TOOLS TO AID STRATEGIC ISSUE IDENTIFICATION[1,2]

Steve Sonka, Donna Fisher, and Randall Westgren[3]

Abstract

This paper reports upon the use of advanced information tools to enhance individual and organizational learning in a specific strategic decision setting. Two tools comprise the system. One is a complex system dynamics model that tracks estimated consumption annually (for the years 2001 to 2025) of six protein commodities in eight regions that encompass the world. The second tool is a 3-dimensional visualization tool that summarizes considerable amounts of information through graphics, color and animation. The purpose of the system is to enhance learning and joint decision making regarding long term uncertainty. Extensive evaluation of the effects of use of the tool with more than 100 decision makers has been conducted. Summary results are reported here.

Introduction

This paper reports on the creation and use of advanced information management tools to assist decision makers in the soybean industry assess strategic options. The tools developed and used include system dynamics modeling and three-dimensional visualization of information. Further the paper provides results of careful experimentation to evaluate the effect of experience with these tools on decision makers' perceptions of the decision environment. The research hypothesis is that if the use of this tool broadens perspectives to a more global and long-term outlook, then the quality of decision making should be enhanced.

Strategic issue management is the conceptual frame underlying this study. Strategic issues are circumstances, internal or external to the firm, that 1) have the possibility of having substantial impact on the organization's overall performance, 2) are uncertain in that the various possible outcomes associated with the issue suggest differing strategies should be implemented, and 3) are controversial in that reasonable people take different positions concerning the most appropriate action to take. Strategic issue management decreases uncertainty through information and issue interpretation, and defines issues for ease of problem resolution. It comprises the following steps: issue identification, formal issue definition, preliminary issue model development, model revision, and data collection. The strategic issues model provides a clear definition of the issues and facilitates the strategic decision making process. This research focuses on issue identification and on an application of advanced information management tools to aid decision makers in the US soybean value chain.

A system dynamics model is developed and employed in this study to explore future scenarios for global protein consumption. The model estimates potential human appetite for six agricultural commodities (beef, pork, poultry, fish, fats and oils, and vegetable protein), on a global basis (with the

---

[1] Presented at the 2001 Annual Meeting of the Western Coordinating Committee for Agribusiness, Las Vegas, Nevada, June, 2001.

[2] This material is based upon work supported by the Illinois Soybean Program Operating Board (ISPOB) under ISPOB Award Number: 98-ISPOB-24-210-2. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the ISPOB.

[3] The authors are, respectively, Director, National Soybean Research Lab and holder of the Soybean Industry Chair in Agricultural Strategy; postdoctoral research associate; and Associate Professor of Agricultural Management; all at the University of Illinois at Urbana-Champaign, USA.

world divided into eight geographic regions), and annually for the years 2001 to 2025. The model also tracks malnutrition by region. Output from the model is presented using three-dimensional, dynamic information display software.

The research project was developed as a strategic decision aid for the Illinois Soybean Checkoff Board. However, to make the experimental results more generalizable, an intervention was conducted with small groups of decision makers from throughout the soybean industry. A total of 121 decision makers from the soy industry value chain participated in the study.

Research Goals

This research focuses on how use of advanced information technology can alter perceptions of the decision making environment in a specific setting, the soybean industry. To do so, the study reports upon the development of a sophisticated modeling framework, that includes a complex simulation model and three dimensional visualization of the model results, and presents initial findings evaluating the effect of use of these tools on decision makers' perceptions of the decision environment.

Specific Problem Setting

Although the approach employed here has general applicability, the model and visualization tool were developed for a specific purpose. That purpose is to enhance the confidence of an organization's decision makers relative to investment decisions regarding strategic marketing and research. The specific organization is the Illinois Soybean Program Operating Board (ISPOB), a quasi-public sector organization, which invests in soybean research and market development for Illinois soybean producers. As such, ISPOB faces many similar challenges of a private firm regarding technological innovation decisions.

ISPOB is part of a system whereby soybean producers voluntary tax themselves to fund efforts in domestic and international market development and research. Although established through congressional action and administered through the US Department of Agriculture, the national and state organizations (such as ISPOB) operate with considerable decision autonomy. Total funding nationally for the organizations varies between $60 and $80 million annually. ISPOB's funding ranges between $12 and $14 million each year. Although professional staff is employed, decision making is the primary responsibility of an elected board of 18 soybean producers who voluntarily serve on the board.

