TOWARDS QUANTIFICATION OF ASSET MANAGEMENT OPTIMALITY

Ype Wijnia[1,2]

Abstract Asset Management as a field of science is relatively new, starting only in the late 60s/early 70s as terotechnology. In its existence it developed from tools and concepts to improve profitability towards a more holistic and integral management system orientation, formalized by ISO55k. Asset management is highly quantitative, in systematically comparing cost, performance and risk of decision options to find the best balance. Yet, no absolute measure exists for determining asset optimality. It is also hard to find any quantification at all justifying the implementation of asset management or even certification. This seems a strange omission. In this paper, it is demonstrated that for assets some form of absolute optimality can be defined. This asset optimality can be expanded to express the optimality of the asset portfolio, and thus the optimality of the asset management system, though barriers exist to do so, like subjective value judgments, uncertainties in the assumptions and complexity of the portfolio. Neither of these barriers however seems fatal to the applicability of the concept on asset management systems. Suggestions for further research include a more precise specification of optimality and research with regard to the applicability on diverse types of assets. This could be beneficial in the debate on the value of asset management.

1 Introduction

Asset management as a separate field of interest is relatively new, given that in 2010 it was still regarded as emerging (Amadi-Echendu et al., 2010). Asset management started as terotechnology in the 1960s, with the first reference to physical

[1] Y.C Wijnia (✉)
AssetResolutions B.V. PO box 30113, 8003CC Zwolle The Netherlands
e-mail: ype.wijnia@assetresolutions.nl

[2]
Delft University of Technology, Faculty of Technology, Policy and Management, The Netherlands
email: y.c.wijnia@tudelft.nl

asset management only made in the 1970s (White, 1975). Terotechnology has a strong focus on increasing industrial profitability (Thackara, 1975), building on disciplines as Reliability and Maintainability and the field of Maintenance Management. This focus was furthered in developments in the North Sea oil industry in the 1980s, which resulted in ageing assets being kept in operation and thus reducing capital requirement(Tombs and Whyte, 1998). Furthermore, a new approach with regard to safety by means of a mandatory safety case (IAM, 2002), introduced risk thinking into asset management (Woodhouse, 2014). More or less in parallel the concept of asset management was picked up in Australia/New Zealand in the 1980s and extended to cover infrastructures assets as well (Burns, 2010). This resulted in several efforts to standardize asset management , like the International Infrastructure Management Manual(NAMS, 2000). A similar development occurred in the UK in the 1990s. To facilitate sharing of knowledge across sectors , the Institute of Asset Management (IAM) developed in collaboration with the British Standards Institution (BSI) a formal specification of the requirements for asset management (BSI, 2004). After an update (BSI, 2008), the specification was furthered into an international standard in 2014, the ISO55000 series (ISO, 2014). Asset management thus developed from a set of tools and concepts to improve profitability into a more holistic and integral management system concerning the whole organisation.

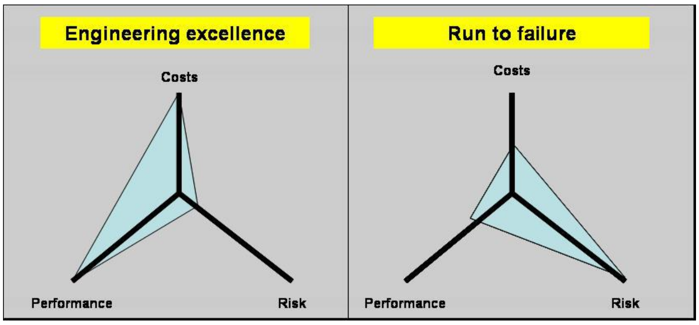

Figure 1: Extremes in the cost/risk/performance balance, adapted from Yorkshire Electricity (Wijnia 2007)

