

ISMC 2022
17th International Strategic Management Conference**FUZZY COGNITIVE STRATEGIC MAP HIERARCHIES IN
PERFORMANCE MEASUREMENT, MODELING AND
REORGANIZATION**

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(a) Department of Financial and Management Engineering, University of the Aegean, Chios, Greece,
mglikas@aegean.gr**Abstract**

The paper focuses on the use of Fuzzy Cognitive Mapping (FCM) in the Balanced Scorecard (BSC) performance measurement framework. We present a state of the art in the areas of performance measurement and BSC. We highlight the limitations of BSC frameworks and the drawbacks identified in strategic maps. We then present the FCM algorithm and its use in decision making as a solution to identified limitations and drawbacks. We elaborate on an FCM methodology and a supporting FCM software application called FCM Modeler for the development of FCM hierarchies. The methodology and the tool are used for the application of BSC in Operations Management (OM). The aim is to facilitate the OM decision making process by utilizing and exploiting the predictive modeling and analysis capabilities of FCMs. We present the design and simulation capabilities of the FCM Modeler tool and the analysis reports that can be produced in an OM Enterprise Resource Planning (ERP) case study.

2357-1330 © 2022 Published by European Publisher.

Keywords: Balanced scorecard, business process management, enterprise resource planning systems, fuzzy cognitive maps, operations management, performance measurement

1. Introduction: Performance Measurement and the Balanced Scorecard

Performance Measurement Systems (PMS) provide managers with sets of measures and indicators that enable managers, stakeholders and shareholders to appropriately analyze organizational performance. They can set targets and objectives to employees, teams, departments, processes and the company as a whole in its strategic plan and link all these targets and objectives in a holistic manner. They can also assess the alignment of employee, process and departmental performance to strategic plan targets and objectives. In cases of poor performance or misalignment between strategic and lower level objectives corrective actions are undertaken so that performance levels reach appropriate standards thus ensuring company prosperity and sustainability (Glykas, 2015; Glykas, 2019a; Glykas 2019b; Glykas et al., 2018; Glykas & Johnichen, 2017; Glykas et al., 2015).

With the ever increasing pace in market conditions only organizations that can evolve and adapt fast to new conditions can survive and prosper. The need for proper design, implementation and utilization of Performance Measurement Systems, is greater than ever for organizations to respond to this challenge (Eccles & Roeser, 2011). The core of performance measurement systems, is the set of measures selected (Ampantzi et al., 2013; Chytas & Glykas, 2011; Glykas et al., 1993a; Glykas et al., 1993b; Glykas et al., 1993c; Glykas et al. 1993d; Glykas & Valiris 1992; Glykas et al. 1992; Pappa et al., 2013; Plakoutsi et al. 2013; Sezenias et al., 2013; Valiris et al., 2005; Valiris & Glykas, 2004; Valiris & Glykas, 2000; Valiris & Glykas, 1999a; Valiris & Glykas, 1999b; Valiris & Glykas 1998; Wilhelmij et al. 1993a; Wilhelmij et al., 1993b; Xirogiannis & Glykas, 2007). Of equal importance are the relationships that exist among measures and in particular the cause and effect relationships among them ought to be properly specified (De Waal, 2003; Glykas, 2013b; Glykas, 2013c; Glykas, 2013d; Glykas, 2013a; Glykas, 2012; Glykas & Chytas, 2004c; Glykas & Chytas, 2004d).

The Balanced Scorecard is one of the most well-known frameworks that can provide this kind of capability and it has been widely used in organizations for many decades (Kaplan & Norton, 1996). It comprises of four distinctive perspectives: the Customer Perspective measuring lead times, quality, performance, service, and costs, the Internal Business Perspective that focuses on core processes and competencies, based on measures such as cycle time, quality, employee skills, productivity etc., the Learning and Growth Perspective that comes from three principal sources, (a) People, (b) Systems, (c) Organizational procedures, and finally, the Financial Perspective based on financial performance measures like cash flow, sales growth, operating income by division, market share by segment, return in equity etc. (Kaplan & Norton, 2004).

Kaplan and Norton (2004) original ideas stated that the Balanced Scorecard should be used on the what to measure as strategic objectives in the four perspectives and their analysis should provide a way or path on how to manage strategy (Rafiq et al., 2020).

The founders of BSC also have suggested the utilization of strategic maps as a means to depict and analyze cause and effect relationships amongst measures (Kaplan & Norton, 2001). Studies have revealed, however, that only 6 in 10 executive managers have confidence in the data exhibited to them (Kellen & Wolf, 2003). The main drawback identified is that in the vast majority of cases organizations disregard the vital interdependencies and trade-offs among measures. The BSC fails to capture indirect

interdependencies between the four dimensions (Marr et al., 2004). In addition, there is a lack of ability for a BSC designer to test scenarios and select the most suitable for the company under examination (Armstrong, 2019; Osterwalder et al., 2014) mainly due to the lack of proper simulation and analysis support. This kind of support is particularly needed in cases that there exists an expansive number of multidimensional factors that can influence relationships and interdependencies amongst measures (Holden et al., 1994; Glykas & Valiris 1999; Glykas & Litinas 1995; Glykas et al., 1994; Glykas 1994; Glykas & Holden 1994; Xirogiannis et al., 2008).

Researchers also indicated that the BSC is in many cases too abstract to present company specific performance measures (Norreklit et al., 2008), and as proof for this kind of performance measures generalization they presented surveys that revealed an extraordinary large number of identical performance measures being used for companies that operate in totally unrelated industries (Glykas, 2013a; Glykas, 2004; Glykas & Chytas 2004a; Stakias et al., 2013).

Based on these findings, Nielsen et al. (2016) have concluded that although research in management has been outstanding in the last fifteen years there is very little progress in the field of performance measurement and in particular in the BSC. The little progress in research related to the balanced scorecard has as a consequence resulted in small progress in research in strategy maps that appear to be bound to the slow progress pace of the BSC framework (Glykas, 2014; Glykas & Chytas 2005; Glykas & Chytas 2004b; Rigby & Bilodeau, 2015).

1.1. A Review of Required Strategic Map Principles

Some researchers argue that for the strategy map to reach full potential in performance management its relationship and direct reference to BSC should be loosened (De Waal, 2003). The most comprehensive study on the requirements of the new era of strategic maps was conducted by Islam (2018). He reviewed 41 publications focusing on strategy maps as well as 333 strategy map frameworks identified in the literature and proposed fourteen principles that should be satisfied for the future generation of strategic maps. The first five principles are mainly concerned with the link between strategic maps and the organization's strategy, vision and mission as well as the with the focus on key focus areas, strategic themes etc.

