Paper submitted to:
R&D Management Conference 2016 *"From Science to Society: Innovation and Value Creation"* 3-6 July 2016, Cambridge, UK

Business Case Earned Value Management

William Alvin Wilby[1], Christopher Paul Turner[2]

[1]Thales UK, The Bourne Business Park, Weybridge, Surrey KT15 2NX, United Kingdom.
alvin.wilby@thalesgroup.com
[2]Thales UK, The Bourne Business Park, Weybridge, Surrey KT15 2NX, United Kingdom.
chris.turner@thalesgroup.com

This paper develops metrics which can improve industrial R&D investment performance. These metrics monitor progress in converting discretionary R&D investments into financial value. In most firms potential R&D projects are analysed in a business plan and managed using roadmaps and gate reviews, to reduce technical risk and increase confidence in the revenue forecast. Investment decisions are underpinned by a business case, which expresses the target value to be created in financial (cash flow) terms. The primary decision metrics are usually "Internal Rate of Return" (IRR) or "Net Present Value" (NPV). All too often, the business case is not then used as a baseline for measuring progress. This lack of scrutiny can lead to a lack of rigour in business cases. Where progress is reviewed against the business case, it is typically measured in terms of changes to IRR or NPV, without realising that these metrics have serious deficiencies as progress measures. We explain the deficiencies of IRR and NPV, develop a robust set of "Business Case Earned Value Management" metrics and discuss the issues that arise in deploying such a measurement framework.

1. Introduction

Businesses in our sectors (defence, aerospace, security and transportation) face challenging conditions when making product R&D investment decisions. Typically development and product lifetimes are long, the external competitive environment is fierce and predicting market demand, phasing and margins is challenging. With limited headroom in financial and engineering resources, long term self-funded product development projects also find themselves in competition with short term funded project work. Self-funded projects often suffer in this competition due to insufficient confidence in the business case.

In recent years, Thales has invested significantly in creating world class processes for planning product development activities, in order to reduce the risks in the investment decisions that it makes. These improvements increase our confidence in the market elements of the investment business case and in our ability to execute the development activities to cost and schedule. But, in common with our peer group and most other capital intensive businesses that we have studied, the ultimate investment decision remains fundamentally rooted in a Discounted Cash Flow (DCF) analysis, the form of which has not changed materially for several decades.

The DCF analysis is used to confirm that either:

- the Internal Rate of Return (IRR) is greater than a hurdle rate, which is usually a risk adjusted Weighted Average Cost of Capital (WACC)
- the Net Present Value (NPV), discounted at the same hurdle rate, is positive

These statements are usually (but are not guaranteed to be) equivalent and answer the question: ***"will this investment increase the value of the firm?"***

Corporate preferences for IRR versus NPV seem to be cultural rather than objective and there is little appreciation of the fundamental differences in the behaviour of these metrics (for an authoritative treatment of discounted cash flow and investment appraisal see reference 1).

Once a business case has been approved, it is rarely used systematically as a reference point ("baseline") for measuring progress over time. This lack of scrutiny leads to poorer quality business cases and investment decisions, a lack of management accountability and inefficient use of shareholder's funds.

Where progress is compared to the original business case baseline, it is typically done by recalculating the "Net Present Value" (NPV) or "Internal Rate of Return" (IRR), both of which have significant weaknesses when used for this purpose.

Both metrics are highly misleading if "sunk" costs are treated incorrectly. Furthermore, IRR is insensitive to delays in the cash flows or changes in the scale of the cash flows whilst NPV, used in isolation, is vulnerable to gaming of future cash flows.

So even though we may have become better at evaluating and controlling the risks inherent in the marketing predictions, and in managing the engineering development process, our ability to capitalise on those improvements is limited by long standing (but not generally recognised) deficiencies in the way DCF analysis is used.

This paper illustrates these deficiencies before moving on to describe the new "Business Case Earned Value Management" (BCEVM) metrics that we have developed, analogous to those for "Earned Value Management" (EVM) in project management, to provide more robust progress measures.

We believe that these metrics have significant potential to align management behaviours with the interests of the firm and its shareholders - but to align behaviours we have to pay as much attention to change management and culture as to the metrics themselves.

2. How Firms Make Investment Decisions

In making product investment decisions, firms must take account of a wide range of stakeholders and different types of value. These values could be tangible (financial value added) or intangible (e.g. strategic fit), but in general the presumption is that they should drive investment decisions that underpin the long term health of the firm and deliver an increase in shareholder value.

In a situation where capital investment is limited and portfolio investment decisions are required, intangible factors may be used to rank priorities between financially comparable investment opportunities, but the cornerstone of the investment decision remains a DCF analysis of the financial added value.

This classical approach to investment decision making, well described in reference 1, is not without its detractors. In reference 2 (see "Thing 2") we find an argument that "Companies should *not* be run in the interests of shareholders".

For our purpose we simply observe that, whether for good or ill, companies in our sectors *do* use DCF analysis systematically for investment decisions, that we have become much better at reducing risk in business cases and development activities, but that the DCF "cornerstone" may not be as robust as people assume and can be improved significantly.

Generating a discounted cash flow that is built on solid data and assumptions is not trivial. Initially one has to consider the following simple questions:

- How many products we are likely to sell?
- What is the cost of the product development and qualification?
- What is the pricing structure?
- What capital investment is required?
- What is a realistic margin?

Although the questions are simple, the analysis is highly complex as pricing structures, margins and market projections are going to change depending on the strategy and approach the firm takes, so typically the firm will produce several investment scenarios, which are underpinned by a common financial model.

Other perspectives that should be considered when formulating a business case include:

- Industrial Strategy including on shore/off shore manufacturing
- Make / Team / Buy
- Route to market

Decisions have to be made on all of these perspectives, and the impact of these decisions on the DCF should be understood. By understanding and modelling the impact on the DCF the firm can trade between options in the decision space to find the optimal business model. At its most advanced, Non Linear Programing and Multi Criteria Decision Analysis can be used to find optimum outcomes from constrained solution spaces.

The business case is the place where all the assumptions and decisions in the business plan converge to formulate the overall financial view that management uses when deciding whether to invest or not. To aid the understanding of complex business models, most firms define a standard template for the financial summary of the business case. This template makes sure we get to a series of true net cash flows, reversing out any non-cash accounting treatments (e.g. profit, depreciation or amortisation).

The cash flow line is then discounted to take into account the "Weighted Average Cost of Capital" (WACC) and the risks captured in the business plan, leading to the generation of the NPV and/or IRR for the potential investment.

