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Integrating web-based data mining tools with business models for knowledge management

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Abstract

As firms begin to implement web-based presentation and data mining tools to enhance decision support capability, the firm's knowledge workers must determine how to most effectively use these new web-based tools to deliver competitive advantage. The focus of this study is on evaluating how knowledge workers integrate these tools into their information and knowledge management requirements. The relationship between the independent variables (web-based data mining software tools and business models) and the dependent variable (strategic performance capabilities) is empirically tested in this study. The results from this study demonstrate the positive interaction effect between the tools and models application on strategic performance capability.

Keywords: Web-based data mining; Knowledge management; Business models; Business intelligence; Business insights; Competitive advantage

1. Introduction

As firms expand and begin to compete in the global marketplace, senior managers are positioning their firms using strategic business initiatives designed to produce competitive advantage. These initiatives range from acquiring new computer-based decision support applications that help increase efficiency and improve effectiveness of the firm to moving massive paper-based information sources into electronic form, to facilitating data mining and insight generation. As these strategic initiatives are implemented, the information storage requirements have caused the firms' data warehouses to expand geometrically. In 1999, it was estimated that 30% of firms' data warehouses contained greater than one trillion characters of data [4]. As a result, the firm's knowledge workers have been presented with a plethora of data to be understood and to be mined. As a part of the integrated effort in managing information and knowledge, firms are increasingly required to use web-based business intelligence and data mining tools coupled with online analytical processing technology to make sense of and to gain competitive insight into this vast volume of data.

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Hence, the implementation of web-based data mining tools has become one of the key priorities for the firm's Chief Information Officer (CIO) [22]. Business intelligence capability can be used in the decision support infrastructure to assist the firm's knowledge workers in the development of strategic business opportunities and can alert the knowledge workers to investigate potential problem areas in current business operations. The firm's knowledge workers can use these intelligence presentation tools and data mining software to uncover market opportunity, monitor product performance, understand changing customer requirements, and manage customer relationships in real-time. Therefore, it can be inferred that with the proper use of these web-based knowledge generation tools, the firm can achieve a significant competitive advantage as knowledge workers develop greater insights into the marketplace [28,29].

As firms have realized the potential of knowledge-based business decisions to achieve competitive advantage, the business intelligence and data mining software tool industry has exploded [26]. This software industry segment has grown from over US$2 billion in sales in 1998 to an estimated US$4 billion in sales in 2001 [4]. Yet, as CIOs race to satisfy the demands of their senior management to provide the knowledge workers with these leading-edge software tools, they have realized a low implementation success rate. Approximately, 25% of the implementation projects begun by firms have been a complete failure resulting in the abandonment of the adopted business intelligence software tools. Among the remaining 75% of these implementation projects, many firms are not utilizing these software tools' functionality as originally intended or are not getting the full value from their resource investment. Expert practitioners in this field have stated that these software applications are high-risk/high-return projects and that these projects are expensive to implement [2,14,16,20,27,30]. Further, despite the importance placed on these knowledge-based systems, only 32% of the firms surveyed were satisfied with the information provided by the resulting applications [17].

There are a variety of reasons to explain the relatively low implementation success rate and the relatively low satisfaction ratings from these projects. The typical reasons identified from recent studies include technical complexity issues, lack of senior management focus, inflexibility of the software tools, and difficulty in assessing benefits provided to the firm. Yet, in spite of these dismal implementation project success and satisfaction ratings, this software tool industry segment continues to experience a dramatic 40% compounded annual sales growth rate. It appears that firms looking to develop a competitive advantage are pushing their IT department to deliver these web-based insight generation tools for their firms' information and knowledge management. Therefore, the firm must determine how to overcome the typical reasons for implementation failure [1], then they must successfully implement these new tools for managing knowledge, and finally, they must determine how to use these web-based tools to deliver competitive advantage. This study develops and empirically tests a conceptual model of integrated web-based knowledge management.

