Maturity of Quantitative Risk Analysis undertaken for Capital Projects

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Introduction

Sponsors of capital projects are commonly required to make investment decisions based on imperfect information, particularly early in the project life cycle. To aid decision making, stochastic models of real world conditions are created to predict project behaviour over time. The risk for project sponsors is that they decide to base funding application decisions on outturn cost and duration predictions derived from poorly developed or evaluated stochastic models. These models typically take the form of Quantitative Risk Analysis (QRA) incorporating Monte Carlo simulation. The objective of a QRA is to calculate the combined impact of the model's various uncertainties in order to create a probability distribution of the possible model outcomes. The reliance that can be placed on results generated by QRA models largely depends on the overall maturity of the risk management practices adopted. In particular the quality of the inputs, the application of enablers, an understanding and management of the constraints, and the construction of the model. In terms of inputs, project sponsors together with project and risk managers have to be wary of garbage in, garbage out. Garbage in, garbage out (commonly abbreviated to the acronym GIGO) is a phrase used in the fields of computer science as well as information and communication technology. It is commonly used to describe failures in human decision making due to faulty, incomplete or imprecise data. In simple language it is used to call attention to the fact that computers that are fed poor quality input data ("garbage in") will as a consequence produce poor quality output ("garbage out"). The significance of the quality of the uncertainty models is brought into perspective when considering the value of current rail projects such as High Speed Two, where the contingency for Phase 1 (London to Birmingham) exceeds £5billion[1]

Maturity of QRA practices

The overall maturity of the in-house approach to QRA implementation can be assessed with the aid of a risk maturity model (commonly abbreviated to RMM) which specifically focusses on the preparation of QRAs rather than the embedding of risk management as a whole. A RMM can be viewed as a set of incremental levels of capability that describe how well the behaviors, practices and processes of an organization can reliably and repeatedly produce required outcomes. Specifically a RMM may identify gaps in current capabilities that detract from the delivery of required risk products (outputs). Primarily the structure of current project risk management maturity models have been influenced by the Capability Maturity Model (CMM) for software produced by the Software Engineering Institute (SEI), a research center located at the Carnegie Mellon University in Pittsburgh, Pennsylvania, United States. The center was established and funded by the U.S. Department of Defense. The reference to maturity models within the APM and PMI Bodies of Knowledge[2] demonstrates that maturity models have now become an established part of documented practice.

[1] House of Commons Briefing Paper, Number SN00316, 3 November 2015.
[2] APM Body of Knowledge 6th edition, 2012 and PMI Body of Knowledge 2013.

Maturity Levels

Maturity models are typically based on a number of maturity levels (see Figure 1) whereby capability criteria (sometimes referred to as attributes[3], perspectives[4] and domains[5]) are assessed against each level, (see Figure 2). The development of an RMM forces risk teams to consider their current, required and target capabilities. The maturity levels included in Figure 1 are based on the Carnegie Mellon University process improvement Capability Maturity Model Integration (CMMI) program.

