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Development of an asset management strategy for a network utility company: Lessons from a dynamic business simulation approach

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Due to market deregulation, network utility companies are forced to transform their asset management to provide better-than-required service quality and maximize financial performance. The author uses a dynamic business simulation (DBS)—a modeling and simulation approach based on system dynamics—to support development of asset management strategies at a couple of network utility companies. The author describes the background and design steps of the DBS approach and evaluates its effectiveness in supporting development of the asset management strategy for one network utility company in the Netherlands, as well as its capacity to become a part of that company's business capabilities.

KEYWORDS: *asset management; business simulation; deregulation; electricity industry; investment policy; network utility; participatory modeling; POWERSIM; simulation design; system dynamics*

The electricity and gas markets in Europe are rapidly changing due to sweeping deregulation efforts (Newbery, 2002; Wenzler, 2003). In the United Kingdom and Germany, gas and electricity markets are already fully open, with domestic consumers free to choose from among competing suppliers. Deregulation is also imminent in a number of other European markets, such as Italy and Spain. The Netherlands fully opened its electricity and gas markets for small-scale consumers (households) in July of 2004 (European Union, 1996, 1998).

Deregulation is not only changing the underlying market structure and the dynamics between different market players but also forcing changes in how professionals and the public think about and approach the utility industry in general. For competition to be able to take place, the commercial trade (supply) in electricity needs to be legally separated from the monopolistic transport and distribution (network) function. These networks have to be accessible in a nondiscriminatory way to all potential suppliers. In addition, some of the large energy conglomerates need to divest some of their operations to reduce their market power. For generation, trading, and retail utility companies to be able to continue to thrive while meeting the needs of regulators, they must transform their organizations and build or improve their business capabilities, including

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trading, marketing, customer relationship management, service management, and data management.

This is true not only for these supply-oriented utility companies but for transportation and distribution (network) utility companies as well. Their first responsibility is to build and maintain networks that deliver electricity, gas, or water to our doorsteps, and their core activity is to keep their assets healthy and operational. Government is increasing the requirements on safety, reliability of supply, and accessibility to energy and related services. Consumers are increasingly more critical about price and service levels, whereas shareholders are increasingly focusing on shareholder value. On the other side, continuous requirements by the regulator for the reduction of transportation tariffs place pressure on the operational expenditures (OPEXs) and capital expenditures (CAPEXs). In addition, there is a growing uncertainty within network utility companies about the right moment for replacing their old assets.

Driven by these changes, one of the domains within network utility companies that requires significant transformation is *asset management* (Burton, 2004; Sklar, 2004). Asset management is a capability required to identify, design, construct, operate, and maintain physical assets of a network utility company, such as the wires, transformers, and pipes. The essence of this capability is obtaining and using the knowledge needed to optimize trade-offs among financial performance, operational performance, and exposure to safety-related risks. Different network investments or maintenance decisions will have different impacts on the level of operational performance. Their cost structure is different, and they are likely to result in different levels of exposure to safety risks. The purpose of asset management is to generate optimal and sustainable financial returns and at the same time ensure that the predetermined levels of safety and customer service are met.

Because of this need to balance financial, operational, and safety aspects, the management of network companies is facing different questions than in the past. The main question is not “Which network design will provide the best service quality?” but instead, “Which network design will provide better-than-required service quality while maximizing financial performance?” Providing the answer to this question was also one of the key challenges facing our client, a large network utility company in the Netherlands. But providing the answer only once is not enough. Due to rapid changes in the technologies used to build and maintain networks, and continuously changing regulation, this question has to be addressed repeatedly and under different assumptions and policy options. The ability to do so required from this particular network utility company the building of a new business capability within its asset management organization—a dynamic business simulation (DBS). This is an approach based on system dynamics principles and used for development of quantitative business models, which in turn can help an organization to test their policy options in a more rigorous way.

The purpose of this article is to demonstrate the effectiveness of the dynamic business modeling approach in helping a network utility company improve its asset management capability. In this article, I first introduce the challenges that network utility companies (in general) are facing in relation to their asset-related operations, as well as the characteristics of a successful asset management capability. I then outline the asset management related problems and questions that our client was facing, describe the reasons why the client opted for a DBS approach, and present one of the simulation models that were developed using this approach. I also describe the simulation development process, the structure of the model, the ways in which the simulation was used, and the results and value it delivered to the client organization. I finish with a number of lessons learned during the development and implementation of the simulation.