The remaining nine principles concentrate on more advanced issues all related to the drawbacks of the BSC identified by the researchers mentioned previously in this section. The study (Islam, 2018) revealed that there is a need for a hierarchical order in line with the organization's strategy and structure (principle 6). It also revealed that strategy maps should be constructed and be based upon strategic objectives that are linked amongst themselves, these business objectives could be mapped across several maps (principles 7 and 8). In strategy maps there is a need for incorporating the time element (principle 9) and in order to provide the notion of sequence (or time) strategic maps should firstly provide the ability of directional arrows between strategic objectives that create cause and effect relationships (principles 10, 11, 12 and 13). These cause and effect relationships depicted in arrows should be labeled with a "performance marker" that declares a positive (+) or negative (-) relationship between strategic objectives etc (principle 14). The study concludes that there are no frameworks observed providing performance

markers with only one notable exception (Cardinaels & van Veen-Dirks, 2010). An example presented by Islam (2018) on the use of a would be future Strategic Map is presented in Figure 1:

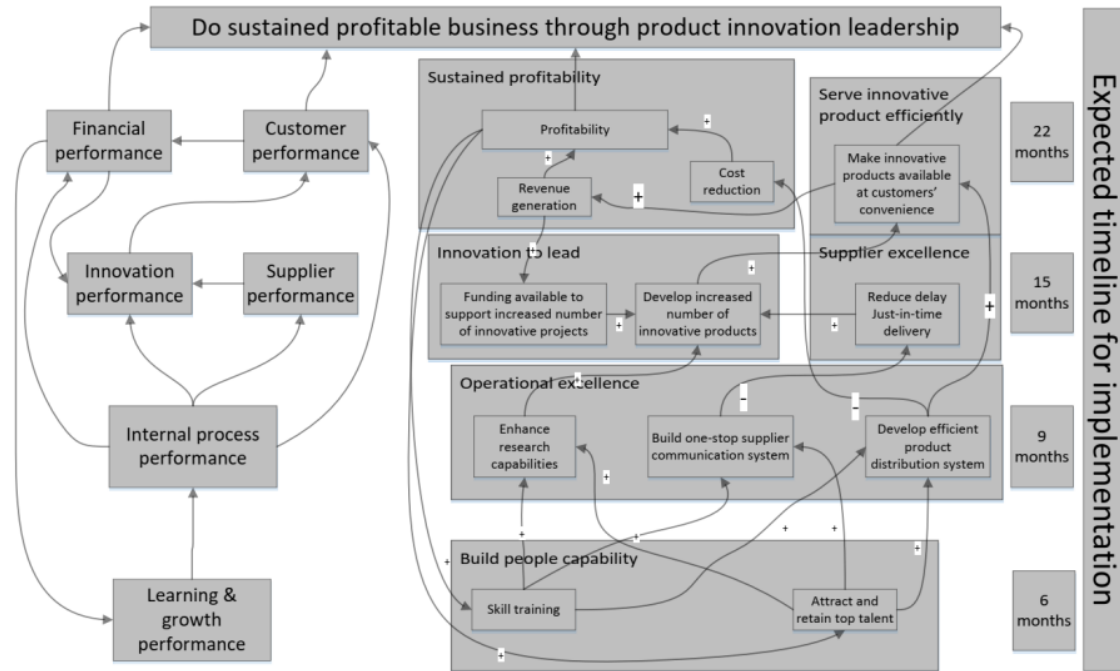


Figure 1. An example of a Strategy Map enhanced with Directional Arrows, Performance Markers and the Time Element as proposed by Islam (2018)

The map proposed can be divided into three distinct areas. The targets area or higher level targets in the left, the focus areas for the achievement of these targets in the middle and the time area in the right. The model proposed by Islam is based on the large number of principles gathered in his study but at the same time raises an even larger number of questions for the researchers in the area.

For example could every focus area in the middle column of the map be considered an expansion of a target? Can the target "Learning and growth performance" be achieved by the elements belonging to the "Build people capability" focus area? If this is the case why do we need both of them being present in a map? Could we create for example a lower level strategic map called "Build people capability" that will be linked to the target concept "Learning and growth performance"? How can we achieve the hierarchy of focus areas, strategic objectives or strategic themes if we do not do that?

Directed arrows create cause and effect relationships amongst concepts like business objectives, focus areas, strategic themes etc. These can have positive or negative markers indicating the type of influence. The flow appears to be bottom up from "learning and Growth Performance" towards "Do Sustained Profitable Business Through Product Innovation Leadership". However, this by no means creates a hierarchical relationship amongst focus areas etc but rather a cause and effect relationship amongst them.

There also appears to be a horizontal relationship between concepts belonging (also horizontally) to the same time slot. For example in the first six months the aim is the establishment of the "Learning and Growth Performance" target and in order to achieve it we need to focus to "Build People Capability" that requires "Skill Training" and "Attract and Retain Top Talent".

However, it is not clear why directional arrows of concepts in focus areas have performance markers (+ or -) and others do not. Does this mean that we have a positive, negative and neutral type of performance marker? Can we scale performance markers (low, medium or high)? Can we have performance markers on directed arrows of target concepts on the left side of the graph?

Can we calculate the level of the achievement of a target? Do concepts-targets have values? Could binary values like true or false be a suggestion? Could these values be true false or neutral (also called trivalent)? Could they be linear values?

The time element in the map resembles project management approaches with concepts (business objectives, strategic themes, focus areas) being represented as tasks and directional arrows being used in task dependencies in the project. A project manager could easily depict the map as a Gantt Chart.

1.2. From BSC to Business Models

The slow progress on BSC research has provided the appropriate conditions for the development of new approaches in the area of value chain creation which was the main focus of the BSC as it was initially developed. The most notable of these frameworks is called "business models" that focus on the analysis of new ways of creating value (Fiel, 2014; Osterwalder & Pigneur, 2010), developed by Gassmann et al. (2020).

The approach is composed of 55 patterns categorized in a four-dimensional framework: the value proposition (what?); value chain (how?); profit mechanism (why?); and target customer (who?). The approach, however, presents weaknesses in the creation of relationships between patterns, let alone the non existence of simulation or testing capabilities (Nielsen et al., 2016) and it is still in its infancy (Groth & Nielsen, 2015).