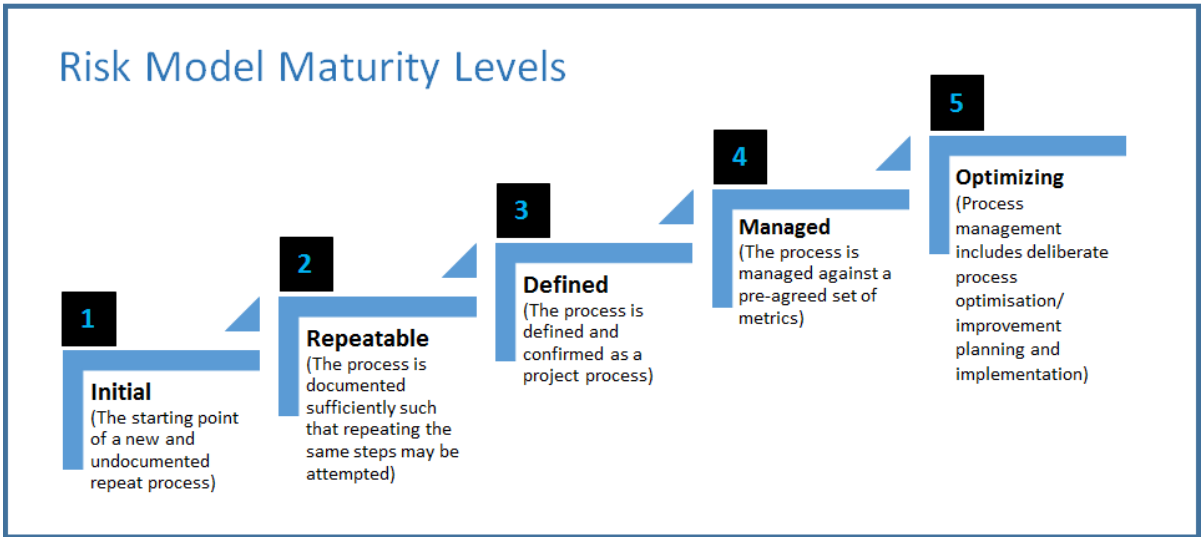

Figure 1: Levels of maturity of quantitative project risk analysis

Diagnosing an organisation's current risk maturity level

The brief descriptions of each RMM level indicates where an organisation stands in terms of the relative maturity of its risk management practices however a more in depth assessment is required to determine both capability gaps and specific areas of improvement. This is accomplished by setting assessment criteria which collectively determine the capability of the organisation at each of the maturity levels. The selection of the proposed assessment Criteria of: Structure, Leadership, Strategy/Policy, Process, People, System and Culture were guided by the EFQM Excellence Model[6] which allows organisations to understand the cause and effect relationships between what their organisation does and the results it achieves. An organisation's risk management capabilities will be dependent on all of the criteria being satisfied in that a robust QRA Process will be worthless without for instance experienced People, a suitable software System, a supportive Culture and Leadership which drives risk management from the top down, promulgating the need to implement risk management to support the achievement of the project objectives. Figure 2 illustrates the structure of a RMM (in the form of a matrix) created by defining the Criteria to be satisfied for each

[3] Hillson, D (1997) Towards a risk maturity model, The International Journal of Project and Business Management, Vol 1, No1, Spring 1997, pp33-45
[4] Hopkinson, M (2011), The Project Risk Maturity Model, measuring and improving risk management capability, Gower Publishing Limited.
[5] Electricity Subsector Cybersecurity Capability Maturity Model (EC-C2M2), Version 1.0, 31 May 2012 developed in the US by the Department of Energy in partnership with the Department of Homeland Security.
[6] The EFQM Excellence model is a non-prescriptive framework for understanding the connections between what an organisation does, and the results it is capable of achieving. It is used to structure a logical and systematic review of any organisation, permitting comparisons to be made with similar or very different kinds of organisation

of the Maturity Levels. Given the extent of the subject matter covered by the Criteria selected, this paper focusses solely on aspects of the Process.

