Informing Mental Models for Strategic Decision Making with ERPs and the Balanced Scorecard: A Simulation-Based Experiment

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Abstract

To make efficient, effective decisions, organizational leaders use strategic frameworks to see how well the organization is accomplishing its goals and implementing its strategies. These strategic frameworks filter great quantities of information about different parts of the organization into a few, critical elements. To process this vast amount of information, these frameworks depend increasingly on sophisticated information systems. Prior behavioral decision making research supports this practice, suggesting that guiding cue selection and increasing information credibility enhance decision performance. Common practice, however, focuses primarily on increasing information credibility and not enhancing cues. This research develops a theoretical model to explain how the decision maker's understanding of the decision context is influenced by the strategic framework and by the information processing system. This research tests the theoretical model with a simulator-based experiment, where 118 MBA and MEng students run a wireless telecommunications firm.

Key words: experiment, mental model, ERPs, balanced scorecard, simulation

Introduction

We inform decision makers to help them make efficient, effective decisions – decisions that lead to positive results. In this direction, decision makers use strategic frameworks, which inform them about how well the organization is accomplishing its goals and implementing its strategies. These frameworks guide the decision maker by making explicit the key strategic elements and how they relate. For example, the strategic framework economic value added (EVA) focuses the decision maker on shareholder value creation (the goal) through its components of revenues, operating expenses, cash taxes, and capital charges (the implementation). To inform the decision maker about what is happening in the real world of the organization, these strategic frameworks filter great quantities of information about different parts of the organization into a few, critical elements These critical elements tend to focus on the organization's stated goals and actions (i.e., shareholder value creation). To process this vast amount of information, for effective and efficient decision making, these frameworks depend increasingly on sophisticated information systems, such as SAP's Strategic Enterprise Management module (SAP, 2000).[1] These modules use best practices in strategic management to select the information that best represents the status of the entire organization (for examples using economic value added and the balanced scorecard, see PeopleSoft, 2000; SAP, 1999).

Belief in the potential benefit is evidenced by the heavy investment in these systems. In 1997, over 20,000 companies around the world spent over $10 billion on these sophisticated enterprise systems (Martin, 1998). By 1998, over 40% of companies with revenues exceeding $1 billion had begun to use them (Caldwell and Stein, 1998). Even with such intense investment in information, research indicates that firms currently use them primarily to replace previous information collection activities, and very few use them to manage the business more efficiently (Davenport, 2000; Vandenbosch and Higgins, 1996). Whether these systems lead to increased decision effectiveness or efficiency is still under debate (Sharda et al., 1988; Todd and Benbasat, 1999). So, though the solution seems obvious – buy a big information system with a great framework – the value that selecting specific strategic information adds to decision making is not clear to or understood by many decision makers. These decision makers often lack the experience (empirical base) from which to evaluate the value added and the framework (theoretical base) with which to communicate it.

Experimental data on the value these information systems provide would increase the ability of leaders to appraise them. A theoretical model explaining the experimental data would provide the framework with which to communicate the value added. To increase credibility, the experiment should include realistic strategic decisions. To increase communicability, the theoretical model should be simple and complete.

This research develops a theoretical model to explain how the decision maker's understanding of the decision context is influenced by the strategic framework and by the information processing system. This research tests the theoretical model with a simulator-based experiment, where graduate students run a wireless telecommunications firm. This paper presents the results.

Influencers of Strategic Mental Model Similarity

For this research, the unit of analysis is the decision maker. The context is strategic resource allocation at the top of a large organization. In this setting, the human-computer interaction literature describes five elements related to informing the decision maker about the decision context (Norman, 1983):

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[1] An Andersen Consulting 1999 study (Andersen, 1999) surveyed 200 CEOs of companies that had implemented an integrated information system, also referred to as ERPs (Davenport, 2000). This study reports that the top three reasons why CEOs invested in an integrated information system were (% that stated this): (1) to improve information accuracy and availability (67%); (2) to improve management decision making (61%); (3) to reduce cost/improve efficiency (51%).

1. the target system
2. the conceptual model of the target system
3. the system image
4. the user's mental model of the target system
5. the scientist's conceptualization of the mental model.

The target system is the organizational decision context. The conceptual model of the target system is a teaching tool created by the decision maker's advisors or teachers as an accurate, consistent, and complete representation of the target system. The system image is the image of the target system that is seen by the decision maker – it is the strategic framework filled with data that the decision maker sees. The system image may or may not be consistent with the conceptual model of the target system. The user's mental model of the target system is created as the decision maker interacts with the target system or system image (Craik, 1943). The user's mental model might not be equivalent to the conceptual model. Finally, the researcher extracts a conceptual model of the subject's mental model (Staggers and Norcio, 1993). A model, as used here, is defined as a representation of structure (cf Oxford English Dictionary), focusing on the component parts (elements) and how they interrelate (relations) to make the structure function.

The strategic framework and supporting information systems exist to inform the decision maker about how well the organization implements and achieves its goals. Therefore, the intent is for the decision maker's mental model to accurately match the organization's decision context. In that sense, the theoretical model in this research (see Figure 1) proposes that *System Image Structural Similarity* (SISS) measures how well the system image structure correlates with the target system, approximating the integrity of the system image. Structural similarity is measured in this research as the proportion of structural elements and relations shared between the information selected and that of an expert map of the decision context (Mathieu et al., 2000; Schvaneveldt, 1990). In the strategic setting, *SISS* measures how well the strategic framework (system image) describes the organizational decision context (target system).