In recent years relationships between patterns has been enhanced and an interesting approach for the interlinking of these 55 patterns has been developed. Patterns (presented as nodes) and their relationships are presented in the so called business models "network". An example of a network diagram is presented in the picture bellow:

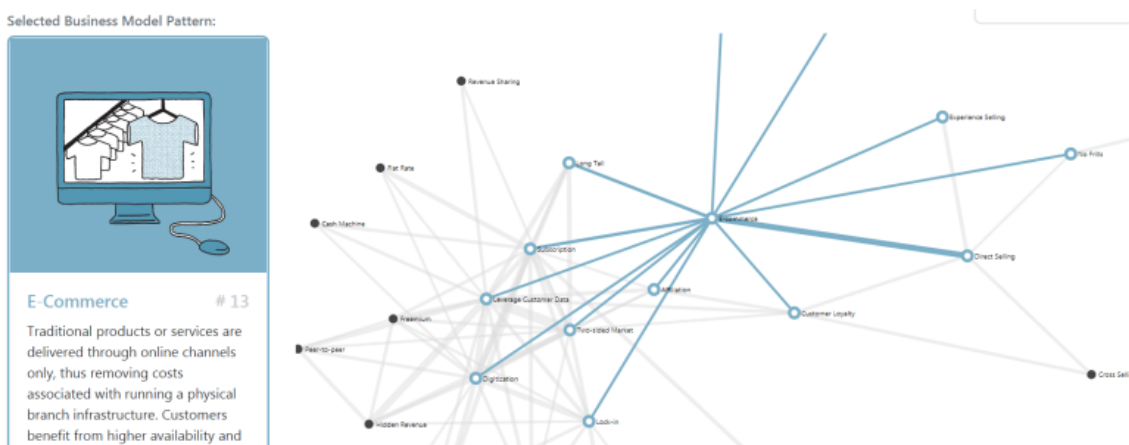


Figure 2. The relationship network for Business Model Pattern E-Commerce

The figure presents a description of the E-Commerce pattern and its relationships to the remaining patterns. The E-Commerce pattern is at the centre of the network. In a similar way the user can select

another pattern related to E-Commerce, for example the "Subscription" pattern and then be transferred to a similar page as shown in the picture below:

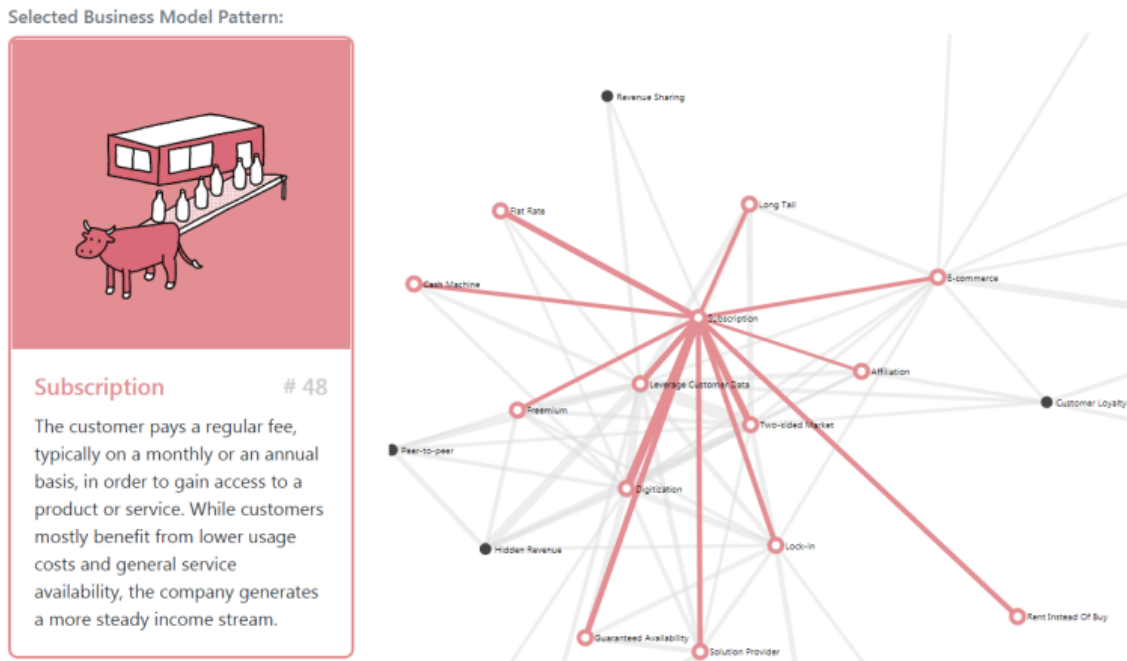


Figure 3. The network relationships for pattern Subscription

In Figure 3, the E-Commerce pattern appears on the top-right area and the Subscription pattern in the centre of the network highlighted. By following this process the user can navigate in a three dimensional space of nodes and relationships and explore pattern linkages. The aim of this network is to provide navigational capabilities for informational purposes and present selected case studies per pattern in additional web pages, however this network map can not by any means be considered a strategy map and there is no relation to Islam's (2018) strategic map principles presented earlier.

1.3. Fuzzy Cognitive Maps in Decision Analysis

Decision analysis focuses on assisting human decision making to choose the most optimal amongst specific alternatives. Each alternative is assessed based on the outcomes of variables-measures or sets of interlinked predefined variables-measures. Decision Trees (DT) is one of the most well known decision analysis methodologies and is based on machine learning techniques like Neural Networks (d'Alché-Buc al., 1994; Xirogiannis & Glykas, 2004; Glykas, 2011a; Glykas 2011b) or Bayesian Networks (Janssens et al., 2006; Janssens et al., 2004; Xirogiannis et al., 2010).

Several researchers have been articulating the benefits of using Decision Trees in Fuzzy Cognitive Maps (Podgorelec et al., 2002; Papageorgiou 2010).

The most notable of these research efforts is the model developed by (Groumpos 2010; Groumpos & Karagiannis, 2013) that combines the FCM model with Decision Trees and Decision Analysis theory.

