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Causality analysis of the technology strategy maps using the fuzzy cognitive strategy map

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The main purpose of this study is to find out the causality relationships between the strategic management of technology (SMOT) objects in the selected Iranian high technology companies, based on the balanced scorecard (BSC) and fuzzy logic approaches. Evaluations of critical technological indicators in the selected high technology-based companies illustrated they have used different cognitive procedures in their strategic management of technology studies, which have previously been discussed throughout the SMOT literature. Technology strategy maps try to make convergences between the objects of SMOT using benefits of the technology balanced scorecard (TBSC) in the high technology environment. Technology strategy maps empower high technology companies in both technology and business areas, based on the four perspectives of proposed TBSC. The first step in our evaluations is based on-field studies questionnaires responded to by 150 personnel from different industries. The next step is based on the empirical collected data from 24 high technology companies; causal and effect relationship analysis between each of these objects was calculated and mapped using the fuzzy cognitive map (FCM). Obtained fuzzy cognitive strategy map (FCSM) simply explains the causality relationships between the objects of the SMOT, which were not well understood in the traditional technology strategy maps.

Key words: Strategy maps, high technology, SMOT, BSC, FCM, FCSM.

INTRODUCTION

In the last decade, the emergence and rapid growth of high technology based companies have accelerated the need for innovative and validated strategic models for business and also provided a capable context for research on these subjects. Industrial interests are in how to effectively manage science, innovation and technology indices, which are growing rapidly in the organizational context. Due to the complexity, dynamics and rate of technological innovation prosperities during increase in organizational and progressive sectors change on a global scale. Changing technologies, such as nano-technology, biotechnology, information technology (IT) and social technology require noticeable opportunities to enforce sectors and provide growth; but they also

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present a potential threat to existing activities of firms. Strategic management is the most expanding topic both theoretically and practically, owing to its multi- disciplinary and multifunctional nature. A number of disciplines are relevant to the academic perspective, such as science, engineering, economics, sociology and psychology. In high technology businesses, contributions from both commercial, technological and strategically functions are critical if correct decision making, and successful products and services are to be delivered to the market. This paper based on the literature findings and qualitative and quantity information obtained in the Iranian high technology companies classifies business strategy and technology strategy objects from four main balanced scorecard perspectives. In defining our SMOT framework, we compose suitable technology strategy map (TSM) from strategic management of technology point of view. TSM is based on practical studies on the 24 selected high technology companies from different industries such as chemical fibre, micro-electronics, precision machinery, civilian aircraft, biotechnology, nanotechnology, software and energy development. Using the fuzzy cognitive maps (FCMs) logic, we expand technology strategy map to a dynamic technology strategy map, named FCSM. FCSM not only shows how technology and business strategies integrate in one cognitive map, but also shows causality relationships and degrees of interrelations between objects in both strategic and technology management. Also it shows the best interrelations among SMOT objects by jointed-cycles and paths in the high technology environment.

This framework is developed based on fuzzy systems by obtaining qualitative and quantitative information on enterprise practices. The empirical and theoretical research was conducted in 2012-2013. The research project was conducted for eight months to develop the technology strategy map using 24 large and small to medium-sized high-technology companies; 150 informants were involved.

The proposed framework that helped us to overcome BSC defaults and failures in the evaluations of high technology companies' performances not only considers business objects, but also spots technology objects. Consideration of correct cause and effect relationships among objects in the technology strategy maps gives us a conceptual insight into monitoring and controlling objects to achieve determined goals (missions). This is empowered by merging fuzzy systems and soft computing systems using fuzzy cognitive maps notions. FCSMs easily show cause and effect relationships, which are extremely important for achieving convergences in strategic management of technology actions.

LITERATURE REVIEW

Technology has different definitions: Pugh and Hickson (1976)defined technology as “equipment”, Reeves and Woodward (1970)defined it as “tools” and finally Thompson and Bates(1957) understood it equals with the term of “hardware". Schon (1967) sees technology as each method's tools, product, process, physical equipment or capabilities in production or doing something which is beyond human capability. Technology is all of the knowledge, products, processes, tools, methods, and systems employed for the creation of goods or in providing services (Khalil, 2000). Margaret and Bruton (2011) integrated these various definitions to define “technology” as the knowledge, products, processes, tools, and systems used for the creation of goods or in the provision of services. Although there is a wide variety in the prior definitions of technology, each definition implies that there is a process involved at the heart of technology: that change is an outcome of technology, and that technology involves a systematic approach to deliver the desired (improvements, objectives, and outputs) outcomes (Margaret and Bruton, 2011). The definition of technology also implies a process that involves the elements of strategic management. Technologies not only improve performance management systems (PMS), but also use performance management systems to map the best strategic roads, helping firms to reach their targeted goals and obtaining determined technological objects. Management of technology (MOT) is an interdisciplinary field that integrates science, engineering, and management knowledge and practice (Khalil, 2000). Therefore, the definition of MOT should also reflect this systematic, strategic approach. Management of technology is defined as linking engineering, science, and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational objectives within an organization. The major shortcoming of this definition is its lack of attention to evaluation and control, which are required for a strategic approach in the management of technology. Evaluation and control involve monitoring technology to ensure that it meets the desired outcomes. It is necessary that after a technology is implemented, the firm monitor changes that may render the technology obsolete, dangerous, replaceable, or competitively weak. A leading example on the need for such evaluation and control is the National Cash Register Company (NCRC). NCRC embarked in the 1960s on their project, because they had no methods and procedures of strategic management of technology (SMOT) in their managerial and control processes (Margaret and Bruton, 2011).

SMOT takes a firm strategic management approach on the subject. Also SMOT offers practicing managers an analysis of how firms should respond to the rapid changes in technologies and innovations that are forcing industries to find new ways to compete. Khalil (2000) categorizes technology according to intense of definitions elements to emerging technology, high technology, low technology, medium technology and appropriate technology. In the high-technology companies, technology may be very complex or progressive. Rogers and Larsen (1984) mentioned the attributes of high-tech firms as follows: an abundance of scientists and engineers within the organization; fast-growing industry; higher R&D expenditure than in any other industry; worldwide market for products. Wheeler and Shelley (1987), for example, investigated forecasts of demand for innovative high-technology products and found them to be uniformly optimistic by 50% or more. They attribute this to a lack of forecaster expertise in consumer behavior, over enthusiasm for high technology, and poor judgment. High technology start-ups, on the other hand, typically aim for future success as the payoff for current activities. These firms need at least an informal and agreed-upon view of their TDS to develop and execute a technology-based business plan. For instance, in devising indicators of high technology development among nations, Roessner et al. (1996) used technology sales as surrogate production measures. This raises some interesting questions of the nature of high technology firms in developing countries and about their experiences; in particular what factors, especially R&D expenditure lead to success. High-tech products are the fastest growing segment of international trade and some 25% of exports from developing countries are in hi-tech products. Others have studied the locational preferences and patterns of different high-technology industries such as biotechnology (Haug and Ness, 1993; Hall et al., 1987) and software (Egan, 1994).

There was different formulation for SMOT named discontinuity in SMOT formulation, entire field of strategic technology management is ambiguous and literature on theoretical frameworks is diverse. Linking business to technology is a managerial challenge in enterprises. Strategic management of technology is assumed to provide a solution to manage complexity caused by technology in dynamic environment (Burgelman et al., 2001; Dodgson et al., 2008). Management of technology is often conducted as part of R&D management or innovation management (Drejer, 1997; Edler et al., 2002; Tidd, 2001). Drejer (1997) has described four schools of management of technology that emphasize R&D management, innovation management, technology planning and strategic management of technology (SMOT). According to Edler et al. (2002), so called 4th generation R&D management sees R&D and technology as strategic instruments for competitiveness and innovations, and stresses theory of explicit technology strategy and integration of technology with business strategy. Current themes in R&D management are open innovation, networked R&D and knowledge management (Chesbrough, 2006; Lichtenthaler, 2008). Innovation management school emphasizes on anticipating technological changes and incubation of innovative products for commercialization. In the technology planning school, the major scope is to manage technology across the company using specific management methods like road mapping and portfolio management (Cooper et al., 1998; Tidd, 2001). SMOT school combines technology and business perspectives through management of technology activities (Phaal et al., 2004; Lichtenthaler, 2008).