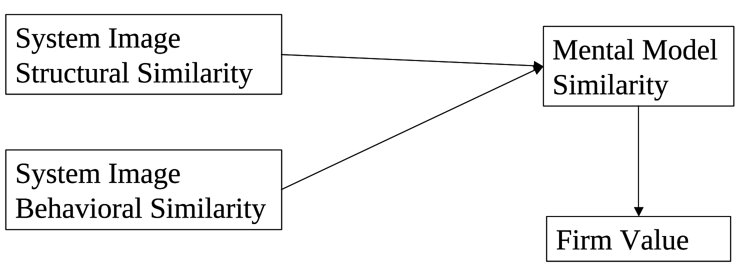

Figure 1: The Research Model

Mental Model Similarity measures how well the user's mental model of the target system correlates with the target system (Mathieu et al., 2000). In the strategic setting, this captures how well the decision maker's understanding (user's mental model) correlates with the organizational decision context (target system). Mental models are commonly used in the behavioral literature, and most often described in terms of their elements and their interrelationships (Borgman, 1999; Craik, 1943; Doyle and Ford, 1998; Johnson-Laird, 1983; Mathieu et al., 2000; Staggers and Norcio, 1993; Stout et al., 1999). Similarity is measured, in this research, as the proportion of elements and relations shared between the decision maker's mental model and that of an expert map of the decision context (Carley and Palmquist, 1992; Rowe and Cooke, 1995).

System Image Behavior Similarity (SIBS) measures how the information in the *System Image* behaves compared to the target system. *SIBS* measures the accuracy, timeliness, and consistency of the information, provided by the information system from the target system, about the effectiveness and efficiency of the decision maker's previous decisions. Behavioral research in dynamic decision making suggests these three attributes greatly influence decision performance (Einhorn and Hogarth, 1986; Kleinmuntz, 1993; Sterman, 1994). Previous research across many other disciplines has also identified these attributes as key attributes in information processing (Barua, Kriebel, and Mukhopadhyay, 1989; Davenport, 2000; Feltham, 1968; Fuerst and Cheney, 1982; Huang, Lee, and Wang, 1999; Zmud, 1978). Similarity is measured, in this research, as the degree to which a specific information system matches the best-in-class status for each attribute. *Firm Value* measures the economic value created by the firm.

The relationships among the variables in the theoretical model have been well studied in the behavioral decision making literature. Research in social judgment theory has studied how selecting more predictive cues (elements and relations) from the background (target system) influences judgment accuracy, which is related to *MMS* (Hammond, 1955; Hursch, Hammond, and Hursch, 1964). This research hypothesizes that *SISS* positively influences *Mental Model Similarity*. This also finds support in the decision support system literature on decision aids (Cats-Baril and Huber, 1987; Kleinmuntz and Schkade, 1993; Silver, 1990; Todd and Benbasat, 1999).

Behavioral research in dynamic decision making has found that people are very susceptible to noisy feedback, leading to much worse than naïve behavior (Einhorn and Hogarth, 1986; Kleinmuntz, 1993; Moxnes, 1998; Paich and Sterman, 1993; Sterman, 1989). These studies suggest *SIBS* positively influences *Mental Model Similarity*. Empirical decision support research shows that as the information accuracy, timeliness, and consistency degrade, decision maker confidence in the information falls, thus they are less likely to use it (Fuerst and Cheney, 1982).

Behavioral and strategy research link *Mental Model Similarity* with improved performance on multiple organizational objectives (Bantel, 1993; Bourgeois, 1980; Mathieu et al., 2000; Porter, 1980; Snow and Hrebiniak, 1980). These studies suggest *Mental Model Similarity* positively influences *Firm Value.*

This research contributes to previous behavioral research by providing an integrated theoretical model and new, more rigorous measurement tools. Previous behavioral research provided rigorous analysis of probable decision rules used by subjects, inferring the mental model that generated it. This paper provides a tool to measure that mental model, which now permits research into whether the scientist's conceptualization of the user's mental model was able to generate the observed behavior.

This research also explains some apparent inconsistencies in the decision support system literature on the effect of *SIBS* on decision making performance (Sharda et al., 1988; Todd and Benbasat, 1999). Most of the research manipulated *SIBS* and not *SISS*. For tactical decisions, which are well structured, increasing *SIBS* improves performance, because the target system is well understood and easy to describe (well-structured). For strategic decisions, which are ill structured, increasing *SIBS* may not improve performance, because the target system is not well understood and is difficult to describe (ill-structured).

Finally, this research contributes to the mental model literature by applying the methods and tools to more complex, social systems. Early mental model research focused on physical systems, like calculators. Recent research has delved into team mental models of jet fighters, still focusing on managing physical systems.

While the research cited above examines pieces of the research model, often with simple tasks, this paper contributes a theoretical model that integrates the pieces and tests the theory with a task that more closely reflects strategic resource allocation.

Research Questions

In summary, this research addresses the questions:

- Is strategic *mental model similarity* influenced by *system image structural similarity* and *system image behavioral similarity*?
- Does strategic *mental model similarity* influence decision performance?

In practical terms, these questions ask whether current, best-practice strategic frameworks and more accurate, timely, consistent information improve the decision maker's understanding of the decision context.

The Task: Strategic Resource Allocation for a Wireless Telecommunications Firm

The experimental task is to make strategic resource allocation decisions for a simulated wireless telecommunications firm every six months over a seven-year period. To test the theory presented above, the experiment will divide the subjects into four groups, altering *system image structural similarity* (low and high) and *system image behavioral similarity* (low and high). The subjects will run the firm under these different treatments in an interactive game. This interactive game or "management flight simulator" (for examples, see Moxnes, 1998; Paich and Sterman, 1993; Sterman, 1989) represents a model of a firm, its customers, and its competition. Subjects manage the firm through a period of strong growth in the market, replicating the current difficulties faced by wireless telecommunication firms (Shepard, 2000).