The challenges of asset management

Because of deregulation and opening of the markets to competition, the pressure is growing for utility companies to operate more efficiently. To accomplish this, these companies have to (both operationally and financially) use their assets as cost effectively as possible. Even the very modest improvements of a few percent can deliver significant results, considering that the network utility sector's asset base runs into billions. For instance, with an annual OPEX of Euro 100m and CAPEX of Euro 80m within a midsized network company, achieving approximately 5% improvement can mean up to Euro 10m of savings annually.

For network utilities, keeping assets healthy and operational is a core activity. Besides security of supply, there is a significant financial case for managing the assets effectively and efficiently. Although energy trading and customer relationship management have been seen as more interesting and exciting areas of utilities business, it is the networks where the profits are actually made. In general, 80% of profits for utilities (electricity, gas, and water) are generated from the core network business (Geoghegan, 2002). This makes asset management one of the key tools that can create shareholder value. For asset management to live up to these expectations, it has to first overcome a number of challenges. The four key challenges are (a) alignment of strategy and operations with stakeholder values and objectives; (b) balancing of reliability, safety, and financial considerations; (c) benefiting from performance-based rates; and (d) living with the output-based penalty regime:

(a) *Alignment of strategy and operations with stakeholder values and objectives:* The biggest challenge facing network utility companies is the alignment of their asset management strategy and operations with stakeholder values and objectives (Accenture, 2003). Shareholders are primarily interested in profitability, cash flow, capital use, and growth. Regulators and consumers are interested in cost efficiency, customer service, and safety, whereas network utility companies are primarily interested in network performance and life-cycle management. Achieving this alignment requires new asset management capabilities as well as a significant shift in the mindsets of people involved. This also means that all infrastructure-related data, analysis, and decisions need to be subject to a single set of stakeholder-driven value criteria.

(b) *Balancing of reliability, safety, and financial considerations:* Minimizing CAPEXs and maintenance expenditures, while providing safe and highly reliable transmission and distribution service, requires an effective, information-based asset management capability (Brown, 2004; Cozzens, 2003). It means being able to make balanced asset-related decisions based on the insights into the dynamic relationship between customer service, regulatory, financial, safety, and operating criteria (Humphrey, 2003).

(c) *Benefiting from performance-based rates:* With the movement toward energy transport tariffs that will be based on asset performance and away from cost-plus regulation, there will be a shift in influences different stakeholders have at the moment. Shareholder returns will become a much more prominent decision factor, resulting in a paradigm shift in the way network utility companies evaluate their investment decisions.

(d) *Living with the output-based penalty regime:* Before deregulation, regulators were implementing incentive schemes that rewarded the focus on controllable OPEXs and cash cost reduction. The new output-based penalty regimes, such as the ones being introduced by the regulator in the United Kingdom, allow regulators to fine companies up to 10% of their revenues for frequent interruptions in supply of energy (Office of Gas and Electricity Markets, 2003).

To overcome these challenges, network utility companies are building new capabilities with regard to the following three key issues: (a) balance between technique, commerce, and operations; (b) commercial focus; and (c) information quality (Accenture, 2003; Wayland, 2004):

(a) *Maintaining an effective balance between technical, commercial, and operational issues:* In most network utility companies different parts of their organizations are responsible for these issues, which sometimes results in conflicting demands. These demands should be managed in such a way that informed and balanced outcomes can be ensured.

(b) *Development of a commercial focus:* Faced with changing commercial realities, successful companies are introducing commercial criteria and analysis in most decision-making processes. They use analytical models, scenario-based planning, and dynamic decision support tools to help them integrate the planning of CAPEXs, OPEXs, resources, and outcomes.

(c) *Management of the information life cycle:* Information systems are very often seen as solutions to all problems a network utility company might have. Successful network companies view information technology as an enabler, and they make a serious effort in improving the information tools they need for supporting their key activities and business decisions. There is no decision quality without information quality.

The case of one network utility company in the Netherlands

The network utility company that serves as a case in this article is one of the largest energy companies in the Netherlands, with an integrated distribution strategy covering transmission, metering, billing, and supply of gas, electricity, and heat. It serves a total of more than 2 million business and residential customers, manages the dense network of mains and service connections, and looks after the energy transmission and distribution activities across that network.