Multiple theoretical and practical frameworks for describing elements of technology management have evolved. The entire field is confusing and boundaries of ideas are blurred, and there are no commonly accepted frameworks (Phaal et al., 2004; Brent and Pretorius, 2008; Cetindamar et al., 2009). In Table 1 is presented main types of technology management frameworks. Each of the framework types emphasizes particular aspects of technology management: processes, routines, methodology, need to integrate technology management with core business and strategic processes, or technology management as management of knowledge flows.

BSC is born from this rich history of measurement and serves the same purpose to business as the timepiece served the ancient mariners. The balanced scorecard is a performance management system that enables businesses to drive strategies based on measurement and follow-up (Figure 1). Since the early 1990s, the balanced scorecard has been applied in numerous large organizations resulting in many positive results that have been chronicled in the management literature (Gumbus, 2005; Koning, 2004; Neely, 2005).

Marr and Schiuma (2003) claim that the BSC is “the most influential and dominant concept in the field of performance measurement research” (Marr and Schumia, 2003). Neely (2005) notes its impact on practice, citing research showing that anything between 30 and 60 percent of firms has adopted the BSC in some form. In academic research, Kaplan and Norton’s writings on the BSC have dominated the citations in articles on performance measurement in the leading academic journals for the last decade (Neely, 2005).

Previously, BSC was considered as an organizational performance measurement tool from four key areas. Since then it has grown into a device for controlling the

Table 1. Main types of technology management frameworks.

Technology management framework type	Example reference
Generic process model	Gregory ,1995; Cetindamar et al., 2009
Technology management functions	Kropsu-Vehkaperä et al., 2009
Technology management routines	Levin and Barnard, 2008
Technology strategy approach	Burgelman et al., 2001
Innovation funnel	Wheelwright and Clark ,1992
Knowledge management	Nonaka, 1995
Methods and tools approach	Phaal et al. 2006;Gerdsri et al., 2009
Integration into core business processes	Metz 1996; Phaal et al., 2004
Integrated management concept	Tschirky, 1991

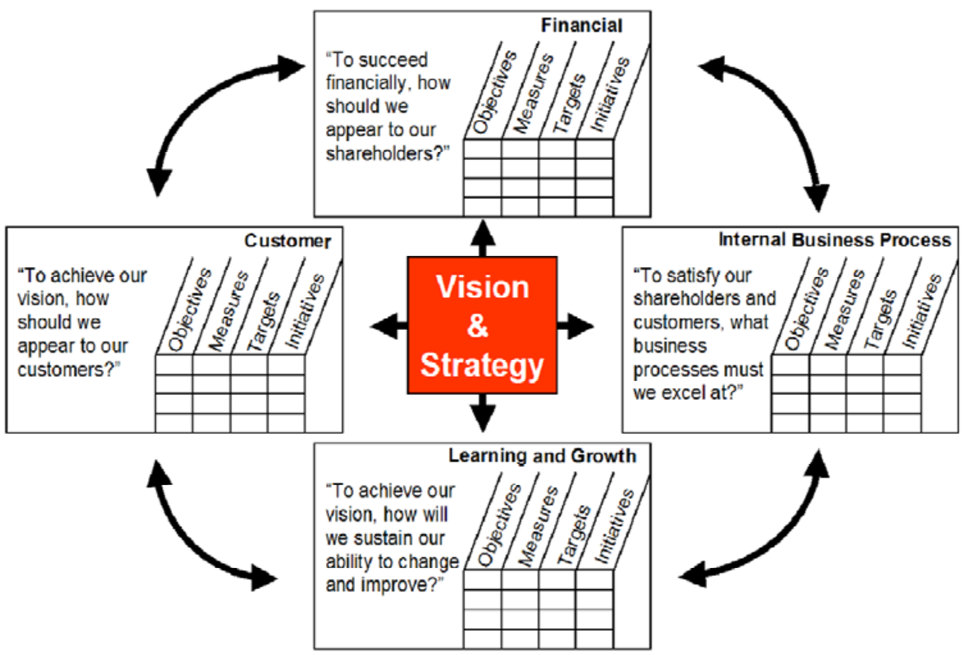

Figure 1. The balanced scorecard and its four aspects.

implementation of strategy (Fink et al., 2005). BSC plays an important role in the strategic performance management studies in high technology companies by linking the performance measures to organizational strategy and goals (Kaplan and Norton, 2000). It has become one of the preferred strategic performance management tools of many prominent public and private sector organizations (Radnor and Lovell, 2003).

The balanced scorecard (BSC) introduced by Kaplan and Norton consists of both financial and non-financial measurements. Kaplan and Norton's BSC classified all technologically developmental indicators into four main perspectives; financial perspective, customer perspective, internal processes and learning and growth perspective (Kaplan and Norton, 1992; Nair, 2004). Kaplan and Norton considered most important principles in their BSC with understanding that a strategy should present the causal model of a company. To do this, the causal relationship between the four perspectives of the BSC is graphically presented in a strategy map which links an organization's BSC to its strategy; cause and effect relationships, performance drivers, and linkage to the financial goals (Kaplan and Norton, 2001). A strategy map is based on the hypotheses comprising causes and effects. Strategy map expresses causal relationships in a sequence the chains of cause-and-effect relationships among the four perspectives of BSC's objects, which reflect dynamically the change of strategies and describe "how an organization create its fundamental values" (Kaplan and Norton, 2004).

Fortunately, up till now some extensions and expansion of balanced scorecard and strategy maps built have been applied in the high technology companies, commercial companies and other types of companies. For example, Amado et al. (2012) integrated the balanced scorecard and data envelopment analysis (DEA) to improve powers of performance assessment in the multinational companies. Tseng used ANP and DEMATEL methods for making new framework for evaluations of Taiwan university's performances from BSC perspectives and exhibited fuzzy network balanced scorecard (FNBSC) as a new form of BSC (Tseng, 2010). Wu et al. (2011) considered 36 indicators in four perspectives of BSC evaluated in educational centers of Taiwan using DEMATEL (Decision making trial and evaluation laboratory), ANP (Analytical network process), VIKOR methods. Furthermore, Wu (2012) proposed another framework for composing strategy maps for 34 companies within the banking industry using DEMATEL technique for considering correct casual relationships among the Key performance indicators (KPI). Eilat et al. (2008) integrated DEA and balanced scorecard approaches for evaluating the R&D projects in their different stages of life cycle. Wang et al. (2010) integrated hierarchical balanced scorecard with non-additive fuzzy integral for evaluations of two Taiwan high technology firm performance, considering the interactive relationship between BSC's different perspectives in the performance area. They applied traditional definition of BSC as a tool for measuring the performances of high technology firms from four BSC perspectives.

In this paper, technology balanced scorecard (TBSC) is considered as a framework for SMOT in the selected 24 Iranian high technology companies. TBSC is a strategic framework for management high technology companies which integrate business strategy and technology strategy as a solution for sustainable growth and maintenance for competitive advantages in today's turbulent environment.

METHODS OF RESEARCH

From strategic management perspective, the role of technology in value creation, business model definition and as a source of productivity is emphasized; and also the effects of technological capability on company's success in formulation and execution of company's business strategy. In an external socio-economic context, technology has a major impact for sustained development and wealth creation. Most managers are in the decisional situation in the high-tech businesses and use business and marketing strategies to obtain competitive advantage. The utilization of technology strategies as an original source for getting competitive advantage is a loss plan in their operational, mid-term and long-term planning and decisions. They should know engagement and bring substitutions of technology strategy into their high technology company, to acquire stable competitive advantages. Previously, only one side of the business took into account the strategy development and balancing trade-off and linkage between business and technology strategy was not well understood. Phaal and Muller (2009) provided a very effective tool for technology management: technology roadmaps. The use of roadmaps, especially technology roadmaps, is widely used throughout the industry and in government policies. They use the basic technology planning function: linking organizational strategic goals to research and development investment decisions while also communicating these linkages visually. Gerdsri et al. (2009) used technology road mapping (TRM) concepts, which integrate technology into business strategy for successful implementation of dynamics of TRM in initiation, development and integration stages. Furthermore, continuation of the enrichments of the TRM implementations using additional tools and techniques customized and facilitated the road mapping processes by integrating decision theory modes and technology forecasting techniques. Many of the researchers emphasized the three critical success factors (CSF): people, process and data in road mapping development (Gerdsri et al., 2007, 2009).

