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Case	Title	(First) author	Topic, chapter and/ or SIG	Client(s)
001	Case project management at Ingalls	Cooper	Project management, litigation, shipbuilding	Ingalls Shipbuilding
002	Case General Motors OnStar	Barabba	Strategy development, automobile industry, telecommunications	General Motors
003	Case pharmaceutical industry	Paich	Health care, pharmaceutical industry	Various
004	Case polio eradication	Thompson	Health care, infection, polio	WHO
005	Case diabetes	Jones	Health care, chronic disease, diabetes	CDC
006	Case process innovation at Du Pont	Repenning	Process innovation, oil industry	Du Pont
007	Case climate	Sterman	Climate	Various
008	Case project management at Fluor	Cooper	Project management	Fluor
009	Case criminal justice	Rouwette	Criminal justice	Ministry of Justice, the Netherlands
010	Case maintenance improvement at ONEgas	Rouwette	Information systems, ERP, oil and gas industry, maintenance	ONEgas
011	Case sustainable water management in Laikipia District (Kenya)	Gallati	Natural resources, water management, sustainability	CETRAD, NCCR North-South, Switzerland
012	Case pharmaceutical product life-cycles	Jones (via UK SD society)	Health care, pharmaceutical industry	Anonymous
013	Case medical device company	Warren (via UK SD Society)	Health care, consumer medical device	Anonymous
014	Case state planning in Sarawak	Dangerfield (via UK SD Society)	National planning	Sarawak State Planning Unit
015	Case supply chain options in pharmaceuticals	Jones (via UK SD society)	Health care, pharmaceutical industry	Anonymous
016	Case International Council on Systems Engineering	Warren (via UK SD Society)	Professional society, membership	INCOSE
017	Case urban dynamics	Swanson (via UK SD Society)	Transport, urban dynamics, land use planning	UK local authorities
018	Case climate change and energy	Bassi	Energy, climate	National Commission on Energy Policy, Environmental Defense Fund, WAI
019	Case energy policy analysis in Mauritius	Bassi	Energy, national planning	Ministry of Renewable Energy and Public Utilities, Mauritius

001 Case project management at Ingalls

Ingalls Shipbuilding in Pascagoula, Mississippi (a division of Litton Industries, Inc.) is an international, broadly diversified industrial corporation with annual revenues in the 1970s of three to four billion dollars. At the time Ingalls was one of the largest shipyards in the world, by any measure - size, capabilities, employment, sales volume. One of its major customers is the United States Navy.

Program overruns, contract disputes, and legal confrontation between defense contractors and the government escalated seriously over the 1970s. In 1969 and 1970 Ingalls was awarded a firm-fixed-price contract by the Navy to build nine (subsequently reduced to five) amphibious assault ships and thirty destroyers. Either of the two programs would have required a significant facilities and manpower expansion for any shipyard; Ingalls more than doubled its workforce for the two programs. Following design changes by the US Navy, the programs experienced huge delays and cost overruns. A system dynamics model was constructed to diagnose the causes of cost and schedule overruns for these two multibillion dollar shipbuilding programs.

The simulation model resolved a $500 million shipbuilder claim against the US Navy. Ingalls Shipbuilding quantified the costs of disruption stemming from Navy-responsible delays and design changes; in June 1978 the Navy agreed out of court to pay $447 million of the claim. Use of the model (which was the basis for at least $200-300 million of the settlement) broke new legal ground, providing the defense and legal communities with a means by which adversary relationships can be avoided and equitable settlements of contract cost disputes achieved. Ingalls now has extended the model to aid strategic decision making in managing its shipyard operations. Each phase of several shipbuilding programs can be accurately simulated. Executives find it valuable as a test bed for evaluating the consequences of alternative policies in bidding and marketing, contract management, program work scheduling, resource management, and cost forecasting.

Since the publication of this case, system dynamics models have been used extensively in project management and legal cases.

More information on this case can be found in

Cooper K.G. (1980). Naval ship production - a claim settled and a framework built. *Interfaces* 10(6): 20-36.

Roberts E.B. (2007) Making system dynamics useful: a personal memoir. *System Dynamics Review* 23 (2/3): 119–136 (http://www.systemdynamics.org/history/making_sd_useful.pdf).

002 Case General Motors OnStar

In 1997, General Motors (GM) assembled a project team to develop its OnStar telematics business. Telematics is the provision of communications services to cars, including crash notification, navigation, Internet access, and traffic information. OnStar is GM's two-way vehicle communication system that provides a variety of services that enhance safety, security, entertainment, and productivity. At the time, GM faced fundamental strategic decisions with respect to OnStar. The default and safe strategy was to market OnStar as a car feature that would improve vehicle safety and security. An alternate strategy was to view OnStar as a service business that could contribute greatly to GM's profits.

