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Verification and Validation for the AQUA Book

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This document has been prepared so as to openly share the Verification and Validation (V&V) considerations that underpin the V&V advice presented in the government Analytical Quality Assurance (AQuA) book, which is hosted on the Treasury web site.

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Executive summary

This guidance is concerned with the Verification and Validation (V&V) that is necessary to deliver appropriate analytical quality in support of successful programmes and their constituent projects and activities. This guidance has been written to underpin the higher-level guidance presented in the Analytical Quality Assurance (AQuA) Book, which is hosted on the Treasury web site. The concept of V&V presented here is based upon an assessment of 'fitness for purpose' rather than seeking to accredit analytical approaches for a stated range of purposes, which is both bureaucratic in ethos and against the advice presented in the literature.

Key definitions:

- Validation – literally meaning to make valid, through the agreement of those judged competent to take such views. The central question that validation raises is the extent to which the right work is being engaged in, given the purpose and constraints placed upon that work. The key output from the validation process is a judgment, based on evidence, concerning the extent to which the work is 'fit for purpose';
- Verification – is concerned with the extent to which the work that has been agreed to is being done in the 'right' or 'accepted' way, given the 'art of the possible'. The key output from the verification process is a judgment, based on evidence, concerning the extent to which the agreed work has been conducted appropriately;
- Programme – a governance structure designed to co-ordinate, organise, direct and implement a portfolio of projects and activities that together achieve outcomes and realise benefits that are of strategic importance;
- Project – a governance structure created for the purpose of delivering one or more business products against an agreed business purpose;
- Activity – a specific piece of work that has been tasked in order to make an identified contribution to an agreed business purpose;
- Commissioner role – the person who commissions analysis for the purposes of a Programme, Project or Activity;
- Analyst role – a person tasked to conduct analysis on behalf of the commissioner;
- Analytical assurer role – a person tasked to provide analytical assurance of the work conducted by an analyst. For small rapid projects the person working as the analyst could also be fulfilling the analytical assurance role, although it is advisable to always have an independent person to provide the analytical assurance check upon the work.

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The purpose of this guidance is to inform all members of a broader programme about what constitutes appropriate V&V for the work conducted. It is envisaged that this document will be of particular interest to:

- The commissioner of the analysis concerned with what constitutes appropriate V&V;
- The Senior Responsible Owner (SRO) tasked to produce an assurance statement for the work that has been undertaken;
- The design authority providing strategic level governance to a programme.
- The person working in the programme assurance role;
- The project manager responsible for day to day delivery;
- The person working in the in the project assurance role;
- The person working in the analytical assurer role;
- People working in the analyst role, concerning what is expected of them, with respect to the conduct of V&V in their work.

This advice:

- Considers what constitutes analytical quality and broadly sets out how analytical quality is achieved (see section 2);
- Presents a four-stage model for the conduct of V&V in analysis activities (see section 3);
- Identifies the V&V activity to be conducted in each stage of the work (see section 4);
- And closes with a consideration of common analytical pitfalls, the key responsibilities of each of the three main roles identified by the AQUA book (commissioner, analyst and analytical assurer) in overcoming them; and it also briefly examines the limits of what is knowable (see section 5).

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1 Introduction

This guidance is concerned with the Verification and Validation (V&V) that is necessary to deliver appropriate analytical quality in support of successful programmes and their constituent projects and activities. This guidance has been written to underpin the higher-level guidance presented in the Analytical Quality Assurance (AQuA) Book, which is hosted on the Treasury web site. The concept of V&V presented here is based upon an assessment of 'fitness for purpose' rather than seeking to accredit analytical approaches for a stated range of purposes, which is both bureaucratic in ethos and against the advice presented in the literature.

The purpose of this guidance is to inform all members of a broader programme about what constitutes appropriate V&V for the work conducted. A glossary of key terms is provided at the end of this paper. Terms in the following list that have not been included in the glossary have been drawn from managing successful programmes (MSP). It is envisaged that this document will be of particular interest to:

- The commissioner of the analysis concerned with what constitutes appropriate V&V;
- The Senior Responsible Owner (SRO) tasked to produce an assurance statement for the work that has been undertaken;
- The design authority providing strategic level governance to a programme;
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(commissioner, analyst and analytical assurer) in overcoming them; and it also briefly examines the limits of what is knowable (see section 5).