Before the deregulation process in the Netherlands began, the asset management practice of this particular network utility company focused mostly on ensuring the quality of its service through technical excellence. Its management did not accept service interruptions, and all efforts were placed on prevention of these interruptions through creating sufficient redundancies in the network infrastructure and scheduled maintenance.

However, with the deregulation-driven separation of the company's network part from its retail and wholesale elements, another factor entered the equation of maintaining the quality of service (i.e., financial performance). Faced with this challenge, the newly created network utility company quickly created a vision for the future—improving financial performance through better infrastructure-related decisions. This new focus on financial performance has challenged asset managers to understand the causal relationships between decisions they make, financial performance, and supply- or safety-related risks.

For example, prior to deregulation, the key question asked by asset managers when considering an extension of the electricity distribution network was "What network design will provide the best service quality and reliability through sufficient network redundancy?" After deregulation, the new questions dealing with an identical situation are "What is the best network design that provides better-than-required service quality while maximizing my financial performance?" "What are the value levers that we can influence to achieve the financial performance targets and regulatory requirements, while minimizing financial and safety risks?" and "What infrastructure-related costs can be reduced without significant increase in risk?"

In addition to understanding the importance of financial performance, the management realized that there was a need for fundamental changes to the investment decision making. This was due to the regulatory risks of capital or revenue correction. Investment decisions would not only need to take into account the regulatory risk considerations (such as changes in transportation tariffs or penalty systems) but at the same time balance them with operational, financial, and technical considerations. Because these decisions would be subject to scrutiny by the regulator, the logic for the investment must be clear, transparent, and justifiable. The results of investment decisions would need to be clear as well, especially in terms of the value they deliver to the company.

Due to these changes, there was a capability gap between what is required to succeed in asset management and what was available at that time within the organization. The ability to understand true profitability of assets, the ability to understand the impact of investments on asset condition or performance, and the ability to understand the regulatory and financial outcomes of such investments were all constrained. This constraint resulted from the lack of a decision support framework (decision support system and people capable of using it) that could effectively integrate technical, financial, and regulatory aspects of asset management. Based on the perception of asset managers within this network utility organization, the key requirements for closing this capability gap were

- Insight into the dynamic relationships between asset management related decisions, clear and uniform decision rules, and comprehensive and pragmatic decision models;
- Information technology infrastructure that is capable of effectively and timely supporting the capture, analysis, and reporting of asset management information and knowledge; and

- An effective asset management organization, effective processes, and people with adequate business understanding and knowledge, capabilities, and motivation.

This capability gap could not have been closed with off-the-shelf work management programs, traditional asset accounting, or reliability-centered maintenance applications. Closing this gap required a unique solution not currently available in the marketplace—a solution that extracts data from multiple existing systems (asset registers, maintenance planning, geographic information system, network-load forecasting) and by selectively combining those data, creates new information for managing the life-cycle process of the company's assets. At Accenture, we call this solution asset management dynamic business simulation (AMDBS).

The initial application of AMDBS was to help asset management organizations make better decisions in their medium- to low-voltage network investments. Some of the questions we addressed were the following:

- Which factors influence the choice between different low-voltage network types (star network, ring network, grid network, or a hybrid network)?
- What are the key short-term and long-term impacts of these factors on overall costs and quality of service?
- What is the sensitivity of different performance indicators to changing external situations such as price, demand, or regulation?
- How can the overall net present value life-cycle cost for a low-voltage network be minimized?
- Is there one particular network layout type and redundancy level that is superior to others under all conditions?
- What is the impact on performance by focusing on proactive maintenance versus scheduled maintenance versus reactive maintenance?
- What is the impact of service interruption related fines (imposed by the regulator) on the financial performance of the organization?

AMDBS

DBS is a modeling approach that enables building of a formal representation of a dynamic behavior of a business system, where the behavior of the system is a direct result of casual relationships between different elements of the system (Wenzler, 2003). The effects of causal relationships are based on assumptions and decision rules, which are then formalized by using mathematical equations. This approach is based on system dynamics principles and originated at MIT (Forrester, 1968; Richardson, 1996; Sterman, 2000). Fundamental to system dynamics is the idea that all dynamic behavior is a consequence of the structure of the system, where the structure refers to how the elements of the system are put together.