The model was developed with experts in wireless telecommunications, enterprise systems, and the balanced scorecard, including senior managers in three wireless telecommunications firms, academics, and strategy consultants. The model was validated using expert knowledge and data from two firms in the industry. The model parameters were then scaled to protect the confidentiality of the two firms.[2]

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[2] The elements in the model include 69 operational variables and 54 financial variables. Of the relationships, 179 were informational flows and 31 were material flows.

The model encompasses external and internal components of the supply chain, as seen in Figure 2. External components include the suppliers of parts for the switching equipment and the customers. Internal components include human resources, technology, service-supporting information technology, and financial capital.

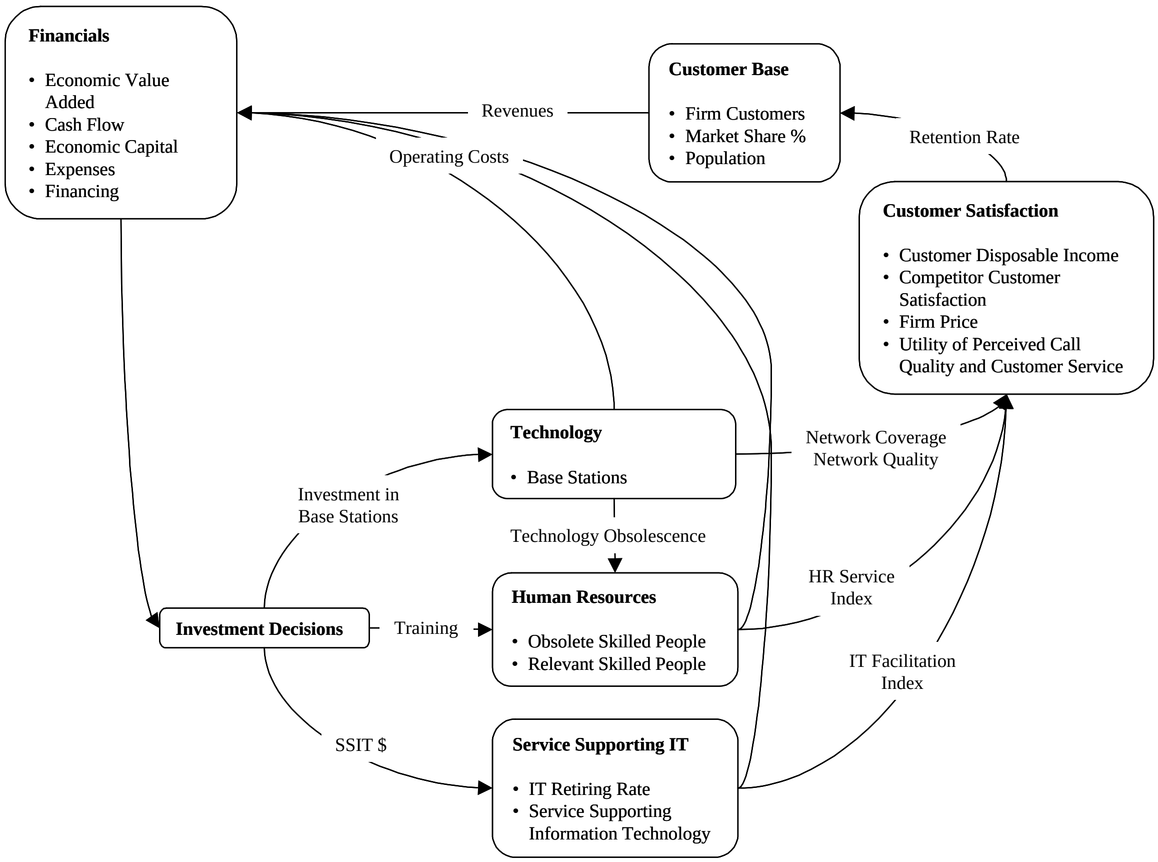


Figure 2: Overview of the Simulator Model

External Components

In the Technology component, the firm orders new base stations to be installed by external contractors. The contractors respond based on their available capacity, which is a function of the size of the overall market. On the other end of the supply chain, in the Customer Satisfaction component, the firm provides services to customers for a fee. The customer chooses to continue with the firm, if satisfied with the service provided for the price paid. Satisfaction is measured relative to both the competitive offering in the marketplace and the customer's disposable income dedicated to wireless telephone services. Satisfaction is measured as a utility function of the price paid for a perceived level of call quality and customer service. Each of these satisfiers is determined by the model endogenously, as explained in the following section. Demand for wireless services is assumed to increase linearly over the seven-year simulation period, with the customer's average disposable income for telecommunication services remaining constant. In the Customer Base component, relative Customer Satisfaction affects movement of customers between the firm and the competition.

Internal Components
Following the logic of the internal value chain, in the Technology component, the technicians maintain the base stations and switching infrastructure. The Human Resources component describes the dynamic of human resource skills as employees are hired or fired, and as they are trained or their skills are obsoleted by changing technologies. The Service Supporting Information Technology component depicts the dynamics of the information systems that support the call centers. The Financials component calculates the financial statements based on the status and flow of resources in the firm. The Investment Decisions component translates the subject's periodic capital allocation decisions on a continuous basis. The model permits hiring, firing, and training people, building new base stations, and buying new information technology. See Appendix A for the logic explaining these decisions.

Method

The subjects were 118 students in the University of Texas at Austin MBA and M.Eng. programs, taking a first-year course in Operations Management. Attendance was given as a homework assignment. The students had an average five years of work experience, ranging from one to thirteen years.

The experiment is a 2x2 design. The two independent variables are system image structural similarity (low or high) and system image behavioral similarity (low or high). This creates four cells, to which the subjects were randomly assigned.

After answering four questions about previous education and experience, the subjects read a written introduction to the case and software. This introduction corresponds to the "conceptual model of the target system," described earlier in this paper.