From a financial perspective one should also consider the impact of the following on the DCF and look to optimise them within the constraints of the accounting entity:

- **Working Capital:** A measure of both a company's efficiency and its short-term financial health. Working Capital = Current Assets - Current Liabilities
- **Capex (Capital Expenditure):** Funds used by a company to acquire or upgrade physical assets, with the annual budget often constrained by management policy to be no greater than depreciation
- **Tax:** Tax should be applied according to local regulation
- **Inflation:** Inflation should be treated consistently across the portfolio to allow investments to be compared

It is also important to consider free cash flow (FCF) when looking at large investments; FCF is a measure of financial performance calculated as operating cash flow minus capital expenditures. Free cash flow (FCF) represents the cash that a company is able to generate after investing money to maintain or expand its product portfolio. FCF is important when making investment decisions at the portfolio level because it allows a company to pursue product developments that enhance shareholder value. Without cash, it's tough to develop new products, make acquisitions, pay dividends (of particular interest to shareholders) and reduce debt

However, net cash (total cash minus total liabilities) should also be considered. Net cash is commonly used in evaluating a company's cash flow and should be managed carefully in any business case. More generally, net cash can refer to the amount of cash remaining after a transaction has been completed and all charges and deductions related to the transaction have been subtracted.

With regard to the order intake and revenue profile of the business case, the firm should endeavour to understand the inherent risk in the profile and reflect this in the discount rate. For example, in companies that have a very lumpy order intake pipe the firm might decide to carry out probabilistic modelling using Monte Carlo approaches to understand the most likely order intake scenario. Equally, the firm should be able to use historic analysis of past sales in a comparable market to further de-risk and understand the order intake to revenue profiling.

The implications of all this analysis are distilled down into a single (or small number if sensitivity analysis is required) set of forecast net cash values over time.

Two fictitious examples (no real projects were harmed in writing this paper) are given overleaf in Tables 1 & 2 and Figures 1 & 2.

Table 1. Discounted Cash Flow Example – Good Investment

Investment Appraisal at a Discount rate of 10%					
Year	0	1	2	3	4
Net Cash	-£100.00	-£ 50.00	£ 50.00	£100.00	£150.00
Discount Factor	*1.0000*	*0.9091*	*0.8264*	*0.7513*	*0.6830*
DCF	-£100.00	-£ 45.45	£ 41.32	£ 75.13	£102.45
Cumulative DCF	-£100.00	-£145.45	-£104.13	-£ 29.00	**£ 73.45**

INTERNAL RATE OF RETURN	**26%**
NET PRESENT VALUE	**£ 73.45**

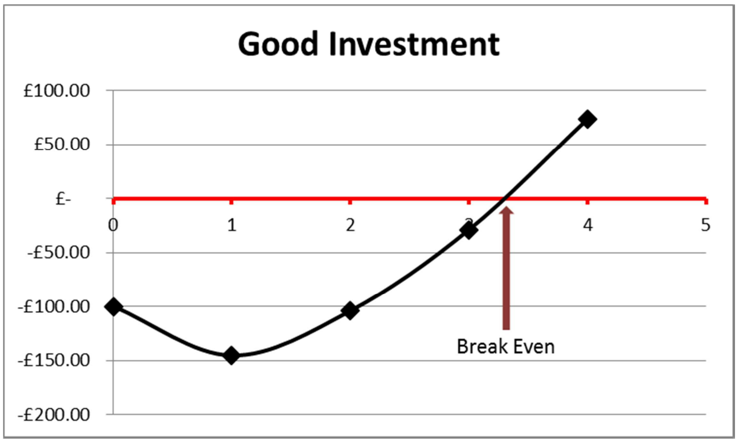


Figure 1. Cumulative DCF Curve – Good Investment

Table 2. Discounted Cash Flow Example – Bad Investment

Investment Appraisal at a Discount rate of 10%					
Year	0	1	2	3	4
Net Cash	-£100.00	-£ 50.00	-£ 50.00	£ 75.00	£150.00
Discount Factor	*1.0000*	*0.9091*	*0.8264*	*0.7513*	*0.6830*
DCF	-£100.00	-£ 45.45	-£ 41.32	£ 56.35	£102.45
Cumulative DCF	-£100.00	-£145.45	-£186.78	-£130.43	**-£ 27.98**

INTERNAL RATE OF RETURN	**4%**
NET PRESENT VALUE	**-£ 27.98**

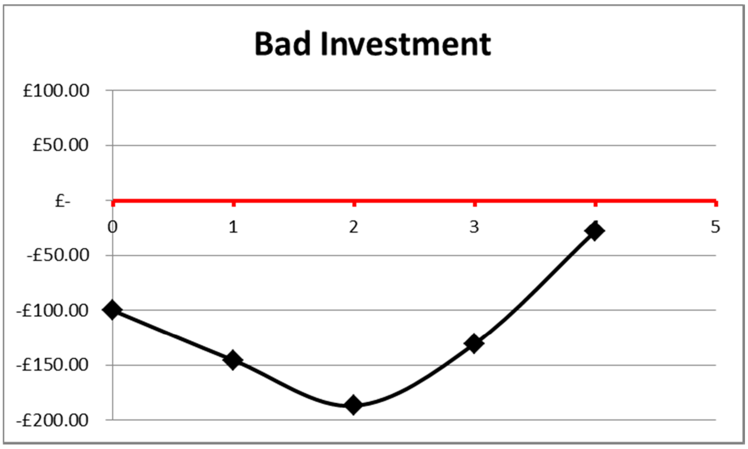


Figure 2. Cumulative DCF Curve – Bad Investment

In principle (assuming of course that we are not subject to any rationing of capital) we would invest in the first case. We would ***not*** chose to invest in the second case, because the IRR is below our hurdle rate, and the NPV is negative (in other words, committing to this project would be expected to reduce the value of the firm).

As well as calculating the NPV and/or IRR, we can calculate some other useful metrics.

For example, in Figure 1 we show the "break even" time – in other words, how long is it until the cumulative discounted cash flow becomes positive. At this point, the project can be declared to have been a success, to have "paid back", at least in terms of increasing the value of the firm.

In itself, the break even or payback time does not tell us whether one investment is better than another, but generally a firm will prefer shorter payback times. We could argue that this preference is really expressing a perception about risk, which might be better handled by adjusting the discount rate. But in any event, a change in the payback time during execution of the project tells us something about progress, even if it does not translate directly into a measure of financial merit.

3. Deficiencies of Classic Metrics

Having dealt with the initial decision to invest, let us now consider how we evaluate the progress of the investment project over time.

Of course this will involve periodic reviews of the market assumptions, technical progress in development, estimated manufacturing costs etc and again we have very well developed tools and processes for this.

For this discussion, we want to focus simply on the quality of the net cash flows and ask whether we are on target to create the financial value predicted by the business case. For this we need simple ways to compare the values of two different sets of cash flows.

Deliberately using the language of project management, let us call the cash flows in the business case the ***baseline***.

At a review point some time later, an ***update*** is provided to the cash flows. Those cash flows occurring in the past are now known (historic), whilst those in the future represent an updated forecast, based on the latest information.

