VALUATION MODELLING STANDARDS:
Guidelines for spreadsheet modelling in the mining industry

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1. Introduction

Spreadsheets have developed in concert with personal computers as the principal means of undertaking data processing on a widespread basis throughout all levels of an organisation. Visicalc, first distributed for personal computers in 1979, is often regarded as the single application which transformed the use of personal computers from hobbyists to the mass business market. Lotus 123, the most widely used spreadsheeting software through the 1980's, was superseded by Microsoft Excel when it introduced its Windows operating system in 1987. Excel has become the de-facto spreadsheet platform of choice, used widely for simple tabular reporting to complex accounting and forecasting, funding projections and reporting tools. Company critical information is input, processed and output by a wide range of personnel, often with little or no auditing or testing.

Key features of spreadsheets include a relative shallow learning curve, apparent structure, almost limitless scalability, a large range of "off the shelf" formulae and functions, the integration in software suites including word processing and presentation software and ease of publication. These result in both organisational benefits and pitfalls.

Horror stories abound as to the consequences of spreadsheet errors, both financial and reputational.

The UK Financial Services Authority (FSA) fined Credit Suisse GBP5.6 million in 2008 stating that it had violated Principles 3 and 4 of its Principles of Business (http://www.fsa.gov.uk/pubs/final/credit_suisse.pdf), stating in its findings;

"A firm must conduct its business with due skill, care and diligence."

"A firm must take reasonable care to organise and control its affairs responsibly and effectively, with adequate risk management systems."

"The booking structure relied upon by the UK operations of Credit Suisse for the CDO trading business was complex and overly reliant on large spreadsheets with multiple entries. This resulted in a lack of transparency and inhibited the effective supervision, risk management and control of the SCG".

Many other significant publicly reported financial and reputational losses are reported by the "European Spreadsheet Risks Interest Group" (http://www.eusprig.org/horror-stories.htm). These publicly reported incidents are likely to represent a fraction of material errors which have not been reported.

Mining projects and operations, due to their high level of capital intensity and technical complexity, are particularly vulnerable to the effects of spreadsheet errors, and potential losses as a result of spreadsheet errors can be significant.

This paper outlines the weaknesses of the spreadsheet modelling environment and presents some examples of areas where the application of standards are beneficial in improving the reliability and accuracy of spreadsheet based financial models.

2. Spreadsheet Error Research

Much research has been documented and published by Professor Raymond Panko, a professor of IT management in the Shidler College of Business at the University of Hawaii, and the European Spreadsheet Interest Group (EUSPRIG), which holds an annual conference on spreadsheet issues.

Spreadsheet development, like any human activity, is prone to human error. Human behaviour research has estimated that the accuracy rates are 99.5%-99.8% for mechanical actions, such as typing, and 95%-98% for complex thought (formula construction and logic development). In isolation these error rates may be acceptable, but considering the number of unique formulae a spreadsheets (ignoring formulae copied across rows), and that the error rate increases as a function of the *exponent* of probability, it is over 95% certain that at least one error is present in a relatively small 200 unique formula spreadsheet. (Panko 2007).

The high incidence of spreadsheet error rates is borne out by many studies, as illustrated in Table 1, which indicates an 88% error rate in over 100 spreadsheets studied (Panko 2009).

Authors	Year	Number of SSs Audited	Average Size (Cells)	Percent of SSs with Errors	Cell Error Rate	Comment
Davies & Ikin	1987	19		21%		Only serious errors
Cragg & King	1992	20	50 to 10,000 cells	25%		
Butler	1992	273		11%		Only errors large enough to require additional tax payments
Dent	1994	Unknown		30%		Errors caused by users hard-wiring numbers in formula cells. Henceforth, all future computations would be wrong.
Hicks	1995	1	3,856	100%	0.012	One omission error would have caused an error of more than a billion dollars.
Coopers & Lybrand	1997	23	More than 150 rows	91%		Off by at least 5%
KPMG	1998	22		91%		Only significant errors

Lukasic	1998	2	2,270 & 7,027	100%	2.2%, 2.5%	In Model 2, the investment's value was overstated by 16%. Quite serious.
Butler	2000	7		86%	0.4%**	Only errors large enough to require additional tax payments**
Clermont, Hanin, & Mittermeier	2002	3		100%	1.3%, 6.7%, 0.1%	Computed on the basis of non-empty cells
Interview I*	2003	~36 / yr		100%		Approximately 5% had extremely serious errors
Interview II*	2003	~36 / yr		100%		Approximately 5% had extremely serious errors
Lawrence and Lee	2004	30	2,182 unique formulas	100%	6.9%***	30 most financially significant SSs audited by Mercer Finance & Risk Consulting in previous year.
Powell, Lawson, and Baker	2007a	25		64%		11 of 25 spreadsheets contained errors with non-zero impacts. Among the ten spreadsheets with non-zero impacts for which error size was reported, all 10 had an error that exceeded $100,000, 6 had errors exceeding $10 million, and 1 had an error exceeding $100 million.
Powell, Baker & Lawson	2007b	50		86%	0.009	Percent of formula cells containing errors that give an incorrect result. Including poor practices, 1.8% of all formulas had issues. Including poor practices, 94% of the spreadsheets had issues.
Total		113		88%		