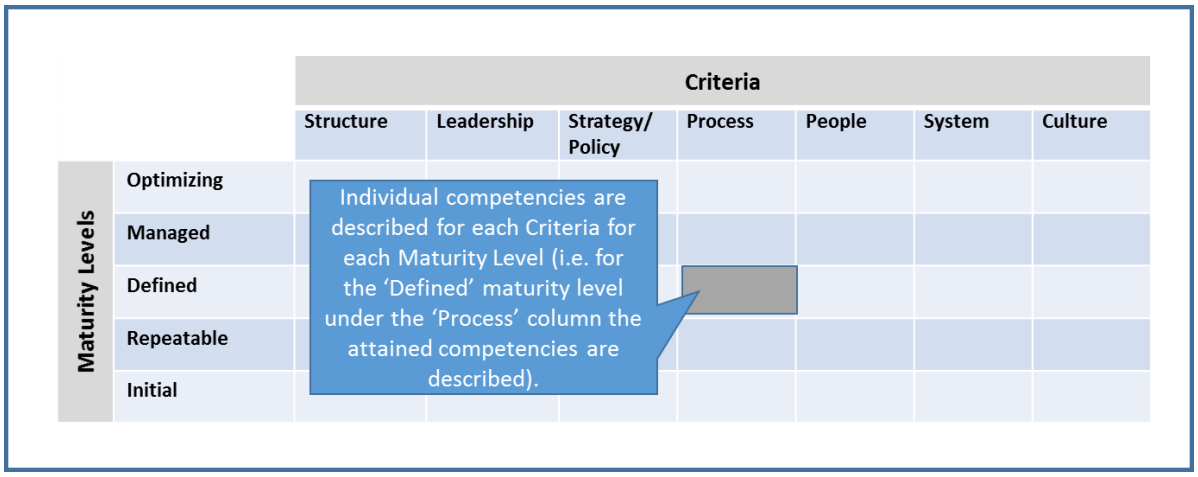

Figure 2: Assessment criteria for determining levels of maturity

Preparation for a QRA using a Process Map

Each brief competency statement included at the intersection of a Maturity Level and Criterion within the maturity model must be underpinned by a clear explanation of the capabilities to be attained. So for example a way of examining an organisation's capabilities for achieving the required 'Process' competencies for Maturity Level 3, 'Define' (highlighted on Figure 5) is to examine what aspects of a simple process map, as illustrated in Figure 3, have been undertaken. The adoption of process mapping is drawn from the IDEF0[7, 8] functional modelling method designed to model the decisions, actions, and activities of an organization or system. Each activity has inputs and outputs where the performance of the activity is influenced by controls (constraints) and mechanisms (enablers). The process of preparing a QRA is directly influenced by the inputs (reference documents) the enablers (aspects which support implementation) and management of the constraints.

[7] See the publication "Simple tools and techniques for enterprise risk management" published by John Wiley and Sons Ltd., for a fuller explanation of the IDEFO process.
[8] IDEF0 is a compound acronym (Icam DEFinition for Function Modelling), where 'ICAM' is an acronym for Integrated Computer Aided Manufacturing.

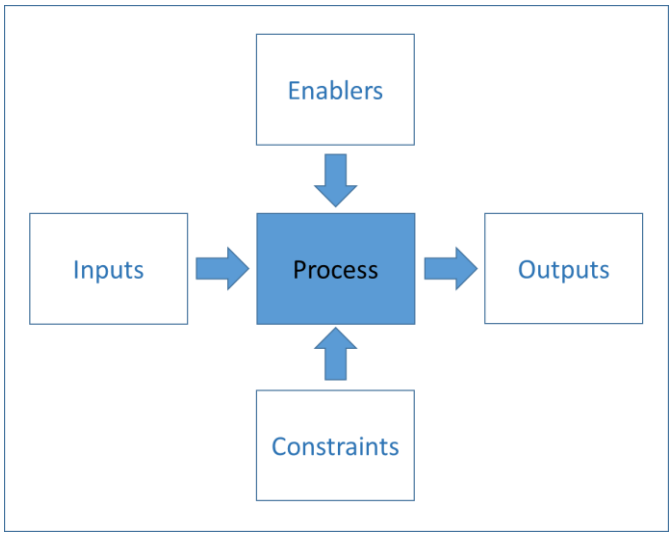

Figure 3: Process map of the preparation of a QRA

Common inputs to support the preparation of a QRA:

- Business Case and strategic objectives (together with Programme and or Project objectives)
- Description of the Programme/Project and Scope of Work.
- Project life cycle, location of gate reviews and approval points.
- Organisational structure.
- Cost Plan (including exclusions, assumptions, cost base such as 1Q 2015, treatment of inflation, commodity prices, discount rates and exchange rates).
- High level Schedule and identification of potential delays.
- Risk Management Plan, Risk Breakdown Structure, Risk Register and analysis of the risks (probability, impact, frequency, proximity, correlation and risk relationships).
- Explanation of how the impact and probability values were arrived at.
- Schedule of the workshops including the names of the attendees, their respective disciplines and their job titles.
- Third party dependencies (funding, approvals, definition of scope, completion of the design)
- Reporting requirements.
- Purpose of conducting the QRA, record of the recipients and a description of how the information will be used.