At the review point, we want to answer two questions:

a) **is the investment project on track?** (*If not, we want to be alerted, so that we can take corrective action!)*
b) **is it worth continuing?** (*Things might not be going to plan, but continuing might still be the best answer*.)

Let us revisit the examples in Tables 1 and 2, but assuming that the first was our "baseline" – the approved business case upon which we chose to invest - and that the second is the view with hindsight at the end of year 1.

Table 3. Progress At End Of Year 1

	History		Future			*discount*	10%
Year	**0**	**1**	**2**	**3**	**4**	**NPV**	**IRR**
Baseline Net Cash	-£ 100	-£ 50	£ 50	£ 100	£ 150	**£ 73.45**	**26%**
Updated Net Cash	-£ 100	-£ 50	-£ 50	£ 75	£ 150	**-£ 27.98**	**4%**
	observed		*forecast*				

We can see that the project is now forecast to perform so badly that, if we had known what we know now, we would not have chosen to invest. But this does not necessarily mean that we should stop the project.

An important principle of investment decisions is that we should ignore "sunk costs" – we can't get them back so they are not discretionary and should be ignored. So the decision to continue depends only on the future cash flows, as shown in Table 4 below:

Table 4. Investment Decision to Stop or Continue

	History		Future			discount	10%
Year	0	1	2	3	4	NPV	IRR
Baseline Net Cash	£ -	£ -	£ 50	£ 100	£ 150	£ 218.91	∞
Updated Net Cash	£ -	£ -	-£ 50	£ 75	£ 150	£ 117.48	164%
	sunk costs		forecast				

Of course, the fact that history has not gone according to plan may cause us to question the accuracy of the forecast going forward. But if we take a purely financial perspective, it is an extremely good investment decision to continue.

The recalculated NPV and IRR figures are not good measures of ***progress***. For example, if the project manager reports that the NPV of the project has improved to £117, from £73 at kick off, this would be highly misleading. (We have kept the recalculation in Year 0 money – if recalculated as a true new NPV the result is even more flattering). The residual IRR increases dramatically – an IRR that is only comparable to the original, after sunk costs are removed, implies a disaster. Once a project is through the investment phase, the residual value should improve dramatically.

As a consequence, it is probable that any development programme, once authorised and with significant sunk investment, will continue even if there have been substantial negative deviations from the original business case.

This has the potential to feed a vicious cycle, where a business case is used simply to get through an investment decision gate and then can be safely ignored, because once the investment has been largely sunk, it will always be better to continue than to stop.

This lack of effective accountability increases the risk that the business case is not an accurate estimate and therefore that, over time, less value will be created than expected.

The obvious approach to measuring a deviation from plan would be to compare the NPV or IRR for the full stream of cash flows, as shown in Table 3.

But there are some subtleties to the behaviour of IRR that are not well understood by the management community.

For example, consider tables 5 and 6 below:

Table 5. IRR with Cash Flows Delayed by 1 Year

	History		Future			discount	10%
Year	0	1	2	3	4	NPV	IRR
Baseline Net Cash	-£ 100	£ 100	£ 100	£ -	£ -	£ 73.55	62%
Updated Net Cash	£ -	-£ 100	£ 100	£ 100	£ -	£ 66.87	62%
	observed		forecast				

Table 6. IRR with Cash Flows Scaled by 50%

	History		Future			*discount*	10%
Year	**0**	**1**	**2**	**3**	**4**	**NPV**	**IRR**
Baseline Net Cash	-£ 100	£ 100	£ 100	£ -	£ -	**£ 73.55**	**62%**
Updated Net Cash	-£ 50	£ 50	£ 50	£ -	£ -	**£ 36.78**	**62%**
	observed		*forecast*				

In these examples, we see that the IRR is unchanged, despite significant changes in the cash flows.

NPV is better behaved as a progress metric, but is particularly vulnerable to gaming (or being more charitable, unfounded optimism). For example, the following cash flows have the same NPV (at a discount rate of ~15%):

Table 7. Same NPV from Different Cash Flows

	History		Future			*discount*	14.965%
Year	**0**	**1**	**2**	**3**	**4**	**NPV**	**IRR**
Baseline Net Cash	-£ 100	£ 100	£ 100	£ -	£ -	**£ 62.64**	**62%**
Updated Net Cash	-£ 170	£ 50	£ 250	£ -	£ -	**£ 62.64**	**37%**
	observed		*forecast*				

If we are reviewing this at the end of year 1, the history is very poor, but dramatically increased revenues in the future will save the day. Of course, this could be realistic, but we would like a metric that at least alerted us to the fact that we had deviated from the baseline.

So NPV and IRR ***must*** be regarded as "investment decision metrics" – they confirm that the expected returns are above the cost of capital – not as metrics to measure progress.

Their deficiencies as progress metrics are intrinsic in the way they are defined.

Let the cash flows (measured at equal time intervals and including the initial investment) be:

$C_0,\ C_1, \dots \dots \dots \dots C_N$

Let the discount rate (weighted average cost of capital or similar) be r.

Then the Net Present Value is:

$$NPV = \sum_{i=0}^{N} \frac{1}{(1+r)^i} C_i$$

To avoid potential confusion for those trying this at home, note that if we denote the EXCEL function for NPV as NPV_E then:

$$NPV = \ C_0 + NPV_E(r,\ C_1 : C_N)$$

The IRR, call it q, is the solution to the equation

$$0 = \sum_{i=0}^{N} \frac{1}{(1+q)^i} C_i$$

For any scaling factor λ:

$$0 = \lambda \sum_{i=0}^{N} \frac{1}{(1+q)^i} C_i = \sum_{i=0}^{N} \frac{1}{(1+q)^i} (\lambda C_i)$$

i.e. the IRR is insensitive to a rescaling of the cash flows. The scaling factor could even be negative, so a loss making project with a negative NPV can still have a positive IRR above the hurdle rate.

If we set $\lambda = \frac{1}{(1+q)^k}$ then

$$0 = \sum_{i=0}^{N} \frac{1}{(1+q)^{i+k}} C_i$$

which is identical to the IRR calculation if we delay all our cash flows by k intervals.

So in IRR we have a metric which is insensitive to changes in the scale of the cash flows and insensitive to time shifts in the cash flows. For these reasons, we argue that it is not a good metric for measuring progress.

A further (well known) criticism of IRR is evident from the above equation. We see that q is the solution to an Nth order polynomial which, in general, has N roots. So the IRR calculation can return multiple values, making the comparison with a hurdle rate rather problematic.

Even more disconcerting is the situation where there are no real solutions for the IRR. This might not upset accountants, but it does upset engineers. Of course, the accountants might argue that it is the engineer's cash flow forecasts that are entirely imaginary!