*In 2003, the author spoke independently with experienced spreadsheet auditors in two different companies in the United Kingdom, where certain spreadsheets must be audited by law. Each audited about three dozen spreadsheets per year. Both said that they had never seen a major spreadsheet that was free of errors. Both also indicated that about five percent of the spreadsheets they audited have very serious errors that would have had major ramifications had they not been caught. Audits were done by single auditors, so from the research on spreadsheet and software auditing, it is likely that half or few of the errors had been caught. In addition, virtually all of the spreadsheets had standard formats required for their specific legal purposes, so error rates may have been lower than they would be for purpose-built spreadsheet designs.
**The low cell error rate probably reflects the fact that the methodology did not inspect all formulas in the spreadsheet but focused on higher-risk formulas. However, error has a strong random component, so not checking all formulas is likely to miss many errors.
***Unlike other authors, Lawrence and Lee (2004) measured "issues" rather than only quantitative errors. This explains why the average "error rate" is higher than those seen in other studies.

The research demonstrates that errors are inevitable in any human activity, and the object of improvement is to minimise the rate of errors and to have systems and tests in place to identify and remedy errors.

Testing and identifying errors is in itself prone to error, with a probability of only 40% - 60% error detection being reported for a tester working alone and 70% - 80% with group inspection detecting of all errors (various sources, as summarised in Panko 2006).

Study Subjects	Sample	% errors detected
Masters of Business Administration students	60	56%
Masters of Business Administration students	113	51%
Undergraduates working alone	60	63%
Undergraduates working in groups of three	60	83%
Undergraduates	228	67%

The spreadsheet modelling environment

Techno-economic spreadsheet models are used in the mining industry inter alia for budgeting, planning, life of mine operations and cash flow forecasting. Valuations of mineral projects from scoping study stages are developed, varying from simple desktop scoping models through detailed full feasibility valuation and financing models, incorporating cost estimation and control (budgeting) areas.

Results of spreadsheet based valuations have a large influence on company strategy and are often released to third parties or into the public domain, in the form of funding applications, company presentations, Stock Exchange Statutory documentation (Competent Person's Reports, 43-101 documents etc.) and mining rights applications.

In the mining industry the typical mineral project valuator has a geological or engineering background, frequently with some commerce/financial background or training. Formal software development experience is limited to early university courses, and is self schooled in Excel.

Spreadsheet modelling is a high level computer programming language. Unlike formal computer languages, a spreadsheet has few rules bounding its structure or programming process. Formal computer languages, such as C, Cobol, Fortran, Java etc follow rules of structure, syntax and procedures with input, variable and output data forms being clearly defined as to type and limitations. Calculations are performed in logically structured modules and subroutines.

Commercial software is developed by teams of programmers and testers with rigorous debugging, version control, Beta (public test) release prior to commercial release, and usually followed by patches (updates) distributed to clients after release. It has been reported that commercial software development allows up to 60% of development time for testing and debugging.

3. Spreadsheet development standards

Some major mining and accounting firms have developed standards and protocols for spreadsheet modelling. The author has performed modelling for three such large multinational mining companies under each organisation's codes. Two of the three recommend a set of principles and procedures under the Excel framework, whilst the third employs a third party software solution. In most mining companies, however, in the author's experience, valuations are performed without such guidance.

The Australian Institute of Mining and Metallurgy has identified the need for some level of standardisation and improvement in spreadsheet valuation and modelling and has published a "Draft Guidelines for Technical Economic Evaluation of Mineral Industry Projects" (The AusIMM, 2011), which includes sections on Guidelines for Spreadsheet Modelling.

Some commercial modelling enterprises have developed standards and guidelines for spreadsheet modelling, usually associated with provision of modelling or training services. Three organisations have published such standards. Additionally several training courses are offered which provide financial modelling training, but without published standards.

The Australian based BPM Consulting have published "Best Practice Modelling Standards" under the name "Spreadsheet Standards Review Board", Financial Mechanics and F1F2 Consulting firms have published the "FAST Modelling Standard" (www.fast-standard.org), the Operis Group (www.operis.com) operates training following the procedures described in the book "Swan, J. (2008), Practical Financial Modelling: A Guide to Current Practice, 2nd Edition, CIMA Publishing" and Navigator Project Finance (www.navigatorpf.com) has recently published the "SMART Modelling Standards" .