2. Knowledge management in a data explosion environment

The competitive global marketplace of the 21st century is characterized by dramatic and increasing turbulence. Insight generation is required from the firm's knowledge worker to understand this turbulent environment, as the only sustainable competitive advantage for firms has become the acquisition and use of knowledge [21,24]. Ultimately, sustaining a competitive advantage in firms demands a combination of three unique prerequisites. These unique elements are skilled and capable people, an organizational culture focused on learning, and the use of leading-edge information technology tools for effective knowledge management. Utilizing web-based software tools, firms' trained and capable knowledge workers can easily and rapidly identify their competitors' realized strategy [18]. They can then quickly develop appropriate action-based responses to the potential competitive threat. It is through this knowledge management focus and capitalizing on the knowledge worker's intuition and skill that the firm can develop its unique competitive advantage [15,27]. The strategic performance capability is an inherent capability that enables firms to respond to environmental changes and select appropriate tactical and strategic business models accordingly. Realization of these capabilities into

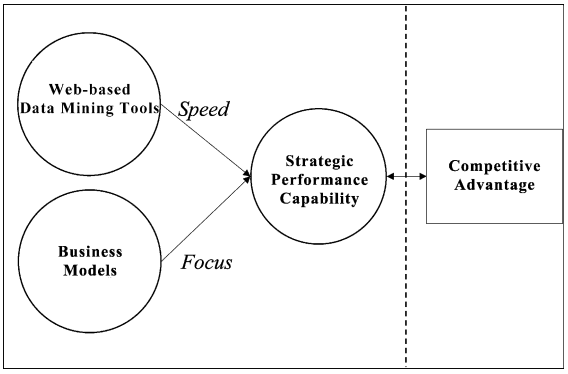

Fig. 1. Web-based knowledge management model.

actual competitive advantage heavily depends upon successful implementation of derived tactical and strategic solutions. Fig. 1 shows a web-based knowledge management model to be tested in this study. The model portrays the linkage between web-based tools to provide insight speed and business models to provide structure and focus for the knowledge workers. The synergistic effect of the tools and models yields strategic performance capabilities for the knowledge workers that ultimately provide unique competitive advantages for the firm.

2.1. Business models provide focus

In the early part of the 20th century, firms emphasized efficiency and productivity as their main competitive levers. These competitive levers focused the firm on controlling the cost of materials, setting the price of the product, and developing differentiation for their goods and services. As the 20th century came to a close, the total quality management movement added another competitive lever to the firm's strategic capability repertoire. These identified competitive levers have now become prerequisites for firms to compete in the current global marketplace. Now, as firms begin the 21st century, new competitive levers are being added to their strategic capability repertoire. Integrating each of these new levers for improving competitive performance has become a major challenge facing firms in the turbulent knowledge era [11]. Increasingly, competitive advantage rests on the firm's ability to better manage the knowledge regarding the critical elements of their environment and thus their ability to use the appropriate competitive lever.

Business models provide the knowledge workers in the firm with focus and aid in developing insight generation. These insights ultimately become the basis for the recommendations from the knowledge worker. The business models utilized by the knowledge workers can be categorized into assessment models, tactical models, and strategic models. Assessment models encompass product, situation, and competitive assessment techniques. Tactical models focus on business portfolio, pricing, and promotional insight generation [18]. Strategic models investigate financial, brand equity, and consumer value topics [9]. These business models assist the knowledge worker in making sense of the competitive landscape and in providing the knowledge workers the needed focus.

Knowledge evocation of relevant information is a critical aspect of creating knowledge-based actions and recommendations. The web-based data mining software tool's guided analysis capability provides a starting point or a prompt to facilitate the creation or update of the knowledge workers' mental model of the firm's competitive status. With strategic business application models fully integrated into the guided analysis function of web-based software tools, the knowledge workers have an extensive proven ability to reduce analysis complexity and a structured methodology of strategic problem surfacing. Still, the knowledge workers need to interpret the volumes of information and develop insightful fact-based decisions. To compete in today's global marketplace, firms need to know more than they have ever known before. To be successful, firms need to know more than their competitors know about customers, markets, technologies, and business processes [18]. And, firms need to know this information before their competitors do. Management-by-fact analysis is the consistent path to competitive advantage. Without proven strategic business models supported by web-based intelligence tools, many teams of knowledge workers fail to achieve a fact-based consensus and, therefore, senior management ultimately must make decisions based on their own subjective criteria. Thus, a web-based knowledge management model that incorporates business models to produce strategic insights potentially can yield competitive advantage.