Unlike the linear flow of spreadsheet models, system dynamics focuses on interrelationships rather than linear cause and effect and sees change as a process rather than a series of snapshots. It operates with feedback loops. The system is made up of these feedback structures, which reflect the actions of one factor on the other. This allows the user to model highly complex systems with relative ease. The modeling/simulation package we chose for our approach was POWERSIM (http://www.powersim.com), both for its modeling capabilities and its graphical interface capabilities (Accenture, 1998).

We have applied the same approach frequently in the past couple of years for other network utilities in Europe. One example was a U.K.-based company that was facing increasing regulatory requirements in addition to aging network assets. It needed to satisfy regulatory compliance, technical performance levels, and financial metrics by carefully choosing an investment strategy that provided the best results given their understanding of the future scenarios. A DBS approach was used to evaluate a series of investment options in various environmental conditions.

The client was facing a drastic change in regulatory requirements. It wanted to examine its operating strategy in a new set of regulations. In particular, it wanted to examine its asset management (CAPEX and OPEX) strategy. Working with the client, Accenture used a dynamic business modeling approach to evaluate the impact of new regulations, performance of new network strategies, and asset management strategies in compliance with the new regulations.

Following new legislation about polluting emissions, the client was facing replacement or modification of compressors (50 stations, 300 compressors) within 5 to 10 years, costing more than U.S.$1 billion. In addition, the market was about to be deregulated, making the best compressor replacement strategy complex. Working with the client, Accenture deployed a dynamic business modeling approach to evaluate a series of compressor replacement strategies, each examining various external factors and their financial impacts.

During the initial discussions with the network utility company about the desired approach to address the asset management challenges, some of the staff proved rather skeptical about the DBS approach. Much of the skepticism originated from the general resistance to adopting a new methodology. The need to add more rigor to the existing tools and methods in solving a new set of business challenges was not recognized and accepted. After a number of discussions and demonstrations of the application and results of DBS methodology at other utility companies, this skepticism was in large part replaced with the conviction that the dynamic business modeling and simulation tool was the right approach. Based on the client's perception, the reasons for this decision included the following.

Ability to capture the implicit understanding of the business. DBSs can provide the rigorous decision support environment in which business assumptions are clearly articulated and agreed on (Accenture, 1998). Usually, the asset management decisions were made using the "rules of thumb" approach or the "best estimate of an expert" approach. Effective models are built in such a way to incorporate this knowledge and provide a framework through which the stakeholders can agree with the key business dynamics. In that way, the model will ensure that the implicit understanding of the business is made explicit.

Ability to balance different stakeholder perspectives. Within asset management there is a need to align a number of (sometimes competing) stakeholder values and objectives by balancing reliability, safety, and financial considerations. DBSs are particularly useful in these situations, and they are often viewed as the only method of finding out an optimum solution for the business.

Ability to model complex systems. Asset management problems are highly complex and cannot be easily addressed using other decision support methods, such as data mining or online analytical processing tools. These tools are very appropriate when there is a need for analyzing large sets of data and discovering rules, trends, or drivers of outcome. They are much less appropriate when there is a need to run a large number of scenarios, perform sophisticated "what if" analyses, understand decision impacts, and make forward predictions (Accenture, 1998). The DBS approach can do this effectively.

Ability to experiment safely. DBSs are also highly cost-effective when compared to the alternative of experimenting on the actual business itself. Building a model of the system may seem an expensive investment of time and resources, but the costs can be very small in comparison to a field trial of a new business proposal. In the case of asset management decisions, field trials are nearly impossible without taking large financial risk.

Simulation development process

The process of developing and implementing the AMDBS at this particular network utility company had three phase, each designed to build on the results of the previous phase.

First phase. The project started with identifying the key value creating opportunities related to investment and maintenance decisions. This provided us with the focus for building an understanding of the business dynamics behind a selected set of decision types and components. The simulation design process followed our standard 10-step process (Accenture, 2000; Vennix, 1996):

Step 1: Define the problem (what are we trying to resolve?)
Step 2: Define the project (how are we going to organize ourselves?)
Step 3: Build conceptual model (what is in, what is out, and how is it structured?)
Step 4: Collect data (what information do we need, and where do we get it?)
Step 5: Build simulation model (how does it all link together?)
Step 6: Verify and validate the model (is it working, and does it make sense?)
Step 7: Experiment and analyze (what is the model telling us?)
Step 8: Communicate results (what is the message, and who needs to hear it?)
Step 9: Implement and use the recommended solution (how do we create impact?)
Step 10: Evaluate the solution (did the results deliver the expected value?)