Some admittedly unrealistic illustrations are given in Table 8. However for projects such as nuclear build, run and decommission, with significant cash outflows at the beginning and end of the programme, these problems with IRR can materialise.

Table 8. Illustration of Deficiencies of IRR

Year 0	Year 1	Year 2	IRR	NPV (10%)
£100	**-£300**	**£221**	**30% OR 70%**	**£10**
-£100	**£300**	**-£221**	**30% OR 70%**	**-£10**
£100	**-£260**	**£178**	**0.3(1+i) OR 0.3(1-i)**	**£11**
-£100	**£260**	**-£178**	**0.3(1+i) OR 0.3(1-i)**	**-£11**

In defence of IRR, it does give a sense of proportionality of the return relative to the investment, but this also means that IRRs are not additive and cannot be summed directly across a portfolio.

NPVs can be summed across a portfolio, but don't give you a sense of proportionality – we would probably want to treat a project with an NPV of £1M generated from an investment of £1Bn differently to one generating £1M from a £10M investment.

Note that NPV does change with scale or delay and is a direct measure (£) of the forecast "value added", but as we have shown, if the forecast for future years is inflated, the increased risk in the phasing of the project is not evident. For this reason, we would like to complement it with a metric that is more sensitive to the phasing of the cash flows.

4. "Business Case Earned Value Management" Metrics

Faced with these deficiencies in IRR and NPV, we wanted to find simple metrics, that needed no more data than NPV or IRR for their calculation, but that would be more sensitive to shifts in the scale and timing of the cash flows. We also wanted these metrics to measure something that, as with NPV, could easily be interpreted in value (£) terms. By calculating the metrics in value (£) terms it also allows portfolio managers or general management to add up investments to measure performance at the portfolio level.

This leads us to want to convert phasing (e.g. this project is a year late) to value (e.g. being a year late is costing us £X in value). Note that whilst our earlier examples simply shifted cash flows in time, this was purely to illustrate the mathematics. In the real world, a delay could reduce market share significantly and therefore the future cash flows would need to be re-forecasted.

For inspiration in designing our metrics we looked at the well-established "Earned Value Measurement" (EVM) metrics used in project management (see reference 3 for a description of EVM):

- Cost Performance Indicator (CPI) - how much value has been earned so far, relative to the actual costs incurred to date?
- Schedule Performance Indicator (SPI) - how much value have we earned so far, compared to the value that we planned to have at this point in time?

We started with a simple geometric approach to plotting progress.

Assume that we are reviewing the progress of a project, defined over N time intervals, at some time t where:

$0 \leq t \leq N$

Then we can define an "Historic Value" (HV) as

$$HV = \sum_{i=0}^{t} \frac{1}{(1+r)^i} C_i$$

and a "Future Value" (FV) as

$$FV = \sum_{i=t+1}^{N} \frac{1}{(1+r)^i} C_i$$

Of course, just as with project EVM, this "historic value" is not necessarily realisable. If a cake is half baked, it doesn't mean that you can sell it for half the value of a fully baked cake!

But if we look at the time it has taken to get to the point of being half baked compared to the baseline plan, and the costs of the ingredients, labour and fuel to get to half baked compared with the plan, we have genuinely useful objective measures of progress.

It is evident that $NPV = HV + FV$, and therefore a plot of FV versus HV is a straight line at -45° to the axes, crossing the axes at $FV = NPV$ (project about to start t<0) and $HV = NPV$ (project complete).

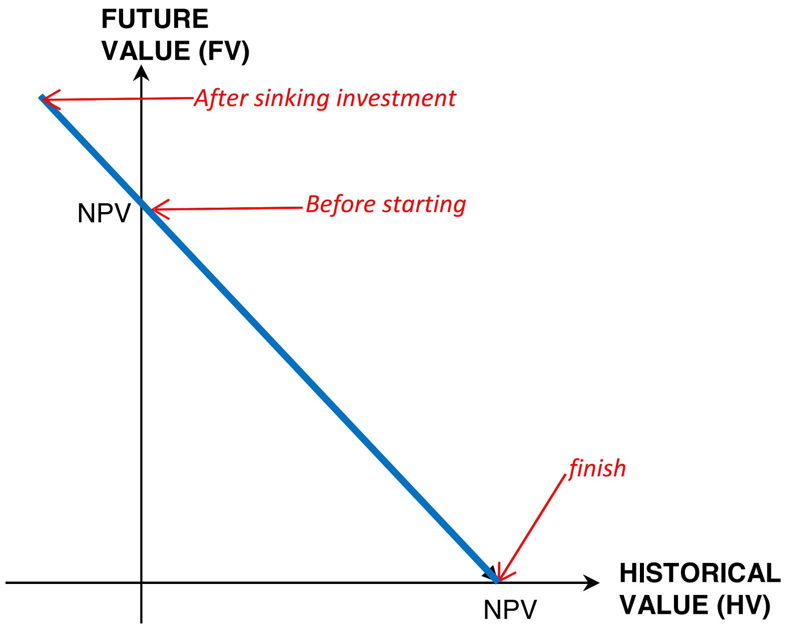


Figure 3. Cumulative DCF Value Line

Consider a point on the line corresponding to a baseline profile, and the equivalent point for the updated profile:

$[HV_b, FV_b]$ for the baseline
$[HV_u, FV_u]$ for the update

Then a measure of the distance between the points is:
$\Delta x = HV_u - HV_b$
$\Delta y = FV_u - FV_b$
$D = \sqrt{\Delta x^2 + \Delta y^2}$

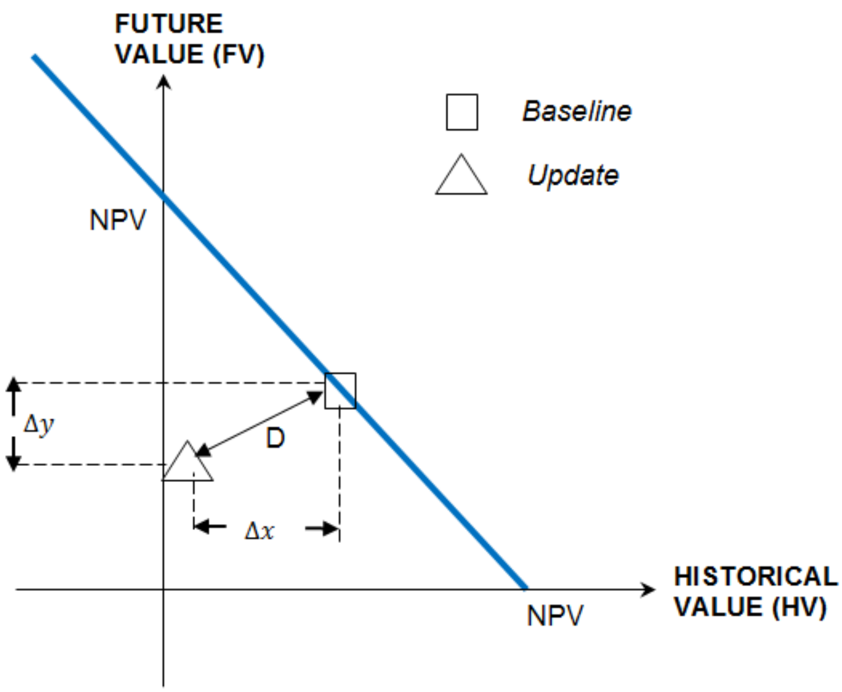


Figure 4. Deviation from Baseline Value Line

In line with EVM, we want to extract a "cost like" metric (representing the value of the business case) and a "schedule like" metric, showing the lead or lag in progress at the review point. Δx and Δy cross couple these two effects, so we need to identify a suitable coordinate transformation.