At the heart of asset management is systematically working towards the optimal mix of costs, risk and performance. Optimization in this context is relative improvement and generally not the best against some absolute number. The diagram above gives two extremes that are often used to indicate the range of options the asset manager has. In asset management decisions, cost risk and performance are generally quantified or even fully monetized(Wijnia et al., 2006). This allows measures to be judged on value for money and thus optimization of the portfolio of measures within constraints(Wijnia and Warners, 2006). Without quantification the impressive results of asset management in the past years are hardly imaginable

(Woodhouse, 2014). Yet, in thinking about asset management as a whole (the asset management system and the asset portfolio) any quantification is rare. There is no quantified rationale for any of the requirements in the standards. Putting it more extreme, it is not even known for certain that certified organisations (against any management system standard) outperform the uncertified organisations (Hodkiewicz, 2015). Given that the whole of asset management is in its core highly quantitative, this seems a very strange omission. But the lack of a definition of asset optimality itself is an omission as well. In this paper, we develop a concept for absolute quantification of the optimality of individual assets. This will be followed by a review of the potential barriers for the application to of this concept for a whole system. The paper ends with recommendations for research to further these initial thoughts.

2 Quantifying asset optimality

Optimality, as a theoretical concept, is very straightforward. It is the best that is possible. Depending on the direction of the value, optimal is synonym with either maximal or minimal. Optimal costs are minimal costs, optimal profit is maximal profit. An optimal asset has no need for maintenance, is 100% reliable, has no losses, does not pose any risks and has infinite life. The cost of the asset then only is the opportunity cost of the capital employed on the asset, whereas the benefit is the production of the asset running at maximum capacity 24/7. In reality, no such asset exist[3]. There will always be some additional costs, failure probability, limited life, losses and so on. Yet, the theoretical concept of an optimal asset provides a good benchmark for assessing the optimality of an actual asset. Consider for example an asset that is in full operation to produce some good or service. This may be a pump in a continuously operated plant, or a transformer in a power grid. The asset is critical to the production process, in the sense that if it fails the process will halt. The availability of the asset is binary, it works or it does not. Failures result in direct production losses and damages, but may also cause losses elsewhere in the production chain or impact safety, the environment or other values (external effects). The condition of the asset deteriorates over time, which increases the failure rate. Planned stops for maintenance are cheaper and shorter than unplanned stops for repairing failures and do not cause external effects. It is assumed both maintenance and repairs reset the condition of the asset to its original value, i.e. the strategy does not impact asset life.

[3] Even though some assets may come very close. Think about cables in an electricity distribution system: no maintenance, very low failure probability, very low losses, very little safety risk, very long life.

Several maintenance strategies can be identified for this asset. The base strategy to be considered is run to failure, one of the extremes of figure 1. This strategy has costs because of the needed repairs, production losses because of (unplanned) downtime and external effects because of the failures. The time between failures depends on the asset condition and the occurrence of random factors and has some variation. If a little bit of preventive maintenance would be applied, some of the faults would be prevented. Because planned actions are cheaper and take less time than unplanned actions, costs go down and availability and thus production goes up. Furthermore, the external effects would decrease. The improvement with regard to costs continues until the reduction of the failure costs precisely offsets the increase of preventive costs. This is the lowest achievable cost for the considered form of maintenance. But this is not necessarily the best achievable performance. If the ratio of unplanned to planned performance loss (i.e. value of unplanned downtime plus external effects versus value of planned downtime) is larger than that of unplanned versus planned costs, increasing the amount of maintenance still would improve performance. The improvement of performance continues until the reduction of unplanned performance loss precisely equals the increase in planned performance loss. This is the best achievable performance, in other words engineering excellence. If the maintenance effort would be increased even further, the total performance would decrease again. In the extreme case, there would not be any unplanned performance loss, because the asset would be permanently offline for maintenance. In general, maintaining beyond engineering excellence would be considered over maintaining, though it depends on the value that is attached to uncertainty. The trajectory from *run-to-failure* to *over-maintaining* is shown in figure 2.