By the end of the first phase, we had developed a basic AMDBS. We had also demonstrated the benefits of this decision support methodology and created the ownership within the asset management organization of the network utility company.

Second phase. Our approach in this phase was aimed at refining the model and coming up with concrete investment policy recommendations. These recommendations were mostly aimed at standardization of the low- and medium-voltage network design and network investment policy. In this phase, the client's involvement increased significantly, focusing primarily on development of business insights and getting an agreement on key assumptions and relationships between all the variables in the scope. Client personnel were also trained to periodically run different scenarios and to use the results to refine their maintenance and investment policy. The DBS model that was developed was to be leveraged (used) on a regular basis as a decision support tool. Supported by the results of the model, the client was planning to continually refine its low- to medium-voltage network design policies and network investment policies, as assumptions would be changing over time.

Third phase. The aim was to build an additional DBS model, as well as build the simulation and modeling capability within the asset management organization itself. The client team took a couple of modeling courses and was trained in using the POWERSIM software tool. The additional model built focused on the high- to intermediate-voltage network design and was then used in conjunction with the low- to medium-voltage model developed in the first phase of the development process.

Structure of the simulation model

The simulation model was built in a modular way, consisting of six major modules, which are briefly described below.

Assets. The physical network structure is defined by the level of redundancy. Redundancy determines the possibility of electricity supply from an alternative route in case of interruption caused by the breakdown of a particular part of the network. A higher redundancy level implies more assets and more backup and should lead to shorter interruptions (customer minutes lost). The model defines a "stock of assets." The initial asset base depends on the level of redundancy, the density and energy usage pattern of customers, the total in-feed capacity, and the buffer capacity for growth. The key asset types that we modeled were stations, cables, and switch-houses for both medium- and low-voltage networks. Dynamic energy losses in cables, as well as static energy losses from stations, were also modeled.

Workforce activities. Installation of the asset base is done at "time zero," which implies that all installation activities already have been performed, with associated costs incorporated. As the demand increases with time, and when the network is loaded beyond the threshold of capacity available, extensions will be added automatically, leading to an increasing asset base. Based on the new asset base, inspection and maintenance is being carried out. Inspection and maintenance policy (that can be changed if needed) determines the required workforce capacity. Inspection activities can also lead to replacement activities, whereas failures will drive restore-and-repair activities, all of which create additional workforce capacity requirements.

Failures. The failures are modeled to occur primarily due to broken cables (mainly caused by digging activities by external parties) and station breakdowns (mostly at random). Both are linearly related to the asset base. Intrusive inspections and maintenance activities have a nonlinear relationship to failures, and although these failures are comparatively rather small, they can have an impact on interruptions that should not be underestimated.

Quality of service. The basic assumption was that the only factor describing the quality of service is the amount of time that the customers have an interrupted supply of electricity (customer minutes lost). The total length of interruptions depends on the frequency and nature of failures and the time needed to restore the service. However, in the case of network redundancy, the impact of these failures on interruptions is (partly) reduced. This is due to early restorations by opening the switches. Different frequency and length of interruptions can have different effects on the quality-of-service indicator. For example, it is an entirely different thing for customers to be down for 1 minute a week throughout the year compared to down for 52 minutes once per year. The regulator might also react differently depending on the nature and length of the interruption of service.

Policy levers (inputs). The key levers that were considered relevant for scenario runs were demand change per customer segment, customer density, fines imposed by the regulator for service interruptions, level of redundancy, percentage of maintenance and replacements, maximum network load, and cost structure per type of asset. These values can be constant during the period the simulation model is being run (e.g., level of redundancy) or they may vary with time during the course of that period (proportion of available resource directed at maintenance or expected increases in demand from customer segments).

Financial performance indicators (outputs). Workforce activities, energy losses, and service interruptions (customer minutes lost) lead to increased costs with time. Costs incurred by the workforce activities consist of material costs, workforce costs, and overhead costs, differing for each type of activity. Depreciation and interest rates also affect costs with time. The model provides the insight into three types of costs: (a) CAPEXs for installations, replacements, and extensions; (b) OPEXs for inspection, maintenance, replacements, energy losses, and service interruptions; and (c) fines related to service interruptions.

Getting to results

Once the model was developed, the design team verified and validated the model to ensure the validity of results and recommendations based on these results.