The proposed model is based on the Nonlinear Hebbian Learning (NHL) algorithm and the resulting Decision Tree-Fuzzy Cognitive Map's (DT-FCM) creation process is presented in figure 4:

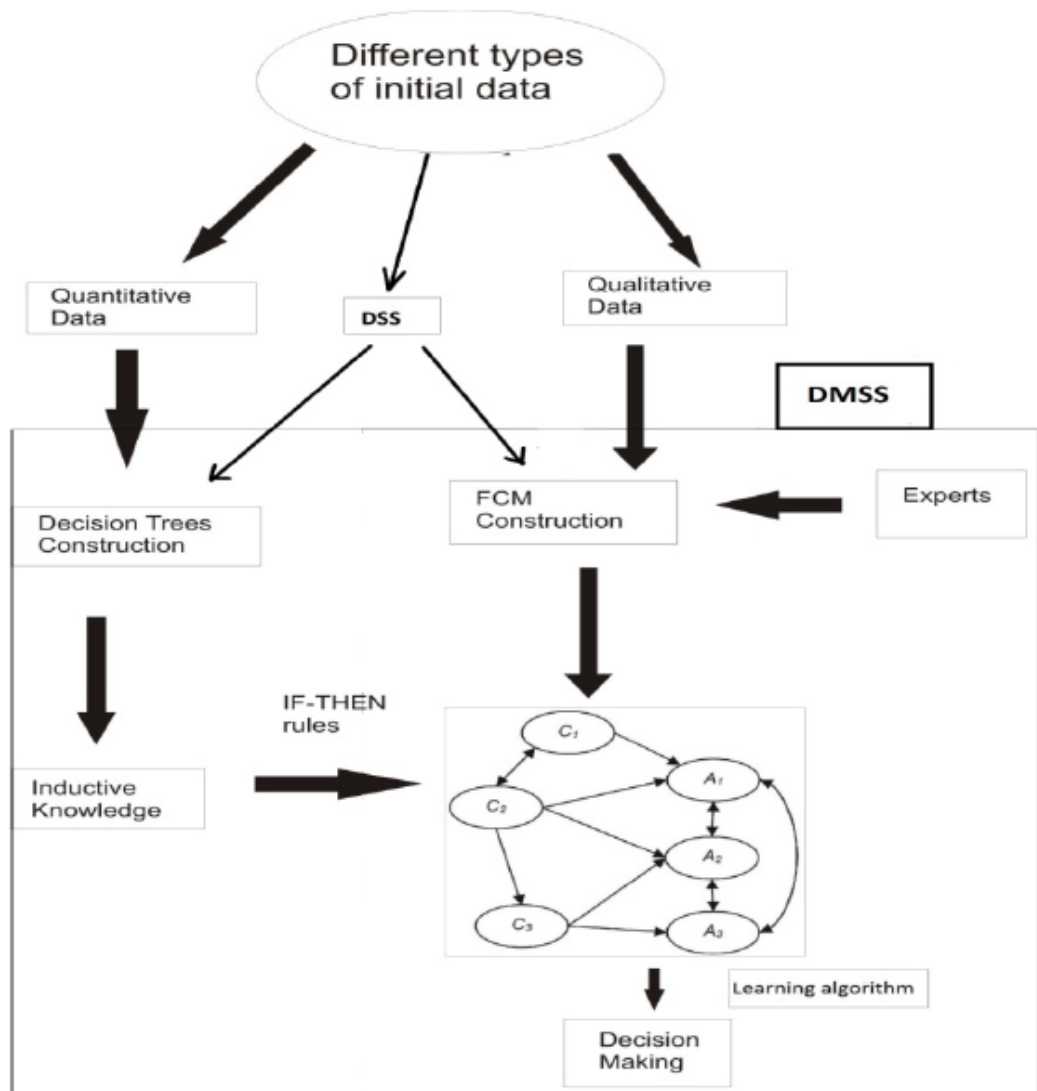


Figure 4. The decision making system constructed by Decision Trees (DTs) and Fuzzy Cognitive Maps (FCMs) (Groumos, 2010)

Experts' knowledge is used as a basis for the creation of Decision Trees and create rules for the construction of their associated Fuzzy Cognitive Maps (FCMs) (Xirogiannis et al., 2008). FCMs allow the assignment of cause and effect relationships with the use of directed weights with values in the range of 1 to -1. The FCM model-mapis created based on experts knowledge (mainly providing the concepts-nodes and their relationships) and if-then (or cause and effect) rules provided via the DT analysis. The FCM algorithm can be assigned historical data value sets (or training sets) to test its validity. Via the use of the supervised NHL algorithm modifications and alterations on FCM design will result in a validated FCM in which sets of initial values produce the expected results (Groumos, 2010; Groumos & Karagiannis, 2013).

The Groumos model provided the basis of the use of FCMs in decision making (Xirogiannis et al., 2010). However, there was a lack of automated software tools to support the model as it required the use of cumbersome and continuous mathematical calculations (Glykas & Xirogiannis 2005; Glykas 2010).

2. The Proactive Balanced Scorecard Methodology (PBSCM)

Chytas and Glykas (2011) proposed a solution to the drawbacks of strategy maps and business models stated above. They provided a tool and methodology that automated and supported the Groupmpos DT-FCM model.

They also used and augmented the tool and their methodology for the application of Fuzzy Cognitive Maps (FCMs) in performance measurement and the Balanced Scorecard approach (Chytas et al., 2010). Research mainly focused on the utilization of Fuzzy Cognitive Maps (FCMs) for the creation of Strategy Maps and their interlinking for the creation of hierarchies. In their model measures are represented by nodes and their cause and effect relationships are presented by directed arcs (Chytas et al., 2008). These directed arcs can be assigned fuzzy values in the range of -1 to 1 as the FCM algorithm suggests.

The resulting methodology and software tool provide the ability of map interlinking via common nodes amongst maps in a hierarchical or sequential manner. The tool also offers simulation capabilities based on the FCM theory and algorithm utilized (Xirogiannis et al., 2004). Simulation has proven to be very suitable for strategic mapping and analysis in a holistic manner with business objectives, represented as concepts or nodes and interlinked in process maps from the strategic level all the way down to maps of individual employees (Chytas & Glykas, 2011).

The proposed methodology called a "Proactive Balanced Scorecard Methodology" (PBSCM) is depicted in figure 5. PBSCM is capable of illustrating non-linear interactions and feedback loops using FCMs and performing what-if scenarios through the use of FCMs simulation.