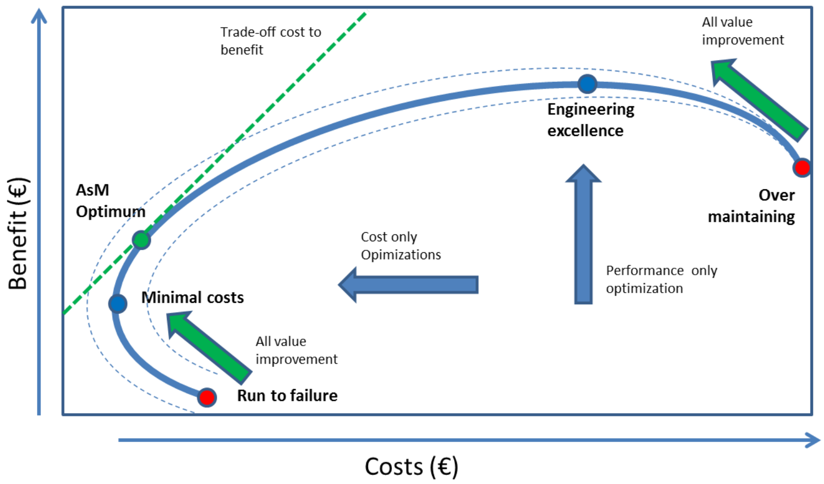

Figure 2: The cost benefit diagram for maintenance strategies

The cost axis comprises all direct costs for the asset, like capital, maintenance, repairs and running costs. The benefits axis comprises the economic value of the production, minus damages and losses elsewhere in the production chain (financial risk) and the equivalent value of other effects like safety incidents (non-financial risk). The dashed lines around the trajectory indicate the uncertainty of the trajectory. The more attention is given, the less the uncertainty is in cost and benefit. In the diagram, options for optimization are also indicated. Cost only optimizations would move the strategy towards the minimal costs extreme, and performance only optimizations towards the engineering excellence extreme. If any of these optimizations would be started from either *run-to-failure* or *over-maintaining*, the first part would be an all value improvement, indicated by the green arrows. But neither of the optimizations would stop at the true optimum of this trajectory. That would be the point where the increase of benefits would be equal to the increase of costs, in other words the point where the trajectory runs in parallel with the trade-off line between costs and benefits. This is indicated by the dashed green line in the diagram. The green point is the asset management optimum, though it has to be recognized that given uncertainties in failure consequences and their probability it is more a range of good maintenance intervals than a single best one.