Strategic decision making is a particular challenge in this setting for several reasons. The term of office for board members is limited to six years, so new members join the board annually. Although committed to enhancing ISPOB's success, each board member has a unique set of operational and tactical challenges that preoccupy the bulk of their attention on a daily basis. Further, short term pressures and challenges tend to demand attention and responses from the board itself. For example, currently low soybean prices and uncertainty about the societal acceptance of biotechnology are urgent concerns. Although urgent concerns, it is not clear that these developments should distract the board's strategic direction.

Complexity and pluralism are features that complicate strategic decision making for the members of ISPOB. Many of the factors that challenge these board members also are problematic for managers and board members in private sector firms and other organizations. The "tyranny of the urgent" works to distract all of us from longer run, strategic issues. And most strategic decisions are addressed in a group setting where each member of the group brings a differing set of perspectives and understandings to the decision.

The Protein Consumption Dynamics Model

To explore the potential for protein consumption on a global basis, a sophisticated systems dynamic model was developed. System dynamics has principles rooted in electrical engineering analogs applied as a problem solving methodology to managed systems. Forrester (1961) led early work in the area. In the early 1990s, Senge's (1990) emphasis on system thinking as a key to learning organizations renewed academic and popular interest in system dynamics. In recent years, system dynamics has been extensively employed to represent and examine complex management problems in a variety of business settings (Morecroft and Sterman, 1994; Roberts, et.al., 1994). Here mental maps and structures based upon human expertise and knowledge are integrated into model frameworks along with quantitative relationships (Checkland, 1981; Coyle, 1998; Jackson, 1991). Learning through feedback is a key conceptual underpinning of system dynamics (Sterman, 1994).

The Protein Consumption Dynamics model developed for this study tracks the estimated appetite for six agricultural commodities (beef, pork, poultry fish, fats and oils, and vegetable protein), on a global basis (with the world divided into 8 geographic regions), and annually for the years 2001 to 2025. The model also tracks malnutrition by region.

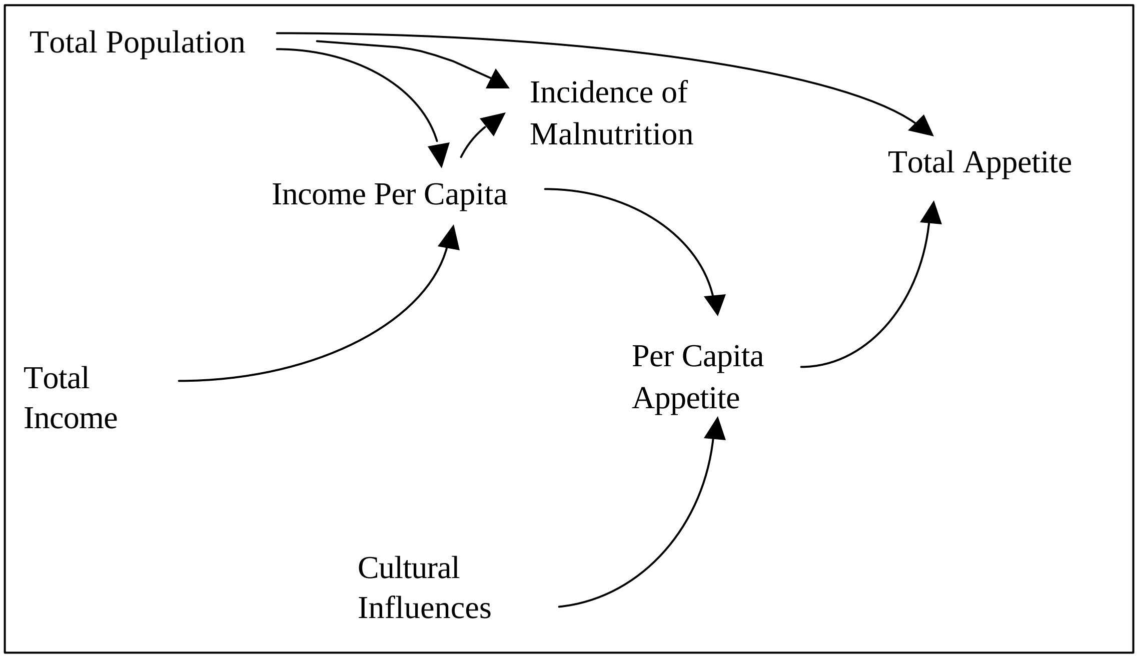
Model Characteristics: For this analysis, eight regions are defined to be relatively homogeneous in terms of income, income growth levels, and food consumption patterns. These regions are:

* China,
* East Asia,
* The Transition Economies (Eastern Europe, Former USSR, and Turkey)
* Latin America,
* West Asia and North Africa (WANA),
* OECD countries (the United States and the other developed nations),
* South Asia, and
* Sub-Saharan Africa.

The model is based upon historic relationships relating food consumption and malnutrition to per capita income by region. The basic assumption is that individual consumption of agricultural commodities is primarily driven by per capita income, at least at low and modest levels of income. For each region, econometric relationships were estimated between the consumption of each of the agricultural commodities and per capita income. Also econometric estimates of the relationship between malnutrition and per capita income were developed.

The model approach employed is called system dynamics, a powerful tool for analyzing complex settings subject to change. The specific software used is called PowerSim. Figure 3 illustrates the relationships made explicit in the system dynamics model. Each year the region's income and population grow based on specified rates. Then that year's per capita income is calculated. The effects of regional cultures and dietary preferences are reflected in the regionally specific econometric relationships estimated between income and food consumption. Therefore, the effect of per capita income and cultural influences are combined to develop estimates of consumption and malnutrition for each region. These per capita estimates are then multiplied times the appropriate population estimates for each region to compute totals.

Figure 3. Relationships underlying the Protein Consumption Dynamics model.



The model framework requires projections of future income and population growth for each region. Population estimates employed in the model are based on projections of the World Bank and the Food and Agricultural Organization (FAO) of the United Nations. These organizations provide alternative projections that describe high, medium, and low rates of population growth.

To explore alternatives with decision makers, a scenario analysis capability is included. Because of bounded rationality (or limits on cognitive capacity), models and scenarios are useful to help decision makers narrow the scope and therefore better comprehend the complexity of their environment. Scenario analysis differs from other forecasting in that it is more descriptive, qualitative and contextual; and that it identifies plausible possible futures. "Scenarios also provide a common means for everyone in the company to think about the future that takes into account many uncertain factors (some of which are qualitative) in a flexible, although estimative, way," (Mason, 1994:66). By focusing on only a small number of potential futures, decision makers will be able to more fully explore the implications of decisions they make today in relationship to these various futures scenarios**.** The three scenarios used with decision makers in this study are:

- Base Case: employs population growth projections consistent with World Bank and FAO medium level projections and income growth projections consistent with those of recent history.
- Lower Population Case: incorporates population growth projections consistent with World Bank and FAO low growth projections and the same income growth projections as in the base case.
- Lower Income Case: uses the population projections of the base case and income growth rates that are 50 % as large as those of the base case.

The Visualization Tool

The capability to produce large amounts of data is both a strength and a weakness of the simulation approach. In the case of the PCD model, estimates are available for 8 regions for each of 25 years for the six agricultural commodities and for two measures of undernourishment. And it is essential that it is possible to compare each scenario value with current and historic values and across the other two future scenarios.

“Visualization—combining computer graphics, computation, communication, and interaction—is invaluable for changing data into information, designing products and supporting complex decision making,” (Brown 1997:1; also see Rheingans & Landreth 1995). Because of recent advances in computing power, visualization capabilities are now becoming available for users of workstations and personal computers that were only available on supercomputers just a few years ago**.** Visualization enables understanding and communicating research results to other researchers and the general public. It helps shape public policy by improving understanding regarding potential outcomes and the relationships between multiple variables (Orland et al, 1997).