2 Purpose

The purpose of V&V is to ensure the quality of content of the analysis, the quality of the process by which it is produced and the quality of outcome that is achieved (Robinson (2002)). These aims can only be achieved if our concept of analytical quality embraces the whole span of the analysis process from the inception of the work through to initial delivery and then formal publication.

These three aspects of the quality of the work are delivered through the analyst, analytical assurance and commissioner roles working together in partnership. The reason for this is rooted in the nature of validation, which fundamentally is a shared collective judgment amongst key parties concerning what is jointly understood to be 'fit for purpose' in a given circumstance (for more information see Kleindorfer et al (1998)).

It is the responsibility of the analyst to focus upon quality of content, supported by the analytical assurer role. It is the responsibility of the analytical assurer role to deliver quality of process, supported by the analyst role. It is the responsibility of the commissioner of the analysis to deliver quality of outcome, supported by both the analyst and analytical assurer roles. Advice on the quality assurance issues to be managed and who should lead on them is presented in part B of the AQuA book, chapter 5, Verification and Validation (The AQuA Book (2014)).

The key V&V issue that the analyst should focus on initially is the conceptualisation of the work. This conceptualisation then frames the expectations against which the quality of their work can be assessed. While the detailed planning and conduct of that work clearly matter, errors are often traceable to the way in which the work was conceptualised. Errors in conceptualisation can be trapped through:

- Taking care to understand the benefits that are sought from the work that has been tasked and then explicitly considering how the work conducted is contributing to the intended goal at each stage of the analysis process;
- Periodically reflecting on how the framing for the analysis has been selected and thus the starting point from which the research was launched, its boundaries and the structural weaknesses of that perspective (Jackson (2003)). In particular:
 - Identify the foundational narrative upon which the research stands and consider if any of the claims made by that narrative appear extraordinary in the light of the emerging findings from the work. Claims that fundamentally shape the research and as a result of the work begin to appear extraordinary, on further investigation often are. Unpicking the beliefs which are causing the customer for the research to founder and thus request analytical support can be one of the most useful insights that an analyst can raise. A means of unpicking such beliefs, when the emerging evidence makes this appear to be necessary is to:

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- Characterise the claims implicit in the narrative upon which the tasking for the analysis is founded;
 - Take a Popperian approach to assessing these claims against the data (Popper (1972, 1979)), particularly with respect to perceived outliers in the data. The reason for 'attacking the outliers' in this way is that the reasons that the outliers do not fit the pattern implicit in the framing narrative helps to identify the causes of misalignment between the narrative and the issues that the customer is seeking to engage with;
 - Formally identify the gap between the accepted narrative and the contradictory evidence;
 - Posit less extraordinary explanations that embrace the previously excluded data;
 - Submit these candidate explanations to progressively more demanding examination and thorough ongoing review until sufficient clarity emerges such that it is possible to propose a new framing for the research upon an evidential basis.
- Consider scoping and boundary issues and their consequences (the boundaries are there to make the work tenable given the time and cost available and to ensure that we minimise 'lost opportunity' from the deployment of staff and other resources). There follows a means of reflecting upon such boundary issues:
 - In order to reflect on the degree to which the defined breadth of the research is appropriate, more broadly frame a conceptual model and then consider what the implications are, including sensitivity analysis that could be conducted in order to work towards an understanding of the degree to which we need be concerned;
 - In order to reflect upon the degree to which the depth of the work is appropriate, consider the extent to which the findings from the components of the analysis align with the evidence for the current baseline of the system being examined;
 - In order to reflect upon the degree to which the granularity of the research is appropriate, consider the degree to which aspects of the emerging findings align with more detailed studies in the area.