In the studies of the high-tech companies, to construct technology strategy map with objects of TBSC from literature reviews and empirical research, we should make this strategy map as a technology road map. The technology strategy map is a powerful communication tool that enables all employees to understand the technology and business strategy, and translate them into the actions which they can take to help the organizational technologically improvement succeed. The financial and customer objectives describe the outcomes the high technology company wants to achieve; objectives in the internal and technology and learning and growth perspectives describe how the organization intends to achieve these outcomes. On the other side, technology strategy map is a diagram that describes how an organization creates value by connecting strategic

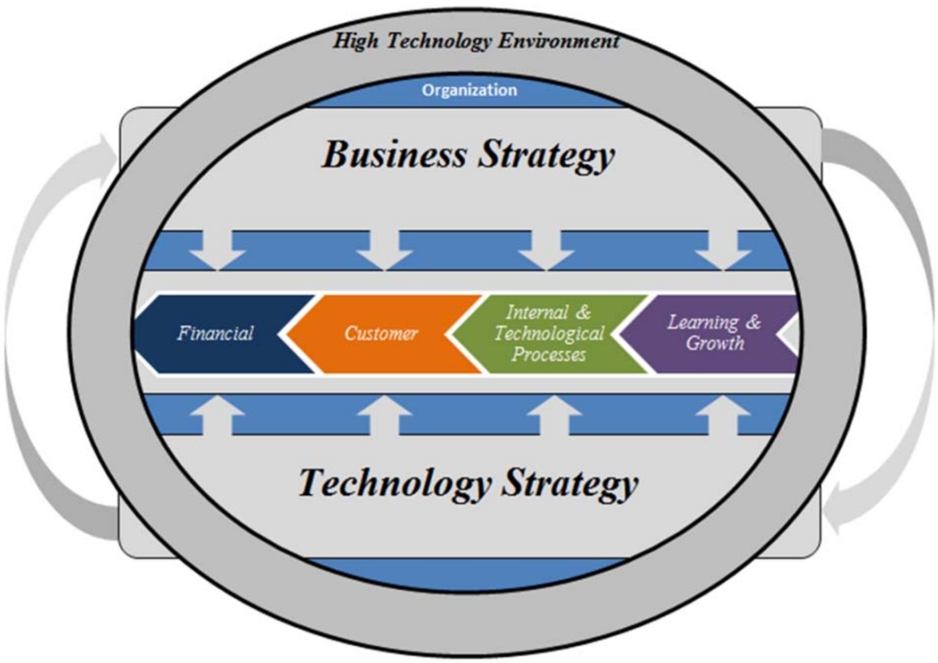

Figure 2. Proposed TBSC for SMOT in the high technology companies.

objectives in the explicit cause-and-effect relationship with one another in the four TBSC objectives. Technology strategy maps are a strategic part of the TBSC framework to describe a strategy for value creation. A simple techno-logy strategy map links strategic initiatives to achieve financial goals, while TSM shows causality among TBSC perspectives, but also it cannot correctly show the degree of causality and interrelations among strategic and technologic objects. The technology balanced scorecard (TBSC) approach helps high technology companies manage the implementation of their strategies. This mea-sures an organization's performance from four key perspectives: financial, customer, internal and techno-logical processes, and learning and growth. The TBSC approach logically links these four perspectives. Improve-ments in learning and growth perspective result in improved internal and technological processes. These results to create better products and services, therefore, higher customer satisfaction and higher market share, leading to enhance financial results for the organization (Norreklit, 2000; Kaplan and Norton, 2004; Marr and Schumia, 2003). Many of the critical high technology company's processes are external, which are ignored in traditional BSC; they are external technology process such as R&D collaboration, investment on joint-ventures and licensing. Thus, a good balanced scorecard should reflect all critical indices in the whole high technology environment without considering nature of indices for achieving convergences in both business strategy and technology strategy. Thus, in strategic management of technology we should consider both technology and business strategies. This is the reason why Iranian high technology companies which use BSC framework in their strategic management studies fail on maintaining high technology advantages. Technology balanced scorecard (TBSC) is composed by the integration of technology processes and internal business processes into internal and technological process perspective substitution of internal business process perspective in traditional BSC (Figure 2). TBSC identifies many cause-and-effect rela-tionships within the business and technology manage-ment. TBSC helps employees and managers appreciate the roles of employee and task as well as the importance of each result to the overall corporate effort.

Defining perspectives of proposed TBSC framework

High technology companies have the essential role in making crediting and wealth for nationals by high impacts on GDP rates. Additionally, high-tech companies acquire competitive advantage for nationals but there is no comprehensive framework for strategically managing technology in either micro or macro levels of strategic management. While companies have evolved to multifunctional strategic orientation where technology has a significant role, there still is no comprehensive frame of reference for strategic technology management. Therefore, absence of convergence between strategic management and technology management causes high-tech companies not to exploit profits of high technology industry. These are phenomena which almost all papers and researchers explain in both strategic management and technology management fields. By analyzing the strategic plans of 24 Iranian high-tech companies, this notion is bolded. Although this was notion cited previously, till now there are no comprehensive methods for achieving coherence among management of technology and business management. Generic process model (also called Gregory model) cannot correctly show technological trends (Table 1). Technology discontinuity is a big problem in high technology companies' studies, which befuddle companies in accepting the agreed critical technological objects that determine strategy ways for reaching organizational prosperities in high technology environments. Technology balanced scorecard is a good lens for looking at the high technology companies' performances from four perspectives. Proposed TBSC not only considers financial objects (for example, return on investments and cost leadership) but also considers non-financial objects (for example, technology innovation, enhancement of customers' satisfaction and retentions, new product development and HR development).

Financial perspective

Financial perspective defines the long-run objectives of high technology companies in today's turbulent environment. High technology companies should give right financial strategic decisions in their investments on the R&D projects, licensing technologies, buying or building etc. Selecting the best strategic decision for making prosperity and obtaining competitive advantage for high technology companies in the long-run terms depend on three critical objects: enhancing return on investments (ROI), cost leadership and risk management.

A high technology company that excels in many operational disciplines can still struggle if its product development decisions are flawed. Product management decisions within high technology companies need to be based in part on the estimated and measured return on product development expense. A clear, consistent practice for analyzing ROI and applying it in decision-making must be driven vertically and horizontally throughout the organization. Such a practice is an inherent requirement to realizing stable decision making and communicating product investment decisions.

If a high technology company decides to achieve a competitive advantage through cost leadership, it must attempt to lower its overall costs as much as possible. High technology invariably is a major weapon in achieving this goal. Costs are, of course, determined by a great many reasons; not all are technological. The cost of production, general and administration costs, the general efficiency of the organization, the state of the market, are all-important reasons. Technology affects costs in three ways: the cost of depreciation of machinery and equipment; the productivity of the production process; the design of the product. The first of these is not really under the individual control of the firm. If it happens to employ machinery that is rapidly becoming obsolescent, it will hardly be able to keep such machinery and still be a cost leader.

The efficiency of production itself is very much under the control of the firm. Employing the best available machinery and the best possible organization of production can make high technology company benefits from technology advantages; and also by using skilled workers and giving them incentives and opportunities to suggest improvements and see to improvement throughout the manufacturing process. By maintaining all the equipment in perfect shape and having a time-saving layout of the production facilities has been seen as improvement in production that leads to improved rates on ROI. Being in partnerships with reliable suppliers of components who deliver perfect quality just in time, thus obviating the need for quality control of components bought and the need for keeping large stocks helps companies to attain cost leadership among other companies. By designing of products for easy manufacturing and using all other appropriate ingredients of modern production management, the firm can increase productivity to the highest possible level. The financial perspective of the TBSC tries to sum up what has been applied in high technology companies and written in dozens of books and articles and has been developed over a good number of years (Womack et al., 1990; Bessant, 1991; Rhodes and Wield, 1994).