The subjects ran the simulator twice. Each time, they ran it over a seven-year period, reviewing performance and allocating strategic resources every six months, for a total of fourteen decision points. The subjects were instructed to run through the first simulation quickly to learn how it works, taking approximately 15 minutes. The subjects then ran the simulator a second time, for which the results were captured, allowing approximately 40 minutes. After the second run, the subjects were asked to describe their understanding of the structural elements and relationships, as described below. Allowing for 5 minutes of set-up time and 5 minutes to save the results, the total time elapsed allowed was 2 hours and 15 minutes.

The subjects were given the same initial resource conditions, the same overall firm structure, and the same competitive environment. The only differences in the four treatments were the operationalization of the two independent variables in the interface, as described below. The interface formalizes the subject's decisionmaking process, as this is the only information they receive.

The Independent Variables

Low *SIBS* was operationalized in the interface with random noise (accuracy) applied to delayed (timeliness) information. Information from different parts of the firm's supply chain have different noise and delays, creating inconsistent information (consistency) in the interface.

Low *SISS* was operationalized in the interface as a linear combination of the financial components driving profitability. High *SISS* was operationalized in the interface by grouping the cause-effect linkages of three key leading indicators of financial performance (customers, internal processes, and learning and growth). See Appendix B for the user interface screen for each treatment. For the analysis, *SIBS* and *SISS* were operationalized as depicted in Table 1.

Treatment	Treatment Description	SIBS	SISS
1	Low SIBS with Low SISS	1	1
2	Low SIBS with High SISS	1	-1
3	High SIBS with Low SISS	-1	1
4	High SIBS with High SISS	-1	-1

Table 1: Operationalization of Independent Variables

Results

Of the 118 subjects, the results for four subjects were not properly saved after the simulation run, so they were not included in the analysis. The 114 remaining were evenly distributed across the four treatments (29 in #1, 27 in #2, 29 in #3, 29 in #4).

The Dependent Variables

The subjects in the experiment develop a mental model of the simulated telecommunications firm. By providing a simulated model of the firm, this experiment provides a known entity, thus the target system is comprehensively described. To capture the subject's mental model, the dependent variable *Mental Model Similarity* was operationalized with measures of the subject's mental model. The measures were calculated from the mental model elicited from the subjects. To elicit this, the subjects followed a laddering process, where they were asked to describe their understanding of the following structural elements and relationships (see Carley and Palmquist, 1992 for an example of this process):

- Structural Elements
    - Objective function
        - The firm's goal/purpose
    - Constraints
        - Relevant stakeholders
        - Stakeholder goals
        - Value-driving resources
        - Actions

- Relationships
    - Between constraints and objective function
    - Between individual constraints
    - Between objective function and constraints

In Norman's framework, presented earlier, the subject's elicited map is the scientist's conceptualization of the user's mental model. The simulator model is the target system. *Mental Model Similarity* was operationalized with the C (closeness) statistic, a measure of the similarity of the two maps (Schvaneveldt, 1990). The C statistic (Goldsmith and Davenport, 1990) is a measure of the shared links across two different networks, ranging from 0 (low similarity) to 1 (high similarity). Recent research has provided some evidence to the reliability of the C statistic (Gualtieri, Fowlkes, and Ricci, 1996; Stout, Cannon-Bowers, and Salas, 1996).

Since the task was to operate the modeled firm, not a real firm, the subjects had no prior specific knowledge. As for general knowledge, the results showed positive, but not significant, effects for experience and education on *Firm Value*.

The dependent variable *Firm Value* was operationalized as the market value achieved by the subject. *Firm Value* was calculated as the market value added (MVA) for the seven simulated years plus the continuing value of the firm (Copeland, Koller, and Murrin, 1996, 285), which incorporates the known cash flows during the simulation and predicted value afterward.[3] Table 2 presents the results.[4]

Paired-samples t-tests were run to test for significant differences in the means for each treatment. Controlling for *SISS*, the difference in mean *Firm Value* between low and high *SIBS* is significant between Treatments #1 and #3 (t_{29}=-3.286, p<0.002) and between Treatments #2 and #4 (t_{27}=-2.696, p<0.010). Controlling for *SIBS*, the difference in mean *Firm Value* between low and high *SISS* is not significant.

Treatment #	**Description (Count)**	**Firm Value *Mean MVA***	**Standard Deviation**
1	Low SIBS with Low SISS (29)	-6.3e9	7.4e9
2	Low SIBS with High SISS (27)	-5.7e9	4.5e9
3	High SIBS with Low SISS (29)	-2.2e9	4.0e9
4	High SIBS with High SISS (29)	-2.5e9	3.6e9

Table 2: *Firm Value* for Treatments

[3] Continuing value was calculated with the long explicit forecast (Copeland, Koller, and Murrin, 1996), which takes the last three years of EVA and calculates the linear trend forward twelve years, then calculates the NPV of this stream.
[4] The negative mean MVAs reflect capital charges that exceeded profits. While many of the firms were profitable over the seven simulated years, on average they destroyed economic value, not unlike real firms. Nevertheless, there are significant differences in the degree to which the subjects destroyed value, on average.