The key V&V issue that the analytical assurer role should focus on is the credibility of the work. While the quality of the content of the work clearly matters, it is the quality of the process which is fundamental to its credibility. Robinson (2002) identified that 75% of the concerns of the recipients of analytical work typically relate to quality of process issues, while 25% of their concerns typically relate to quality of content

issues. This view was founded in Robinson’s own research experience and for the purposes of the advice presented here and in the AQuA book was cross checked through a ‘crowd sourcing’ exercise across experienced analysts in the Civil Service. This process identified that 80% of the errors that occur in analysis are typically with respect to quality of process issues and 20% are typically with respect to quality of content issues. The specific errors identified through this process are addressed in part B of the AQuA book, chapter 5, Verification and Validation, in terms of the responsibility of each of the roles (analyst, analytical assurance and commissioner) to guard against these faults.

The key V&V issue that the commissioner role should focus on is the acceptability of the work. In particular, it is the responsibility of the commissioner role to understand the benefits that the analysis is seeking to support and in consequence who should be ‘bought-in’ concerning the process of V&V that is put in place. In doing this it is useful to remember that “essentially all models are wrong but some are useful” (Box and Draper (1987)). As a consequence of this, the commissioner of the analysis has a key role in shaping the work and in assisting in the interpretation of the results, from what is necessarily the simplified context of the research into the ‘real world’ context in which the intended benefits are sought (more detail concerning these responsibilities is presented in part B of the AQuA book, chapter 5, Verification and Validation).

The inter-relationship between these key aspects of quality is illustrated below in Figure 1.



Figure 1: The quality triangle

3 Transparency of process

The AQuA book identifies four stages to the analysis process. Each stage in this process needs to be captured so as to enable the analysis to be delivered with appropriate transparency. Four forms of transparency have been identified in the construction of this advice, one for each stage of the work. The stages of the work are illustrated in Figure 2 and further described below:

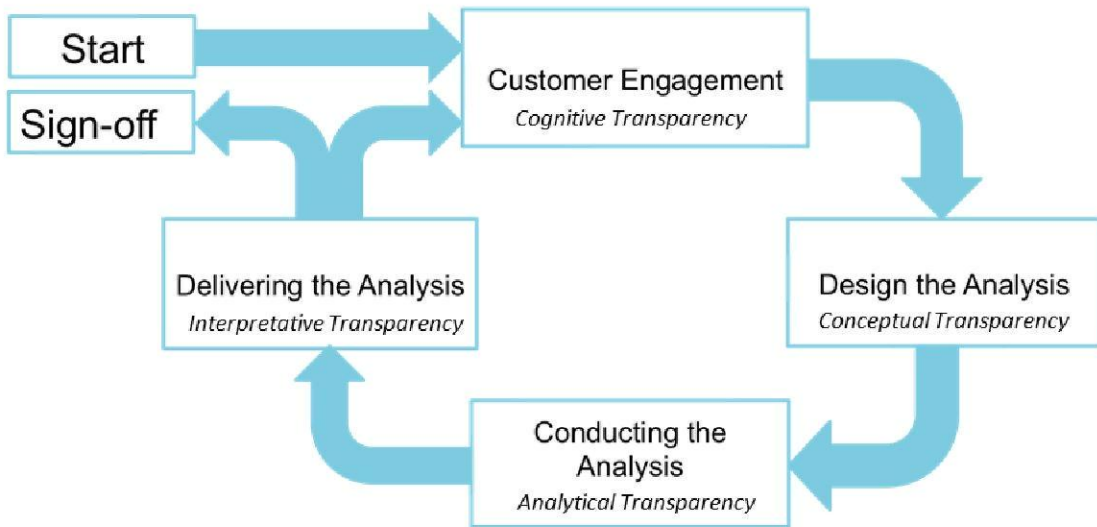


Figure 2: The stages of the work

- **Customer engagement:** The aim of customer engagement is to surface the purpose or purposes of the work and identify the benefits that the analysis is seeking to contribute to. In consequence it seeks to identify the breadth and depth of enquiry that is needed and the range of perspectives that are to be taken into account through an open dialogue which seeks to agree an appropriate balance between analytical tractability and appropriate constraints. Customer engagement is facilitated through cognitive transparency:
 - *Cognitive Transparency:* The purpose of cognitive transparency is to be clear about the benefits that the analysis is being commissioned to support, the assumptions upon which the analysis shall stand and the reasons for the selection of this view of the world. It is recommended that this understanding is formally recorded in an analytical estimate, although for very fast turnaround work it is acknowledged that it may be necessary to do this after the event. The analytical estimate is a living document, the purpose of which is to act as a vehicle to record the understanding derived from an open engagement with the commissioner of the research, in order to reach a view on the analytical tractability of the work, noting the limitations of the constraints within which that work would be required to proceed. The idea behind this approach is that reflecting back the analyst's