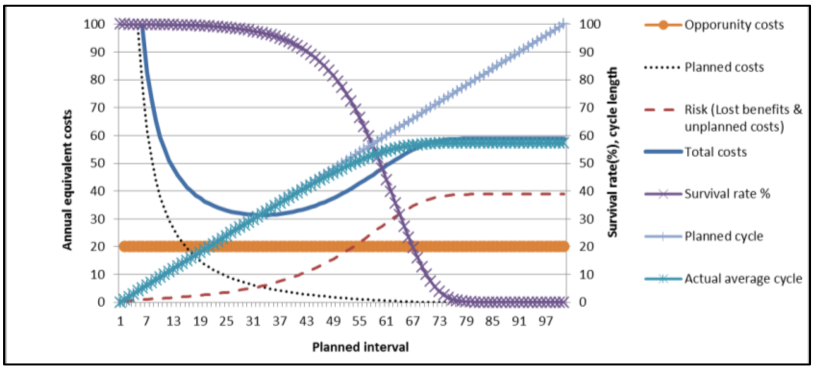

Figure 3: Total cost of ownership for various maintenance intervals

When instead of the production value the value of the lost production (production at 100% availability minus actual production) is considered, the diagram can be plotted a total cost of ownership (TCO) optimization. This is demonstrated in figure 3. The trajectory now is represented by the x-axis, with *over-maintaining* at the origin and *run-to-failure* at the right hand side. The optimum is where the total costs are minimal, again reached when the increase of planned costs is equal to the decrease in risk. For optimal assets (100% availability, infinite life, no maintenance cost and no risk), the opportunity cost of the employed capital (interest * investment) is the lowest possible TCO. This means that it is possible to define optimality in an absolute sense: the opportunity cost divided by the total costs of ownership (both to be expressed in annual equivalent terms). In the example above this would mean an opportunity cost of 20 divided by a TCO of 30, resulting in 66% optimality.

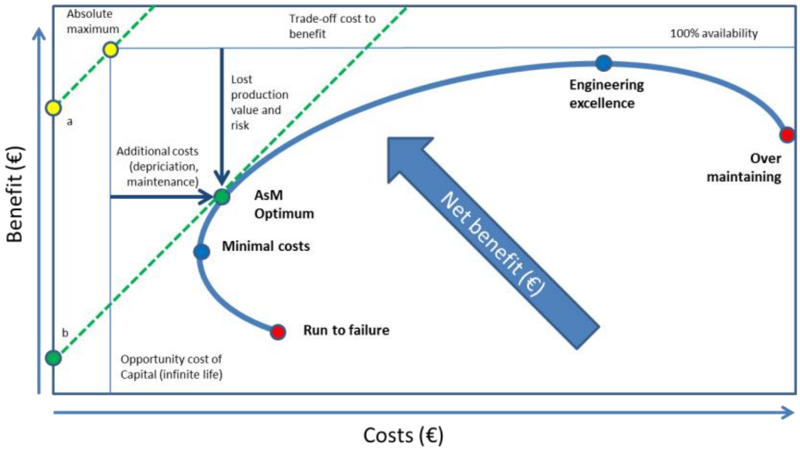

Figure 4: constructing the absolute optimality. Points a and b indicate the net benefit

This absolute optimality can also be constructed in the cost benefit diagram, as shown in figure 4. By following the trade-off line through the absolute maximum, the intersection with the y-axis gives the theoretical net benefit, *point a* (value of full production minus the opportunity costs). For any point in the diagram (i.e. combination of costs and benefits), the intersection of trade-off line through that point and the y-axis gives the realized net benefit. This is the optimal net benefit minus production losses and risk, and minus additional costs like depreciation and maintenance. The absolute optimality is the ratio between the realized net benefit and the theoretical net benefit. In the diagram the line through the AsM optimum is drawn, to construct the realized net benefit of the optimal maintenance interval, *point b*. The maximal net benefit is equivalent to minimal TCO, though the ratio between minimal and actual costs in general is not the same as the ratio between the net benefits.

3 Barriers to quantifying system optimality and their relevance

It has to be recognized that being able to quantify optimality of an asset does not immediately mean the system optimality can be quantified the same way. Two main barriers exist to do so. First of all, it requires a consistent monetization scheme for risk, otherwise the value of two risks is not necessary equal to the sum of their individual values. In many individual cases (so called normal risks, judged on their expected value) acceptable monetization factors can be found, even though aspects like safety, the environment and reputation are notoriously hard to monetize. But for some assets, like nuclear power plants, these cannot be applied, as the risks for those assets often are judged on potential effect (e.g. number of fatalities) without considering probability. This results in a variable value per expected unit of misery. If a portfolio considers such non-normal assets, system optimality cannot be determined. However, even in mixed portfolio's the optimality of the normal part may be of interest. This therefore is not a fatal problem for determining system optimality.