Verification of the model included a code check (i.e., every notion that is used in the model is checked for clarity) and a dimension check (i.e., in every equation, the variables on the right-hand side and the variables on the left-hand side should be matching). These checks helped to ensure that no errors were made while representing the model in POWERSIM and that all equations in the model were consistent with each other.

Validation was done by using four different tests: (a) a structure confirmation, (b) a parameter confirmation, (c) an extreme condition test, and (d) a sensitivity analysis. During structural confirmation, the comparison was made with already-existing asset management models and the format of model equations was compared to real-life relations (as understood by asset managers). Parameter confirmation was conducted both conceptually and numerically. Conceptual comparison meant that the parameters had to correspond to the elements in the real-life system, and the numerical comparison meant that the numerical value had to be the same as the real-life one, within a certain degree of accuracy. An extreme condition test was used to evaluate the model behavior under extreme conditions of a number of variables, whereas the sensitivity analysis was done to test the behavior of the model under slight changes in the input values.

Once the model had been validated, we developed and ran a number of scenarios designed to help answer the initial business questions. Scenarios were developed and run in four different groups, focusing on different aspects of the questions we were trying to answer. One scenario group was used to compare different network types with each other. Another group was used to analyze the impact of energy demand dynamics (such as demand growth, customer density, and customer segmentation) on network performance. A third group of scenarios was used to analyze the impact of fluctuating energy prices. Scenarios within the fourth group were used to analyze the impact of regulatory decisions, such as discount rates and service interruption fines.

After running and analyzing a number of different scenarios, the simulation team had reached a number of conclusions. In general, they demonstrated the need for a speedy network development standardization and optimization, with the potential of huge cost savings. Some of the key specific conclusions included the following:

- The analysis showed that there is one particular low-voltage network structure (the way in which the network of electricity cables and transformers is being designed) that will always be more cost-effective, suggesting it becomes a new low-voltage network design standard.
- Other network structures (than the one recommended by the model results) can lead to an annual increase in total costs (OPEXs and CAPEXs) of up to 25%.
- For medium voltage, there seems to be a bigger-than-expected difference in reliability of different network structures (frequency and length of interruptions in electricity supply).

- The influence of energy losses (through the cables) proved to be much more significant than assumed, and the dynamics of annual energy usage proved to have a big impact on network structure related costs.

The primary value of the DBS approach to asset management can be directly associated to the quality and consistency of decision making across the organization and the establishment of an audit trail for troubleshooting. For instance, in one of many model-building workshops, we asked four network developers from different regions what network design they would use for an imaginary neighborhood. As expected, the four answers were all different. However, the fact that the difference between the two extreme answers included a 50% difference in assets (length of cables) surprised everyone. Moreover, the difference in the asset amount did not even include the maintenance and other resulting activities. The lessons learned through experimenting with various scenarios were captured and turned into a standard part of the network design process. Resulting standardization of network design has been a big leap forward in the network utility's approach to network development, with potentially significant reduction in investment while maintaining expected service levels.

Another benefit of the approach was that the implicit understanding of the business was made explicit and that business assumptions were clearly articulated and agreed on (for some of them, for the first time). The simulation model integrated financial, technical, operational, and service quality parameters, forcing asset managers to look at the aspects of decisions that they usually do not consider (e.g., people with engineering backgrounds are forced to look at the operational and financial implications of their decisions). This has significantly increased their understanding of the effects their decisions have on the business beyond their own departments. In addition, the components of the simulation model represent collective knowledge of the client and can be reused in different models as appropriate to lessen the development time. DBS also provided the focus for the information management initiatives by identifying key information that is required to manage the business.

Probably the most important benefit of the DBS was the change in asset managers' thinking process and approach. This is often overlooked in such projects, but it is always the people who solve (and often create) business problems, not the model. Through workshops and hands-on experience, we not only helped create time-bracketed policies and guidelines on certain business decisions but also created tremendous value for the client by shaping their way of thinking—necessary to ensure the company's continued success in the liberalized market.

Lessons learned

Reflecting on the whole development and implementation process, we have identified a number of issues encountered throughout different steps in the process and the ways in which we addressed them. Some of the key lessons learned are presented below.

Level of systems thinking. During the definition of the problem, we realized that our client did not have sufficient systems-thinking background and modeling knowledge to visualize the consequences of a certain problem choice on scope definition. To help the client with making this choice, we developed a simple problem evaluation and prioritization approach where we actually developed simple business cases for each problem in relation to the ease and value of modeling. The result was a clear (and accepted) problem definition.