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understanding to the commissioner role serves to identify and clear up any misunderstandings that may occur during the tasking process, producing a shared understanding of 'the art of the possible' given cost and time constraints. Since the analytical estimate seeks to surface the assumptions upon which the analysis is founded it also serves as a vehicle by which the evidence arising from the analysis can be considered, allowing the basis upon which the work has been constructed to be questioned if one or more key assumptions no longer appear to hold. The analytical estimate thus serves to ensure that as far as possible there are no surprises arising from the conduct of the work, but where such surprises do arise it provides a point of reference to help identify their source and provide a basis from which they can be managed.

- **Design the Analysis:** The design of the analysis should be firmly based upon the mutually agreed requirements identified through customer engagement. For this reason it has been recommended that the results of customer engagement are formally captured through an analytical estimate which provides a comparator against which the 'fitness for purpose' of the design can be assessed. Such assessment both enables the design to be tested for completeness and the coverage of the customer engagement to be reflected upon in the light of issues raised by the production of the design. The design of the analysis is facilitated through conceptual transparency:
 - *Conceptual Transparency:* The purpose of conceptual transparency is to be clear about the process by which the benefits for which the analysis that has been commissioned shall be obtained. It is recommended that this process is formally recorded, both in a concept of analysis and as appropriate in the documentation of the methods, techniques or models used or specifically developed for the work. The concept of analysis should clearly set out the issues to be addressed by the analysis and the means by which it is proposed that the intended work shall be achieved. Care should be taken to ensure that the concept of analysis addresses all of the requirements agreed within the analytical estimate. It is recommended that the concept of analysis is supported by documentation setting out the verification and validation status of all methods, techniques and models to be used. A way of providing this information is through a validation logbook or for smaller methods, techniques or models a validation logsheet. This verification and validation documentation should set out:
 - The purpose or known competence of the method, technique or model;
 - The history of usage in the relevant field of application;
 - Those currently known to competently deliver this capability (in full or in part with any known limitations on their current competence identified);
 - Evidence or reference to evidence concerning the verification of the approach against the requirements that it seeks to address;

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- Evidence of validation of the approach through inspection both of the approach and its results by relevant experts in the field and through comparison to evidence previously reported; and
 - Any known limitations of the approach.
- As with the analytical estimate, the aim of the concept of analysis and the documentation for methods, techniques or models used (including formally recording their verification and validation status), is to ensure that there are no surprises arising from the conduct of the work as far as possible, but where such surprises do arise it provides a point of reference to help identify their source and provide a basis from which they can be managed.
- **Conducting the Analysis:** As far as possible the conduct of the analysis should follow the design set out in the concept of analysis. None the less it is recognised that information sources may have previously unrecognised limitations which will need to be managed in order to ensure proper delivery of the work. This will require consideration of uncertainties and dependencies in the data, with appropriate use of parametric variation in order to help bound the problem space. Thus the role of the analyst is: to ensure that the right inputs are introduced into the agreed analysis process in the right way; that any input error that does occur is sifted from the results set through validation checks; and that the recognised results conform to the process that was intended. The enactment of the analysis is facilitated through analytical transparency:
 - *Analytical Transparency:* The purpose of analytical transparency is to be clear about the process that it actually proved possible to conduct, given emergent limitations of process and technique. Central to this are considerations concerning the extent to which the research is: Repeatable; Independent; Grounded in Reality; Uncertainty Managed; and Robust (captured in the acronym RIGOUR) outlined in Chapter 5 of the AQuA book. It is recommended that the data used in the analysis is captured in a master data and assumptions list which is subject to validation through peer and expert review. The work itself should be captured in technical reporting which includes: the purpose of the work; the method; the results; any significant limitations or caveats associated with the conduct of the work; preliminary interpretation setting the results in the context of previous research and elucidating the mechanisms which both lead to conformity with previous research and those mechanisms which drive key differences.
- **Delivering the Analysis:** As identified in Chapter 5 of the AQuA book, commissioner, analyst and analytical assurer all have key roles in the delivery of the analysis. The reason for this is that the translation from the simplified representation of the world reflected in the analysis to the complexities and perturbations introduced by a more complex reality require a measure of interpretation in order to map the results to the context of their intended application. This translation process needs to be jointly owned, such that: the