A review of the BPM, FAST and Operis methodologies concluded that "in our judgment, we find credible the assertion that careful use of the FAST, Operis, or SSRB spreadsheet engineering methodology will lead to enhanced productivity, accuracy, and maintainability of large financial spreadsheet models" (Grossman 2010) .

Miracle Solutions, a South African consultancy, has developed an outline of methods to comply with section 404 of Sarbanes Oxley legislation within the Excel framework (http://www.auditexcel.co.za/sox_S404.html#eighth).

4. Spreadsheet error types

Spreadsheets errors can broadly be defined into two types, patent and latent errors.

Patent errors are those which lead to incorrect results some causes being:

- Incorrect logic
- Incorrect referencing
- Incorrect input assumptions
- Omission of important elements

Latent errors: may lead to incorrect results under some cases:

- Hard inputs in formula
- Formula changes across rows
- Over-complex formula
- Opaque functions
- Inputs mixed in calculation sheets
- Hidden sheets, rows or columns
- Circular references
- Hidden circularities

It is important for the modeller to recognise the error types, sources and consequences.

5. Sources of errors

Errors may be caused by many factors including insufficient or inappropriate experience, absence of standards and procedures or best practice protocols, over-confidence, time pressures or insufficient planning.

Mineral projects are by nature multi-disciplinary, and valuation models inevitably have explicit or implicit technical parameters of valuation importance, for example resource depletion, production scheduling, process material balances, stockpiles and blending. In addition specialised accounting areas are present, for example working capital, royalty and taxation regimes, financing arrangements and covenants and costs of capital.

Financial forecasting, particularly in the minerals industry, is a multidisciplinary task and experience is required for a single valuator to become sufficiently proficient in all technical and accounting areas, and for testers and auditors to be able to identify errors in areas outside of their specific areas of expertise.

The financial modeller is reliant on a multitude of inputs, often from several sources and decision makers require results within limited time, often before or shortly after inputs have been finalised. In addition first results are remembered, and any changes have to be explained at length. Valuation is completed at the end of a study, once technical parameters have been finalised and costs estimates performed. There is always danger in valuation that when the valuation does not yield the “required” or “expected” results the project team is requested to adjust assumptions to yield the expected outputs. Undocumented modifications are made in the model under time pressure without clear sources and results of changes.

Overconfidence has been demonstrated to be a frequent source of poor modelling It has been stated that “if risk to the enterprise is to be reduced, individuals need to become aware of the reality of the quality of their work” (O'Beirne, P. 2006), and “The .... fundamental thing to understand from human error research is that making large spreadsheets error free is theoretically and practically impossible….. {and to attempt to do so} is a testament to the profound human tendency to overestimate their ability to control their environment even when they cannot”. (Panko, 2007).

6. Error reduction procedures

It has been demonstrated in formal computer programming that following staged and structured development procedure results in fewer errors, and the following phases are common.

6.1. Project Definition

Initial project definition requires and elements of design to be identified in conjunction with the final model user to ensure that the design will accommodate expected inputs and defined outputs.

It is important to identify and agree early in the development process the sources of data, format of inputs, specific required outputs, and to define a project timeline where these sources of information will be made available to the modeller.

A critical area which is frequently initially ill defined is the time resolution of a model. Different valuation inputs are developed in different time resolutions by engineers, accountants and others. For example, capital forecasts are often performed, at a project level, on monthly estimates, production forecasts on a monthly/quarterly/annual basis depending on stages of production, pre-production development, production ramp-up and steady state operations. Taxation is usually an annual calculation, on-mine stock holdings may span multiple months of production and so on. A common agreed set of time resolutions, ideally consistent over the entire project life must be agreed with all parties prior to commencement of modelling.

6.2. Spreadsheet design

Best practice design incorporates structures which are consistent, logical and transparent. Consideration can be given to the following logical structure.

6.2.1. Foundation sheets

The foundation sheets comprise hard coded model assumptions in dedicated sheets, including.

Inputs - All input parameters in dedicated input sheets separated into the following types:

- Point inputs such as tax rates, unit consumption rates etc.
- Time series inputs such as production schedules, project capital forecasts.
- Timing elements such as potential time variability of inputs.
- Indexation for individual price and cost components and inflation assumptions.
- Clear documentation of input sources.

6.2.2. Working sheets

Working sheets include a build-up of calculations in a logical sequence, with logic flowing top to bottom and left to right on individual sheets, and progressively between successive sheets.

Adherence to calculation rules and structures assists in minimising errors and allows for improved ease of auditing and testing. Some frequent recommendations include:

- Unique labels for calculated outputs.

- Linking calculated outputs as a complete line item, including labels.

- Uniform structure of each time series sheet with labels, units, row totals and time series occurring in the same column of each sheet and each sheet being in the same time resolution.

- Consolidation of time periods on separate sheets, not within the time series.

