Strength in numbers

Mathematical models can consistently and objectively identify the investments that will provide the best results for the company – but there's always room for improvement, says **Robert Kuik**.

TenneT TSO B.V. owns and operates the high voltage and extra high voltage electricity grid in The Netherlands: about 7,000 kilometres (km) of overhead lines, over 10,000km of underground cables and about 300 substations, with voltage levels ranging from 110 kilovolts (kV) to 380kV.

The company's main objective is to ensure the continuity of electricity supply 24 hours a day, 365 days a year. To fulfil this obligation, properly balancing maintenance and expansion activities is of the utmost importance. At the same time, TenneT is bound by a regulatory regime that keeps a close watch on the efficiency and effectiveness of all cost-related activities. The increasingly onerous conditions for financing these activities requires reliable and predictable cash-out figures.

Investment strategy

For these reasons, TenneT has for several years now operated using a risk-based investment strategy based on balancing certain asset management business drivers: risk, performance and cost.

To optimise the company's investment portfolio against these business drivers, each proposed investment project is scored in terms of its added value and its risk of deferral, across so-called performance indicators that relate to TenneT's strategic business values. Each of these business values comprises one or more performance indicators: for example, the business value Quality of Supply comprises the indicators Customer Minutes Lost, Energy Not Served, and Asset Health Index.

Added value is assessed in terms of the benefit that would result if the project were funded. The risk of deferral is assessed in terms of what could potentially happen if the project were deferred for one year, or until the next budget request cycle. A reduction in risk as a result of executing an investment project is captured as added value, while an increase in risk as a result of delaying such a project is captured as a risk of deferral.

In this way, two scores (a value score and a risk-of-deferral score) are generated for each performance indicator and for each proposed investment project. On an annual basis, all investment projects are sequentially analysed in terms of their added value (performance), risk of deferral (risk) and cost. Based on the results, some projects are selected for the annual investment plan, while others are deferred for one or more years.

Current optimisation methodology

TenneT currently optimises its investments by quantifying the impact of each proposed project on its business values. Formulas, tables and weighting factors associated with each performance indicator are used to objectively calculate added value and risk of deferral for each investment project. Both added value and risk of deferral are effectively assessed using three questions:

- What is the situation before the investment project is executed?
- What will be the situation after the investment project is executed?
- What happens when the investment project is deferred?

> **"Today's investment plans need to be weighed against their impact on risk, performance and cost."**

The risk of deferral is determined by the answer to the third question, while the added value is determined by the differences between the situation before and after the investment.

From single year to multiyear optimisation

TenneT's current methods are best suited to single-year optimisation: that is, to identify the investments from the total project portfolio that should be executed in a particular year. Multiyear analysis, by contrast, will allow the company to determine the optimal selection of projects over a longer time span.

For projects with a run time of several years, a multiyear optimisation technique provides several advantages, among them:

- less chance of projects being split
- a result based on multiyear instead of single-year effects on risk, performance and cost
- the potential to shift investments both back and forth in time.

A kind of multiyear analysis can be achieved by performing consecutive single-year optimisation runs, one for each year within the desired time span – but this approach can lead to projects being split. For example, a project with a run time of three years might end up being selected for investment in the first year, deferred in the second, and selected again in the third and fourth years. This undesirable phenomenon can be prevented by performing a single optimisation run that considers the complete multiyear time span.

Adding, replacing or modifying components within the electricity infrastructure carries long-term consequences as the lifetimes of components might run up to 50 years or even more. So decisions about whether to execute capacity expansions and replacement programmes need to be challenged on their long-term effectiveness and efficiency. Today's investment plans need to be weighed against their impact on the future risk, performance and cost profile.

Finally, the multiyear optimisation technique allows projects to be shifted over the complete multiyear time span, instead of calculating to invest or to defer a project on a yearly basis.

The mathematics of multiyear optimisation

Behind the scenes of TenneT's investment-optimisation process is a complex mathematical methodology, which can be expressed as a linear programming (LP) problem. Modelling the decision-making process as an LP problem allows the company to solve it by maximising added value or minimising risk, taking into account certain constraints on, for example, yearly cash flows, resources, project exclusivities or dependencies, and then applying a standard set of algorithms.

In the single-year optimisation model, each project is assigned a single variable which, when the model is run, shows whether that project should be selected for investment that year or deferred until the next year. The key difference with TenneT's new multiyear optimisation model is that each project is instead assigned a multivariable. The model takes into account the optimisation time span and the time needed to complete each project, and the multivariable shows in which year each project needs to start to achieve the best long-term result in terms of risk and performance.