High technology companies may opt to share technology with partners abroad because collaborations give them more advantages to compensate for higher appropriate risk. A company may also perceive that partnership decreases competitive risk from poorly performing operations more than it increases the competitive risk from technology loss. This perception might occur because a partner has better country-specific knowledge, access to distribution and production factors, and complementary resources. At an extreme, a high technology company may be able to gain foreign cost and sales advantages only by producing abroad in some type of partnership. This is because a host government restricts imports and foreign-owned operations, or a company may fear economic and political risk more than technology appropriation risk and seek out a local partner who will share financial exposure.

Customers' perspective

Most managerial studies have shown an increasing realization of the importance of customers' retention and satisfaction in any business (Chabrow, 2003; Holloway, 2002; Needleman, 2003). If customers of high technology companies are not satisfied, they will eventually find other suppliers who will satisfy them. Because technological collaboration puts more synergies among high technology companies, partnership with our supplier is necessary. In the high technology companies, interaction and participation in the marketplace is the primary source of information regarding what the next set of product/service requirements might be. Interaction and participation in the marketplace is the touchstone of the organization in the marketplace. It yields the most precious information of how the used models can evolve once the next product feature is introduced. There is no market report or analysis that can provide the adequate and timely information on what product/service features to bring to market. Given that, systematically capturing and operating on market experience data is a strategic function. The gem of insight that sparks innovation, births the next feature set, and results in market leading products and services lies within this stream of experience data.

Poor performance from this perspective is thus a leading indicator of future decline, even though the current financial picture may look good. In developing indicators for satisfaction, customers should be analyzed in terms of kinds of customers and the kinds of processes for which a high technology company is providing a product or service to those customer groups (Ydstie, 2004; Erensal et al., 2006; Hofmann and Orr 2005; Reisman, 2005; Cho et al., 2012). Frequently considered TBSC objects from the customer perspective of high technology companies include enhancing market share, enhancing customer satisfaction and retention and partnerships with suppliers.

Internal and technological processes perspective

Objects and indicators based on this perspective allow the chief technology officers (CTOs) to evaluate how well their company is running, and whether its products and services conform to customers' requirements (the mission statement). For high technology companies, this is a strategic imperative as shrinking product cycle collapses the window of profitability and product success (Ydstie, 2004; Erensal et al., 2006). Customers are increasingly demanding on lead times, while operations teams are increasingly adverse to inventory. Forecast accuracy that can support or refute product plans for market penetration has become critical for product success. Internal and technological objects and indicators of high technology companies must accurately reflect processes most intimately with a high technology companies' unique missions. Most important TBSC objects for the internal and technological processes perspective include the technology innovation process, enhancing manufacturing process, new product development, Increased responsiveness, technology innovation, technology transferability, enhancing manufacturing process, new products development, developing R&D projects and teams, managing the product life cycle, strutting industry, academic and institutes and patent registration (Ernst, 2003; Song et al., 1997; Ydstie, 2004; Hofmann and Orr 2005; Liao, 2005; Reisman, 2005; Erensal et al., 2006; Cho et al., 2012).

Learning and growth perspective

This perspective includes relating leading edge technologies to the employees and corporate cultural attitudes related to learning technology leadership (Hofmann and Orr 2005). Kaplan and Norton (2000) emphasize that learning includes not only training, but also teamwork, ease of communication among workers, and technological tools (Song, 1997; Kaplan and Norton, 2000). In high technology companies, people, the only repository of knowledge, are the main resource and should be in a continuous learning phase. Appropriate objects can guide managers in focusing facilities where they can help the most. One such enabler of HR development, multi-skilled employees, has been proposed to be one of the preconditions for organizational responsiveness (Challis and Samson, 1996; Hofmann and Orr, 2005). Furthermore, this claim has been applied to a wide range of job classifications from assembly-line workers to engineers and technicians (Rogerson, 1993). In this paper, the multi-skilled worker (MSW) is defined to be a cross trained employees with productivity, flexibility, quality, and employee's morale. Frequently cited TBSC measures for the learning and growth perspective in the selected Iranian high technology companies emphasize HR developments (employee's education and skill levels, employee's turnover rates and multi-skilled employees); information systems capabilities (percentage of front-line employees with on-line access to technology information, percentage of technology processes with real-time feedback); employees' satisfaction and motivation; maintenance project management skills; enhancing creativity; learning technology leadership and improving organizational training effectiveness (Challis and Samson 1996; Burn and Szeto 2000; Sacristán et al., 2003; Ydstie, 2004; Hofmann and Orr, 2005). For composing technology strategy map, 240 personnel from 24 high technology companies were needed to answer correspondence question with 1-4 score. Scores depend upon the amount of strength each object has on the company's business strategy and technology strategy. The research was conducted by the contribution of top-manager, operational-managers, median managers, supervisors and co-workers in strategic management and chief technology officers (CTOs). Analyses of gathered results from 150 surveys are available in Table 2. The main process of this paper is exhibited in Figure 3.

Casualty analysis in the technology strategy maps using FCSM

Making FCM framework for technology strategy maps

A cognitive map (CM) is a directed digraph for showing causality between concepts in complex foundations; it was introduced by Axelrod (1976) in political complications. The fuzzy set theory is the most powerful tool for modelling uncertainty atmosphere; it was introduced by Zadeh (1975). His groundbreaking work led to the expansion of possibility theory. The theory of possibility is a cognitive process. The fuzzy set theory provides a mathematical model for evaluating the human inference process. As against probabilistic or statistical representations, the fuzzy set theory seeks to identify subjective reasoning and assign degrees of possibilities in reaching conclusions (Zadeh, 1975a; 1975b; 1975c).

A fuzzy cognitive Map (FCM) is a graphical representation, consisting of nodes indicating the most relevant factors of a decisional environment; and the links between these nodes representing the relationships between those factors. FCM is a modeling methodology for complex decision systems, which has originated from the combination of fuzzy logic and neural networks. A FCM describes the behavior of a system about concepts; each concept representing an entity, a state, available, or an attribution of the system (Kosko, 1986). FCMs have been applied in simulation, modeling of organizational strategies, support for strategic problem formulation and decision analysis, knowledge bases construction, managerial problems diagnosis, failure modes effects analysis, requirements analysis, systems requirements specification, urban design support, relationship management in airlines services and web-mining inference amplification (Rodriguez-Repiso et al., 2007). Kardars et al. (1998) used FCMs for strategic information system planning (SISP) and used FCM methodologies for considering causality relationships between 165 variables and 210 relationships in both information technology (IT) and business areas. Xiao et al. (2012) integrated FCM and fuzzy soft set for supplier selection problem based on risk evaluation, by considering dependent and feedback effect among criteria on the decision-making process. Carvalho (2013), focuses on FCM as tools to model and simulate complex social, economic and political systems on point of views; discussing the structure, the semantics and the possible use in the qualitative systems. Glykas (2012) presents the application of a fuzzy cognitive map (FCM) framework and its associated modelling and simulation tool to strategy maps (SMs) and resolve limits of SMs. He used combination of BSC and FCM for placement of different performance measurement scenarios using the fuzzy cognitive strategic (FCSM). His considered FCMs allow simulation of SMs as well as interconnection of performance measures in different SMs which enable the creation of SM hierarchies. Also Glykas (2013) elaborates on the application of fuzzy cognitive maps (FCMs) in strategy maps (SMs) in the business process performance measurement which was experimented in the two banking. Chytasa et al. (2011)'s works proposed a proactive balanced scorecard methodology (PBCSM). They proposed decision aid may serve as a back end to balanced scorecard development and implementation. Using FCMs, they used the proposed method to draw a causal representation of KPIs (Chytasa et al., 2011).

Current study follows Rodriguez-Repiso et al. (2007)'s FCM framework in causality relationships, which gives easier solution for composing and evaluating fuzzy cognitive strategy maps (FCSM). For making our FCM framework in current study, we define concepts as nodes; we use C_i for concept i (for i =1, 2,…, 23; we have 23

Table 2. Perspectives, objects and indicators of TBSC approach.