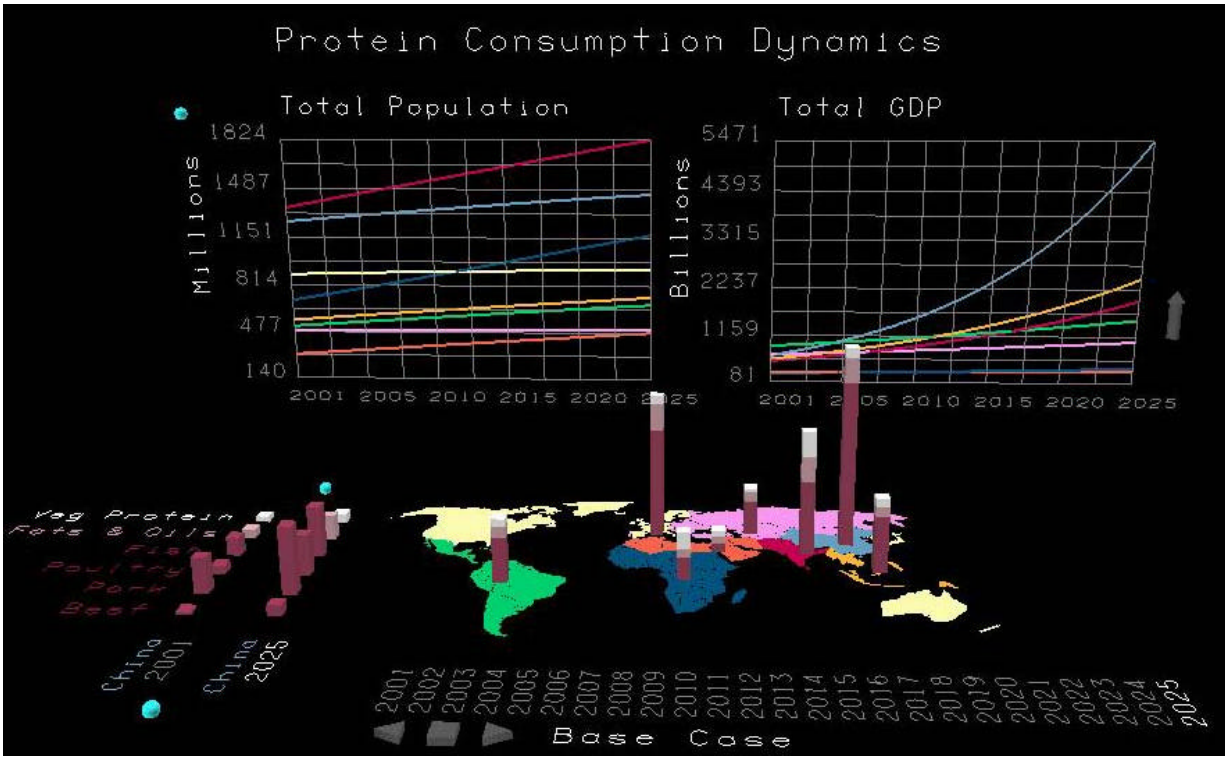
Visualization should make it easier to see and understand the interrelationships within the multitude of information typically produced in simulations. Hopefully this understanding will enable decision makers to more full comprehend their environment. Results from the PCD system dynamics model are displayed using Visible Insights’ 3-dimensional visualization tool, In3D. Selection of this particular tool was done in collaboration with visualization experts at the National Center for Supercomputing Applications at the University of Illinois based upon the decision making needs noted above as well as the typical programming considerations.

Figure 4 is a photograph of the visualization model. Clearly a single, static black and white photograph cannot completely convey the impact of the visualization. The following brief discussion highlights a few of the features of the tool:

- The visualization screen shown in Figure 4 is comprised of four “sections”.

    - ❖ The regional population and GDP totals are positioned on the back wall of the visualization. These can remain visible as output values are displayed to allow the observer to continually link back to the driving forces in the simulation.

Figure 4. Visualization of the results of the Protein Consumption Dynamics model



- ❖ Each region of the world is shown on the back-right area of the "floor" of the visualization. Color coding of the regions is linked to the population and GDP totals and to the comparison section of the visualization.

- ❖ The front-right area of the "floor" displays a list of the years from 2001 to 2025.

- ❖ The left part of the "floor" contains comparison bar charts where the user can compare output results across time or across scenarios for the six commodities or for the undernourishment variables.