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analyst is content that the interpretation is a fair reflection of the meaning of the results from the process that was run; the analytical assurer is content in terms of the mapping to the extant literature (both that conformity has been achieved where that is appropriate and that new insights stand given proper considerations of process (structures that effect change, their levers and the functioning of their mechanisms (Harré R (1970))); and that the commissioner is satisfied with the work that has been engaged in, the process by which it was produced and how it relates to the context in which advice is required. Furthermore, once satisfied, it is the responsibility of the commissioner role to ensure that the analysis has the impact that it deserves (see Collins (2001)). The interpretation of the analysis is facilitated through interpretative transparency:

- *Interpretative Transparency*: The key to interpretative transparency is to be clear about the reasons for selecting the assumptions which were adopted and the alternatives that were considered in making the interpretation of the analysis that is offered. This enables the commissioner of the research and the customers to judge for themselves the extent to which they accept the findings of the work. It is imperative that the customer reporting of the analysis is tailored for each intended audience. It is recommended that the key findings are presented first along with any significant limitations or caveats associated with the work in order to assist the busy reader. Other information to include is the relationship between this analysis and previously reported findings (including appropriate referencing), the reasons both for similarities and key differences and the recommendations that in consequence are being made.

4 Stages of the work

The key purpose of the approach to verification and validation that is presented here is to enable the analyst to:

- Orient onto the current stage of the work and reflect on the purpose it is seeking to fulfil;
- Consider that purpose in light of the current plans and the assumptions and beliefs in which they have been founded;
- Provide guidance on the key considerations to resolve when engaging with the phenomena central to this stage of the work;
- Verify that they have done what they intended, capturing evidence to show the extent to which this has been achieved; and,
- Validate the product that they have generated against the requirements placed on them.

This process is illustrated below in Figure 3.

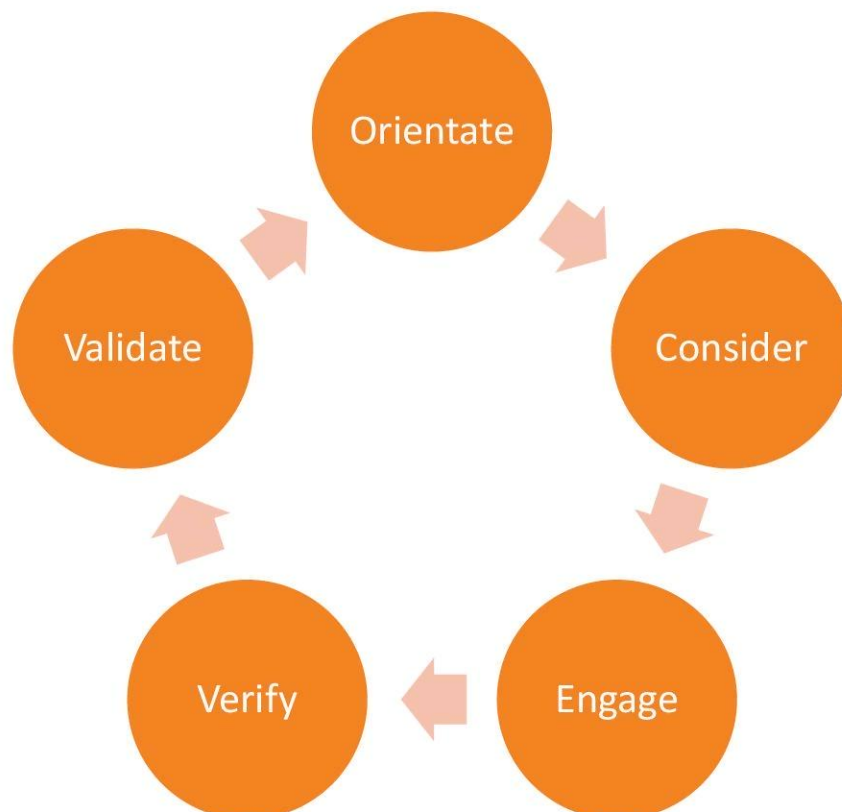


Figure 3: The verification and validation process

Orientate: The purpose of this first step is to clarify what has been asked of the analyst at this stage in the work and the role that this has in producing the benefits