GM formed a project team to consider alternative strategies for OnStar. GM makes important strategic decisions through the dialogue decision process, in which the project team interacts with the decision board that is responsible for actually making the decision and committing resources. Dynamic modeling can be a part of this process. In this case, application of modeling was difficult. In the vehicle business, GM has decades of experience and plentiful historical data. Modelers can build on a wealth of previous analyses and examples of best practice. The OnStar business was very different in that the telematics market did not exist. To cope with the inherent uncertainty, we needed a modeling process that would allow integration of various methods and data sources. A simulation model was our core tool in the OnStar strategy project. The final model had six key sectors: customer acquisition, customer choice, alliances, customer service, finances, and dealer behavior.

In late 1997, the project team recommended a very aggressive strategy that included installation on all GM vehicles, recruitment of other manufacturers into the OnStar system, making the first year of service free and aggressively pursuing alliances with content partners. Through 2001, the implementation of the OnStar business strategy has progressed very much as expected. The project contributed to creating a new enterprise mental model for GM, in which the transactions revenue is augmented with a stream of revenue from service businesses like OnStar. The OnStar project also created the new telematics business which did not exist before GM implemented its strategy. Today, Wall Street analysts project that the industry will grow to $12 billion over the next 10 years. By far, OnStar's most important contribution is saving lives. OnStar answers thousands of emergency calls each month and has often made the difference between life and death.

More information on this case can be found in Barabba V., Huber C., Cooke F., Pudar N., Smith J., Paich M. (2002). A multimethod approach for creating new business models: the General Motors OnStar project. *Interfaces* 32(1): 20–34.

003 Case pharmaceutical company

Pharmaceutical companies are faced with major problems in developing and marketing new products. Examples are determining a product's market potential under different scenarios, formulating effective marketing strategies, determining what benefits to stress during Phase 3 trials and determining resource allocation between products. In the past a variety of approaches has been used to deal with these problems, such as product diffusion models, macro – flow models, portfolio optimization and product choice models as well as a number of system dynamics applications.

The approach we use is based on multiple modeling approaches which are used to pull together a set of common structures. Each of these structures can be used to find leverage points and answer questions such as what share of share of new patients can we capture? How many patients that switch therapy can we capture? What share of patients can we capture that return to therapy?

So far more than seventy studies across most of the major pharmaceutical and biotech companies have been completed. Patient flow modeling has become an accepted. Many of these cases result in revised marketing decisions and projections. Customers indicate satisfaction with the ability of the approach to integrate multiple data sources, modeling approaches, and time frames.

More information on this case can be found in Paich M., Peck C., Valant J.J. (2005). *Pharmaceutical product strategy: using dynamic modeling for effective brand planning.* Interpharm/CRC: Boca Raton, FL.

004 Case polio eradication

Following successful eradication of smallpox and impressive progress in the elimination of polio in the Americas, in 1988 the World Health Assembly committed to global eradication of wild polioviruses by the year 2000. By 2000, the Global Polio Eradication Initiative (GPEI) had significantly reduced the global circulation of wild polioviruses. However, in 2002–3, faced with insufficient funding to continue intense vaccination everywhere, the GPEI focused its vaccination efforts. At the time, wild polioviruses continued to circulate in six countries, but many other countries remained vulnerable to importation. Political and logistical challenges led to outbreaks and exportations, and between 2004 and 2006 wild polioviruses appeared again in previously polio-free African and Asian countries. Toward the end of 2005, debate began about abandoning the goal of eradication. How could the world continue to justify the significant use of resources (both financial and human) on polio, particularly with the number of cases globally already so low and so many other disease control and health services programs in need of resources? In 2006 a prominent editorial questioned whether polio eradication is "realistic" and expressed concern that "international assistance for polio could have negative effects on other public health efforts". The editorial suggested that "the time has come for the global strategy for polio to be shifted from 'eradication' to 'effective control'".

Given our then current work on assessing the risks, costs, and benefits of post-eradication policies we could use many of the components we previously developed to model a shift from eradication to control. Notably, our dynamic disease outbreak model for polio allowed us to estimate potential numbers of cases. Our analysis came at a critical time. In February 2007, the WHO Director-General, Dr Margaret Chan, convened an urgent stakeholder consultation to discuss the option of switching to control. We had the opportunity to present the preliminary results of this work at that meeting. Following publication of the paper, an article about the paper published in the same journal as the editorial mentioned above noted that our analysis provided "a nail in the coffin for the idea that there is a cheap and painless way out". Since then, efforts have continued to focus on finding the resources needed to complete eradication and on dealing with the other complex challenges that remain. National and global health leaders and financial supporters have recommitted to completing eradication, and this has led to several hundreds of millions of dollars of resources.