- A key feature of the visualization is animation. Each of the regions on the world map contains a tri-colored bar which represents the (potential) demand for the various commodity groups. (The lower (and darkest) segment of each bar shows the total for meat and fish, the middle segment shows fats and oils, and the top (and lightest) segment indicates vegetable protein.)

  - ❖ As the model animates through time, the size of the bars changes to reflect how the specific population and income growth scenario affects potential appetite on a region-by-region basis.

  - ❖ Movement through time is shown by highlighting the list of years at the front of the world map. The presenter of the visualization controls the animation by selecting the scenario and clicking on the appropriate arrow at the front of the floor. By selecting the box between the arrows, the simulation can be stopped at any year. (In Figure 4, results for the base case are being shown and the highlighting of the year 2025 denotes that the levels of the bars indicate values for that year of the simulation.)

- The visualization also allows results for individual regions and specific commodities to be explored in more detail (the area on the left). The entire screen can be tilted on end so that the viewer can more easily observe the relative height of the two rows of bars shown in this section. In Figure 4, the bars represent estimates for China and the comparison is between years for that region in the Base Scenario. Similarly comparisons can be made between regions and between scenarios.

- A feature not shown in Figure 4 facilitates comparison across scenarios. Two bars can be displayed in each region, where each bar indicates a differing scenario. Then the animation will track the growth of each bar in each region separately, automatically comparing results across the scenarios of interest.

- Although also not shown in Figure 4, simulation results for the number of undernourished and the proportion undernourished can be shown in similar fashion to the commodity appetite estimates. The bars for commodity appetite now displayed in Figure 4 are simply replaced by corresponding bars for the undernourishment variables.

The initial public demonstration of the visualization capability was at the Global Soy Forum '99, a soybean industry event in August, 1999, attended by nearly 2,000 sector decision makers from 66 nations. The visualization tool and the PCD model were a key part of the opening keynote session of the event to provide a common reference point regarding future protein for that four day event. Since then the tool has been used numerous times in public presentations and small group strategic discussion sessions. Experience to date indicates that four key implications typically will be identified and form the basis for further strategic discussion:

1. There is an important disconnect between some of the industry's key skills and capabilities and those it will need in the future. The industry's growth over the last 25 years occurred mainly in the OECD countries. Therefore its marketing and policy expertise are heavily focused on the needs of customers in those regions. However, that region is unlikely to be the source of significant volume growth in the future.

2. With income growth, the indicated appetite for animal protein (particularly in the China, East Asia, and South Asia regions) grows substantially. However, the capability to actually produce and deliver the necessary products may not develop to satisfy the projected appetite for biologic and policy reasons. This may offer more potential for vegetable protein, however.

3. Projected growth in appetite is relatively robust with respect to population growth but is more sensitive to income growth. Estimates of projected appetite decline only slightly between the base case and the lower population case as higher per capita incomes in the latter case nearly offset the declines due to a smaller population. However, estimates fall significantly between the base case and the lower income case.

4. Even with optimistic income growth, malnutrition in the Sub-Saharan Africa and WANA regions persist at frightening levels. With lower income growth, malnutrition intensifies in other areas of the world as well. Therefore, humanitarian needs for food is likely to be a fixture of the next 25 years. Historically, the soybean protein complex has not been a significant component of humanitarian food responses. For moral and business reasons, strategies that heighten the industry's role in humanitarian responses warrant careful consideration.

Experimentation

More interestingly for the topic of organizational learning, a set of small group sessions with industry decisions makers has been conducted as careful experiments to discern the effects on learning that experience with these capabilities have. These groups have included the members of the ISPOB who commissioned the work. In addition, at the request of ISPOB, similar sessions have been held with decision makers from throughout the soybean value chain. In doing this, the goal is to provide a common platform for learning to occur, not only within ISPOB, but also with decision makers in allied organizations and from firms at other levels of the value chain. Each of these small group sessions typically is conducted with 4 to 8 industry participants. Following Creswell (1994), we are more concerned in this study with expert perceptions than in statistical accuracy. Therefore, the experimentation is with a number of hand-selected subjects who have special knowledge of key issues within the soybean industry. The subjects received a treatment that includes both tabular and visualized information.