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that are sought. Pausing in this way serves to guard against rushing into the work, without first understanding the success criteria. The aim is to ensure that what the analyst sets out to do in 'best faith' is what the commissioner of the work would most wish of them, so as to produce work that can in principle be considered to be reliable. The evidence captured in the orientate step serves to frame the considerations made in the validate step (see below).

Consider: The second step is to pause again and consider if the plans that frame the envisaged approach to this phase of the work align so as to enable the realisation of the success criteria, identified in the orientate step (above). In considering these plans it is useful to reflect upon the extent to which the assumptions and beliefs upon which the current plans were founded continue to hold, given what has been learnt in the orientate step. Should potential merit in changing the plan be identified then this should be made known to the quality assurer role for validation of this view and with their agreement made known to the commissioner role with a view to authorising a variation to the plan. The evidence captured in the consider step serves to frame the assessments made in the engage and verify steps (below).

Engage: The third step is to engage with the phenomena which are the subject of the analysis at this stage. When engaging with the appropriate phenomena there are five validation criteria that need to be considered. Again there should be a pause before proceeding, to do a final conceptual check that the work as planned (captured in the consider step (above)), makes sense in terms of the questions that these criteria raise. Adequate transparency (for the purposes of the work being conducted), concerning how these criteria were addressed, provides a key part of the evidence needed for consideration in the validation step below. The criteria are as follows:

- *Reliability:* which considers the degree of alignment between what is studied in the analysis (in terms of breadth and depth), given the constraints upon the work, and the benefits that it is designed to provide;
- *Face Validity:* which considers the degree to which the stakeholders who prove key, consider there to be an adequate alignment between the characterisation of the issues being examined in the analysis and their understanding of the 'problem space'. Lack of alignment between key stakeholders' expectations concerning what is examined and the detail of the work leads to lack of confidence in the product of that work;
- *Criterion Validity:* which considers the detailed engagement with the phenomena being examined in the analysis and the extent to which the work actually engages with the phenomena that it claims to;
- *Construct Validity:* which considers the adequacy (for the purposes of this analysis) of the representation of how the phenomena being examined are structured, the key factors to which they respond and the mechanisms by which they do this;
- *Content Validity:* which considers the interpretative weight that the work proposed can bear, as a result of its breadth, depth and granularity. The aim is

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to match the interpretative value that can be derived from the analysis to the need to produce insight in order to enable the delivery of benefits.

Verify: The fourth step is to verify the extent to which the work conducted aligns with the work that was planned and to capture evidence as to the extent to which this is the case. The evidence from the verify step is combined with the evidence from the previous steps in order to produce the evidence that is considered at the validate step (below). Reasons for variation from the plan can include 'human error', lack of some of the required data within the required timescales, or a need to make an ad hoc change to the analysis plan due to the emergence of additional constraints that were not anticipated at the time the analysis plan was constructed. Where variation from the plan has occurred, the analytical assurer role needs to consider if aspects of the work need to be repeated or if the differences can be adequately controlled and understood through appropriate parametric variation, which is then tasked to the analyst.

Validate: The validate step considers all of the evidence gathered in the previous steps conducted at this stage in the analysis process. It is recommended that this validation step is conducted as a gated review with one of four possible outcomes:

- The work is accepted and permission is given to proceed to the next phase (from customer engagement to designing the analysis; from designing the analysis to enacting the analysis; from enacting the analysis to delivering the analysis; and from delivering the analysis to formal publication);
- The work is accepted, but noted as having limited utility with respect to the benefits that were sought, with particular reservations noted. A decision is then made concerning how to proceed (the work could be re-shaped through returning to an earlier stage in the analytical process, the work could continue with noted caveats, or the work could be put on hold or stopped);
- The work is noted as still having potential, but only if identified issues can be resolved, with a decision made on granting permission to examine these issues further;
- The work is rejected, with reservations noted and a decision made concerning how these issues should be actioned.