The second problem can be found in system complexity. If several assets are interlinked, it may be very difficult to capture all consequences of failing assets. This is especially true in redundant systems, where normally any asset may fail without consequences, but catastrophes may occur if several assets fail at the same time. Whether this is a problem depends on the difficulties in predicting the behaviour of the system as a whole from the behaviour of the elements of the system and their interactions, assuming these are understood reasonably well. Outcomes of the (often large and complex) optimization model then are very difficult (if possible at all) to validate (Morgan and Henrion, 1992) and the acceptance of the optimum then depends more on the "belief" that the model is right than on factual evidence. But for systems consisting of relatively independent assets this is not relevant and system optimality can be a useful concept.

4 Concluding remarks

Optimizations of assets are highly quantitative, weighing costs against performance and risk. Yet, for asset management systems optimization is highly qualitative. One of the problems behind this is that asset optimality is not yet expressed as an absolute number, which would be needed to "add" the optimality of several assets. In this paper it was demonstrated that such an absolute quantification is possible. Several barriers exist for translating asset optimality into system optimality, but the first impression is that the barriers are not fatal for the concept, even though system optimality will not have meaning for all systems. Further research first of all will have to identify the conditions under which optimality can be determined for individual assets. Our guess is that it should be possible for assets with only normal associated risks, but other limitations may apply. Secondly, the conditions and limitations for adding asset optimality into system optimality need to be established. Consistency of valuation and independence of assets are at least relevant. In parallel, research is needed on the precise formulation of optimality and the rules for adding asset optimality into system optimality. If such a concept of system optimality including the rules for its employement could be developed it would be very beneficial in discussing the value of asset management.

References

Amadi-Echendu, J. E., Willett, R., Brown, K., Hope, T., Lee, J., Mathew, J., Vyas, N. & Yang, B.-S. 2010. What Is Engineering Asset Management? *In:* Amadi-Echendu, J. E., Brown, K., Willett, R. & Mathew, J. (eds.) *Definitions, Concepts and Scope of Engineering Asset Management.* Springer London.

BSI 2004. PAS55-1 Asset Management. *Part 1: Specification of the optimal management of physical infrastructure assets.* London.

BSI 2008. PAS 55-1:2008 Asset Management. *Part 1: Specification for the optimised management of physical assets.*

Burns, P. 2010. *The History Project* [Online]. Available: https://www.amqi.com/index.php/historyproject [Accessed june 24 2011].

Hodkiewicz, M. R. 2015. The Development of ISO 55000 Series Standards. *In:* Tse, P. W., Mathew, J., Wong, K., Lam, R. & Ko, C. N. (eds.) *Engineering Asset Management - Systems, Professional Practices and Certification.* Springer International Publishing.

IAM 2002. *International Infrastructure Managament Manual*, UK Institute of Asset Management.

ISO 2014. ISO 55001 *Asset Management-Management systems-requirements.* Geneva.

Morgan, M. G. & Henrion, M. 1992. *Uncertainty- A guide todealing with uncertainty in Quantitative Risk and Policy Analysis,* Cambridge (UK), Cambridge University Press.

NAMS 2000. *International Infrastructure Managament Manual*, NAMS.

Thackara, A. D. 1975. Terotechnology - What it is all about. *Chart Mech Eng,* 22**,** 88-90.

Tombs, S. & Whyte, D. 1998. Capital Fights Back: risk, regulation and profit in the UK offshore oil industry. *Studies in political economy,* 57**,** 73-101.

White, E. N. 1975. Terotechnology (Physical asset management). *Mining Technology,* 57**,** 5.

Wijnia, Y. C., Korn, M. S., de Jager, S. Y. & Herder, P. M. Long Term optimization of asset replacement in energy infrastructures. 2006 IEEE Conference on Systems, Man, and Cybernetics, 2006 Taipei, Taiwan.

Wijnia, Y. C. & Warners, J. P. 2006. Prioritizing investment. The value of portfolio decisions in electricity infrastructure management. *29th IAEE Annual International Energy Conference 2006: 'Securing Energy in Insecure Times'.* Potsdam.

Woodhouse, J. 2014. Asset Management is Growing up. Tutorial at the 9th WCEAM, Pretoria.