2.2. Web-based software tools provide speed

To meet the competitive global challenges of the 21st century, the firm's knowledge workers require improved tools for understanding the changing markets and customer requirements. Historically, forecasting tools were the primary business insight generation tools used to analyze the competitive landscape [6]. The business objective for using these insight-generation tools was to help knowledge workers predict the future of a given market segment or the success of a particular product line. These forecasting tools aided in reducing decision uncertainty by providing a degree of confidence to those decisions related to the success of market segments or product lines. Today, much more is required. Timeliness in uncovering opportunity and speed in decision-making are the minimum requirements to uncover potential market niches and respond to the market opportunity. To develop that information and to gain competitive insight into uncertain market situations, knowledge workers seek to manage uncertainty by bringing forth evidence on the problems they encounter [5].

Web-based data mining software tools are becoming the backbone of managing knowledge to gain a competitive advantage for the firm. Web-based data mining tools are being migrated from batch-based or client server oriented tools. The batch-based or client server oriented tools provided knowledge workers analytical solutions on a request basis with a static and potentially outdated data. The adoption, diffusion, and infusion of web-based tools into the firm are expected to be similar to client server oriented tool adoption [7]. Web-based tools begin to revolutionalize the way knowledge workers access, analyze, and retrieve information from the decision support system. The key advantages of these web-based tools when compared to traditional batch-based or client server oriented tools include ease-of-use, universal access across information technology platforms, and single minute response and feedback based upon dynamic and real-time data.

As knowledge workers assess the competitive landscape facing the firm, they utilize the firm's technological infrastructure filtered by the firm's balanced scorecard [18,19]. The knowledge worker's mental model becomes the basis used to understand the competitive environment, to apply web-based software tools, and to proactively interpret strategic response scenarios [8,16]. Web-based software tools can enhance the mental models of the knowledge workers leading to faster responses in decision situations [30]. By using the firm's knowledge bases, the knowledge workers can rapidly identify various competitive threats, potential problem areas, and business opportunities. The web-based software tools in the firm's technical infrastructure provide the knowledge workers with the ability to reduce the complexity of the competitive situation. These tools can enhance the provided information value by increasing the speed of data gathering, by enabling multidimensional analysis, and by providing knowledge workers with simple complexity reduction tools. The knowledge workers, however, are still required to evoke relevant insights and highlight out-of-variance conditions as compared to the strategic business plan or market forecast.

Web-based software tools provide the features and capabilities to facilitate the knowledge workers' insight generation speed [13]. The specific capabilities required by knowledge workers of web-based software tools are information presentation, knowledge evocation, and analytic capabilities [18]. The information presentation requirement capability is structured to allow the knowledge worker to rapidly create graphs and tables and then to view the uncovered information in various chart formats as well as displaying the data in various tabular formats [31]. The knowledge evocation requirement capability provides the knowledge worker with access to the expert information on the particular topic. This capability allows the firm to capture expert insight for sharing and future analysis. The analytic requirement capabilities allow the knowledge worker to dynamically create new calculations to produce new performance measures and to dynamically create new categories or dimensions of analysis to aid insight generation. The purpose of the web-based software tools and these capabilities is to provide the knowledge worker with insight generation speed for real-time market response.

2.3. Combining focus and speed to create strategic performance capabilities

Overall, the combined usage of web-based software tools by knowledge workers and skilled application of strategic business models improves their strategic performance capabilities. These tools can also provide

enhanced capabilities to represent business strategic concepts and business models through an intelligent agent based guided analysis resulting in expert representation. These models and tools are used to provide the knowledge workers with focus and speed. Generally, as the knowledge workers' web-based software tool knowledge and performance increases, the knowledge workers' assessment, insights and pattern identification skills increase regardless of the knowledge workers' business model skills [11]. Understanding this expected rate of improvement from these web-based software tools and business models helps the firm in the allocation of its scarce organizational resources. Understanding this expected rate of improvement can help to explain and to provide insight into why these web-based software tools experience the identified implementation failure rates and low satisfaction ratings.