More information on this case can be found in Thompson M. and Duintjer Tebbens R. (2008). Using system dynamics to develop policies that matter: global management of poliomyelitis and beyond. *System Dynamics Review* 24(4): 433–449.

005 Case diabetes

Diabetes mellitus is a growing health problem worldwide. In the United States, the number of people with diabetes has grown since 1990 at a rate much greater than that of the general population; it was estimated at 20.8 million in 2005. Total costs of diabetes in the United States in 2002 were estimated at $132 billion.

Health planners in the National Center for Chronic Disease Prevention and Health Promotion of the Centers for Disease Control and Prevention used system dynamics simulation modeling to gain a better understanding of diabetes population dynamics and to explore implications for public health strategy. A model was developed to explain the growth of diabetes since 1980 and portray possible futures through 2050.

The model simulations suggest four characteristic dynamics of the diabetes population. First, it shows obesity's role in driving the growth of prediabetes and diabetes prevalence. Second, the model quantifies the "backing up" phenomenon (in which reduced outflow from a population stock causes a buildup in that stock) that may undercut the benefits of management and control efforts. Third, management and control efforts alone are unable to reduce diabetes prevalence in the long term. Fourth, there are significant delays between primary prevention efforts and downstream improvements in diabetes outcomes.

More information on this case can be found in Jones A.P., Homer J.D., Murphy D.L., Essien, J.D.K., Milstein B., Seville D.A. (2006) Understanding diabetes population dynamics through simulation modeling and experimentation. *American Journal of Public Health* 96: 488-494.

006 Case process innovation at Du Pont

Improvement programs such as Total Quality Management are embraced by many organizations but are often discontinued before full benefits can be reaped. With ever-increasing numbers of new techniques and methods available, as well as consultants ready to facilitate implementation, discovering improvement programs is no longer a problem. Instead successfully implementing these programs has become the biggest challenge. A research program spanning a decade, based on observation of over a dozen cases at company sites, interviews, surveys and literature analysis discovered a paradox in improvement programs. Although many organizations strive to improve performance by working smarter, what happens instead is they elevate 'work harder' to their standard operating procedure. They fall into the capability trap: the pressure maintain performance drives them to work harder, which prevents learning about ways to do the work smarter.

A case study at Du Pont shows how process improvement may be implemented successfully. In 1991, a benchmarking study showed that Du Pont spent more on maintenance than its competitors yet its mechanics worked more overtime and plant uptime was lower. An in-house team developed a system dynamics model of these issues. Policy analysis with the model showed that, while repairs to breakdowns had to continue, the company simultaneously had to invest additional resources in planned maintenance and training. This would in the short term reduce uptime and increase costs, and only show benefits later. In order to facilitate a learning process for the thousands of people that would be involved in implementing these changes, the team developed an interactive role-playing game called the Manufacturing Game. The game is based on the model and accurately captures time delays, costs and other parameters describing a typical plant. The game is used in multi-day workshops across the company and proved popular.

By the end of 1992, 1200 people had played the game and more than 50 facilitators had been trained. In plants that implemented the program by the end of 1993, the mean time between mechanical failure for pumps rose by an average of 12% each time cumulative operating experience doubled, maintenance costs fell an average of 20%. In 23 comparable plants the learning rate averaged 5% and maintenance costs increased by 7% on average.

More information on this case can be found in Repenning N.P., Sterman J.D. (2001). Nobody ever gets credit for fixing problems that never happened: creating and sustaining process improvement. *California Management Review* 43(4): 64-88.

007 Case climate

Although there is strong scientific consensus on the causes and risks of climate change, among the public there seems to be widespread confusion and complacency. The gap between scientific and public understanding may in part arise from a difficulty in grasping issues characterized by long time delays. Surveys indicate that a majority of US, Russian, Chinese and Indian citizens prefer a 'wait and see' or 'go slow' policy to emission reductions. For many, uncertainty about the risks of climate change means that costly actions to reduce emissions should be postponed. Wait-and-see works well in simple systems with short lags. We can wait until the teakettle whistles before removing it from the flame because there is little lag between the boil, the whistle, and our response. However, there are substantial delays in every link of a long causal chain stretching from implementation of policies to emission reductions to changes in atmospheric green house gas concentrations to surface warming to changes in ice sheets, sea level, agricultural productivity, extinction rates, and other impacts.

