence of risk factors and their outcomes within these physical stages, as well as linking the risk factors through chains of cause and effect.

8. The way forward

It is widely accepted that efforts to identify and avoid potential risks in IS projects are commonly rewarded. Weigers (1998) states

> *"anything you can do to improve your ability to avoid or minimize previous problems on future projects will improve your company's business success and reduce the chaos and frustration that reduces the quality of worklife in so many software organizations."*

This author goes on to make specific suggestions about what needs to be done, and indeed how to go about it. His suggestions are not limited to the documentation of risk assessment, but also the actual perceptions of those involved in the assessment process. Both informal and formal assessments are important, as are the strategies employed in risk mitigation. Apart from the obvious need to evaluate, identify and mitigate, the overall aim is for an organisation to self-improve via the new knowledge gained, i.e. to maintain and update the corporate knowledge base. The Department of Defence (DoD) risk Management Guide for DoD Acquisition (2003) includes a step called "Analogy Comparison/ Lessons-Learned Studies". This step uses lessons learned plus historical data to identify similar risks or risk areas in the current project. They argue that any new project is originated or evolved from existing projects or represent a new combination of existing components or subsystems.

The availability of a high quality historical knowledge base is therefore important. Causal maps can offer far more information than purely textual documentation formats and in a compact and highly-visual format (Huff 1990). Repositories of historical project data are common, but large collections of detailed information gathered during a project's lifecycle are difficult and time-consuming to analyse. There are many ways of gathering data relating to past projects. Some employ surveys, interviews, emails or reports to summarise the history of the project (McConnell 1997), (Collier 1996) and (Wiegers 1998). However, the need for a more structured method of documenting past projects in a more clear representation, is vital.

It is important to recognise that ontological issues are important in situations characterised by disparate groups of people, with different roles and with potentially different ways of expressing concepts. As Gruber (1993) points out, “One problem is how to accommodate the stylistic and organizational differences among representations while preserving declarative content.” Stylistic differences relate in our case studies to the language structures used. In our opinion, a common ontology for risk is required, and the issues involved should be conveyed to potential users of causal mapping techniques. The measurement of risk factors and their interdependences also offers exciting possibilities for elicitation, modelling and simulation.

9. Further work

9.1 Risk modelling techniques

The use of CCMs in the management of IS/IT project risk is currently not widespread. In this context, the authors see the use of CCMs as a means of making visible the perceptions of project stakeholders with regard to the causes of shortcomings in completed IS/IT development projects. While no map can be justifiably claimed to be completely accurate in its identification of the source of unwanted project outcomes, they can promote debate and further investigation. This in turn should improve managerial decision-making.

Two major challenges are clear. The first is to move from the diagnosis of the sources of past problems to the prediction and forecasting of potential problems in new projects. While stakeholders may be able to identify such factors as ‘insufficient budget’ or ‘inappropriate experience’ as contributors to project shortfalls in completed projects, the identification of these risk factors in the proposals for new projects is not necessarily straightforward.

9.2 Measurement of risk’s cause and effect

The risk assessment process, guided by the process of causal mapping, introduces the concept of expressing the degree to which a risk factor exists in a project, and also the impact such a risk factor has (or is likely to have) on related risks. One approach of measuring the impact is by using a coloration approach (Aladwani 2002). In the authors’ experience, stakeholders are commonly unable or unwilling to give precise values to these, but are usually more open to expressing them as an (expert) opinion, i.e. as a ‘fuzzy’ value (Negnevitsky 2002) that does not commit the participant to likely inaccuracy. In spite of potential inaccuracies, in the authors’ experience, expert judgment, tacit though it may be, is valuable and quite often close to reality. Fuzzy representation and reasoning approaches (Kosko 1986, Tsadiras and Margaritis 1997) and neuro-fuzzy and system dynamics (Rodrigues 2001) techniques may well hold the key to usefully capturing such risk data, and making the ensuing models functional.

10. Conclusions

The framework described in this paper can be used to document the knowledge that team members gained through experience. This knowledge can be presented in a single map, essentially visualising the ‘big picture’ of the past project as a pedagogical post-evaluation method. The elicitation process involves the identification of risk factors, their likelihood of occurrence, and their likely impact on other risks within the cause and effect relationships at the heart of the model. The use of CCMs throughout this process has been observed to facilitate ‘brainstorming’ and to achieve consensus in a more intuitive and effective way than with more conventional approaches. The availability of an agreed general risk model of a specific project is also useful, not only in evaluating the accuracy of past diagnoses, but also in providing the means to develop and challenge stakeholders’ mental models of perceived future events.

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