The Hypotheses

The hypotheses developed in the beginning of the paper were tested through regression analysis. The correlation matrix for the regression analysis, in Table 3, shows a suggestive correlation between the independent variable *SIBS* and the dependent variable *Mental Model Similarity*. *SIBS* shows a significant relationship with *Firm Value*. *SISS* shows a significant relationship with *Mental Model Similarity* and not with *Firm Value*. There is no significant interaction effect of the independent variables and *Firm Value.*

	SISS	**SIBS * SISS**	**Mental Model Similarity**	**Firm Value**
SIBS	0.018	-0.018	0.154~	0.358***
SISS		0.018	0.229*	0.021
SIBS * SISS			-0.108	-0.039
Mental Model Similarity				0.221*

*** p<0.001 ** p<0.01 * p<0.05 ~p<0.1

Table 3: Correlation Matrix for Theoretical Constructs

To test whether *Mental Model Similarity* mediates the relationship between the independent variables and *Firm Value*, as proposed in Figure 1, *Mental Model Similarity* must show a significant relationship with the independent variables and *Firm Value* must be significant with *Mental Model Similarity* (Baron and Kenny, 1986). Mediation attempts to "explain how external physical events take on internal psychological significance (Baron and Kenny, 1986, 1176)."

As shown in Figure 3, regressing *Mental Model Similarity* on the independent variables ($R^2_{adjusted}$=0.069, p<0.026) showed a suggestive effect for *SIBS* (â=0.166, t=1.636, p<0.105), a significant effect for *SISS*, and no significant interaction effect for *SIBS*SISS*.[5] Regression of *Firm* Value on the independent variables ($R^2_{adjusted}$=0.140, p<0.002) showed no effect for SISS, a significant effect for *SIBS*, and a very suggestive effect for *Mental Model Similarity* (â=0.181, t=1.735, p<0.086).

Three conditions support the hypothesis that *Mental Model Similarity* mediates the effect of *SISS* on *Firm Value* (Baron and Kenny, 1986):

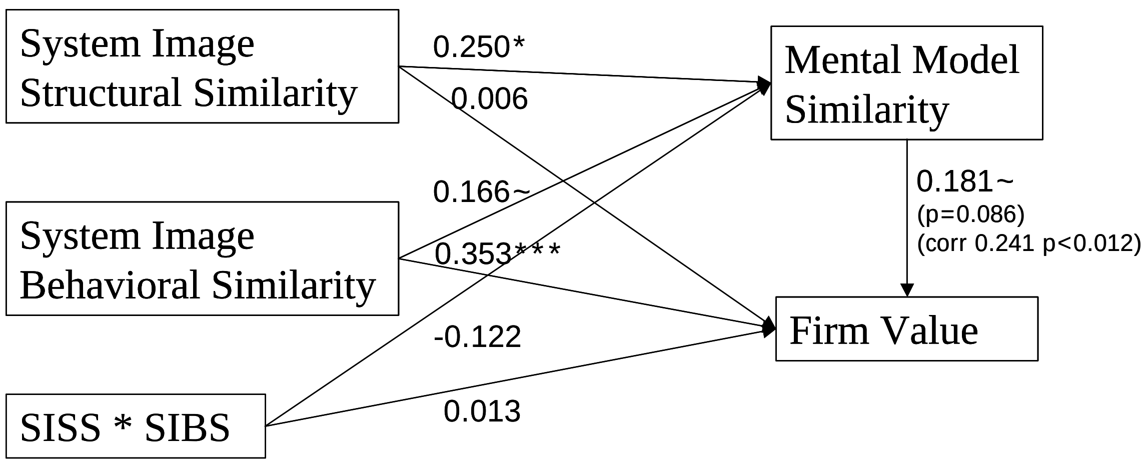
1. *SISS* significantly influences *Mental Model Similarity*
2. *SISS* does not significantly influence *Firm Value*
3. *Mental Model Similarity* significantly influences *Firm Value*

There is also support for the hypothesis that *Mental Model Similarity* mediates the effect of *SIBS* on *Firm Value* (Baron and Kenny, 1986):

[5] To control for potentially low measurement validity due to the subject's frustration with their poor performance, these analyses block on "mental model coherence" a measure of the consistency of the subject's mental model (Schvaneveldt, 1990). Only coherence levels above 0.0 are used, resulting in treatment #1 having 20 subjects, #2-22, #3-26, and #4-26.

1. *SIBS* suggestively influences *Mental Model Similarity*
2. *SIBS* significantly influences *Firm Value*
3. When *Mental Model Similarity* is added to the regression of *Firm Value* on SIBS, the influence of *SIBS* decreases and it is significant.

Combining these results for *Mental Model Similarity* with the decreasing standard deviation for higher *SIBS* and *SISS*, as seen in Table 2, seems to indicate that the subjects tended to converge in performance with increasing mental model similarity to the target system – they had more similar mental models and tended to perform more similarly.[6]



~p<0.1 *p<0.05 **p<0.01 ***p<0.001
For regression of MMS (PFCInfo) on independent variables, with MM Coherence > 0.0, R2-adj=0.069 (p<0.026).
For regression of Firm Value (MVA7 + Continuing Value), R2-adj=0.140 (p<0.002).

Figure 3: Test for Mediation of *Mental Model Similarity*

These findings (difference in means, correlation, mediation, regression) provide support for the hypotheses that *SISS and SIBS* positively influence *Mental Model Similarity* and that *Mental Model Similarity* positively influences *Firm Value*.