The strategic thinking and questioning skills of the knowledge worker facilitate the strategic performance capability development. These capabilities enable the knowledge worker to provide the competitive insights and ultimately aids in the development of the strategic direction for the firm. This area of strategic performance capability encompasses assessment skills, insight generation skills and critical questioning skills, the use of various decision-making methodologies and pattern generation and insight generation ability. Each of these skill capabilities is used to uncover opportunity and identify competitive threats facing the firm.

However, the expansive functionality and complexity of web-based software tools can prove to be counterproductive for the firm when with a limited understanding of business models, knowledge workers can rapidly arrive at incorrect conclusions when assessing the competitive environment and determining strategic opportunity. However, with a good understanding of various business models, these tools can increase the demonstrated strategic performance capabilities of the knowledge workers. Nevertheless, with a limited understanding of business models, the knowledge worker can use the guided analysis capability of the web-based software tool and achieve a demonstrated dramatic increase in performance [12]. This allows the firm's experts or consultants to store application specific knowledge and problem surfacing routines in the knowledge management system and to enable access by novices or those knowledge workers with limited business model knowledge.

2.4. Achieving competitive advantage

The complex information for the performance measures originates from the firm's balanced scorecard, from benchmark studies, from market research, and from internal and external data sources [19]. The various internal data sources to be used are obtained from the firm's e-commerce systems, sales transaction systems, financial and accounting systems, human resource systems, and plant operation systems. An often-overlooked area for obtaining data sources to support performance measures is from the firm's market research databases. These databases can contain customer satisfaction information and quality performance information on products and services that the firm provides. The external data used for analysis usually originates from an outside organization. Organizations that have information of interest to the firm include web-based business intelligence organizations, trade associations, industry organizations, and local, state, and federal government agencies. These external organizations can provide the firm with data on competitors' sales and market share, regional demographics, and industry trends.

Web-based data mining tools analyze the firm's environment and achieve a variety of benefits. These benefits range from controlling costs to increasing profitability. Web-based data mining software tool usage has allowed management of various firms to increase the efficiency and effectiveness of their firms by helping knowledge workers manage and control costs through more informed planning and by allowing knowledge workers to respond in real-time to customers' demand in managing the customer relationship. These web-based data mining tools provide management of the firm with information to increasing the profitability of products and services through tailoring business offerings. The knowledge workers in the firm have been able to reduce the time required for insightful analysis and decision making from days to minutes and have allowed the knowledge workers to visualize exception conditions requiring immediate action.

Thus, to achieve competitive advantage by focusing on web-based data mining tool usage requires continuous training for the knowledge workers [10], because

the underlying technology for web-based tools changes rapidly. These software manufacturers are continually providing new features and functionality. Achieving competitive advantage requires understanding tools capability to represent business models and knowledge workers accurate selection and representation of business models to solve decision problems.

3. Research process and data collection

This study focused on understanding the various issues related to successful implementation and productive use of web-based presentation and data mining tools by the firm's knowledge workers. To gain this understanding, educating students on the application of content-oriented knowledge, critical questioning skills, and web-based data mining tool usage and skills was required. Graduate and undergraduate business students were utilized as the sample for this study. The assessment instruments were administered in a classroom setting. The web-based software that was utilized was DecisionWeb™ developed and supported by Comshare of Ann Arbor, MI and the multidimensional analytic database software used was SQL 7.0 OLAP Services™ developed and supported by Microsoft.

The research model in Fig. 1 postulates that the independent variables ''Web-Based Data Mining Tools'' and ''Business Models'' affect the dependent variable ''Strategic Performance Capabilities''. The research model highlights the concept of business focus and insight speed on the knowledge worker's strategic thinking competence. A personal assessment questionnaire was used to ask the students to rate their ability to perform various technical functions with web-based data mining software, to apply and articulate various assessment, tactical, and strategic business models, and to engage in critical questioning and develop insights. Their opinions were captured via a 7-point Likert scale questionnaire with the rating scale from very weak (1) to very strong (7).