- Consistent formulae within each row such that the first formula in a time-series can be safely copied across all time periods.

- Calculations performed only once for any final or intermediate result, and all future references to a calculation result linking to the original calculation result.

- Calculations performed in blocks, with all "ingredients" of a calculation visible with and precedents clearly labeled.

- Appropriate anchoring of rows and/or columns such that calculation blocks and contained logic can be directly duplicated.

6.2.3. Presentation sheets

Output and presentation sheets comprise the final model product, and should be developed in conjunction with the end-user in the definition stage. Some common recommendations include:

- Linking of required presentation information to calculation or input sheet source with no calculations contained on presentation sheets.

- Summary inputs, outputs and charts and key results can be presented in dashboard structures.

- Development of output sheets for specific end users.

6.2.4. Control sheets

Various control sheet types provide information, regarding the spreadsheet aiding in navigation and structure, uses and limitations of the model, version control, change logging and error trapping.

An easily navigable, well documented model is beneficial to users and auditors and to the developer, with notes providing capabilities and limitations to the model's functionality.

Version control and change tracking is essential in latter stages of model development, particularly once outputs have been provided to third parties. Changes in output metrics inevitably occur as updated input parameters are included or errors are uncovered. It is important to log these diligently both from an audit and reporting perspectives.

Error identification and trapping is important to implement from the start of model development. Critical metrics must be identified, such as plant capacity not being exceeded, balance sheets balancing, and recognisably flagged in a clear fashion.

7. General modelling recommendations

Some common themes occur in the various modelling standards.

7.1. Colour coding standards

Color coding improves readability of the model. Some areas where specific colour coding is recommended to identify:

- Inputs
- Exports from one sheet to another
- Imports from previous sheets
- Check cells
- Reverse logic (where logic breaks the left to right, top to bottom convention)

7.2. Formula construction rules of thumb

Individual formulae are often too long or complex to understand easily. There is a "rule of thumb" which states that a single formula should not be longer than the developer's thumb. Avoidance of the following is recommended:

- Nested IF statements
- Many different functions in a single formula
- Several levels of parentheses
- Excel names
- Arrays
- Off-sheet precedents
- Semi-anchored ranges (e.g. SUM($J45:N45)
- Nested logical functions (e.g. MIN/MAX constructions in turn inside other MIN/MAX elements)
- Sign switching one or more times (e.g. MAX(MIN(x, -y), MAX(w, -x)))

Several of the above can be reduced by splitting the formula into smaller components.

7.3. "Dangerous" functions

Several inbuilt Excel functions are either prone to error or reduce the ability to audit a model effectively. The following functions are often criticized.

7.3.1. INDIRECT

Referencing cells indirectly removes a direct audit trail to precedent inputs to a calculation.

7.3.2. OFFSET

Referencing cells using the OFFSET function removes a direct audit trail to precedent inputs to a calculation. The function has some uses however, for example in depreciation calculations.

7.3.3. NPV (and XNPV)

Use of the NPV function obscures the important calculation of NPV. Timing of discount factors cannot be directly viewed. It is recommended that the modeler creates discount factors from first principles for transparency.

The XNPV function takes account of the date of discount but the formula remains opaque as to the actual discount factors applied.

7.3.4. LOOKUP

Referencing cells in lookup tables removes a direct audit trail to precedent inputs to a calculation. In addition, when no exact match exists errors occur unless sorted.

7.3.5. Rounding functions

The use of rounding functions reduces the accuracy of the model, and rounding errors inevitably occur. Formatting data to the required decimal places results in the required presentation, whilst maintain data integrity.

7.3.6. ISERROR

Error trapping using the ISERR function (for example removal of DIV0 errors) may obscure real errors in code.

7.4. Circular calculations

Avoidance of circular calculation is recommended, as they require iteration to be set to ensure convergence. The use of Data Tables for sensitivity analysis is compromised, as these do not internally iterate. In addition unintentional circularities may be obscured by intentional circularities. Reconstruction of logic will in most cases eliminate the need for circular calculations.

7.5. Hard coding within formulae

Hard input constants within formulae reduce the transparency unless well document. Transparency is enhanced by placing constants on input sheets.

7.6. VBA Macros

The use of VBA Macros eliminates any direct audit trail.

7.7. Model creep

Models developed for a specific purpose are often expanded upon as projects develop. For example, a project valuation model may upon cursory inspection be regarded as suitable for budgeting or financing purposes resulting in new code being shoehorned into structures or original code being changed and previously audited logic becoming invalid. It is invariably better practice to develop individual models suited to purpose.

8. Conclusion

In order to reduce error frequency, auditing and testing of models need to be formalized in their development, with appropriate time and resources being budgeted. It is advised that best practice is followed, and that standards are developed which will assist the mineral project valuator in developing transparent, well documented models which are reliable and can be transferred to other users with minimal training.

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