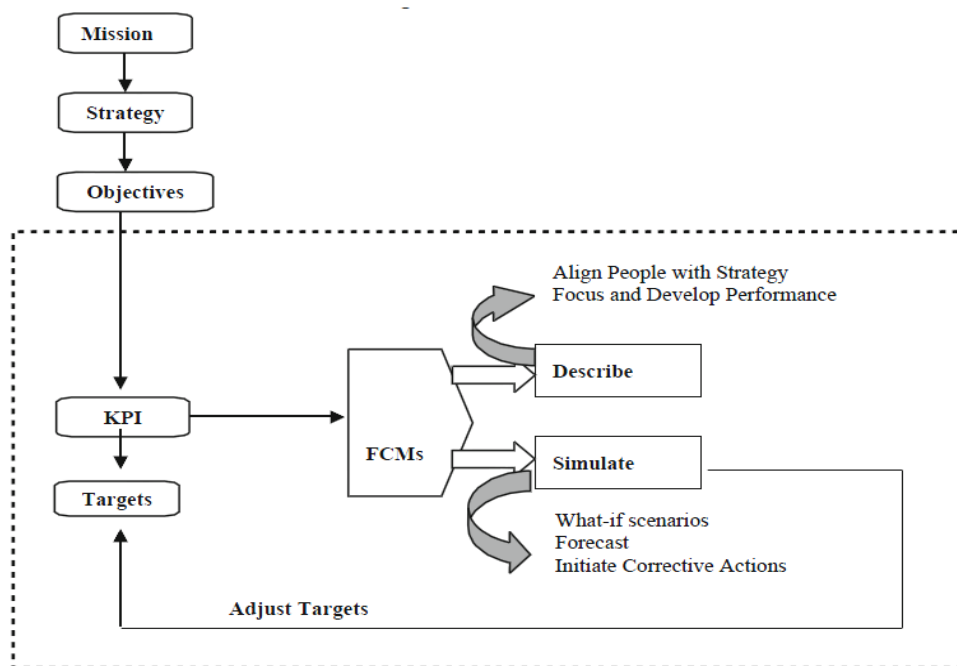


Figure 5. The PBSCM (Chytas and Glykas, 2011)

The PBSCM stages of FCM creation and their interlinking for the development of strategic maps are presented in table 1. Maps are created by business domain experts and/or professionals specializing in the fields of Performance Measurement and if possible in the BSC:

Table 1. Inputs and Outcomes of the PBSCM

Stage	Input	Outcome
1. Establishing the Mission, Vision, Strategic Objectives, Perspectives and Critical Success Factors (CSFs)	1. Interviews with Middle and Top Management 2. Internal Company Data	1. Mission 2. Vision 3. Strategic Objectives 4. Perspectives 5. CSF
2. Identify Key Performance Indicators (KPI)	1. CSF	1. KPI in each perspective
3. Establish Targets	1. KPI	1. Target for each KPI
4. Define Relationships among the identified KPI	1.KPI	1. FCM with no Weights
5. Assign linguistic Variables to Weights and Concepts-(KPIs)	1. FCM with no Weights	1. Final FCM with Weights and Concept values.
6. Continuous Improvement	1. Final FCM	1. Adjust Targets

3. The FCM Modeler Tool

In the FCM Modeler Tool concepts-nodes represent decision variables or business metrics-measures. Relationships amongst concepts are represented by directional arcs (Glykas, 2013a). Directional arcs depict the cause and effect relationships amongst concepts-nodes. In figure 6 for example the “Technical Capability” cause concept-node affects the “ERP Vendor” concept:

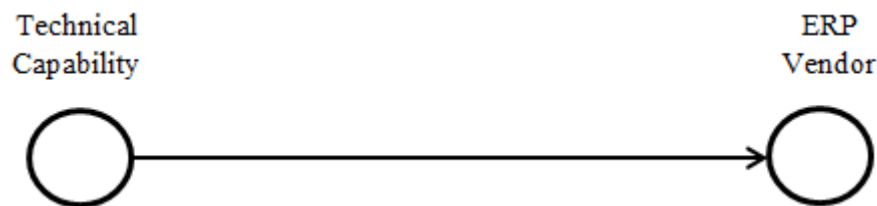


Figure 6. Example of FCM Concepts and Links

FCM Modeler Tool concepts-nodes states have three distinct values in the most widely used triangular mode, namely:-1,0 and1 as illustrated in **Error! Reference source not found.7.**

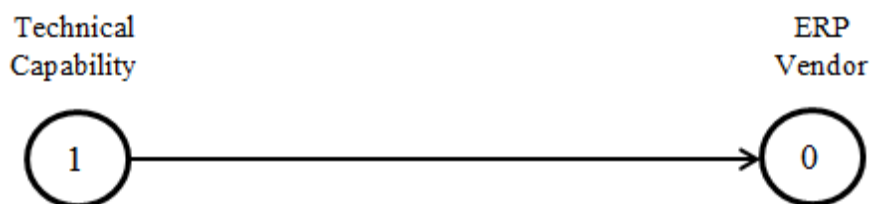


Figure 7. FCM node values example

The values of the concepts above can be externally defined. During simulation concept values are calculated in accordance with the FCM algorithm i.e on the sum of multiplications of node value times arc value of all incoming directed arcs. In cases of positive causal relationships, an increase in the value of the cause concept will increase the value of the effect concept and vice versa. In negative causal relationships, an increase in the value of the cause concept will decrease the value of the effect concept and vice versa. The degree of belief or certainty that a relationship exists is numerically signified with a number in the bipolar interval of $[-1, \dots, 1]$. The negative values in that range signify a negative causal relationship, while the positive values mean a positive causal relationship.

The graph in figure 8 shows schematically the assignment of a relationship weight (+0.7) to our example.

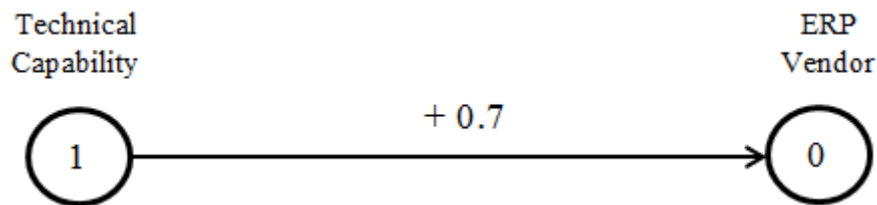


Figure 8. Positive Causal Relationship Example.

In the example above the Technical Capability concept has a positive causal relationship which will increase the ERP Vendor concept and in simulation the value of ERP Vendor will become one (1) as the thresholds in the trivalent simulation mode are two: -0,5 and 0,5. This means that if the sum of all incoming directed graph multiplications (concept value * arc value) is equal or greater than 0,5 the value of the effect node will be one (1), if the sum is in the range $-0,5 > \text{sum} < 0,5$ then effect concept value will be 0, if the sum is less or equal to -0,5 then the effect value will be -1.