Considering the plot again:

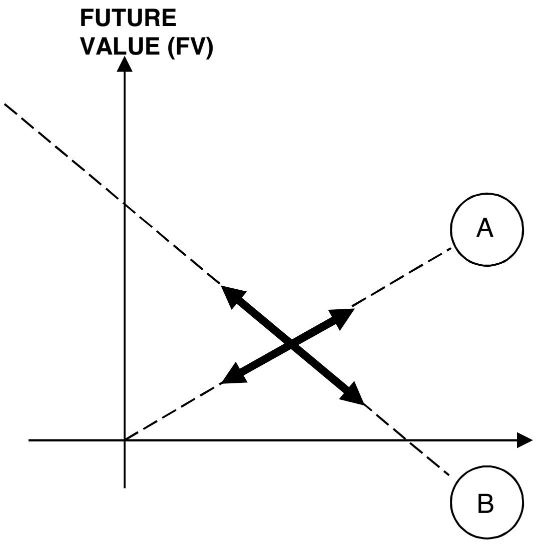


Figure 5. Earned Value Axes

We see that we would like our schedule metric to be invariant along axis A (if we scale the same cash profile up and down, the total value changes, but the lead/lag should be zero). We also want our value metric to be invariant along axis B (if we delay our programme but inflate back to a constant NPV, the total value change should be zero).

This means that the measurement axes are non-orthogonal, but we can transform them to an orthogonal basis by a suitable affine transformation to get:

$$\Delta \mathrm{a} = \Delta \mathrm{x} + \Delta \mathrm{y} = \Delta \mathrm{NPV}$$

and

$$\Delta \mathrm{b} = \frac{1}{\sqrt{\mathrm{FV}_\mathrm{b}^2 + \mathrm{HV}_\mathrm{b}^2}} \left(\mathrm{FV}_\mathrm{b}\, \Delta \mathrm{x} - \mathrm{HV}_\mathrm{b}\, \Delta \mathrm{y}\right)$$

Finally, we recognise that during the investment phase, the project moves up the value line, before turning and heading "downhill" towards the end point. In order to keep the signs of Δa and Δb consistent, we simply reflect points moving upward in the end of the value line.

To be precise, if t_{mn} is the time at which the most negative cumulative DCF occurs, and V_{mn} is the historic value at that time, then any point with $t < t_{mn}$ is mapped as follows (the baseline and update are treated in identical fashion):

$$[HV\ ,\ FV] \rightarrow [2V_{mn} - HV\ ,\ 2(NPV - V_{mn}) - FV\ ]$$

This gives us a very simple geometric representation of progress, where the distance between an update point and a "baseline" point gives a measure of progress, and the distance between the points is effectively measured directly in financial value (£) gained or lost. (For more complex cash flows, an alternative value function can be defined as required. A key part of project EVM is to define the value metrics at the point of baselining.)

As these metrics are in units of value, they can be aggregated at a portfolio level (e.g. a development centre or business unit), to measure the performance of a defined area of the business if required.

The "reflection point", corresponding to the point of most negative cumulative DCF, adds a time based metric that usefully complements the breakeven/payback time (Figure 6).

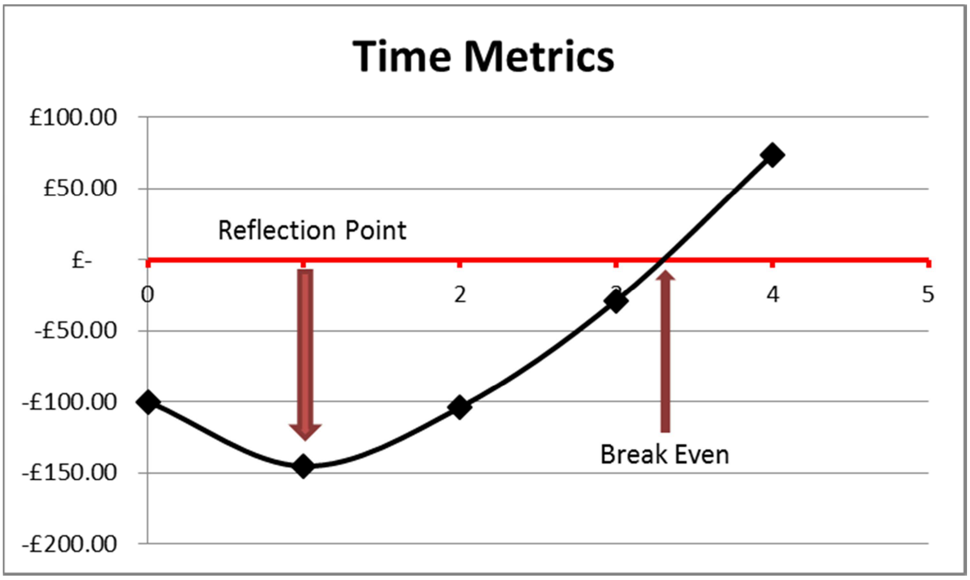


Figure 6. Time Metrics and Reflection Point

Being late to market because of product delays will impact future sales. This effect must be included in re-estimates of the future cash flows to quantify the impact, but a change of X months in the forecast reflection point or breakeven point is a useful indicator.

For businesses such as Fast Moving Consumer Goods (FMCG), where time to market is critical and discounted cash flow less important, additional time based metrics such as those in Reference 4 may be useful.

For dashboard reports on investment projects, it is also desirable to normalise the values Δa and Δb in a similar way to the EVM metrics SPI and CPI.