Perspective /Object	Indicators	Mean	SD	α
Financial				
(F1) Enhancing return on investment (ROI)	Return on technological investment	2.81	0.63	0.74
	Return on capital investment	3.13	0.25	
	Return on product development expense	3.21	0.24	
(F2) Cost leadership	Production reduced costs	2.14	0.35	0.65
	General and administration reduced costs	2.23	0.67	
(F3) Risk management	Technology ranking of products and process compared to competitors	2.86	0.14	0.77
Customer				
(C1) Enhanced Market Share	Number of new customers	3.22	0.15	0.70
	Brand price	2.84	0.24	
	Market share (%)	3.17	0.10	
(C2) Lift up customer satisfaction and retentions	Customer satisfaction index	2.68	0.46	0.63
	Decreased customer's complaints	2.49	0.78	
(C3) Partnerships with suppliers	Number of suppliers	2.20	0.33	0.65
	Number of outsourced projects	1.89	0.74	
Internal and Technological Processes				
(I1) Increased responsiveness	Product delivery reduced time	2.65	0.38	0.67
	Shortage response time	2.17	0.52	
	On-time deliveries	3.23	0.45	
(I2) Technology innovation	Number of explored technologies	3.42	0.08	0.78
(I3) Technology transferability	Number of licenses	3.58	0.24	0.75
	Number of Joint-ventures	2.47	0.50	
(I4) Enhancing manufacturing process	Field	3.65	0.13	0.66
	Decreased defect rates	3.24	0.25	
	Average time taken to manufacture orders	2.87	0.34	
	Setup time	2.89	0.34	
	Manufacturing down time	3.23	0.21	
(I5) New Products development	Number of new products/ services	2.76	0.36	0.72
(I6) Developing R&D projects and teams	Number of internal R&D projects	3.25	0.18	0.69
	Number of external R&D projects	2.74	0.64	
	The level of participation in problem definition	2.28	0.75	
	Percentage of projects based on teamwork	3.2	0.67	
(I7) Managing product life cycle	Product/process life cycle time	3.25	0.16	0.77
(I8) Strutting industry, academic and institutes	Number of new treaties	2.67	0.30	0.61
(I9) Patent registration	Number of newly registered patents	2.28	0.59	0.73
Learning and Growth				
(L1)Training leading-edge technologies	Number of scientists	3.24	0.26	0.79
	Leading-edge technology training (Hrs)	2.78	0.45	
	Number of multi-skilled employees	2.93	0.69	
(L2) HR development	Employee educational level	2.86	0.53	0.61
	Employee turnover rates	2.27	0.77	

Table 2. Contd.

(L3) Employees satisfaction and motivation	Employee satisfaction scores	2.35	0.30	0.75
	Number of motivational incentives	2.78	0.55	
	Percentage of employee suggestions implemented	2.91	0.47	
(L4) Information system capabilities	Percentage of front-line employees with on-line access to technology information	2.68	0.29	0.73
	Percentage of technological processes with real-time feedback	2.69	0.32	
(L5) Maintenance project management skills	Percentage of people engaged in decision-making	2.45	0.55	0.68
(L6) Enhance creativity	Number of accepted innovative proposal	2.38	0.41	0.73
	Number of new process improvement ideas generated	2.12	0.38	
	Number of suggestions per employee	3.46	0.58	
(L7) Learning technology leadership	Technology protection plans	3.76	0.56	0.69
	Number of technology acquainted	2.85	0.66	
(L8) Improve organizational training effectiveness	Index of training effectiveness	3.57	0.11	0.71

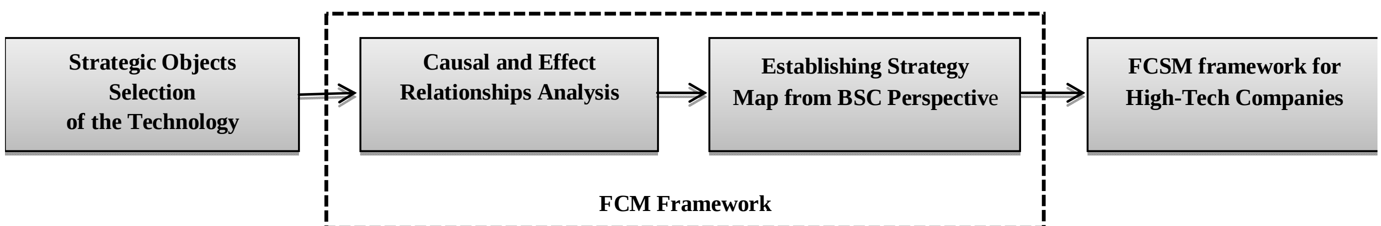

Figure 3. FCSM framework process for the Iranian high-tech companies strategic planning.

objects from four TBSC perspectives) (Pelaez and Bowles, 1995; Tsadiras, 2008).

To determine the strength between two concepts (for example, i and j seen in W_{ij}), we should first define sign of the strength between concepts. If an increase in one concept causes increase in amounts of another concept, we conclude there is positive relationship between the two concepts. When an increase for the number of one concept causes decrease in amounts of another concept, consequently, we conclude there is negative relation between the two concepts. If there is no logical or empirical relation between two concepts, we infer there is no relationship between the mentioned concepts.

According to the above subjects, we concluded that the amounts of these relationships in FCM can be positive or negative or zero defined as follows:

$$\begin{cases} W_{ij} > 0 & \text{Describes a positive casual relationship} \\ W_{ij} < 0 & \text{Describes a negative casual relationship} \\ W_{ij} = 0 & \text{Without any casual relationship} \end{cases} \quad (1)$$

For example, in the current study, it is obvious that all the relationships in our technology strategy map have positive relationships with other objects. Increase in amounts of ‘HR development (L2)’ activities causes increase in ‘training leading-edge technologies (L1)’ (Figure 4). So we conclude there is a positive relationship between ‘L1’ and ‘L2’ (Rodriguez-Repiso et al., 2007; Kosko, 1986). For obtaining the amount of these relationships, we use Rodriguez-Repiso et al.’s methodology, based on four matrixes consisting of the initial matrix of

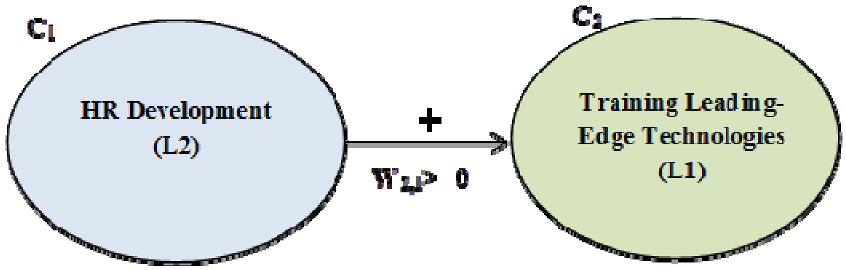

Figure 4. Sample of relationships in strategic management of technology implementation.

concepts (IMC), fuzzified matrix of concepts (FMC), strength of relationships matrix of concepts (SRMC) and final matrix of concepts (FMS).

In the first step, we compose the initial matrix of concepts (IMC). IMC is created by collecting empirical data from 24 high-tech companies, which was conducted by a contribution of top-manager, operational-managers, planet managers, supervisors, co-workers and chief technology officers (CTOs). IMC is made by those who have been educated in the strategic management of technology practices and have applied strategic technology improvement tool sets in their companies. Total objects rolled in strategic management of technology in the high technology companies according to the four TBSC perspectives are 23 objects. Finally, we concluded all empirical data from each high technology companies are in one column according to CTO which describes a high technology situation from four TBSC perspectives. $O_{i,j}$ describes elements in row i and column j according to CTOs suggestion of jth high technology company based on empirical results of ith object. Also we show row i in the corresponding matrix with V_i (Rodriguez-Repiso et al., 2007).