A closer look at the dependent variable *Firm Value* shows that while *SIBS* and *Mental Model Similarity* significantly influenced overall value created (MVA plus "continuing value"), the results were not significant for MVA and were significant for the "continuing value." *SISS* does not influence either. *SIBS* did not significantly influence MVA, but did significantly influence the "continuing value" (âs=0.345, t=3.47, p<0.001). A detailed analysis of the *SIBS-Firm Value* relationship shows that lower *SIBS* leads to a significant increase in investment in infrastructure (i.e., base stations and information systems), which might indicate a hampering of the subjects' ability to calibrate their investment decisions with lower *SIBS*. This finding supports the future refinement of the *MMS* construct into two constructs, *Mental Model Structural Similarity* and *Mental Model Behavioral Similarity*. This disaggregation might absorb some of the strong influence of *SIBS* on *Firm Value*, and explain the lesser influence of the *SIBS* construct on *MMS.*

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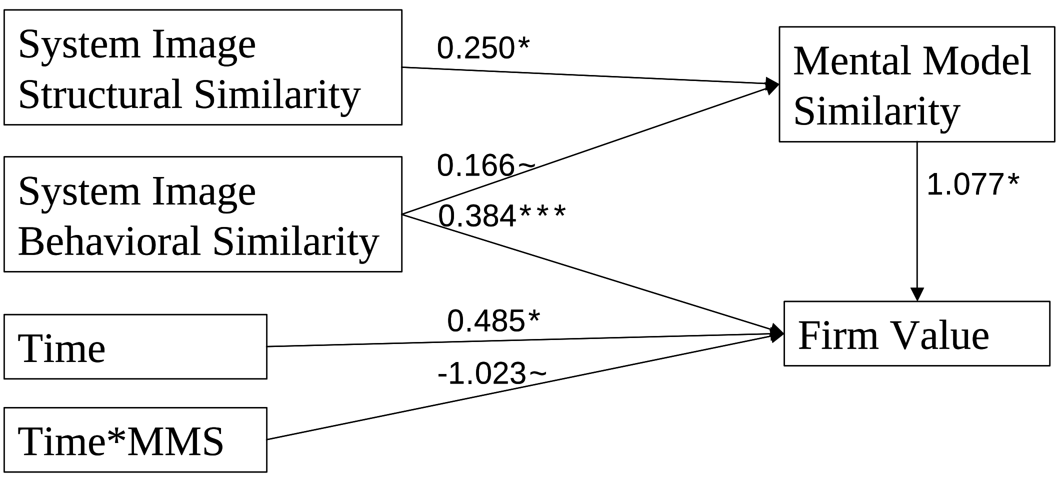
[6] This is a potential area of research for influencing the holy grail of "shared mental models" with technology, in addition to the well-known group decision support techniques of the learning organization (Senge, 1990).

Finally, *MMS* did not significantly influence MVA, but did suggestively influence the "continuing value" (âs=0.179, t=1.734, p<0.087). These results potentially indicate that *MMS* does not explain short to medium-term financial indicators, but does partially explain long-term performance.[7]

Refining the regression model shows in Figure 4 that the amount of *Time* the subject spent, during the simulation, had no influence on *MMS* and a significant influence on *Firm Value*. There is also a suggestive negative interaction effect of *Time* and *Mental Model Similarity* on *Firm Value*. The negative interaction effect might be interpreted as subjects with lower *MMS* that spent more time performed worse than those that spent less time, while subjects with higher *MMS* that spent more time performed better than those that spent less time. This finding is consistent with organizational research on strategic issue diagnosis (Dutton, 1993; Dutton, Fahey, and Narayanan, 1983). In this revised model, the influence of *MMS* on *Firm Value* is significant.



~p<0.1 *p<0.05 **p<0.01 ***p<0.001
For regression of MMS (PFCInfo) on independent variables, with MM Coherence > 0.0, R2-adj=0.069 (p<0.026).
For regression of Firm Value (MVA7 + Continuing Value), R2-adj=0.201 (p<0.000).

Figure 4: Revised Regression Model

Discussion

Summary

The findings in this research provide support for the theory developed in the beginning of the paper. The results suggest the following potential contributions of this research. First, *Mental Model Similarity* influences *Firm Value*. Though seemingly obvious, this suggests that for practitioners, the goal is to provide the decision maker with a rich image of reality rather than the current trend of overloading them with evermore financial and operational information.

[7] This finding would be particularly interesting in industries where the "continuing value" represents between 50% and 125% of the total value (Copeland, Koller, and Murrin, 1996, 286).

In demonstrating the influence of *System Image Structural Similarity* on *Mental Model Similarity* and *Firm Value*, this research informs the use of strategic frameworks for decision making. This research provides *System Image Structural Similarity* as a measure for determining which frameworks provide a more complete yet parsimonious image of reality, thus permitting comparison of frameworks such as EBIT and the Balanced Scorecard.

This research also confirms the influence of *System Image Behavioral Similarity* on *Mental Model Similarity* and *Firm Value***.** For practitioners, these finding suggest that accurate, timely, and consistent information reinforces the benefits of more complete strategic frameworks. As for generalizability, this experiment tested graduate students in a simulated experiment. Though they had an average of five years work experience, and there was no significant experience effect, their general knowledge of the elements and relations in a business model might not reflect that of senior executives. Further, resource allocation decisions in real firms might potentially include many more variables, though great care was taken to describe the main elements of a service provider offering wireless telecommunications using standard strategic elements.

Future Directions

Future research in this area might explore the generalizability of the findings, further detail of the mental model, shared mental models, and cognitive tradeoffs in the *System Image*. Further testing with executives might indicate the degree to which a strong business understanding provides a stronger base mental model. The *Mental Model Similarity* construct should be divided into the structural elements and relations (*Mental Model Structural Similarity*) and the calibration of the mental model (*Mental Model Behavioral Similarity*).

The preliminary findings in this research that the technology (*SIBS* and *SIBS*) led to less variance in performance should be further developed to determine the potential contribution this would make to attainment of shared executive mental models. Cognitive limitations also constrain the number of elements and relations that the decision maker can process. Further research on the ratio of convergence to number of elements and relations might indicate an optimal level for strategic decision making.