Defining a "Total Value Performance Indicator" (TVPI), intended to behave like CPI, and a "Value Conversion Performance Indicator" (VCPI), intended to behave like SPI, we get:

$$\mathrm{TVPI} = 1 + \frac{\Delta \mathrm{a}}{\mathrm{NPV}_{\mathrm{baseline}}}$$

$$\mathrm{VCPI} = 1 + \frac{\Delta \mathrm{b}}{\mathrm{NPV}_{\mathrm{baseline}}}$$

These dashboard metrics can be interpreted as follows:

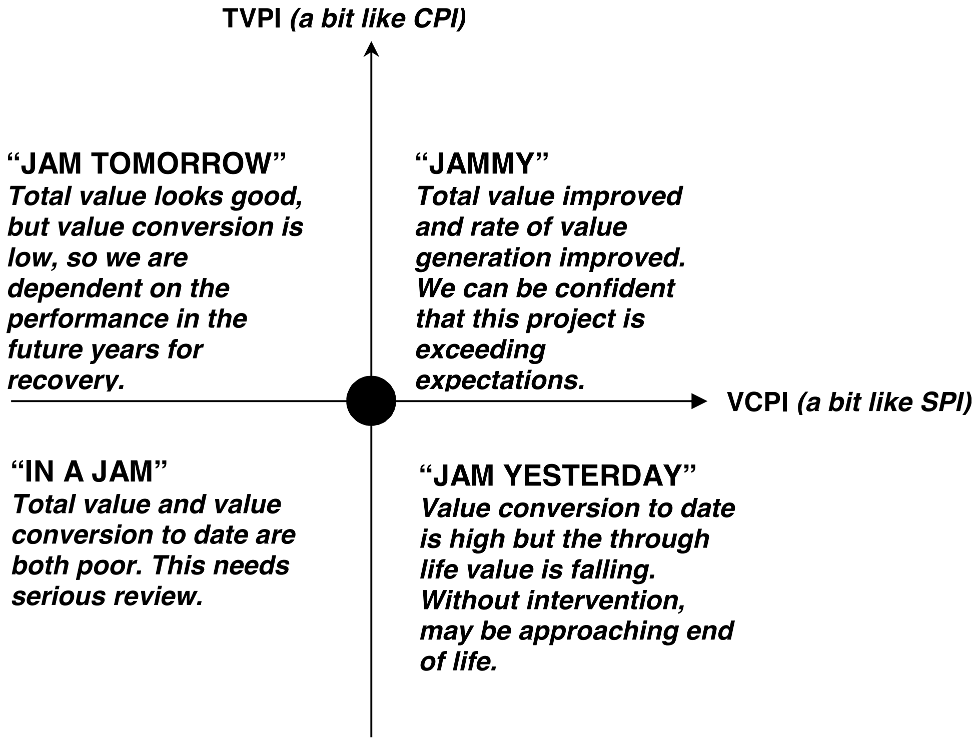


Figure 7. Interpreting BCEVM Metrics

The point at the centre (TVPI=1, VCPI=1) represents a project which is exactly on target.

An illustration of this approach is shown at Figure 8 overleaf.

In order to demonstrate the robustness of the metrics, Figure 9 shows the case of a project where the updated IRR and NPV are unchanged from the baseline, but there is a material change to the profile of the project.

Finally, Figures 10 and 11 demonstrate the equivalence in scaling of the Total Value and Value Conversion axes.

The history of both cash flows is the same, so Figures 10 and 11 represent two alternative futures.

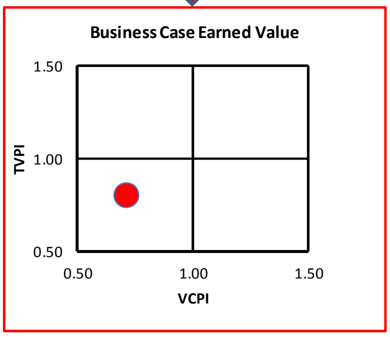
Figure 10 shows a project which aims to hold the original value (NPV) despite delays, so TVPI = 1 and VCPI is reduced, showing the delay in realising the original value.

Figure 11 by contrast assumes that there will be no future cash flows and therefore the investment project is complete. By definition, a project which is complete will have VCPI = 1 (just as SPI=1 in classical EVM), but TVPI now reflects the loss of value.

So depending on the assumptions for future cash flows, the values of TVPI and VCPI will change, but the scale of the deviation from the baseline is still evident and consistent.

This illustrates the equivalence in scaling but also the robustness of this pair of metrics to attempts to game the future cash flows.

		Year 0	1	2	3	4	5	6	7	8	9	10	NPV
Discount Rate	10%												
Baseline Net Cash Flow		-£ 150	£ 80	£ 185	£ 210	£ 210	£ 210	£ 210	£ 210	£ 210	£ 210	£ -	£ 921
Update at end of year	4	-£ 100	-£ 150	£ 80	£ 185	£ 210	£ 210	£ 210	£ 210	£ 210	£ 210	£ 210	£ 737
		H	H	H	H	H	F	F	F	F	F	F	



	Δa	TVPI
Total Value	-£ 184 →	0.80
	Δb	**VCPI**
Value Conversion	-£ 264 →	0.71

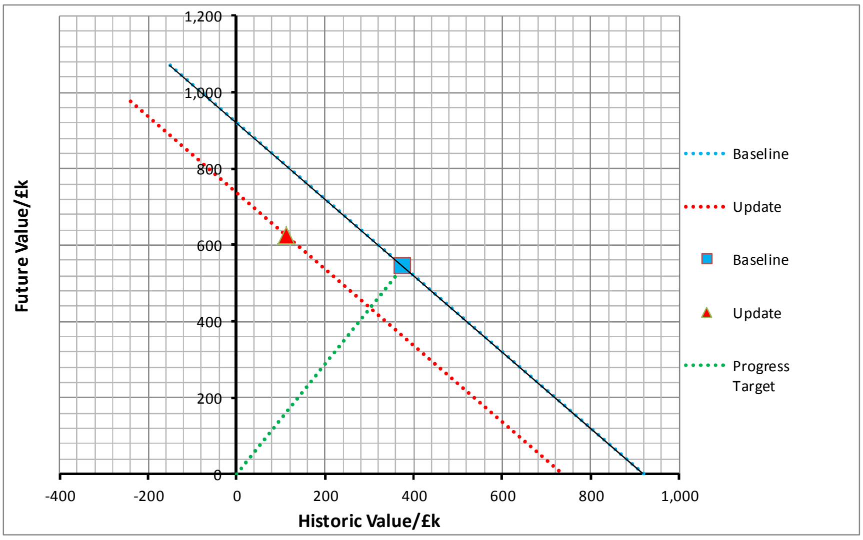
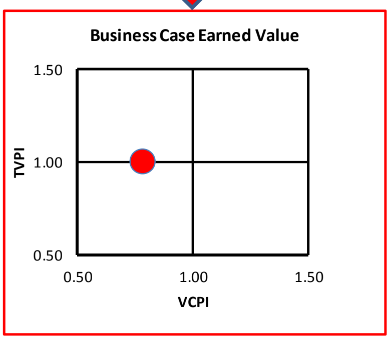