Three pretests were conducted in developing the questionnaire used in the study. The first pretest was with 29 Midwest veterinarians participating in the Executive Veterinary Medicine Program, of the University of Illinois, Urbana-Champaign. The second pretest was conducted with ten producers and managers in the Illinois Soy Leaders group. The final pretest was conducted with three faculty members from the College of Agricultural, Consumer, and Environmental Sciences, University of Illinois, Urbana-Champaign.

As a result of the pretests, the nature of the questions did not change significantly but the number of questions was reduced and wording changed slightly on the others. A self-evaluation question was added after the pretest. In addition, the revised questionnaire was reviewed by consultants at the Survey Research Institute of the University of Illinois, and received positive comments with only a few additional changes.

Data are collected through *before* and *after* questionnaires that elicit the strategic issues map from participants (Doyle, 1998). Subjects also engage in a group discussion regarding what they have learned from the exercise. This discussion occurs after administration of the second questionnaire. The analysis looks at how the individual's maps change, as well as how maps within and between groups change. Content analysis software (Nud*ist VIVO) is used to evaluate differences between the *before* and *after* questionnaires. Transcripts of the group discussions are also analyzed.

The *before* questionnaire contains 4 questions. Question 1 asks for questions the respondents have regarding the future of the industry. Question 2 asks for the key issues to be worked on in the industry. Both questions 1 and 2 are taken from Grinyer.[4] In addition, both of these questions contain a part 'b' which asks the respondents to provide a ranking of his/her responses. Question 3 requires the respondent to make an explicit decision regarding research funds allocation, (similar to Wilson, et al's [1989] on-line judgment). Question 4 asks for a self-evaluation of how confident the respondent is about the previous decision. The questionnaires are number identified for internal tracking purposes, with the *before* and *after* questionnaires having the same id number for a given subject.

The *after* questionnaire has the same questions 1, 2 and 3. Question 4 solicits the decision criteria that influenced the previous decision (following Wilson et al, 1989). Question 5 of the *after* questionnaire is identical to Question 4 on the *before* questionnaire. Finally, information on a few demographic factors are collected.

Initial Analysis

Psychology and organizational behavior scientists struggle with how to measure the decision making process. One attractive approach is to focus on the decision maker's cognitive map (perception) of the problem environment (Huff 1990). Cognitive maps help decision makers organize the over abundance of information to which they are exposed. The cognitive processes associated with strategy formation (and decision making) are based on maps that individuals have of the world around them. These maps can represent the individual's interpretations about the world (Mintzberg et al, 1998).

A qualitative research methodology is used to explore the effect of the modeling tools on cognitive maps. Qualitative research exhibits the following characteristics:

---

[4] These two questions were modeled after work done by Peter H. Grinyer and other staff members at the, Management Department, University of St. Andrew, Scotland. For more information on their work see Check-Teck, et al, 1992.

1. Data source is in a natural setting with the researcher as the key instrument
2. The research is descriptive in nature
3. Process is more important than outcome or product
4. Induction is used to analyze the data
5. Major focus is on meaning or participant perspective (Bogdan & Biklen, 1992)

Accordingly this effort describes how the cognitive maps of soy industry decision makers are influenced with the use of sophisticated visualization of information (2). It is concerned with the nature of these decision makers' perceptions (5), which are captured during interaction with subjects (1). Content analysis (4) is used to evaluate the changes in perceptions (3).

Data collection for this study took place from January to April of 2000. Primary data are collected through the use of a *before* and an *after* questionnaire designed to solicit subjects' cognitive maps (or perspectives on the soybean industry).

Table 1 provides demographic information for the subjects of the experiment. The gender mix is heavily male dominated, which is representative of the industry. Most of the subjects have at least some post-secondary education, with nearly 65 percent having college degrees. The subjects are spread across a number of sectors including producers, researchers, service providers and agribusiness students (undergraduates and graduates).[5]

Table 1. Subject Demographics for the Protein Consumption Dynamics Experiments

Demographic Category	Sub-category	Number of Participants
Gender		
	Male	93
	Female	28
Education		
	High School	4
	Vocational/Associates	13
	Some College	26
	Bachelor's Degree	23
	Master's Degree	26
	Doctoral Degree	29
Age	Average	38.5
Occupation		
	Producer	26
	Researcher	28
	Service Provider	33
	Agribusiness Student	34
Total		121