Appendix A

The Decisions

The subjects make decisions by allocating financial resources, every six months, to human resources, information technology, and infrastructure. Assuming that the task is to maximize shareholder value maximization each time period, the objective function of the model can be described with Equation 1.[8] The left-hand side describes the price per customer of monthly service. On the right-hand side, the first set of brackets describes the firm's cost exposure per

[8] This equation is equivalent to economic value added (EVA, see Ehrbar, 1998), which is revenues less operating expenses less cash taxes less capital charges. Market Value Added (MVA) is the present value of future EVAs. See http://www.sdsg.com/new/sd01paper/model _formulas.htm for the complete model formulation and description. The variables in Greek letters are time invariant. The others may vary over time.

customer, reflected in its operating costs. The second set of brackets describes the firm's net capital exposure per customer, reflected in its capital investments and depreciation.

EVA = Revenues – Operating Expenses – Cash Taxes – Capital Charges
For EVA > 0,
Revenues > Operating Expenses + Cash Taxes + Capital Charges

$$r_c > \left[\frac{p * s_h}{c} + \frac{c * r_c * r_a}{c} + \frac{t_{infra} * r_{toc}}{c} + \frac{d * c_d}{c} \right] + \left[\frac{a_t * c_{wacc}(k_{infra} + k_{ssit} + k_t)}{c} - \frac{(a_t * c_{wacc} - 1)(k_{infra} * r_{dinfra} + k_{ssit} * r_{dssit} + k_{ot} * r_{dt})}{c} \right]$$

Equation 1

Starting with price per customer $ñ_c$, the model assumes a very competitive market and that reducing price would only result in a price war, so price cannot be changed. As for cost exposure, the resource of employees p can be changed by hiring or firing. Assuming the firm has been reengineered, administrative costs $c*ñ_c*ñ_a$ and technical operating costs for the infrastructure $t_{infra}*ñ_{toc}$ are assumed to be efficient and not changeable. The cost of debt $d*c_d$ is not changeable. In the second set of brackets, the resources of infrastructure k_{infra}, service supporting information technology k_{ssit}, and training k_t, can be changed by investing in them or letting them depreciate. The after-tax effect $á_t$ equals the inverse of one minus the tax rate and is assumed to be constant. The amount of asset depreciated each time period depends on the existing asset amount and the depreciation rate $ñ_d$, which depend on prior investments, so path dependency assumes that depreciation on previous assets cannot be changed going forward. In summary, the model permits hiring, firing, and training people, building new base stations, and buying new information technology.

Appendix B

The user interfaces used in the experiment are presented in the following screen captures.