Potential Enablers:

- ISO 31000.
- Risk Management Strategy, Policy, Plan, reporting template and risk breakdown structure.
- QRA procedure (including a description of the most suitable distributions [continuous and discrete] and their use and sensitivity analysis).
- Risk management software.
- Assurance framework (identifying and mapping main sources of assurance), timetable and requirements.
- Sources of assurance such as the Three Lines of Defence model proposed by the UK's HM Treasury.
- QRA maturity model.
- Lessons learned.

Potential Constraints:

- The capabilities of the risk personnel assigned to undertake the QRA.
- The time allocated to undertake the QRA.
- Lack of availability of project team members to participate in risk management workshops.
- Availability of required software.
- Limitations placed on the review of the results.
- The level of maturity of the QRA practices.
- Degree of complexity of the model constructed with the potential for errors in the formulae.

Process:

- Construction of an auditable Quantitative Risk Analysis model which accurately reflects the inputs, in terms of for instance the characteristics of the threats and opportunities, correlation between threats, threat relationships, opportunity relationships, anticipated frequency of the threats and cost estimate and schedule uncertainty.
- Consideration to be given to a series of 'watch points' which if go unheeded will undermine the value of the QRA.

Process 'watch points'

Experience (supported by the risk management literature) highlights that a series of issues which might be referred to as 'watch points', should receive close scrutiny in the preparation of QRAs. The quality of QRAs and the reliance that may be placed on the recorded results will be directly influenced by the degree of attention paid to these issues.

- *Vocabulary*: Determine if a common risk management vocabulary has been established and communicated across the project.
- *Model not representative of the actual project*: The model must be representative of the actual project which requires the project modeller to have a thorough understanding of the project[9]. This includes as an absolute minimum the project objectives, project scope, life cycle, procurement route and approvals regime.
- *Assumptions*: Examine whether the assumptions are clearly articulated, consistently applied across all project documents and are not overly optimistic.
- *Dependency*: The dependency between the risks needs to be mapped. The convenience of computer software can seduce analysts into a naïve approach that assumes threats are independent and overlooks the importance of the dependency between sets of threats[10, 11].
- *Low probability high impact risks*: Determine whether rules have been established and checks run for the inclusion of risks with a low probability and very high impact, taking account of the possibility that the true probability may be much higher than has been estimated[12]. Modelling very high impact very low impact risks can significantly distort QRA results and such risks warrant being modelled within separate scenarios.

[9] Smith, N.J (1999) Managing risk in construction projects, Blackwell Science Limited, pp163.
[10] Chapman, C and Ward, S (2003) Project Risk Management, processes, techniques and insights, second edition, John Wiley and Sons Limited, pp207.
[11] HM Treasury (2009) Risk Management assessment framework: a tool for departments, pp23
[12] HM Treasury (2015) Infrastructure Early financial cost estimates of infrastructure programmes and projects and the treatment of uncertainty and risk.