When more than one independent variable is included in a research study, a factor design is necessary [3]. A factorial study is then defined as a study in which the effect of two or more independent variables (i.e. factors) are investigated each by itself and then in interaction with each other on the dependent variable. In a factorial design, the goal is to estimate the interaction effects and the main effects. The interaction effect may positively or negatively reinforce the main effect or the independent variables. A positive interaction effect provides a result that is greater than the effects of each factor separately. A negative interaction effect provides a result that counteracts the effects of each factor.

The classification of the responses from the survey was based upon subjective measures of achieved skills and capabilities. The achieved level of business model application and the proficiency in the use of web-based tools were measured using a 7-point Likert scale. The web-based tool group scores were classified as high if the student's summated score was above the group mean and classified as low if the student's summated score was below the group mean. The business model group scores were classified as low if the student's summated score was in the lower third of the group; medium if the student's summated score was in the middle third of the group; and high if the student's summated score was in the top third percentile of the group.

4. Model and analysis

Various statistical analyses were performed on the data. The assessment instrument was first checked for reliability using the Cronbach alpha. Multivariate regression was performed to study the impact of business model capability and web-based data mining tool skill on strategic performance capability.

4.1. Instrument reliability

Reliability analysis facilitates the study of the properties of the measurement instruments and the various items that make up those measurement instruments. There were 64 items covering three major categories in this assessment survey. The students rated their perceived skill on various areas using a Likert scale rating with a one (1) defined as being very weak and a seven (7) defined as being very strong. Each of the instruments had an alpha rating greater than 0.96 with the business models instrument at 0.97, the tools instrument at 0.98, and the strategic performance capability instrument at 0.96.

4.2. Sample characteristics

The sample for the study was undergraduate seniors and MBA students from a Midwestern university. The students were recruited from senior marketing and MBA capstone courses for participation. The variables that describe the students used in this study include gender, age, perceived software tools ability, perceived computer ability, and job satisfaction rating. The composite view of the respondents was an individual considered skilled at computer usage (69% rated their computer capabilities as either very skilled or skilled) and were mostly under 26 years old (65% of the respondents indicated that their age was less than 26 years old with the range of ages from 21 to over 36 years old). The group involved in the study was approximately evenly split by gender (females were 40% and males were 60%) and by perceived time of day that they were most alert (day or night). These individuals were satisfied with their current job (69% rated their satisfaction with their current job as very satisfied or satisfied).

4.3. Multivariate regression

The analytical method used for the study was regression analysis. The data was prepared for multivariate regression analysis by coding vectors to represent the main effects and the interaction effects. This method of coding is preferred as the regression equation obtained reflects the effects of the factors and their interaction [23]. The interaction effects are obtained by multiplying each of the coded vectors from one factor by each of the coded vectors from the other factor. The number of vectors coded is the number of categories in the main factor minus one [23]. Using this methodology, the number of vectors required for data mining tools is one. The data is coded as one (1) for those responses labeled as low and minus one (−1) for those responses labeled as high. The business models main factor has two vectors, as there are three categories (low, medium, and high). The data for the first vector is coded as one (1) for those responses labeled as low, zero (0) for those responses labeled as medium, and minus one (−1) for those responses labeled as high. The second vector was coded as zero (0) for low, one (1) for medium and minus one (−1) for high. The multiple regression was then performed with the dependent variable regressed on the three dummy variables. R^2 indicates the proportion of the variance accounted for in the regression equation. The regression equation for the dependent variable of "Strategic Performance Capability" was obtained and is listed in Table 1. For the equation listed in Table 1, the R^2 is 0.715. The MANOVA results listed in Table 2 highlight that each of the main factors had a significant effect on the dependent variable and, more importantly, a significant positive interaction effect occurred between the two independent variables on the dependent variable.