A key comparison for the analysis is the change in the *before* and *after* answers to the question asking the respondents to identify key future issues for the sector. Table 2 lists 17 responses mentioned frequently. (These responses were among the top 10 listed in either the *before* and *after* questionnaire.) Interestingly the responses can be grouped into three categories. One group of six responses was

[5] Agribusiness students were included for two reasons. First, many of the students are from farms where soybeans are produced. Second, many of these students will be future decision makers of the industry.

considered to be relatively important in both the *before* and *after* questions. A second group of six was listed by many more respondents for the *after* questionnaire than for the *before* version. Conversely five issues were listed by substantially fewer respondents for the *after* questionnaire than for the *before* version.

	Before Questionnaire			After Questionnaire			
Strategic Issues	Frequency	Percent of respondents identifying the issue	Rank	Frequency	Percent of respondents identifying the issue	Rank	Change
Category A. Increase in Rank							
Income growth	1	0%	76	33	27%	10	66
Population growth	2	2%	68	35	29%	9	59
Malnutrition	6	5%	55	41	34%	6	49
Meeting demand	8	7%	44	37	31%	8	36
Developing countries	9	7%	35	38	31%	7	28
New geographic markets	18	15%	14	49	41%	2	12
Category B. Stable Rank							
Global demand	22	18%	9	47	38%	5	4
Marketing	28	23%	6	48	40%	3	3
New products	29	24%	5	48	40%	3	2
Soy foods	40	33%	3	64	53%	1	2
General research	22	18%	9	29	24%	11	-2
Health benefits	25	21%	8	24	20%	13	-5
Category C. Decrease in Rank							
New uses[6]	45	37%	1	22	18%	18	-17
Biotechnology acceptance	44	36%	2	18	15%	21	-19
Price o f Soybeans	22	18%	9	13	11%	32	-21
Biotechnology impact	27	22%	7	12	10%	36	-23
GMO	37	31%	4	15	12%	29	-25

Table 2. Significant Strategic Issues Identified in the Before and After Questionnaires

The composition of the latter two groupings is of particular interest. Issues among the group mentioned much more frequently after exposure to the study information relate to long term demand enhancing factors, building demand in developing nations not currently emphasized in marketing, and responding to malnutrition. Conversely, issues among the group mentioned much less frequently tend to be shorter run in nature. This suggests that involvement with the model results and the visualization successfully raised the participant's awareness and sensitivity to longer run strategic issues.

A second set of results (Table 3) examines the participant's preference as to research allocation decisions after seeing the visualization model. In the *before* questionnaire, respondents focused more on new product development and developing new markets. In the *after* questionnaire, the group directed even more resources toward developing new markets and shifted away from new product development and genetics research. In the *after* questionnaire, the subjects still recognized the importance of the local issues, but this perspective expanded to include more global and long-term issues.

Research Area	Mean	Change from *Before* Questionnaire
Production Research	15.99	-0.04
New Product Development	19.28	-2.54
Marketing Research: Strengthen Existing Markets	18.98	+1.07
Marketing Research: Develop New Markets	25.08	+3.33
Genetics Research	16.43	-2.27
Other	4.25	+0.45
Total	100.00	0.00

Table 3. *After* Questionnaire responses on Preferred Research Budget Allocation

Results indicate that the groups have more consistent cognitive maps of the decision making environment. And according to Choo (1998), developing a shared meaning influences both learning and decision making.

Summary

This paper reports upon the use of advanced information tools to enhance individual and organizational learning in a specific industry setting. Two components comprise the system. One is a complex system dynamics model that tracks estimated consumption annually (for the years 2001 to 2025) of six protein commodities in eight regions that encompass the world. The system dynamics model is designed so that alternative scenarios of the future can be examined using population and income projections of the World Bank and the UN's Food and Agricultural Organization. The second component is a 3-dimensional visualization tool that summarizes considerable amounts of information through graphics, color and animation.

The research project was developed as a strategic decision aid for the Illinois Soybean Checkoff Board. However, to make the experimental results more generalizable, an intervention was conducted with small groups of decision makers from throughout the soybean industry. A total of 121 decision makers from the soy industry value chain participated in the study. Results indicate that decision makers' perceptions changed after exposure to visualized presentation of complex modeling results.