- *Pre or post-mitigation values*: The QRA report must make it explicit whether the pre or post mitigated risk values have been included in the model. There is a tendency for post mitigated values to be overly optimistic and unsupported in terms of how they would be accomplished.
- *Audit trail*: For model results to have any validity the risk impact values must be auditable in terms of their source and underpinned where appropriate by the Cost Estimate or Schedule. There should be a record of the workshops held, the attendees and the risk information recorded.
- *Double counting*: Avoid double counting of risk allowances/monies within Cost Plans and Risk Registers[13]. Avoid double counting of risks where risks of only slightly different wording are included in the same model.
- *Avoid unallocated risk exposure*: All contingency sums should be based on 'bottom-up' risk registers and not undefined uncertainty.
- *Changes in scope*: It is made explicit that there will not be a draw-down from the contingency to fund changes in scope.
- *High probability risks:* Determine whether rules have been established for high probability risks (over 90% probability) to be removed from the risk register and QRA model and included in the Anticipated Final Cost.
- *Impact of assessed schedule delay on the cost QRA:* Ensure that the assessed schedule delay is reflected in the cost QRA as delays commonly have a cost impact (such as indirect costs emanating from the client and project management teams).
- *Assurance review:* Determine whether the model has been reviewed in terms of the common calculations (probability x impact), the suitability of the distributions adopted and the cells included in the analysis. Reviews are particularly important when the modellers are inexperienced.
- *QRA report:* The results of the QRA are accurately and clearly reported in the QRA report so that an unambiguous recommendation can be made to support project decision making (see section below entitled 'QRA Report').

QRA Report

A QRA report is a communication tool to convey the answers to the questions posed by the project[14] and commonly aid decision makers to determine the project contingency to be set aside. An example of the contents of a report is included below however the actual contents need to be tailored to the requirements of the client and the project. Prior to the preparation of the report it should be determined at what level the contingency will be set. For instance will it be the 50th, 75th of 80th percentile?

- Title, author, date, version and document reference number.
- Contents page.
- Summary.
- Purpose (the questions to be answered) and recipients of the report.
- Introduction to the project and its position along the project life cycle.
- Decision questions addressed and those not addressed.
- Discussion of the available data and relation to the model choice.

[13] Managing Cost Risk & Uncertainty in Infrastructure Projects Leading Practice and Improvement: Report from the Infrastructure Risk Group supported by: The Institute of Risk Management, pp17.
[14] Vose, D (2008) Risk analysis, a quantitative guide, John Wiley and Sons Limited, pp68.

- Major model assumptions and the impact on the model results if incorrect (commonly illustrated in a table).
- Discussion of modelling strategy.
- Overview of the model structure.
- Presentation of the results (graphical representations avoiding tables of statistics).
- Discussion of possible options for improvement (extra data that could be collected and its likely impact on the results).
- Recommendations on level of contingency.
- Appendices
    - Model validation (independent review of the inputs, enablers, constraints and process)
    - List and location of inputs
    - References
    - Technical notes

Representing the findings of risk maturity reviews

A way of representing graphically the outcome of successive maturity assessments is with the aid of a spider diagram. The achievement of a maturity level is illustrated by the concentric lines of the web whereby 20% represents achieving the 'Initial' maturity level, 40% represents achieving the 'Repeatable' maturity level and so on. In this particular example while the aspects of 'People' and 'Process' have improved, there has been no improvement in the risk management 'Culture'.

Figure 4: Spider diagram illustrating improvements in risk maturity across successive reviews.

Conclusion

Early in the project life cycle, sponsors of capital projects are commonly required to make investment decisions based on imperfect information. To aid decision making, Quantitative Risk Analysis models are used to predict the outturn cost and completion date. The risk for project sponsors is that they decide to base funding application decisions on outturn cost and duration predictions derived from poorly developed or evaluated Quantitative Risk Analysis models. The reliance that can be placed on results generated by the models largely depends on the overall maturity of the risk management practices adopted. The quality of the models will be determined in part by whether comprehensive process maps are prepared and followed and whether the 'watch points' described are taken cognisance of and reflected in the approach adopted. Even if the model construction has been robust, if the QRA report does not clearly define the questions it sought to answer, the findings and particularly the recommendations for the size of contingency, sponsors may not be adequately supported during their decision making processes.