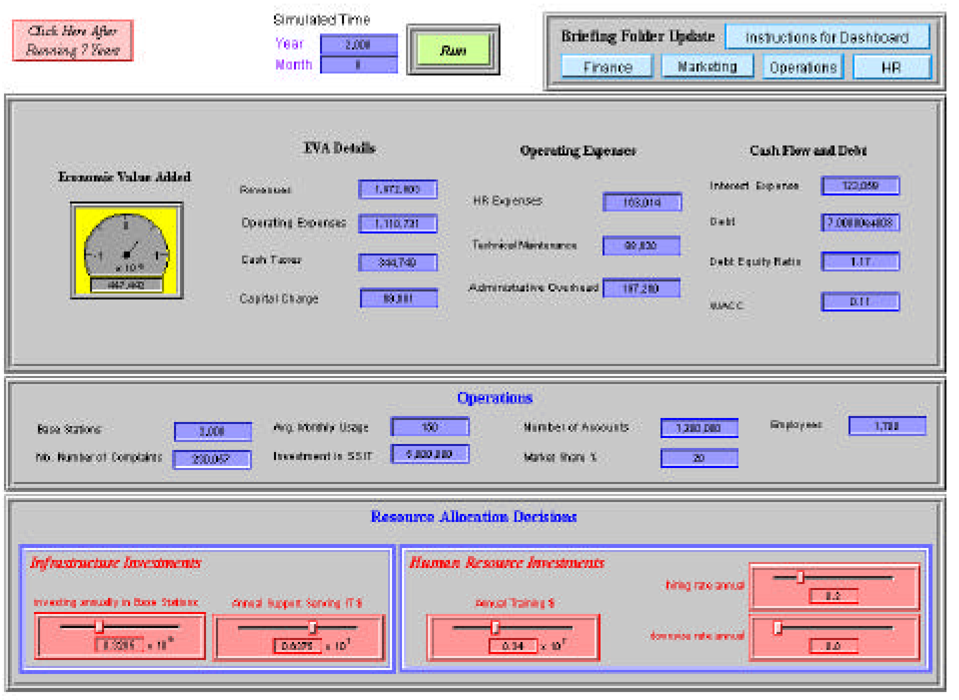


Figure 5: Treatment #1 – Low *SIBS* with Low *SISS*

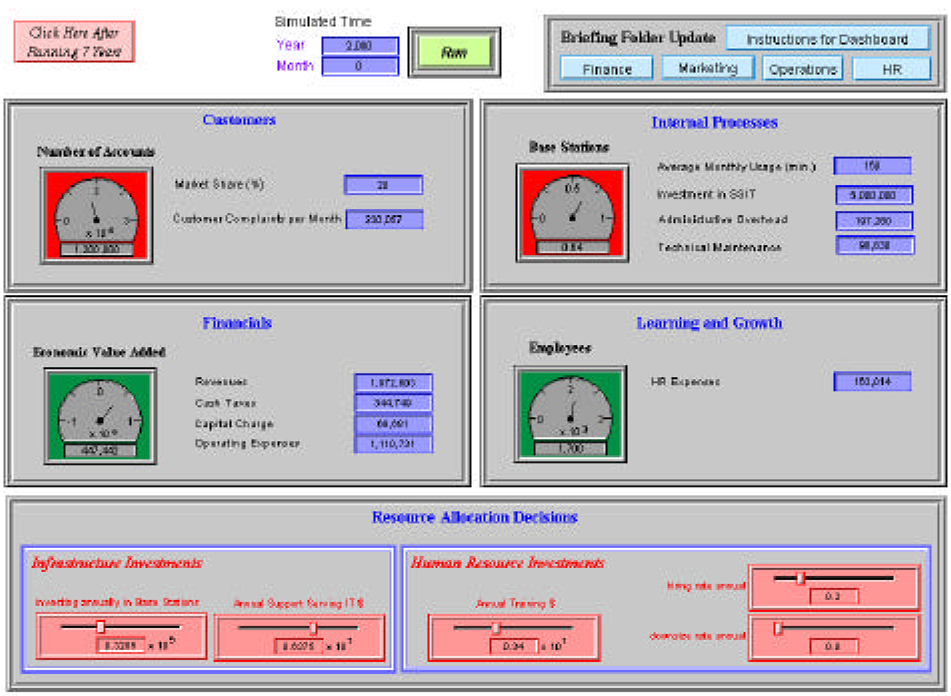


Figure 6: Treatment #2 – Low *SIBS* with High *SISS*

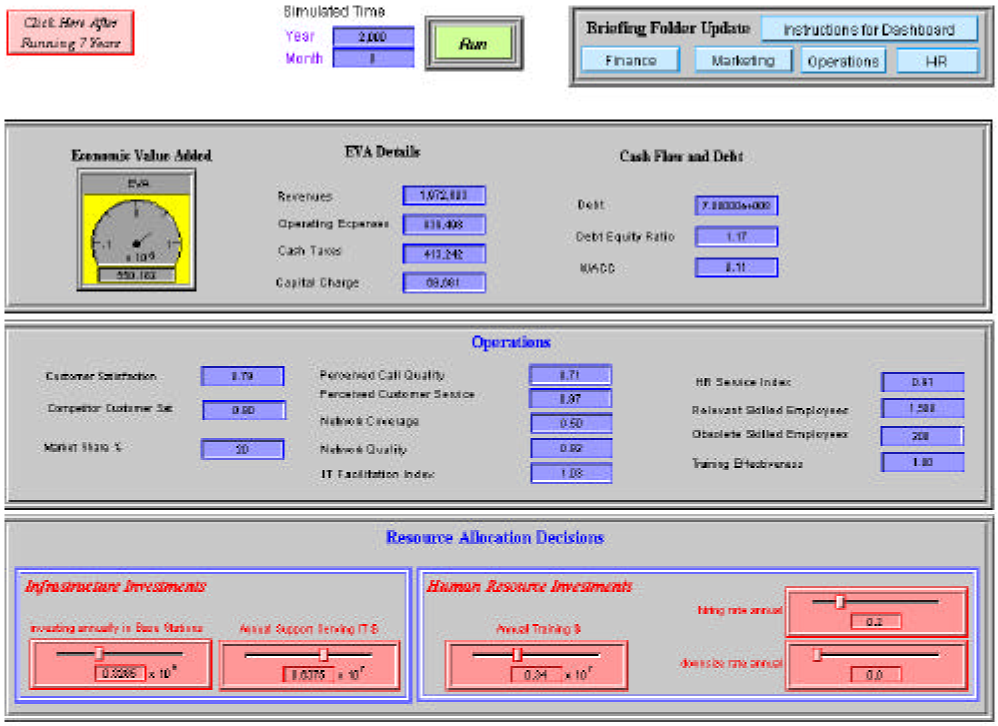


Figure 7: Treatment #3 – High *SIBS* with Low *SISS*

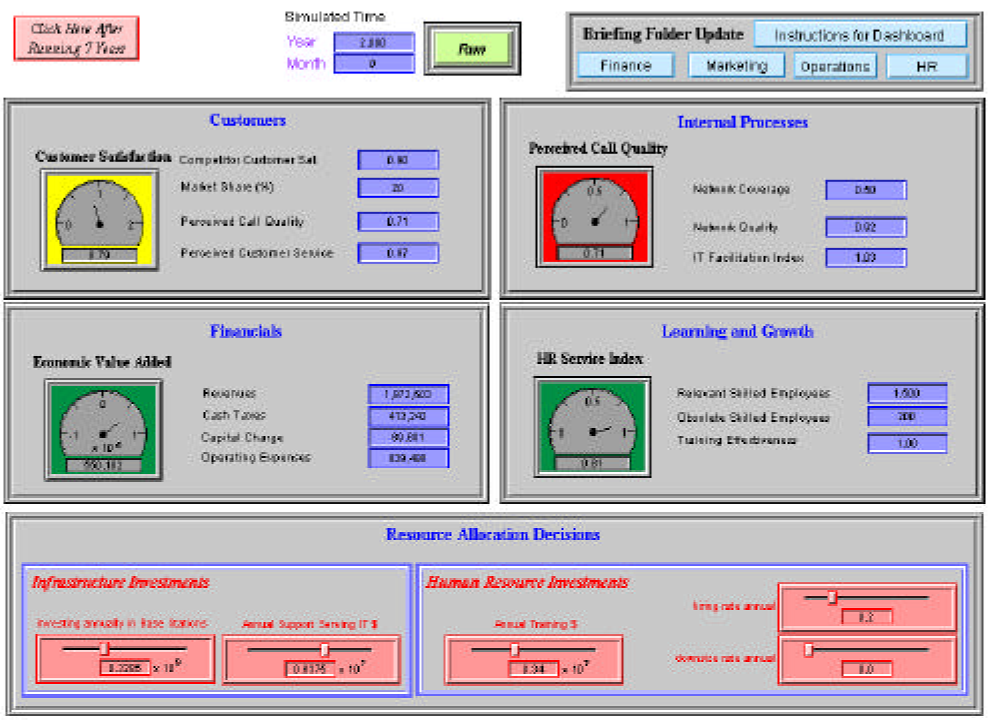


Figure 8: Treatment #4 – High *SIBS* with High *SISS*

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