A fundamental cause of the difference in perceived urgency may be the ability to understand stocks and flows, or the concept of accumulation. Accumulation is pervasive in everyday experience: our bathtubs accumulate the inflow of water through the faucet less the outflow through the drain. Nevertheless, research shows that people have difficulty in relating the inflow and outflow to the level of a stock, even in familiar contexts such as bank accounts and bath tubs.

The scientific community has a vital role to play in building public understanding. First, the Summary for Policymakers that accompanies reports of the Intergovernmental Panel on Climate Change is far too technical to change people's mental models. Second, clarity, while necessary, is not sufficient. When common sense and science conflict, people often reject the science. We need new methods for people to develop their intuitive systems thinking capabilities. Bathtub analogies and interactive management flight simulators through which people can discover, for themselves, the dynamics of accumulation and impact of policies have proven effective in other settings. Third, climate scientists should partner with psychologists, sociologists, and other social scientists to communicate the science in ways that foster hope and action rather than denial and despair.

An example of a management flight simulator on climate change can be found on http://climateinteractive.org/
More information on this case can be found in Sterman J.D. (2008). Risk communication on climate: Mental models and mass balance. *Science* 322(5901): 532-533.

008 Case project management at Fluor

Fluor is one of the world's largest engineering and construction firms, with 2008 revenues over $20 billion. The US-based firm operates in every major business sector and geography. A large part of Fluor's work is organized in the form of projects, which are typically market-driven with aggressive cost and schedule targets and evolving client needs. It is the tension among these different objectives that is often the underlying dynamic for generating changes on projects. In an initiative by Fluor's Chairman, a comprehensive quantitative review examined all Fluor projects over several years. For many in the industry, there is a misperception that contractors improve their performance with more changes. This company-wide review was unequivocal in refuting that notion. There is a clear, unambiguous relation between the level of changes and the cost and schedule performance of projects: more changes bring ever-worsening performance on projects.

After Fluor had identified and quantified the business need for improving the practice of project change management, two external consultants first built and piloted and validated a project model to assess change impacts on several initial projects. In the four years since then, the model has been used in the "Change Impact Assessment" system to conduct thousands of analyses on over 100 client projects. Fluor projects analyzed with this model range in size from less than $10 million to more than $10 billion. The system rapidly tailors a model to simulate each engineering and construction project. Each model is then used to foresee future cost and schedule impacts of project changes, and most important, test ways to avoid the impacts.

Hundreds of project managers and planners have been trained in the ongoing internal use of the system. In addition to providing a better understanding of the project-wide effects of changes, the cost savings identified for Fluor and its clients exceed $1.3 billion.

More information on this case can be found via
http://www.systemdynamics.org/conferences/2009/proceed/papers/P1427.pdf
http://www.systemdynamics.org/newsletters/2009-10oct/application%20award%20paper.pdf

009 Case group model building at the Ministry of Justice

In 2003, Significant consulting and the Methodology group of Radboud University Nijmegen started a modeling project for the Ministry of Justice in the Netherlands. The aim of the project was is to gain insight into the combined effects of three developments: an increase in the case load, investments in different phases of criminal justice administration and contextual developments such as increased complexity of cases. A group of representatives from the police force, public prosecution, courts and sentence execution, probation services, WODC (Scientific Research and Documentation Center) and different departments of the Ministry of Justice participated in constructing the model from January to August 2004. The project was named Simulatiemodel Strafrechtsketen (simulation model criminal justice chain) or SMS. The final model shows the case and person flow in the Dutch criminal justice system over a period of 14 years on a monthly basis. It contains hundreds of equations and 41 views in Vensim.

In addition to answering the original questions, the model was also used to gain insight into the effects of a proposed law. Under the new law, the public prosecution will settle a proportion of cases which are now the responsibility of courts. Several members of the original modeling team participated in an update of the SMS model which was finalized in March 2006. The modeling effort pointed to larger than expected case loads at several points in criminal justice administration, for which IT systems would need to be adapted. As a result implementation of the law reform was postponed for one year. Results of the SMS project were disseminated beyond the reference group in a number of ways. The Ministry of Justice announced the completion of the modeling effort in its communications on the Safety Plan. A flight simulator based on the model was used in training of new employees for different departments of the ministry. The process and results of the model were (and are) met with enthusiasm in many organizations, resulting in a number of other group model building projects on topics such as DNA sampling, traffic fines, and impact analyses on new legislation and policies.