QRA Maturity Model

Level	Level Name	Structure	Leadership	Strategy/Policy	Process	People	System	Culture
5	**Optimising**	The organisational structure includes sufficient capacity for benchmarking with other projects, seeking continuous improvement and refining processes.	Senior managers re-enforce and sustain risk capability, organisational resilience, embedding RM and commitment to excellence.	The RM strategy and policy (and the described accountabilities and responsibilities) are re-examined for their suitability against the project & risk culture.	The process is regularly assessed against other projects and recommended practice included in standards, guides and publications.	Risk personnel capabilities are reviewed against planned improvements in delivery, processes and reporting requirements.	Reports, dashboards, software capabilities and information for decision making are more closely integrated to make reporting more efficient / effective.	Vision, strategy and policy for RM (and the benefits sought) are benchmarked against similar organisations with the view to improve the value-add of RM.
4	**Managed**	Rm resources are balanced in a pro-active manner against the needs of the project in terms of recorded responsibilities and reporting requirements.	Senior management support a 'top down' approach and are proactive in embedding RM across the project life cycle and driving RM implementation.	Accountabilities and responsibilities for RM are established against project objectives, process metrics, and QRA reporting requirements.	Metrics are defined to measure whether the process and its outputs are 'fit for purpose'.	Regular performance reviews are conducted against pre-determined criteria with specific reference to facilitation, building models & reporting.	Software administration is implemented against protocols and metrics.	The desired risk culture and risk-related behaviour is actively communicated and promoted to staff to support the preparation of QRAs.
3	**Defined**	Organisational structure includes permanent positions for RM to deliver the stated risk management objectives.	The conducting of RM (and QRAs) is mandated by senior management to support decision making and progress monitoring and management.	RM is mandated within the risk management strategy and policy and accountability and responsibility for risk management are established.	There is a clear understanding of the parts of the process map to be considered for the preparation of a QRA and the 'watch points' to be taken cognisance of.	Risk personnel are experienced users of the RM software and together with defined processes are able to produce consistent models.	Software selected / purchased to suit decision making, option selection, determination of contingencies and the in-house QRA process.	QRAs are routinely prepared, are part of 'business as usual' and project team members are familiar with the data to be provided to support the process.
2	**Repeatable**	The number of RM positions within the organisational structure are insufficient to deliver the RM objectives	Senior managers take the lead to ensure that approaches are being developed for the preparation of QRAs.	While a risk management strategy and policy have been prepared accountability and responsibility have yet to be finalised.	QRAs are prepared against ill-defined, incomplete or under-developed processes and an ill- considered process map.	Risk personnel have been trained in the use of the RM software but are not yet proficient in its use.	Software selected / purchased to suit the decision making requirements of the project but data capture and reports are still being refined.	While the process of preparation is understood and repeatable, QRA production is not yet part of 'business as usual'.
1	**Initial**	Organisational structure does not reflect the RM objectives.	Senior managers articulate the need for QRAs and the adoption of industry common practice in the preparation of contingencies.	Accountability and responsibility for risk management is ad-hoc, not formalised and is established in pockets across the organisation.	The process map constituent parts such as the inputs, constraints, enablers, process and outputs have yet to be defined.	The risk team are aware of the available software tools but not all members of the team have be trained in their use.	Software purchased, but administration rights, reporting, risk scoring, filtering, and folder structure still being developed.	QRAs are prepared on an ad-hoc basis by individual specialists to support decision making and or define contingencies.

Figure 5: Risk Maturity Model (RMM)

About the Author

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Robert J Chapman is an international risk management specialist and Director of Dr Chapman and Associates Limited (www.drchapman-assoc.com). He is author of 'Simple tools and techniques for enterprise risk management' 2nd edition, published by John Wiley and Sons Limited and 'The Rules of Project Risk Management, implementation guidelines for major projects' published by Gower Publishing. He holds a PhD in risk management from Reading University and is a fellow of the IRM, APM and ICM and a member of the RIBA. He has provided risk management services in the UK, the Republic of Ireland, Holland, UAE, South Africa, Malaysia and Qatar on multi-billion programmes and projects. Robert has passed the M_o_R, APM and PMI risk examinations and provided M_o_R risk management training to representatives of multiple industries. He can be reached by email at robert.chapman@drchapmanassociates.co.uk