Figure 8 Update with Lower Total Value and Slower Rate of Progress

		Year 0	1	2	3	4	5	6	7	8	9	10	NPV
Discount Rate	10%												
Baseline Net Cash Flow		-£ 150	£ 80	£ 185	£ 210	£ 210	£ 210	£ 210	£ 210	£ 210	£ 210	£ -	£ 921
Update at end of year	4	£ -	-£ 165	£ 88	£ 204	£ 231	£ 231	£ 231	£ 231	£ 231	£ 231	£ 231	£ 921
		H	H	H	H	H	F	F	F	F	F	F	



	Δa	TVPI
Total Value	£ 0 →	1.00
	Δb	**VCPI**
Value Conversion	-£ 199 →	0.78

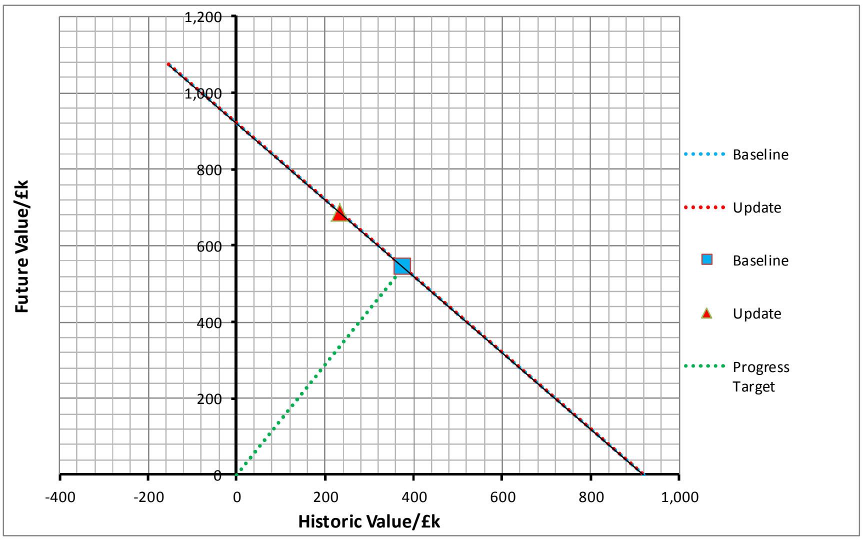


Figure 9 Update with Same NPV and IRR but Slower Rate of Progress

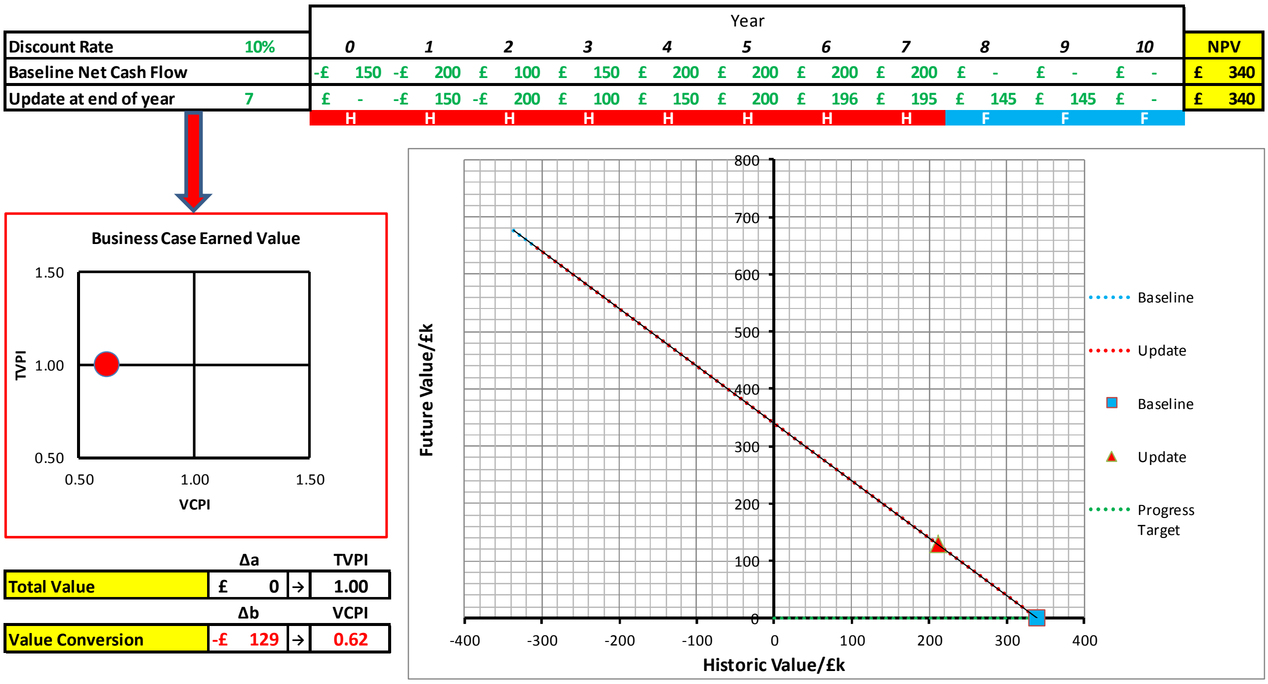


Figure 10 Project Extended To Restore Total Value

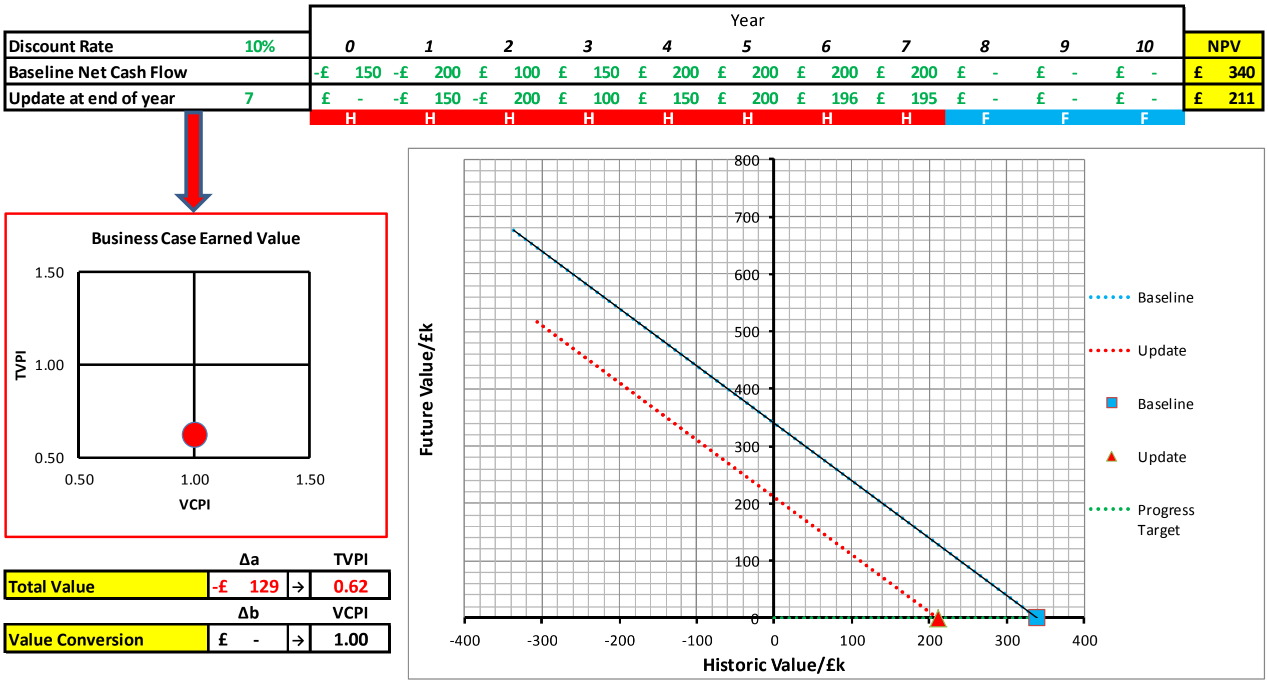


Figure 11 Completed Project With Reduced Total Value

5. Implementation Challenges

The preceding discussion may seem complicated, but this does not mean that using the approach is complicated!
It is straightforward to code an EXCEL VBA function (or an SQL function) that can produce a metric set such as Table 9 below from a single function call.

Table 9 BCEVM Metric Set (from a single Excel VBA Array Function)

BCEVM 1.0c	HV	FV	NPV	Most Neg Val	Most Neg Month	Break Even Month
Baseline	£ 141	£ 779	£ 921	-£ 150	11	30
Update	-£ 112	£ 849	£ 737	-£ 236	23	50

Metrics	VCPI	TVPI
Value Increase	**-£ 262**	**-£ 184**
Normalised to NPV	**0.72**	**0.80**

IRR	
94%	Baseline
51%	Update

In other words, if you have the cash flow information that would allow you to calculate NPV and/or IRR using those standard functions, there is no implementation overhead in using BCEVM for progress reviews at the level of the individual project.

However, if the prevailing culture in a business unit does not require such progress reviews, then having a better way of doing what you don't do anyway has little impact! In these cases we have had to treat the challenge of BCEVM deployment as a change management programme with all that implies (see reference 5 for example).

The Product Line Management community plays a vital role in developing our next generation of products and Thales has investigated heavily in developing our Product Line Managers and supporting them with best practice guides and training in how to develop robust business cases. We have also invested heavily in Integrated Business Planning (IBP) and Product Policy tools and processes that include R&D project reviews and product competitiveness reviews.

In developing the BCEVM approach, we deliberately chose to emphasise the analogy with project EVM, as EVM is familiar due to its use in managing the engineering development on all complex R&D development projects. It is also a mandatory approach on any government funded projects. So by using the BCEVM approach we aim to influence the project team through progress measures that seem tangible and familiar, rather than the intangible or abstract (from their perspective) notion of shareholder value creation.

One of our most surprising findings in starting to implement BCEVM was that in many cases the R&D development community did not have the financial tools to associate sales activities and profits with particular products. This meant that business cases were built on assumptions of product sales and margins that would never actually be measured! Based on discussions with other firms, we believe that this "open loop" approach to business cases may be surprisingly prevalent.

Over the past few years, Thales has worked on improving its enterprise tooling, especially Sales Planning, Integrated Business Planning (IBP) and Enterprise Resource Planning (ERP) tooling, in order to automate the capture of the "top line" part of the business case, as well as the "bottom line" product development performance.