Though it takes longer to reach a solution using the multiyear model, the outcome is worth it, as the example overleaf shows.

First published in *Assets*, the magazine for Members of the IAM. May 2013

Head to head

This example scenario uses a hypothetical portfolio containing ten investment projects, all with different time spans, costs and added values (see Table 1). Some of the projects are single-year (like Project 4), while others are multiyear (like Project 1). The added value column represents the score resulting from the assessment of the benefits of each project against the performance indicators specified in the business value framework.

For this example, let's assume a budget constraint of €30 million for each year.

Table 2 shows the result of optimising this portfolio using consecutive single-year analysis. This five-year portfolio would generate 78 percent of the total available added value at a cost of €146 million. Project 6 is deferred for the entire five-year optimisation period, while Projects 1, 2 and 5 are split (that is, paused for a year at some point after starting).

Table 3 shows the result of optimising the same project portfolio using multiyear analysis. This five-year portfolio would generate 87 percent of the total available added value at a cost of €143 million – so more value is achieved with less money spent, which is one of the major anticipated advantages of the multiyear method.All the projects now start in a different year. Project 5, and not Project 6, is deferred for the entire period. More importantly, not one project is split. This is another of the anticipated advantages.

The results of the new multiyear method look promising in this and a number of other example scenarios TenneT has run. In all cases, the multiyear method achieves better results in terms of either higher value or lower costs. Moreover, the scenarios have shown that only the single-year method results in projects being split.

TenneT is continuing to investigate the potential of multiyear optimisation modelling, especially regarding larger project portfolios and real-life scenarios.

Table 1: Investment projects in example portfolio

Project	Cost (millions of Euros)						Added value
	Year 1	Year 2	Year 3	Year 4	Year 5	Total	
Project 1	5	25	25			55	**2.0**
Project 2	1	8	7			16	**1.0**
Project 3	5	5				10	**0.1**
Project 4	12					12	**3.0**
Project 5	20	25				45	**1.0**
Project 6	7	13	12	5		37	**2.0**
Project 7	8	15	15	1		39	**5.0**
Project 8	5	10				15	**2.0**
Project 9	6					6	**4.0**
Project 10	3					3	**1.0**

To find out about TenneT's mathematical optimisation methodologies and solving methods in more detail, visit Assets Online: www.theIAM.org/magazine

Authors' biographies

Dr Robert Kuik has over ten years' experience in asset management and risk management within the energy sector. Currently he is Senior Risk Manager with TenneT's Asset Management Department, responsible for drafting, implementing and executing an investment strategy based on balancing risk, performance and cost.

Dr Ir Jok Tang has several years' experience in mathematical modelling and solving various practical problems. He is currently a mathematical consultant at the Dutch engineering and scientific software firm VORtech, responsible for consultancy projects for various clients, including TenneT TSO and UMS Group.

Drs Coen Boschker has four years of consulting experience serving electric and gas utility markets. As a UMS Group consultant with a background in IT, his main focus is on the implementation and development of IT tools supporting risk and portfolio management at European utility companies, including TenneT.

Table 2: Optimum five-year investment portfolio according to consecutive single year analysis

Project	Length (years)	Expenditure (millions of Euros)				
		Year 1	Year 2	Year 3	Year 4	Year 5
Project 1	3			5		25
Project 2	3	1	8		7	
Project 3	2					5
Project 4	1	12				
Project 5	2				20	
Project 6	4					
Project 7	4	8	15	15	1	
Project 8	2		5	10		
Project 9	1	6				
Project 10	1	3				
Total expenditure:		**30**	**28**	**30**	**28**	**30**

Key: Project selected / Project not selected / Project split

Table 3: Optimum five-year investment portfolio according to multiyear analysis

Project	Length (years)	Expenditure (millions of Euros)				
		Year 1	Year 2	Year 3	Year 4	Year 5
Project 1	3					5
Project 2	3			1	8	7
Project 3	2				5	5
Project 4	1	12				
Project 5	2					
Project 6	4	7	13	12	5	
Project 7	4	8	15	15	1	
Project 8	2				5	10
Project 9	1				6	
Project 10	1					3
Total expenditure		**27**	**28**	**28**	**30**	**30**

Key: Project selected / Project not selected