In the next step, we compose fuzzified matrix of concepts (FMC) by using data from Table 3, and translate this matrix to a fuzzy matrix by using Likert scale (VH=9, H=7, M=5, L=3, VL=1) and the following formulas:

$Max(O_{iq}) \Rightarrow X_i(O_{iq})=1$ and $Min(O_{ip}) \Rightarrow X_i(O_{ip})=1$; for

p,q=1, 2, 3,…, 24; i=1,2,…,23

$$X_i(O_{iq}) = (O_{iq} - Min(O_{ip}))/(Max(O_{iq}) - \quad (2)$$

It seems every row illustrates the intense of each object in our empirical research according to CTOs suggestion which contributed to SMOT processes and evaluations based on empirical data (Table 4). In some studies similar to this study, it is difficult to assign a numerical score for each object from SMOT between 0 and 100. For facilitating this work, we changed Rodriguez-Repiso's algorithms using linguistically variables standby numerical scale according to the collected empirical research, without missing main FCM concept, which is much closer to the fuzzy concept of FCM (Rodriguez-Repiso et al., 2007; Kosko, 1986). In the third step, we need to compute adjacency of two concepts C_i and C_j using two kinds of formulations. If two concepts, C_i and C_j have a direct positive relationship we use $X_1(V_j) - X_2(V_j)$ for distance among the two concepts; but if two concepts have reverse relationship, we use. $X_1(V_j) - (1 - X_2(V_j)$. Subsequently, by defining two types of formulations, there comes another two formulations for computing distance, using absolute assignment for the two mentioned formulations and we obtain $d_j = | X_1(V_j) - X_2(V_j))|$ for direct relations and $d_j = | X_1(V_j) - (1 - X_2(V_j))|$ for diverse relations. According to the above subjects another variable should be defined as AD as follows:

$$AD = \frac{\sum_{j=1}^{m} d_j}{m}$$

At last, adjacency of the two concepts rows (Concepts) defined with S determines:

$$S = 1 - AD.$$

Some computed values between concepts (Table 5) might be impossible in technology strategy maps of high technology companies and do not exist empirically; thus should be ignored. Also mathematics computes acquire this deleted relationship. In doing this work, we obtain final matrix of concepts (FMS) as seen in Table 6.

Casualty analysis in the TSM

Proposed FCSM framework for technology strategy maps of high technology companies improves organizational

Table 3. Empirical data collected from 24 high technology companies (IMC).

TBSC Object	High tech company																							
	HT_1	HT_2	HT_3	HT_4	HT_5	HT_6	HT_7	HT_8	HT_9	HT_{10}	HT_{11}	HT_{12}	HT_{13}	HT_{14}	HT_{15}	HT_{16}	HT_{17}	HT_{18}	HT_{19}	HT_{20}	HT_{21}	HT_{22}	HT_{23}	HT_{24}
F1	VH	H	M	VH	VH	VH	H	VH	VH	M	H	VH	VH	VH	VH	M	H	H	L	M	VH	VH	VH	VH
F2	VH	H	H	H	H	H	VH	M	H	VH	VH	M	M	VH	H	M	M	M	H	VH	M	M	H	VL
F3	M	L	H	L	L	H	L	L	VL	L	L	L	L	L	VH	VH	H	H	VH	VL	M	H	VH	M
C1	M	H	VH	L	M	L	H	L	H	M	L	H	VH	H	H	VH	H	M	L	H	L	M	L	M
C2	VH	H	H	VH	H	H	M	H	VH	H	VH	M	H	VH	VH	H	M	L	M	VL	M	M	VL	H
C3	H	H	M	VH	VH	VL	H	VH	H	VH	VH	H	H	VH	H	L	M	M	M	H	M	H	M	VH
I1	H	VH	M	H	H	VH	VL	M	H	L	VH	M	M	M	L	VH	H	M	L	L	H	M	L	L
I2	VH	H	M	M	L	H	M	M	H	H	VL	L	M	M	H	H	M	VH	VH	H	H	VH	H	VH
I3	VH	M	H	VL	VL	L	M	M	H	H	M	H	L	VL	VH	M	H	L	L	L	VH	L	VH	VH
I4	M	VH	H	M	M	M	H	VH	M	M	H	VL	VH	H	M	VH	VH	VH	H	VH	VH	M	H	VH
I5	M	M	L	VH	H	M	L	L	H	M	L	L	VH	M	H	VL	VL	L	M	M	H	H	M	H
I6	VH	H	H	M	H	VH	H	VH	M	H	VH	L	L	L	VH	VH	H	H	VH	VL	M	H	VH	M
I7	VL	H	H	M	VH	VH	VL	H	VH	H	VH	VH	H	H	VH	H	L	M	M	M	H	M	H	M
I8	L	L	L	H	M	M	H	VH	VH	VH	VL	H	VH	H	VH	VH	H	H	VH	H	L	M	M	M
I9	M	VH	VL	M	M	H	VH	L	VH	VH	VH	H	M	M	M	VH	H	L	M	H	M	M	VL	L
L1	H	H	M	VH	VH	VL	H	VH	H	VH	VH	H	H	VH	H	L	M	M	M	H	M	H	M	VH
L2	H	M	L	H	H	H	VH	M	L	VH	H	H	VH	H	H	M	H	VH	H	VH	M	H	M	L
L3	M	L	H	H	L	VH	VH	M	VH	L	VH	M	M	M	M	H	M	VH	VH	L	M	M	M	L
L4	VH	VH	VH	M	H	H	L	M	VH	VH	VH	VH	VL	H	H	M	VH	VH	VL	H	VH	H	VH	VH
L5	M	VH	H	M	M	M	H	VH	M	M	H	VL	L	L	L	H	M	M	H	VH	VH	VH	VL	H
L6	VH	VL	M	M	H	VH	L	VH	VH	VH	H	M	L	L	H	L	L	VL	L	L	L	L	M	M
L7	H	M	VH	VH	VL	H	VH	H	VH	VH	H	H	L	M	L	H	L	H	M	L	H	VH	M	L
L8	M	M	H	M	VH	VH	VH	M	M	M	M	H	M	VH	VH	M	L	L	M	VH	VH	M	H	L

Notation : VH is abbreviations of very high influences; **H** is abbreviations of high influence; M is abbreviations of medium influence; **L** is abbreviations of very low influences; and **VL** used for very low influences.

strategies in both business and technology areas. Technology strategy map conquers balanced scorecard (BSC) traditional defaults discussed throughout the literature such as need for fuzziness in causal relationships, dynamic relationships and interactions among strategic

Table 4. The fuzzified matrix of concepts (FMC).