Table 1
Regression results

Variable description	Regression coefficient	Unstandardized coefficients	t	Sig.
Constant		5.545		
Data mining tools				
Coded Variable—X_1	X_1	−0.392	−4.293	0.000
Business models				
Coded Variable—X_2	X_2	−0.452	−3.769	0.000
Coded Variable—X_3	X_3	0.170	1.719	0.088
Interaction				
Interaction—$X_1 \cdot X_2$	$X_1 \cdot X_2$	0.255	2.570	0.011
Interaction—$X_1 \cdot X_3$	$X_1 \cdot X_3$	0.050	0.415	0.679

$Y = 5.545 - 0.392X_1 - 0.452X_2 + 0.170X_3 + 0.255X_1 \cdot X_2 + 0.050X_1 \cdot X_3$.
$F_{(5,137)} = 68.792$, $p < 0.01$.

Table 2
MANOVA results

	df	F	Sig.
Overall main effects	8,268	2.86	0.005
	4,134	6.36	0.000
Interaction effect	8,268	2.85	0.005

5. Discussion and conclusion

The main effect for the web-based data mining tools and for the use of business models was significant at the 0.01 level. The $X_1 \cdot X_2$ interaction effect was also significant at the 0.05 level. At the low business models level, web-based data mining tools with guided analysis functionality enable the novice knowledge worker to achieve insight and success with relatively

little investment in effort. At the medium business models level, web-based data mining tools provides the knowledge worker with the functionality required to perform in-depth analysis to gain insights, yet the knowledge worker does not have the capability to utilize the results. At the high business models level, web-based data mining tools with the presentation management functionality enables the knowledge worker to generate more options and to evaluate more alternatives. The positive interaction effects indicate a synergistic effect that is occurring between the business models and data mining tools.

A model was proposed highlighting the integration between technology and knowledge worker capability and its impact on the firm's competitive advantage. As such, this research has focused on investigating the relationship of web-based tools and business models on strategic performance capabilities. To develop leading-edge competitive insights, knowledge workers must have access to web-based data mining tools that are integrated with the firm's strategic business models. This integration will manifest itself as firms require knowledge workers to become skilled in strategic opportunity identification. In addition, web-based data mining tools must integrate business application models and various external data sources to provide the knowledge workers with a complete picture of the turbulent, dynamic competitive environment leading to effective knowledge management.

As previously described, the knowledge workers' mental model provides the initial knowledge base for the firm. Their mental models of the environment are based on many things including proven strategic business models and their paradigm of the industry and market in which the firm operates. Their paradigms indicate when to apply various analytic models. The decision problem yields strategic performance measures involved in understanding the environmental situation. Web-based data mining tools provide the ability to understand and interpret the generated information. Combined, they provide the knowledge worker with the ability to focus. Thus, business intelligence is viewed as the ability of the knowledge worker in the firm to apply specific knowledge to respond proactively to the environment. Then, specific knowledge is formulated into action plans.

This market-oriented approach to planning recognizes that environmental scanning, sense-making, customer-value, and strategic planning activities must be shared throughout the firm [25]. It is a core competency of the firm that must be developed and shared in its decision support system. In fact, the ability to manage knowledge may be the only remaining source of competitive advantage for the firm. In this knowledge era, all of the stakeholders in the firm must be involved in the environmental scanning and sense-making function of the firm.

The results provide an insight into the combined effect from these web-based software tools and business models in improving strategic performance capabilities. Understanding the synergistic improvement effect can help to explain why web-based software tools alone experience the identified implementation failure rates and low satisfaction ratings. A combination of business model application and integration with web-based software tools is required.

Firms that are oriented towards continuous learning and knowledge management will have less unconverted data than their less learning oriented competitors. In turbulent environments, firms should have a corporate culture with knowledge management processes that yield the flow of the right information and knowledge to the right people at the right time for the right reason. Firms are implementing web-based data mining tools to develop the speed that enables the firm to achieve competitive advantage in the global marketplace. Yet, web-based data mining tools embedded in the decision support system are not the ultimate panacea. The road to success is not paved with gold and a one-size business intelligence or data mining tool does not fit all firms. Those firms intent on achieving success must be cognizant of the caveats and must provide their knowledge workers with the appropriate web-based business intelligence and data mining tools, business models, and training required to achieve strategic insights that ultimately translate to competitive advantage.

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