More information on this case can be found in: Rouwette E.A.J.A., Vennix J.A.M., Van Hooff P., Jongebreur W. (2007). *Modeling crime control in the Netherlands: insights on process.* In Sterman, J.D., Oliva, R., Langer, R.S., Rowe, J.I., Yanni, J.M. (Eds.) Proceedings System Dynamics Conference Boston, 2007, cd-rom: 1-26.
(http://www.systemdynamics.org/conferences/2007/proceed/papers/ROUWE343.pdf)

010 Case maintenance improvement at ONEgas

ONEgas is a company owned by Shell and NAM and is responsible for gas production in the Netherlands. This modeling effort focused on the maintenance process in ONEgas. The maintenance processes at the ONEgas platforms are supported by the SAP PM module. After the implementation of SAP Blueprint it turned out to be difficult to improve the performance of the maintenance process. Uncovering the structure behind the large amount of data captured in the SAP system was thought to be a necessary to identify improvements.

Four facilitated system dynamics (group model building) sessions were held at ONEgas. The model was constructed over a period of seven months, integrated participants' opinions with SAP system data. After testing and validation the model was used to test improvements in maintenance in different scenarios. Recommendations focused on capacity for work preparation and base crew, purchase time for material and effective working hours. Final results were captured in a report, presentation to management and a management flight simulator.

An extensive evaluation shows that participants have increased their insight into the maintenance process and are committed to implementing recommendations. The direct client was highly satisfied with the outcomes of the modeling effort.

In summary, the benefits delivered in this case are more insight into the maintenance process in ONEgas and recommendations on how to improve its performance. Participants in the model building process indicate their confidence in conclusions and willingness to implement recommended changes.

More information on this case can be found in Venderbosch, T. (2007). *Using Group Model Building to optimize the maintenance process in an ERP environment at ONEgas.* Unpublished master thesis, Radboud University Nijmegen, Nijmegen.

011 Case sustainable water management in Laikipia District (Kenya)

Sustainable management of natural resources is a vital concern in most countries and regions worldwide. In Laikipia District in Kenya, located at the foothill zone of Mt. Kenya, water is required in the upper zone for irrigation agriculture, horticultures and livestock production as well as for urban areas. In the lower zone water is required for wildlife and natural habitats.

In an earlier study (Gallati 2008) a system dynamics model has been developed to better understand possible dynamics in collective irrigation management focusing on the feedbacks between social mechanisms of collective action and the performance of the irrigation practices. In Laikipia, however, it turned out that this model was not applicable due to the fact that large immigration had taken place in the last decades preventing inhabitants from developing close relations of exchange and reciprocity, which had been key preconditions of this model.

A stakeholder workshop in 2009 revealed that the transition towards new water management practices is one of the key concerns in the area. Based on these insights a system dynamics model has been developed to demonstrate the effect of new water management practices in different zones along the river reflecting the fact of varying rainfall and agricultural options from uphill to downhill zone and down to the plains. In particular the users can experiment with different options such as storage capacity, increase of water use efficiency, use of flood flow, adaptation of agricultural practices, etc. in order to analyze the effect of these practices on overall production and income. As such it is envisaged to support local participants in adopting a river (basin) perspective. The usefulness of the model is being evaluated in a second stakeholder workshop in 2010. Based on this experience further model development will be evaluated. One option is to further develop the model into a tool for broader use in capacity building and training for sustainable water management in collaboration with local or international institutions.

The project is developed in collaboration with CETRAD (Centre for Training and Integrated Research in Arid and Semi-Arid Areas Development; www.cetrad.org) in Nanyuki, Kenya and is part of a larger research initiative on sustainable natural resources management. It is supported by NCCR North-South in Switzerland, which is funded by the Swiss Development Agency and the Swiss National Fund.

Contact and further information: Justus Gallati, Lucerne University of Applied Sciences justus.gallati@hslu.ch.

More information on this case can be found in: Gallati J. 2008. *Towards an improved understanding of collective irrigation management: a system dynamics Approach.* [PhD Dissertation]. Berne Switzerland: University of Berne.

012 Case pharmaceutical product life-cycles

A leading global pharmaceutical company wanted to understand the interdependencies between resource levels and experience through the life-cycle of drug products. It was also interested in the impact of organisational design on its ability to manage the product pipeline.

In a series of workshops, we developed further an internal qualitative model of the system and produced a quantitative simulation tool for assessment of the likely impact of investment in resources & training. This project model enabled multiple drug products to be evaluated throughout their life-cycle as they affect resource requirements (numbers of people, experience etc) and also to assess the relationships between organisation capabilities and life-cycle progress and success.
The work built on a number of previous engagements with the client and benefited greatly from the experience gained by the modeller and the client team. Using large-scale posters of model overview diagrams, the modelling team were able to bring into the design and development phase a number of senior executives with the experience required in order to gain confidence in the approach.