TBSC Object	High tech company																							
	HT1	HT2	HT3	HT4	HT5	HT6	HT7	HT8	HT9	HT10	HT11	HT12	HT13	HT14	HT15	HT16	HT17	HT18	HT19	HT20	HT21	HT22	HT23	HT24
F1	1.00	0.67	0.33	1.00	1.00	1.00	0.67	1.00	1.00	0.33	0.67	1.00	1.00	1.00	1.00	0.33	0.67	0.67	0.00	0.33	1.00	1.00	1.00	1.00
F2	1.00	0.75	0.75	0.75	0.75	0.75	1.00	0.50	0.75	1.00	1.00	0.50	0.50	1.00	0.75	0.50	0.50	0.50	0.75	1.00	0.50	0.50	0.75	0.00
F3	0.50	0.25	0.75	0.25	0.25	0.75	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.25	1.00	1.00	0.75	0.75	1.00	0.00	0.50	0.75	1.00	0.50
C1	0.33	0.67	1.00	0.00	0.33	0.00	0.67	0.00	0.67	0.33	0.00	0.67	1.00	0.67	0.67	1.00	0.67	0.33	0.00	0.67	0.00	0.33	0.00	0.33
C2	1.00	0.75	0.75	1.00	0.75	0.75	0.50	0.75	1.00	0.75	1.00	0.50	0.75	1.00	1.00	0.75	0.50	0.25	0.50	0.00	0.50	0.50	0.00	0.75
C3	0.75	0.75	0.50	1.00	1.00	0.00	0.75	1.00	0.75	1.00	1.00	0.75	0.75	1.00	0.75	0.25	0.50	0.50	0.50	0.75	0.50	0.75	0.50	1.00
I1	0.75	1.00	0.50	0.75	0.75	1.00	0.00	0.50	0.75	0.25	1.00	0.50	0.50	0.50	0.25	1.00	0.75	0.50	0.25	0.25	0.75	0.50	0.25	0.25
I2	1.00	0.75	0.50	0.50	0.25	0.75	0.50	0.50	0.75	0.75	0.00	0.25	0.50	0.50	0.75	0.75	0.50	1.00	1.00	0.75	0.75	1.00	0.75	1.00
I3	1.00	0.50	0.75	0.00	0.00	0.25	0.50	0.50	0.75	0.75	0.50	0.75	0.25	0.00	1.00	0.50	0.75	0.25	0.25	0.25	1.00	0.25	1.00	1.00
I4	0.50	1.00	0.75	0.50	0.50	0.50	0.75	1.00	0.50	0.50	0.75	0.00	1.00	0.75	0.50	1.00	1.00	1.00	0.75	1.00	1.00	0.50	0.75	1.00
I5	0.50	0.50	0.25	1.00	0.75	0.50	0.25	0.25	0.75	0.50	0.25	0.25	1.00	0.50	0.75	0.00	0.00	0.25	0.50	0.50	0.75	0.75	0.50	0.75
I6	1.00	0.75	0.75	0.50	0.75	1.00	0.75	1.00	0.50	0.75	1.00	0.25	0.25	0.25	1.00	1.00	0.75	0.75	1.00	0.00	0.50	0.75	1.00	0.50
I7	0.00	0.75	0.75	0.50	1.00	1.00	0.00	0.75	1.00	0.75	1.00	1.00	0.75	0.75	1.00	0.75	0.25	0.50	0.50	0.50	0.75	0.50	0.75	0.50
I8	0.25	0.25	0.25	0.75	0.50	0.50	0.75	1.00	1.00	1.00	0.00	0.75	1.00	0.75	1.00	1.00	0.75	0.75	1.00	0.75	0.25	0.50	0.50	0.50
I9	0.50	1.00	0.00	0.50	0.50	0.75	1.00	0.25	1.00	1.00	1.00	0.75	0.50	0.50	0.50	1.00	0.75	0.25	0.50	0.75	0.50	0.50	0.00	0.25
L1	0.75	0.75	0.50	1.00	1.00	0.00	0.75	1.00	0.75	1.00	1.00	0.75	0.75	1.00	0.75	0.25	0.50	0.50	0.50	0.75	0.50	0.75	0.50	1.00
L2	0.67	0.33	0.00	0.67	0.67	0.67	1.00	0.33	0.00	1.00	0.67	0.67	1.00	0.67	0.67	0.33	0.67	1.00	0.67	1.00	0.33	0.67	0.33	0.00
L3	0.33	0.00	0.67	0.67	0.00	1.00	1.00	0.33	1.00	0.00	1.00	0.33	0.33	0.33	0.33	0.67	0.33	1.00	1.00	0.00	0.33	0.33	0.33	0.00
L4	1.00	1.00	1.00	0.50	0.75	0.75	0.25	0.50	1.00	1.00	1.00	1.00	0.00	0.75	0.75	0.50	1.00	1.00	0.00	0.75	1.00	0.75	1.00	1.00
L5	0.50	1.00	0.75	0.50	0.50	0.50	0.75	1.00	0.50	0.50	0.75	0.00	0.25	0.25	0.25	0.75	0.50	0.50	0.75	1.00	1.00	1.00	0.00	0.75
L6	1.00	0.00	0.50	0.50	0.75	1.00	0.25	1.00	1.00	1.00	0.75	0.50	0.25	0.25	0.75	0.25	0.25	0.00	0.25	0.25	0.25	0.25	0.50	0.50
L7	0.75	0.50	1.00	1.00	0.00	0.75	1.00	0.75	1.00	1.00	0.75	0.75	0.25	0.50	0.25	0.75	0.25	0.75	0.50	0.25	0.75	1.00	0.50	0.25
L8	0.33	0.33	0.67	0.33	1.00	1.00	1.00	0.33	0.33	0.33	0.33	0.67	0.33	1.00	1.00	0.33	0.00	0.00	0.33	1.00	1.00	0.33	0.67	0.00

objects.

The present, research addresses the problems of the balanced scorecard by using the soft computing characteristics of fuzzy cognitive maps (FCMs). FCSMs connect such objects as enhancing customers' satisfaction and retention, risk management, enhancing process management, new product development, technology leaderships, innovation, human resources, information system capabilities and learning with one another in one graphical representation. Technology strategy mapping helps greatly in describing

Table 5. The strength of relationships matrix of concepts (SRMC).

TBSC Object	F1	F2	F3	C1	C2	C3	I1	I2	I3	I4	I5	I6	I7	I8	I9	L1	L2	L3	L4	L5	L6	L7	L8
F1		0.64	0.52	0.51	0.71	0.74	0.63	0.64	0.64	0.63	0.65	0.66	0.69	0.63	0.54	0.74	0.58	0.47	0.71	0.57	0.63	0.63	0.61
F2	0.64		0.58	0.57	0.78	0.78	0.72	0.73	0.63	0.68	0.64	0.73	0.72	0.67	0.75	0.78	0.76	0.66	0.71	0.67	0.68	0.71	0.71
F3	0.52	0.58		0.59	0.59	0.49	0.64	0.71	0.67	0.61	0.64	0.79	0.59	0.65	0.58	0.49	0.60	0.67	0.56	0.63	0.59	0.60	0.60
C1	0.51	0.57	0.59		0.60	0.58	0.62	0.59	0.61	0.60	0.61	0.51	0.57	0.67	0.67	0.58	0.60	0.54	0.51	0.58	0.52	0.55	0.60
C2	0.71	0.78	0.59	0.60		0.77	0.73	0.68	0.66	0.63	0.69	0.74	0.77	0.66	0.72	0.77	0.60	0.61	0.66	0.66	0.71	0.70	0.58
C3	0.74	0.78	0.49	0.58	0.77		0.65	0.68	0.61	0.67	0.71	0.66	0.71	0.70	0.68	1.00	0.68	0.51	0.68	0.66	0.67	0.68	0.60
I1	0.63	0.72	0.64	0.62	0.73	0.65		0.66	0.61	0.65	0.67	0.70	0.73	0.59	0.76	0.65	0.61	0.67	0.66	0.68	0.69	0.70	0.60
I2	0.64	0.73	0.71	0.59	0.68	0.68	0.66		0.69	0.72	0.70	0.73	0.66	0.69	0.65	0.68	0.64	0.61	0.71	0.71	0.61	0.69	0.57
I3	0.64	0.63	0.67	0.61	0.66	0.61	0.61	0.69		0.59	0.61	0.67	0.61	0.56	0.58	0.61	0.52	0.54	0.69	0.60	0.68	0.65	0.61
I4	0.63	0.68	0.61	0.60	0.63	0.67	0.65	0.72	0.59		0.63	0.70	0.65	0.70	0.66	0.67	0.65	0.56	0.68	0.82	0.52	0.59	0.58
I5	0.65	0.64	0.64	0.61	0.69	0.71	0.67	0.70	0.61	0.63		0.57	0.67	0.66	0.64	0.71	0.66	0.55	0.57	0.64	0.67	0.64	0.65
I6	0.66	0.73	0.79	0.51	0.74	0.66	0.70	0.73	0.67	0.70	0.57		0.70	0.67	0.65	0.66	0.59	0.66	0.67	0.71	0.70	0.67	0.56
I7	0.69	0.72	0.59	0.57	0.77	0.71	0.73	0.66	0.61	0.65	0.67	0.70		0.68	0.68	0.71	0.58	0.59	0.70	0.61	0.69	0.68	0.67
I8	0.63	0.67	0.65	0.67	0.66	0.70	0.59	0.69	0.56	0.70	0.66	0.67	0.68		0.71	0.70	0.72	0.60	0.56	0.60	0.64	0.65	0.57
I9	0.54	0.75	0.58	0.67	0.72	0.68	0.76	0.65	0.58	0.66	0.64	0.65	0.68	0.71		0.68	0.73	0.65	0.65	0.69	0.64	0.71	0.61
L1	0.74	0.78	0.49	0.58	0.77	1.00	0.65	0.68	0.61	0.67	0.71	0.66	0.71	0.70	0.68		0.68	0.51	0.68	0.66	0.67	0.68	0.60
L2	0.58	0.76	0.60	0.60	0.60	0.68	0.61	0.64	0.52	0.65	0.66	0.59	0.58	0.72	0.73	0.68		0.64	0.59	0.60	0.60	0.65	0.67
L3	0.47	0.66	0.67	0.54	0.61	0.51	0.67	0.61	0.54	0.56	0.55	0.66	0.59	0.60	0.65	0.51	0.64		0.49	0.60	0.65	0.71	0.61
L4	0.71	0.71	0.56	0.51	0.66	0.68	0.66	0.71	0.69	0.68	0.57	0.67	0.70	0.56	0.65	0.68	0.59	0.49		0.60	0.64	0.65	0.55
L5	0.57	0.67	0.63	0.58	0.66	0.66	0.68	0.71	0.60	0.82	0.64	0.71	0.61	0.60	0.69	0.66	0.60	0.60	0.60		0.59	0.69	0.59
L6	0.63	0.68	0.59	0.52	0.71	0.67	0.69	0.61	0.68	0.52	0.67	0.70	0.69	0.64	0.64	0.67	0.60	0.65	0.64	0.59		0.68	0.64
L7	0.63	0.71	0.60	0.55	0.70	0.68	0.70	0.69	0.65	0.59	0.64	0.67	0.68	0.65	0.71	0.68	0.65	0.71	0.65	0.69	0.68		0.58
L8	0.61	0.71	0.60	0.60	0.58	0.60	0.60	0.57	0.61	0.58	0.65	0.56	0.67	0.57	0.61	0.60	0.67	0.61	0.55	0.59	0.64	0.58	

the technology strategy and communicating this strategy among executives and their employees. In this way, alignment can be created around the strategy, which makes a successful implementation of the strategy easier. We should bear in mind that often, the implementation of a constructed strategy is the biggest challenge. In the strategy-focused organization, Kaplan and Norton transformed their balanced scorecard,