5 Common Analytical Pitfalls

There are three main levels of potential pitfall that those involved in the analytical process need to be aware of:

- The framing of the analysis;
- The choice of approach within the selected frame;
- The engagement with the detail of the work.

It follows that each of the three analysis roles (commissioner, analyst and analytical assurer) has a role to play in mitigating and managing the potential pitfalls that may become apparent during the course of the work. In particular the commissioner role should lead on the framing of the analysis, the analytical assurer role should lead on the choice of approach within the agreed frame and the analyst role should lead on engagement with the work, using the approach that has been chosen. The conduct of work at each level is subject to review by the person responsible for the shaping decision at the level above.

It should further be noted that an apparent oddity identified at one level in this hierarchy can point to a problem in the level above. As such, those responsible for each level of potential pitfall should remain open to evidence both from the level above and the level below of a need to reconsider their approach. Each level of pitfall is further discussed below.

Framing: The fundamental decision made with respect to any analysis is how it is framed in order to give access to the benefits sought by the commissioner role. It is for this reason that the commissioner of the analysis owns this decision, but is also the reason why the commissioner needs to remain open to evidence from the conduct of the work that a different framing could realise these intended benefits more easily.

The following mistakes concerning the framing of the work have been identified by Salt (2008); while this paper specifically focuses upon simulation its findings can be generalised to other forms of analysis. The mistakes that have been identified are:

- Assuming that as a perfectly accurate external observer the commissioner role can accurately specify the programme of research that is required. Reasons why this is not the case are expanded upon in Jackson (2003). Instead the commissioner role owns the need for the research, expressed through the framing in order to realise the benefits that are sought in consequence of the analysis. It is the analytical assurer role that owns the programme of work to realise this aim and the analyst role that owns the work to realise the programme that has been agreed;
- Assuming that additional detail in the research necessarily delivers additional benefit. It can simply cause the work to take longer with no appreciable improvement in the quality of outcome to be derived from the

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work, although considerations of face validity (see section 4 above) can sometimes over rule this;

- Assuming that using more frames of reference for the analysis necessarily produces a more useful understanding. While the use of different frames can help to 'triangulate' onto an understanding of a phenomenon where there are concerns about the veracity of any given method the use of additional frames should not be engaged in needlessly;
- Assuming that dynamic systems can adequately be analysed through static models. Senge P (1990) identifies that: "The real leverage in most management situations lies in understanding dynamic complexity, not detail complexity". This insight is discussed in greater detail in Georgiou (2007);
- Assuming that since analysis has been conducted the findings can simply be accepted as a 'fact'. It is for this reason that the commissioner of the research has an important role in the interpretation and promulgation of the work. Furthermore, it is important that the reporting of the analysis reveals not only what is known but also areas of uncertainty, Jackson (2003);
- Assuming that analysis can accurately predict. While analysis can be indicative, given stated uncertainty bounds, such as the weather forecast, there are generally too many factors in operation for the future state of a system to be predicted with certainty.

Choice of approach: The choice of approach to the analysis is dependent on the frame, including issues of timeliness and allowable resource. It is the responsibility of the analytical assurer role to assess the 'fitness for purpose' of the work against the requirements of the frame within which that work has been set and to consider if the frame chosen is the most effective way to unlock the intended benefits of the work. If the analytical assurer believes that the intended benefits the commissioner seeks could better be reached through a different framing of the problem space then they should make this known along with the evidence which leads them to believe this. The key pitfall with respect to choice of approach is:

- Assuming that since an analytical approach has been successfully used in a similar context in the past that such an approach should be mandated. It is the responsibility of the analytical assurer role to advise on the choice of analytical approach or approaches, given the benefits that are sought and the limitations of cost and resource that are available.