The organisation now has a quantitative model in which to evaluate the possible impact of investment in resources, training etc on the product portfolio and, ultimately, on profitability. We delivered a comprehensive "cockpit" user interface enabling involvement by non-expert users and model development continues in the light of user feedback.

The effective management of product life-cycles is of critical importance to pharmaceuticals, made worse by the 'ticking clock' of the patent life for a drug. Better management of this issue can be worth many millions of dollars for a single product, and since this project enhances decision-making across numerous products, it is delivering very considerable overall value.

For more information on this case, please contact Lee Jones at Ventana systems UK.

013 Case medical device company

The company faces total loss of sales for a consumer medical device - very well known amongst the 100,000 users and doctors - with the ending of a patent in 2010. It has developed a replacement product, but faces the challenge of migrating patients and doctors from the existing brand, which will have to happen very fast. What kind of marketing and sales effort should be made, over what period of time, with what likely results?

The project started with a one-day workshop with the four person management team, mapping the resources involved - patients, doctors, specialists, sales force - estimating key numbers and causal relationships. The second step was a three week modeling effort between one expert and two key executives. The third and last step involved a half-day workshop reviewing and confirming results, and testing strategy options.

The project resulted in several benefits to the company. An initial idea - to capture patients via a website proved impossible because usage would be too low, and their engagement with the new brand limited. Direct sales effort and marketing to doctors would not work, because the medical condition was too rare to engage their interest. The solution was to involve specialists in the routine training-updates that doctors have to undertake, then follow up with sales calls to those specific doctors who had attended the training. This would require five times the previously estimated cost and effort, but deliver attractive results. Current sales volume, worth €1 million in annual profits, would disappear with the loss of the current product. Pre-existing plans would fail to rebuild more than half this profit over three years, and lose most of the market to competitors. The revised strategy, though costly, would more than recover the existing profits in two years, due to the better profit margin on the new product.

For more information on this case, please contact Kim Warren at Strategy Dynamics.

014 Case state planning in Sarawak

The Centre for Operational Research & Applied Statistics at the University of Salford was awarded a contract during 2003-2005 to offer a more scientific basis on which to formulate future economic and social policy in Sarawak, East Malaysia. The direct project clients were members of the State Planning Unit (SPU). The State, on the northern coast of Borneo, was a former British colony which joined the federated nation of Malaysia in 1963. The purpose of the model was to help government officials manage a change from a predominantly resource based economy to a knowledge based one.

A team consisting of a project director, scientific director, development economist and two research assistants gradually secured the information needed to construct the model. A prototype model derived from a high-level map was developed quickly at an early stage in the project. Regular presentations were made as the model was developed, culminating in a special conference of senior State government officials and the modeling team when the final report was presented. The final model consisted of 15 sectors and around 450 equations and mappings. A microworld was constructed around the model to aid its use by non-technical officers. The primary aim was to elevate the standard of modeling used by State Government officials. Malaysia as a whole is a planned economy which needs a more scientific basis for constructing their 5-yearly plans. The need to improve, substantially, the education system, involving fewer school drop-outs and more significant progression to higher education, particularly in the sciences, were strong features of model runs. Also, there was emphasis on the State incubating R&D schemes which would absorb the increased numbers of scientifically skilled graduates. Perhaps an over-riding conclusion was that we had exposed and convinced government officials as to the merits of SD as a methodology in this sphere of application.

It is difficult to place a monetary value on its impact. However, the potential benefits to the economy as a whole arising from enhancements to the education system and the incubation of successful enterprise are considerable. The project implanted an awareness and knowledge of SD in Sarawak and in Malaysia more widely - the Borneo Post carried a headline "*Government to introduce System Dynamics model*" explaining the project and its outcomes.

Dangerfield B.C. (2006). *A system dynamics model for economic planning in Sarawak*. In: Proceedings of the International SD Conference, Nijmegen.
(http://www.systemdynamics.org/conferences/2006/proceed/papers/DANGE453.pdf)

015 Case supply chain options in pharmaceuticals

A global pharmaceuticals company wanted to evaluate future supply-chain options for a group of drug products.

In a series of workshops held with knowledgeable personnel over a six week period, the team (comprising the modeller and all workshop attendees) developed a simple simulation to help understand the likely implications of organisational change involving a significant capital investment. The model centred on several aspects of the change, including co-location of a number of pharmaceutical production facilities and the possible impact of changes in the structure of the organisation on the ability of the supply chain to satisfy future customer demand while reducing overall stock levels. It had been thought that a simulation of the possible impact of moving from the AS-IS to the TO-BE organisation would help the decision-makers but that the traditional simulation approach used by the organisation would not be able to report in time for a major decision point in the investment project. The model's results were reviewed at each stage and amendments made to reflect feedback from participants. Final scenario runs included sensitivity analysis and presented the possible performance range of selected Key Performance Indicators.