An arc value of zero (0) indicates that there is no relationship between the cause and effect concepts and therefore there is no need for an arc to exist between the cause and effect concepts.

4. The FCM Modeler Tool: Rules for Strategic-Operations Map Design

In the FCM modeller tool, FCM concepts or nodes are classified into three categories (Glykas, 2013a):

- i. **Cause:** Have only outgoing arrows
- ii. **Intermediate:** Have incoming and outgoing arrows
- iii. **Effect:** have only incoming arrows

There are some basic rules that FCM designers should follow:

Rule A:“A map has to contain at Least Two nodes and a relationship between them”

Cause nodes in an FCM have to be triggering nodes, i.e. they have to get a value either from a lower level FCM or from the external environment. Intermediate nodes are also allowed to become triggering nodes but it is a good standard to create FCMs with cause nodes as triggering nodes.

Rule B: “Cause and intermediate are triggering nodes that take values either from lower level FCMs or from the external environment”

Only effect or intermediate nodes from a lower level FCM may be linked to cause or intermediate nodes of a higher level FCM. The ideal situation is to link effect nodes from a lower level to cause nodes in a higher level FCMs.

Rule C: “Only effect or intermediate nodes from a lower level FCM can be linked to cause or intermediate nodes of a higher level FCM. The user should try to link effect from lower to cause in higher level FCMs.”

Another synchronization constraint is related with the number of links that a single node can have with nodes from lower level FCMs.

Only one node from each FCM at a lower level is allowed to be linked with a node of an FCM at a higher level for consistency purposes. If the user wants more than one node at a lower level to be linked with one node at a higher level then, the user must create additional FCMs to cater the case.

Rule D: “A node in a higher level FCM cannot be linked with more than one nodes of lower level FCMs.”

The FCM modeler tool provides all necessary functionality for the design of FCMs. It also provides functionality for FCM map simulation. The calculation of the next state of an effect node is calculated by the sum of multiplications of the value of each cause node multiplied by the weight of its causal relationship. For instance, if we draw a map in the FCM modeler tool as show in figure 9 the concepts “Technical Capability”, “Reputation” and “Ongoing Service” influence the concept “ERP Vendor” with positive causal relationships with weights of 0.5, 0.2 and 0.3 respectively:

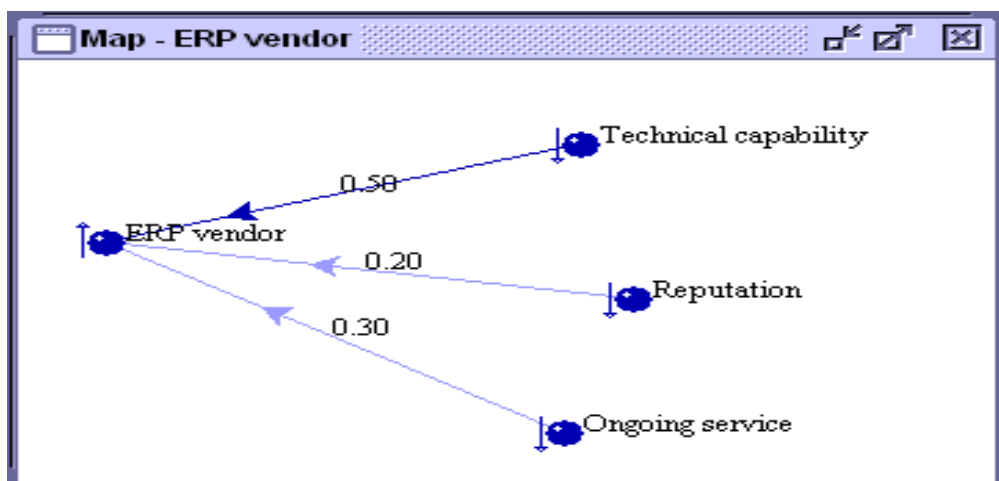


Figure 9. The "ERP Vendor" Map Weights

The FCM calculation formula of the next state of ERP Vendor during simulation is:

$$\text{Value of Technical Capability} * 0.5 + \text{Value of Reputation} * 0.2 + \text{Value of Ongoing Service} * 0.3 =$$
$$\text{Value of ERP Vendor}$$

Beside each one of the three cause concepts of the ERP Vendor map (Technical Capability, Reputation, Ongoing Service) there is a downward pointing arrow (↓), this means that the concept's initial value will be calculated by a lower level FCM whose simulation should finish before the enactment of simulation of the ERP Vendor FCM.

Beside the effect concept node ERP Vendor there is an upward pointing arrow (↑) which declares that at the end of the simulation of the ERP Vendor FCM the value of this concept will be passed to a concept of a higher level FCM (or FCMs) with the exact same name.

5. FCM Hierarchies in ERP Selection for Operations Management

The FCM Modeler Tool includes four different map categories in accordance to the BSC perspectives:

- i. **Business Category** including all metrics related to core business activities.
- ii. **Social Category** including all human resources related and external stimuli concepts.
- iii. **Technical Category** including all infrastructure and assets related concepts with emphasis on technology infrastructure.
- iv. **Integrated Category** including basically concepts falling under more than one of the above three categories and all strategy related concepts.

FCM hierarchies are considered "Projects" in the FCM Modeler tool. The first time a user opens the application is presented with an empty project structure (i.e. Business Models, Social Models, Technical Models, and Integrated Models). Via concept-node interlinking the FCM Modeler tool creates the FCM Hierarchy or "Project". For each FCM the system identifies higher and lower level FCMs until the hierarchy has been formed. The hierarchical decomposition of concepts in FCMs produces a group of dynamically interconnected hierarchical FCMs. In order to test its validity, the FCM Modeler tool was used in a multinational firm, in which the operations management department has used it in the ERP selection process. The aim was to solve problems in the ERP selection process as stated by Cebeci (2009) and Bieńkowska et al. (2016). Due to confidentiality reasons we present a sample of the full study. Eleven FCMs were created for this particular application. The figure below depicts the concepts-nodes that are interlinked amongst these FCMs:

From Map	To Map	Target Node
ERP vendor	Suitable ERP	ERP vendor
Appropriate ERP System	Suitable ERP	Appropriate ERP system
Ongoing Service	ERP vendor	Ongoing service
Technical Capability	ERP vendor	Technical capability
Reputation	ERP vendor	Reputation
System Reliability	Appropriate ERP System	System reliability
System Flexibility	Appropriate ERP System	System flexibility
User Interface and Operations	Appropriate ERP System	User interface and operations
Complete Functionality	Appropriate ERP System	Complete functionality
Total Cost	Appropriate ERP System	Total cost

Figure 10. Project Links Window

Based on the node interlinking mechanism of figure 10 the system creates the hierarchy shown in picture 11:

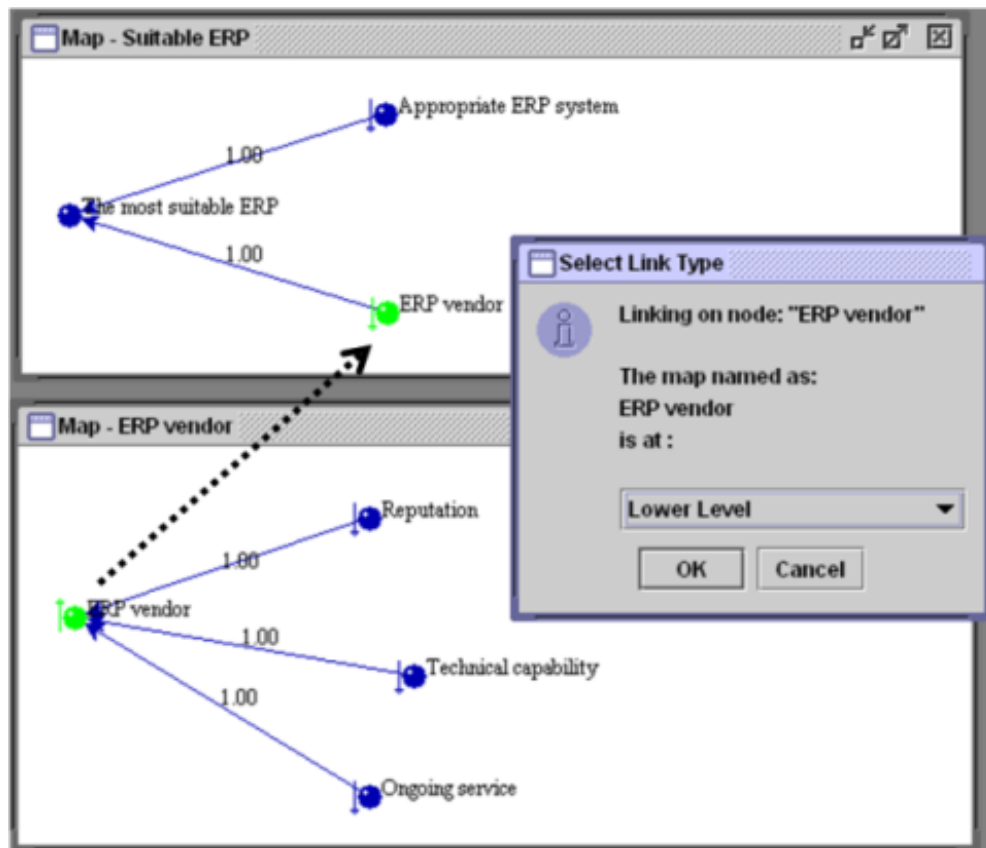


Figure 11. Sample Map Hierarchy

Figure 12 presents the system interface for the generation of the hierarchical relationship between two FCMs, the “Suitable ERP” and “ERP Vendor”. The two FCMs are linked via the concept “ERP vendor”:

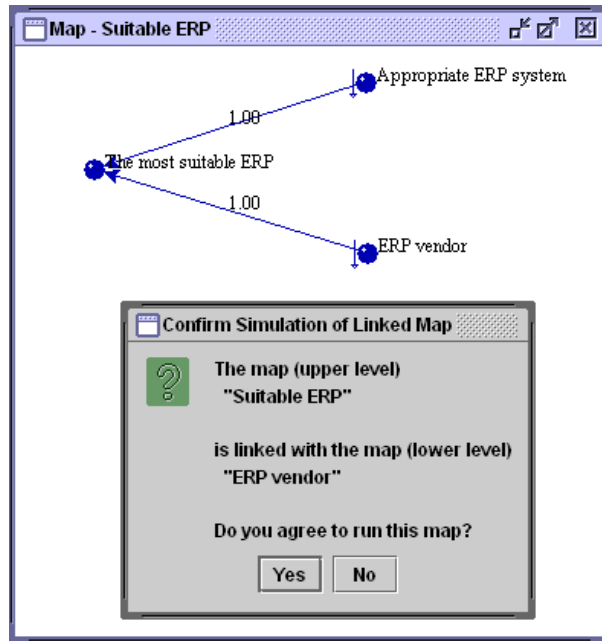


Figure 12. FCM concepts interconnection mechanism

5.1. Simulating Projects-FCM Hierarchies.

During simulation the user can either select to run the lower level map or assign external values to interlinked nodes. The final FCM hierarchy of our example is shown in figure 13:

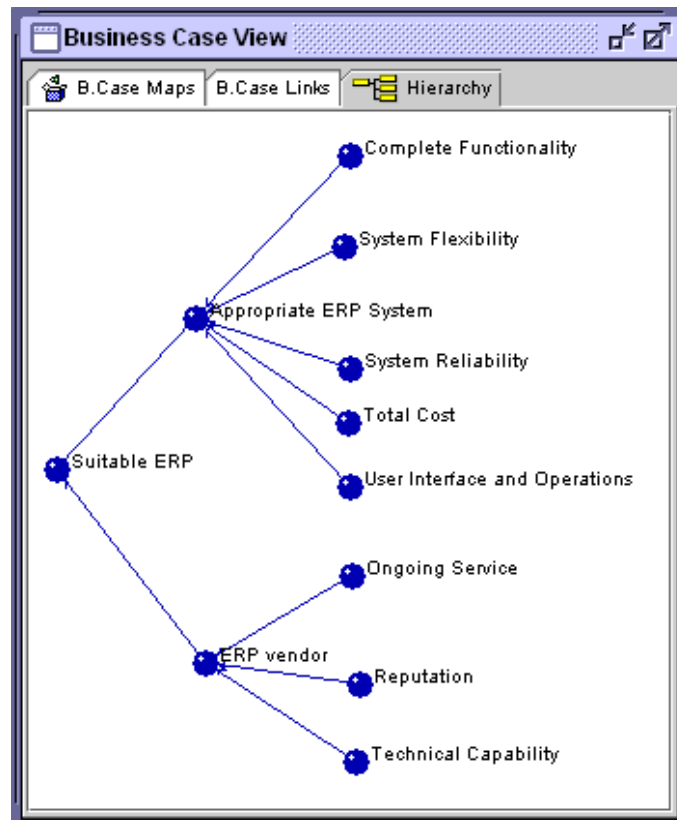


Figure 13. User-defined Map Decomposition

The "Simulation" module of the FCM Modeler Tool is depicted in the picture bellow. FCM simulation can commence via the "run" option and paused at any point in time via the "Pause" option. Simulation can also be performed on a step by step basis via the "Step" option thus the user can monitor closely concept-node value modification during simulation. The "Reset" option reassigns initial concept-node values. The set of these initial FCM concept-values are set by the domain experts when the model is applied to a company and is called a "Business Case". Each company can have its tailor made business case.

There are three simulation modes in the FCM Modeler tool algorithm as shown in picture 14:

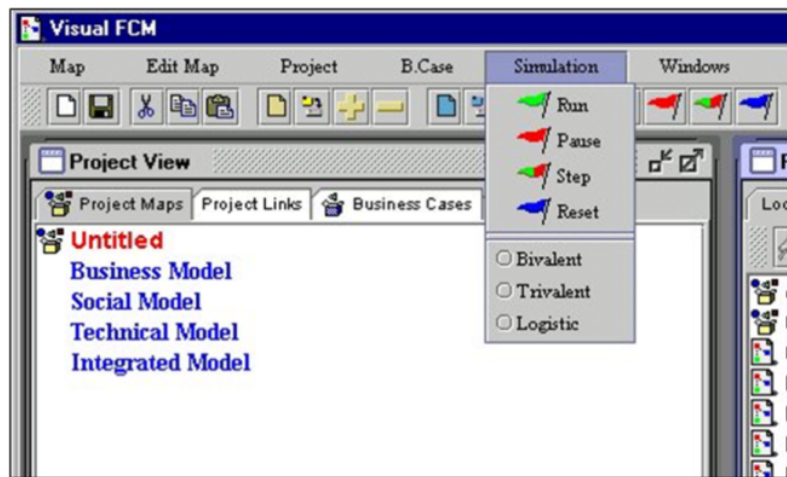


Figure 14. SimulationOptions on Project and Business Cases

- i. **Bivalent** $S_i(x_i) = 0, x_i \leq 0, S_i(x_i) = 1, x_i > 0,$
- ii. **Trivalent** $S_i(x_i) = 1, x_i \geq 0.5, S_i(x_i) = -1, x_i \leq -0.5, S_i(x_i) = 0, -0.5 < x_i < 0.5$
- iii. **Logistic** $S_i(x_i) = \frac{1}{1+e^{-cx_i}}$

The default FCM algorithm is set to Trivalent.

During FCM hierarchy simulation the user is informed on the existence of FCM dependencies and then decides on whether to select interlinked node values from external inputs, as set in the company specific business case, or via the simulation of low level maps.

Table 2 presents how the FCM Hierarchy how the hierarchy algorithm works during simulation:

Table 2. The FCM Hierarchy Simulation Algorithm

Step	Algorithm Process
1	Get the FCM dependency information
2	Does the active** FCM depend on other FCMs?
3	If yes go to the next non processed*** FCM that this FCM depends on and mark it as active
4	If the active FCM does not depend to any FCM and it is the start FCM then go to 11
5	Repeat Step 2 to Step 4 until the active FCM does not have any dependencies
6	Apply the FCM Algorithm
7	Mark the active FCM as processed
8	Pass the simulation results to the previous FCM that depends on the present active processed FCM and

- mark it as active
- 9 Repeat Step 2 to Step 8 until the Start FCM* has been reached
 - 10 Repeat Step 2 to step 9 until the Start FCM does not have any dependencies
 - 11 Apply the FCM algorithm
-

* Start FCM. The FCM that a user wants to simulate,

** Active FCM. The FCM on which the FCM algorithm will be applied,

***Non-processed FCM. An FCM that has not been simulated

Reports are produced in the form of HTML files and provide the user with a detailed, step-by-step description of the simulation of FCM hierarchies. Reports present the Business Case Hierarchy as the project is now used for a specific company. It also shows the step by step change in Concept Values including their initial or external values at each step. By analyzing these reports, the user can extract very useful information on the validity of: the model, the cause and effect relationships and the produced results via the application of the FCM algorithm. Reports are also used for training set and historical data analysis and simulation.

6. Conclusions

We presented Islam's (2018) proposed fourteen principles for proper strategy map frameworks. The first five principles are mainly concerned with the link between strategic maps and the organization's strategy, vision and mission as well as the with the focus on key focus areas, strategic themes etc. We presented the "Proactive Balanced Scorecard Methodology" (PBSCM) that provides the capability of illustrating non-linear interactions and feedback loops using FCMs and performing what-if scenarios through the use of FCMs simulation. PBSCM covers and expands Islam's first five principles.

The remaining nine of Islam's principles concentrate on more advanced issues. The study revealed that there is a need for a hierarchical order in line with the organization's strategy and structure (principle 6). It also revealed that strategy maps should be constructed and be based upon strategic objectives that are linked amongst themselves, these business objectives could be mapped across several maps (principles 7 and 8). In strategy maps there is a need for incorporating the time element (principle 9) and in order to provide the notion of sequence (or time) strategic maps should firstly provide the ability of directional arrows between strategic objectives that create cause and effect relationships (principles 10, 11, 12 and 13). These cause and effect relationships depicted in arrows should be labeled with a "performance marker" that declares a positive (+) or negative (-) relationship between strategic objectives etc (principle 14).

FCMs as exemplified by the extended FCM Modeler Tool and the capability of simulation hierarchy can provide a solution to all aforementioned Islam's advanced principles (6 to 14). FCMs can further enhance the BSC and strategic maps frameworks as they provide simulation capabilities of FCMs hierarchies with concepts-nodes being interlinked amongst maps. They also allow the assignment of negative or positive fuzzy weights in cause and effect relationships between concepts and provide "fuzzy weighted performance markers".

The validity of the use of FCMs in BSC and strategy maps was tested on an application on operations management and ERP selection in a multinational firm. In the future the methodology and the

tool will be further tested in the field of operations management in several core operations of firms operating in different industries.

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