Table 6. The final matrix of concepts (FMS).

TBSC Object	F1	F2	F3	C1	C2	C3	I1	I2	I3	I4	I5	I6	I7	I8	I9	L1	L2	L3	L4	L5	L6	L7	L8
F1																							
F2	0.64																						
F3	0.52																						
C1	0.51	0.57	0.59																				
C2		0.78		0.60																			
C3			0.49	0.58																			
I1					0.73																		
I2		0.73		0.59	0.68		0.66				0.70												
I3						0.61							0.61										
I4									0.59				0.65										
I5				0.61																			
I6									0.67														
I7				0.57							0.67												
I8										0.70	0.66	0.67				0.70							
I9								0.65			0.64												
L1																						0.68	0.60
L2																0.68		0.64		0.60	0.60		0.67
L3														0.60					0.49				0.61
L4										0.68													
L5												0.71		0.60					0.60				
L6																				0.59			
L7							0.70								0.71								
L8															0.61				0.55			0.58	

introduced in 1992 in the Harvard business review as a performance measurement system, to a strategic management system. A lot of that transformation was done in introducing the so-called strategy map. In our proposed FCSM all of the information about high technology companies is contained in one page; this enables relatively easy strategic communication through four FCSM perspectives: financial; customer; internal;

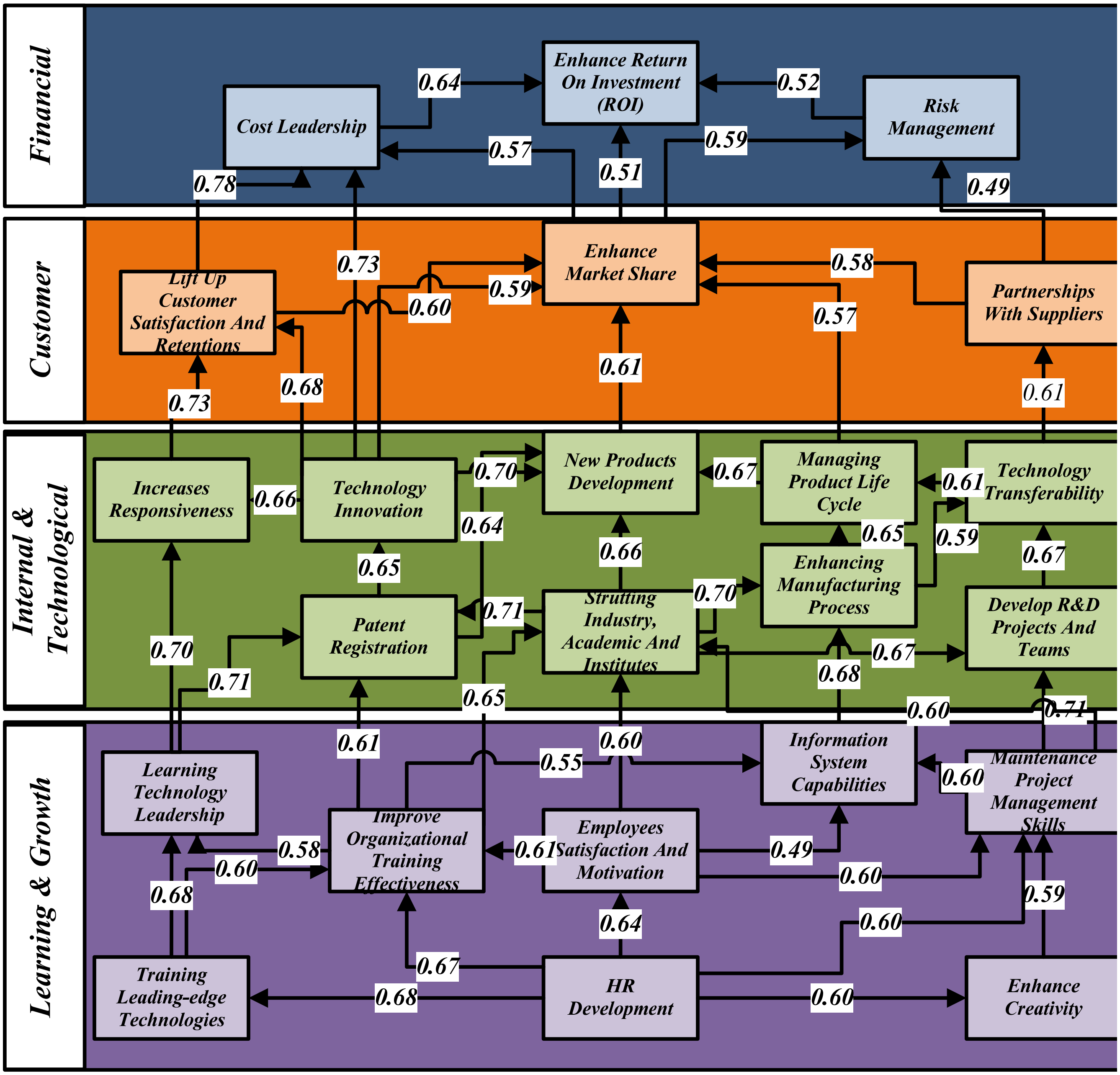

Figure 5. Proposed FCSM for the high technology companies.

learning and growth. Financial perspective of FCSM looks at creating long-terms shareholders' value and builds from a productivity strategy of improving cost structure, asset utilization and a growth strategy of expanding opportunities and enhancing customers' value. Strategic improvement is supported by price, quality, availability, selection, functionality, service, partnership and branding. From an internal and technological perspective, operations and technology management processes help to create product and service attributes while innovation, regulatory and social processes help with relationships and image. All of these processes are supported by the allocation of human, information and organizational capital, which comprise company culture, leadership, alignment and teamwork. Finally, cause and effect relationships are described by connecting arrows (Figure 5).

Conclusion

In this paper, the results of the strategic management of technology (SMOT) practices in high technology companies' context are concluded from four perspectives of TBSC. Proposed TBSC is considered as a framework for technology management in the Iranian high technology companies. This paper also presented an application of FCMs in TSM and proposed the FCSM by considering 23 objects and 49 relationships between these from four TBSC perspectives in the high technology companies' context. In an increasingly complex and dynamic environment, practitioners in high technology companies are facing a challenge on how to strategically manage technology to sustain the company's competitiveness. The main theoretical contribution of the research is composing the new framework for reaching the determined goals which technology management from TBSC approach. TSM framework unites strategic management, organizational management and technology management viewpoints to enterprise management, and enhances knowledge in strategic technology management. It was also shown the important role of fuzzy cognitive maps in causality relationship analysis between TBSC objects in presented technology strategy map. A FCSM not only shows how technology and business strategies integrate into one cognitive map, but also shows causality relationships and degrees of interrelations between objects in both strategic and technology management. Also a FCSM shows interrelations among SMOT objects by jointed-cycles and paths in the high technology environment. Current study provides a context for future researchers to work on the SMOT by considering more objects and interrelationships, using data mining and another statistical analysis technique.

Conflict of interest

Author have not declared any conflict of interest

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