Engagement with the work: While those commissioning analysis and working in the analytical assurer role are drawing on their experience in order to shape the work, it is the analyst who is engaging with the details of the evidence that indicates how well those shaping decisions have been made. The following types of pitfall have been identified:

- A key pitfall in conducting analysis is the degree of self-awareness of the analyst with respect to the extent to which their prior beliefs may be driving the way in which they conceive, conceptualise, analyse and subsequently

interpret their work. The commissioner and analytical assurer both have roles in helping the analyst to overcome any such prior views. In particular the following mechanisms assist the analyst to address such limitations: the framing of the analytical question; the identification of the stakeholder group for the analyst to engage with; and the verification and validation processes (described above in section 4) assisted through transparency of process (described above in section 3). Other approaches that can help to ensure due RIGOUR in the conduct of the work (see section 3 above) are described in Petty et al (2012). One of these approaches is the use of a reflexive journal in which the analyst takes time to consider the shaping effect of their beliefs upon the analytical process, the extent to which emergent evidence may indicate a need to modify such beliefs and the means by which this emergent view could be verified and validated. Georgiou I (2007) identifies that it is not possible to simultaneously conduct analysis and consider how the emergent meaning of the research may suggest a need to re-frame the work, either in terms of the choice of approach or the overall framing of the work. Instead specific timeouts are required in which to use the reflexive journal. An example of the use of a reflexive journal while conducting analysis is provided by Boulton (2011). The analytical assurer role is there to provide the analyst with a sounding board for emergent views deriving from the use of the reflexive journal.

- There are also three well-known philosophical problems which have the potential to limit insight delivered by analysis (DiFate (2007)), in particular:
 - *The Ravens Paradox* which illustrates the limitations of 'bootstrapping' through logical argument, since almost anything can be asserted to be evidence of a pre-held view through such argument DiFate (2007). The use of *criterion validity* (see section 4) protects against the vices of the Raven's Paradox;
 - *The Grue Paradox* which seeks to assert either that the nature of the way things interact has changed or is about to change and hence seeks to shape the analysis through greatly limiting the data set that is drawn upon or demands that the analysis is founded upon a theoretical posit that reflects the assertion which has been made DiFate (2007). The use of *construct validity* (see section 4) protects against the vices of the Grue Paradox, particularly if an analytical approach which allows the examination of dynamic complexity is used (Harré (1970), Senge (1990) and Georgiou I (2007));
 - *Underdetermination of Theory by Evidence* which leaves the analyst with no sound way of distinguishing between the veracity of a set of different hypotheses concerning a phenomenon, all of which could be valid given the evidence currently available DiFate (2007). Such problems have for example bedevilled archaeological interpretation (Hodder (1986, 1991, 2003)). Where this problem occurs it is vital to be clear about the range of possible interpretations that can be placed upon the evidence available (Jackson (2003)).

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Glossary

Activity

An activity is a specific piece of work that has been tasked in order to make an identified contribution to an agreed business purpose.

Analyst role

The analyst is a person tasked to conduct analysis on behalf of the commissioner.

Analytical assurer role

The person tasked to provide analytical assurance of the work conducted by an analyst. For small rapid projects the person working as the analyst could also be fulfilling the analytical assurance role, although it is advisable to always have an independent person to provide the analytical assurance check upon the work.

Commissioner role

The commissioner is the person who commissions analysis for the purposes of a Programme, Project or Activity.

Programme

A programme is a governance structure designed to co-ordinate, organise, direct and implement a portfolio of projects and activities that together achieve outcomes and realise benefits that are of strategic importance.

Project

A project is a governance structure created for the purpose of delivering one or more business products against an agreed business purpose.

Validation

Validation literally means to make valid, through the agreement of those judged competent to take such views. The central question that validation raises is the extent to which the right work is being engaged in, given the purpose and constraints placed upon that work. The key output from the validation process is a judgment, based on evidence, concerning the extent to which the work is 'fit for purpose'.

Verification

Verification is concerned with the extent to which the work that has been agreed to is being done in the 'right' or 'accepted' way, given the 'art of the possible'. The key output from the verification process is a judgment, based on evidence, concerning the extent to which the agreed work has been conducted appropriately.

List of abbreviations

AQuA	Analytical Quality Assurance
RIGOUR	Repeatable; Independent; Grounded in Reality; Uncertainty Managed; and Robust.
SRO	Senior Responsible Owner
V&V	Verification and Validation

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