The experimental results indicate that decision makers' perceptions changed after exposure to visualized presentation of complex modeling results. Decision maker perceptions changed to reflect more long-term thinking about the industry, indicating that the visualized presentation of complex information can influence strategic behavior. After exposure to the information, the greater focus on more demand-oriented issues such as the marketing of existing products in expanded markets is indicative of some of the changes in cognitive maps held by study participants. Likewise, the use of soy products to alleviate malnutrition became a more important strategic issue, whereas historically human nutrition needs received little strategic attention. This change in focus suggests the need for redirection in both research and market development agendas.

Sources:

Bogdan, R. C. and S. K. Biklen, 1992, *Qualitative Research for Education: An Introduction to Theory and Methods*, Boston: Allyn and Bacon.

Brown, J. R., 1997, "Visualization and Scientific Applications," in Earnshaw, R., J. Vince, ad H. Jones, *Visualization and Modeling*, San Diego: Academic Press. 1-11.

Check-Teck, F., Grinyer, and P. McKiernan, 1992, "Strategic planning in the ASEAN region," *Long Range Planning*, v. 25, Oct. 1992, p. 80-90.

Checkland, P.B., 1981, *Systems Thinking, Systems Practice*. Chicherster, UK: Wiley.

Choo, C. W., 1998, *The Knowing Organization: How Organizations Use Information to Construct Meaning, Create Knowledge, and Make Decisions*, Oxford: Oxford University Press.

Coyle, R.G., 1998, The Practice of System Dynamics: Milestones, Lessons and Ideas from 30 Years Experience. *System Dynamics Review*, v. 14, p. 343-365.

Creswell, J. W., 1994, *Research Design: Qualitative and Quantitative Approaches*, Thousand Oaks, California: Sage Publications, Inc.

Doyle, J. K., 1997, "The Cognitive Psychology of Systems Thinking," *System Dynamics Review*, 13(3):253-265.

Forrester, J.W., 1961, *Industrial Dynamics*. Portland, OR: Productivity Press.

Kreps, D. M., 1990, *A Course in Microeconomic Theory*, Princeton: Princeton University Press.

Huff, A. S., (ed), 1990, *Mapping Strategic Thought*, New York: John Wiley & Sons, Inc.

Jackson, M.C., 1991, *Systems Methodology for the Management Sciences*. New York: Plenum Press.

Mason, D. H., 1994, "Scenario-based Planning: Decision Model for the Learning Organization," *Planning Review*, April/March, 6-11.

Mintzberg, H., B. Ahlstrand, and J. Lampel, 1998, *Strategy Safari: A Guided Tour Through the Wilds of Strategic Management*, New York: The Free Press.

Morecroft, J.W.D. and J.D. Sterman, 1994, *Modeling for Learning Organizations*. Portland, OR: Productivity Press.

Orland, B., C. Ogleby, I. Bishop, H. Campbell, and P. Yates, 1997, "Multi-media approaches to Visualization of Ecosystem Dynamics," Internet WWW page, at URL: <http://imlab9.landarch.uiuc.edu/papers/>.

Roberts, N., Andersen, D.F., Deal, R.M., Garet, M.S., and W.A. Shaffer, 1994, *Introduction to Computer Simulations: A System Dynamics Modeling Approach*. Portland, OR: Productivity Press.

Rheingans, P., and C. Landreth, 1995, "Perceptual Principles for Effective Visualizations," in Grinstein, G., and H, Levkowitz, Eds., *Perceptual Issues in Visualization*, Berlin: Springer, 59-73.

Senge, P.M., 1990, *The Fifth Discipline: The Art and Practice of the Learning Organization*. New York: Currency-Doubleday.

Sonka, S., L. M. Cloutier, and M. Banik, 1995, *Organizational Learning Models of Strategic Alliances*, Working Paper presented at the American Agricultural Economics Association Organized Symposium on Using Firm-Level Models for Strategic Management Research in Agricultural Economics.

Sterman, J. D., 1994, "Learning in and About Complex Systems," *System Dynamics Review*, 10:291-330.

Wilson, M. G., G. B. Northcraft, and M. A. Neale, 1989, "Information Competition and Vividness Effects in On-Line Judgments," *Organizational Behavior and Human Decision Processes*, 44:132-139.