The model was able to demonstrate the likely improvement in performance between the AS-IS and the TO-BE scenarios, both in stock reduction and in the reducing manufacturing cycle times and the conclusions were presented to senior decision-makers during their next meeting on the subject.

The work was completed in a short period of time and was vital to the correct investment of many millions of dollars that would not have been evident from conventional analysis. The success was due to an effective synergy between the client and modeller; the former having the relevant expert knowledge and enthusiasm, the latter having considerable experience of pharmaceutical industry modelling.

For more information on this case, please contact Lee Jones at Ventana systems UK.

016 Case INCOSE UK (professional society)

INCOSE is the International Council on Systems Engineering (SE) representing an interdisciplinary field that focuses on how complex projects should be designed and managed. INCOSE UK, like its counterparts in other countries, has grown strongly over recent years, as the benefits of professional systems engineering have become clear. Although the organization had a well-written strategy document, it needed to turn this into a clear and quantified set of outcomes, and an equally clear set of actions that would lead to these outcomes.

The members of INCOSE UK's Board had already produced a rough causal map of how they believed their organization worked - how skilled SEs were developed, why members joined, what impact their professional work had made and so on. They were interviewed to get identify what objectives they felt INCOSE UK should have, of what scale, and over what time. They were then asked to estimate key indicators of the organization's state and how this was developing over time. This included, for example, the number of significant projects on which SE is applied, the number of qualified practitioners, the number of organizations who adopted formal SE methods, and so on.

Lastly, they were asked to estimate the rate at which these features of the SE field in the UK could potentially develop, and what factors would bring about that progress. Two rounds of team meetings compared and distilled these estimates into an integrated, quantified map of how the INCOSE UK 'system' has worked and might be developed.

The INCOSE UK system diagram, agreed by the Board, displayed a quantified picture of how the organization might develop systems engineering in the UK. This included a detailed, time-phased action plan to increase the visibility of SE, to grow demand for SE work, to encourage education and training of SE professionals, and to grow INCOSE membership and activity. Note that a working system dynamics simulation model was not regarded as necessary for INCOSE UK to have high confidence in the conclusions and recommendations of the study. Since INCOSE is a professional membership organization, rather than a commercial firm, the project's value will show up in the achievement of the aims included in the strategic plan, in particular in terms of visibility, impact and growth of the profession. As at end-2009, indicators of all these factors are running well ahead of expectations.

For more information on this case, please contact Kim Warren at Strategy Dynamics.
See also http://www.kimwarren.com/files/INCOSE_UK_Strategy_Report_2008.pdf

017 Case urban dynamics

The Urban Dynamic Model (UDM) is a simulation of how transport interacts with population, employment and land-use over long periods of time, typically ten years or more. It was developed to help understand how transport could contribute to economic regeneration by improving the ability of employers to recruit a workforce and their access to customers and suppliers, and by improving access to employment opportunities. For example, the vicious circle of congestion is familiar to us all but is almost impossible to capture in traditional models. In short, the cycle includes improved transport which reduces travel time, making businesses easier to access for customers, generating increased employment, leading to more transport activity and increased congestion.

The UDM was developed over a number of years, beginning with a fairly simple model built in 2000. This was used in one of a series of large scale transport studies commissioned by the government at the time. Its role at that time was to test the regeneration claims being made for a proposed by-pass that would have passed through an area of outstanding natural beauty. Models of this type must be able to represent the spatial characteristics of the study area, usually using a zone structure, and the road and public transport links connecting the zones together. Other applications followed, and then in 2005 we were commissioned by the Department for transport to carry out a study into the impact of transport on business location decisions. Current guidance from the Department for Transport emphasises the wider role of transport in supporting the economy, but also points to the need for reducing carbon dioxide emissions.

The UDM is generic, and has been applied widely in the UK with local authorities. Conclusions vary from one application to another, but some of the findings we have reported include measures to generate employment can appear to have a significant effect if examined very locally, but we often find that some employment is transferred from elsewhere, and the net effect can be less than might first appear, city centres remain the best locations for many types of employer because they provide the best access to a workforce and bring 'agglomeration' benefits that employers enjoy by being clustered together. Studies of major programmes of transport investment typically involve expenditure of tens or hundreds of millions of pounds. The measured benefits are usually expressed in money, and expressing both the social and economic impacts of investment and can also run to hundreds of millions of pounds.