This will allow us to capture good actual and forecast data from multiple communities (Sales / Engineering / Supply Chain…) and to ensure that this data aligns with the same boundaries as the business case. In particular, it helps to align the business cases with the management and accounting centres that that exist within the firm, so that we can get a Profit & Loss (P&L) perspective as well as an investment appraisal perspective.

Unifying the perspectives of the different functional communities around a single version of "ground truth" performance not only closes the feedback loop to the baseline business case, but has a positive effect on management cohesion and commitment.

6. Conclusions

In an ideal world, management behaviours and decisions would be aligned to shareholder interests and the wider interests of the firm and we would have robust quantitative metrics to measure R&D investment performance in situations with high uncertainty.

Based on our observations across our industrial sectors and peer group companies, the reality is very different.

We found that NPV and IRR were not well understood by the business managers and project managers responsible for investment decisions and for the delivery of R&D projects.

We discovered that NPV and IRR, whilst generally appropriate for financial investment appraisal decisions, have significant deficiencies when used to measure the progress of an R&D project against a baseline business case. In particular, the behaviour of IRR for projects with delays or reductions in the scale of the cash flows is far from intuitive.

This means that other management objectives may dominate management decisions. For example, if there is an annual budget for profit, or competition for resources from a funded program, there is an incentive not to invest. In order to meet this short term objective, management may choose to delay an R&D investment, even though the business case is sound and their decision destroys financial value.

Using BCEVM metrics makes the consequences of such decisions clearer, for example "yes we can save £100k this year, but that will destroy £300k of value".

BCEVM also closes the loop with the original business case, measuring deviations from the baseline plan, thus driving more rigour and accountability into the preparation of the business case and the associated investment decision. With this increased rigour and robust monitoring, management confidence in the outcomes of the investment will increase.

In an Earned Value Management approach we are free to define whatever form of value function we think is most suitable. In this paper we have derived one simple approach, where the BCEVM metrics use the same source data as for NPV and IRR, but are significantly more robust than IRR or NPV when used as progress metrics.

Successful implementation of a BCEVM framework requires it to be treated as a change project and for the necessary enterprise tools to be developed, so that metric calculations are automated and that the parameters which drive the business plan assumptions are actually observable during the execution of the project.

We believe that deployment of a BCEVM framework can improve the alignment of management behaviours to the interests of shareholders and the firm and will result in improved value generation from R&D activities.

References

1) Brealey,R A, Myers, S.C. and Allen, F. 2014. Principles of Corporate Finance. 11^{th} ed. McGraw-Hill Education.
2) Chang, Ha-Joon. 2011. 23 Things They Don't Tell You About Capitalism. Penguin.
3) APM Guidelines. 2008. Earned Value Management. Association for Project Management. Buckinghamshire, UK.
4) House. C. H. and Price.R. L. 1991. "The Return Map: Tracking Product Teams." Harvard Business Review January-February 1991: 92-101.
5) Kotter, J P. 2012. Leading Change. Harvard Business Review Press.