Level of sponsorship. Very often, the modeling and simulation projects are not sufficiently anchored in the organization, which can result in the lack of sponsorship and commitment at the right levels of the organization. When defining our project structure and roles, we quickly realized that the sponsorship at the management level was large, but at the operational level, we encountered some resistance. Because the productive participation of these people was crucial, we continuously needed to "sell" the approach within the organization. This has cost us much time. One way to avoid this is to ensure that the team is formed and anchored in the organization right from the start.

Shifting objectives. During the conceptual model building, we encountered another "classic" modeling issue—the shifting objectives. As the understanding of the dynamics of the problem grew, the objectives started to be questioned more often, and the scope was starting to have more and more permeable boundaries. To contain this process and remain focused, we decided to split the DBS approach into three phases. Phase 1 delivered a basic model, and Phases 2 and 3 were used to expand the boundaries of the problem definition to accommodate the changing objectives.

Data requirements. Getting the right data, of the right quality, and at the right level of detail was another challenge we encountered. For some elements of the model, it not only was difficult to get the right data but also to get any data at all. The solution was twofold. Some of the data that the model-building team needed were invented (generated) by the team itself—mostly by making educated guesses and assumptions. Other missing information was treated as a range (bandwidth) of possible quantities, which was then used to run different scenarios. A large proportion of development time was devoted to knowledge gathering and assumption validation, but the unintended benefit was that the lack of data provided the focus for the information management activities the asset management organization was already involved in.

Appropriate timing. The timing and pace of model building is also one of the critical success factors. If model results are an important input for the annual planning cycle, it is very important that the results are ready in time. In our case, the results were to be used to define a new medium- to low-voltage policy document, which had to be an integral part of the next year's asset plan. Because asset plans are made once a year, and budgets are allocated once a year, being late is not really an option. Because of the delays encountered in the beginning of the project, we had to increase the speed of model building. One of the things we did was to divide the model into different modules and develop them in parallel. Although integrating the modules required some attention, we did save time. Another important thing we learned is that we should have planned the project based on the client's ability to model rather than our own ability.

Validity of the model. Another challenge was encountered during the verification and validation of the model. Some of the asset officers found it difficult to believe that the model was a valid representation of reality. This was partially due to the complexity of the model, the required change in mind-set (i.e., away from looking at a wall of numbers on spreadsheets), and the unexpected results the model was producing. This lack of belief was mostly present with the people who were not involved from the beginning of the project but, instead, were brought in at the time of validation. The main lesson for us was to make sure that all decision makers are involved to the extent possible from Day 1 of the project. Understanding is a precursor to believing.

Flexibility of the model. During experimentation and analysis, we also encountered the issue of model flexibility. Because the results for one part were unexpected, there was a need to run additional analyses to gain confidence in those results. To allow for experimentation that was more rigorous, the model had to be modified. Although the modular approach allowed for easier modification, the model was not as flexible as we would have wished. Although we might have asked for more development time, it would have helped us if we had designed the model for flexibility from the very beginning.

Communicating the results. The simulation model we built was a complex one, and results for one part were counterintuitive and unexpected. This created a challenge for the team in communicating the findings and recommendations based on those findings to the organization. Our fear was that it would be a wrong message at a wrong time. Our fears proved to be unfounded, but developing the key messages and communicating the results to the organization is an issue that will always require special attention.

Conclusion

Because of the need to balance financial, operational, and safety aspects, the management of network utility companies is facing different questions than in the past. To effectively address these questions, companies need to develop new business capabilities, DBS being one of them. This capability is characterized by its ability to capture the implicit understanding of the business, balance different stakeholder perspectives, model complex systems, and experiment in a safe environment.

The network utility company that served as a case in this article recognized the need for such business capabilities. Once implemented and used, the simulation not only delivered valuable insights into the network design related business questions but also improved the quality and consistency of decision making across the organization. In addition, the simulation supported the organization in articulating its business assumptions more clearly and making the implicit understanding and knowledge explicit. Most important, it helped change asset managers' thinking processes and approaches to asset management. This change could happen only through inclusion, which is probably one of the key lessons learned from this project. Understanding is a precursor to believing; without continuous involvement of asset managers in all steps of the simulation development and implementation process, the success would have been limited.

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