For more information on this case, please contact John Swanson at Sdgworld.
See also http://www.steerdaviesgleave.com/services/byService/modellingandforecasting/

018 Climate Change Impacts on Energy-intensive Manufacturing Sectors

Four industries – iron and steel, aluminum, paper and pulp, and chemicals – account for nearly half of the energy consumed by U.S. manufacturing industries and over 10 percent of total U.S. energy consumption, making them highly vulnerable to volatile energy prices. Millennium Institute and High Road Strategies collaborated on three connected study commissioned by the National Commission on Energy Policy, the Environmental Defense Fund and AFL-CIO Working for America Institute (WAI) and developed with support from industry association organizations, to examine how increased energy prices associated with comprehensive and mandatory cap-and-trade climate policy proposals currently being considered by the U.S. Congress would affect the competitiveness of these industries in the long term. The studies also examined the industries' capabilities and opportunities to mitigate adverse cost impacts and improve their economic performance under different climate policy scenarios.

In short, the findings strongly suggest that over the long-run, technologies are available to enable energy-intensive industries to achieve sufficient efficiency gains to offset and manage the additional energy costs arising from a climate policy. However, the authors also strongly believe that the industries analyzed will need additional measures that both mitigate these cost impacts in the short-to-medium term, and policies that encourage and facilitate the transition of energy-reliant companies to a low-carbon future, while enhancing their competitiveness in global markets.

Findings of these studies being circulated starting from Aril 2009 are substantially contributing to the debate on the introduction of climate regulations, both in the US and abroad.

More information on this case can be found in Yudken J.S. and Bassi A.M. (2009), Climate change and US Competitiveness. *Issues in Science and Technology*, Fall Issue.

Bassi A.M. and Yudken J.S. Potential challenges faced by the U.S. chemicals industry under a carbon policy. *Sustainability* 1: 592-611. Special issue on Energy Policy and Sustainability.

Yudken J.S. and Bassi J.S. (2009). *Climate policy and energy-intensive manufacturing: the competitiveness impacts of the American energy and security act of 2009.* High Road Strategies and Millennium Institute, February 2010, Washington DC, USA. Prepared for the Environmental Defense Fund (EDF).

019 Case energy policy analysis in Mauritius

Under the leadership of the Ministry of Renewable Energy and Public Utilities of the Republic of Mauritius and with support from UNDP, the Millennium Institute (MI) has carried out an assignment on supporting formulation and evaluation of Mauritius' longer term energy policy framework. The goal of this project is to empower the Ministry of Renewable Energy and Public Utilities, and the Government of Mauritius, with a flexible, integrated, dynamic and user-friendly uniquely customized simulation model that allows for the evaluation of energy policy proposals to make informed decisions on longer term policy planning. This model was jointly developed with a team of experts, including representatives from Ministry of Public Infrastructure, Land Transport and Shipping, the Central Electricity Board (CEB), the Electrical Services Division (ESD), the Mauritius Sugar Industry Research Institute (MSIRI), the Central Statistics Office (CSO), the Maurice Ile Durable (MID) Fund, the University of Technology Mauritius (UTM).

Because of its flexibility and ease of use, in addition to its integrated and dynamic nature, the Mauritius Model allows for a cross sectoral analysis of the impacts of the energy policy provisions, with simulations running from 1990 to 2025. This is important when operating in such a rapidly changing environment and volatile time. The project included continuous group modeling sessions and daily exchanges with key stakeholders, to end with a two-day workshop and with a presentation to the Deputy Prime Minister of the Republic of Mauritius.

Results of the analysis proved to be of considerable value to the Ministry of Renewable Energy and Public Utilities, and led to an update of the longer-term energy policy document later approved. The utilization of an integrated, cross sectoral, national development model also served to bring together several ministries, the private sector and universities to jointly analyze results, both opportunities and challenges, arising from the implementation of the energy strategy.

More information on this case can be found in Bassi A.M. (2009). *Systems modeling of long term energy policy, Mauritius.* Prepared for the Ministry of Renewable Energy and Public Utilities, Republic of Mauritius, and UNDP Country Office Mauritius and Seychelles, Port Louis.
Balnac K., Bokhoree C., Deenapanray P., Bassi, A. M. (2009) *A system dynamics model of the Mauritian power sector.* Proceedings of the 27th International Conference of the System Dynamics Society, July 26 – 30, 2009, Albuquerque, NM, USA.
(http://www.systemdynamics.org/conferences/2009/proceed/papers/P1395.pdf)