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“Fuzzy Cognitive Maps in Operations Management”

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Abstract

The present thesis aims at presenting in the best possible way the implementation of Fuzzy Cognitive Maps (FCMs) in Operations Management with the aid of a novel tool: the FCM Modeler Tool. This is a novel approach to supplementing typical operational strategy formulation projects by utilizing the fuzzy causal characteristics of Fuzzy Cognitive Maps with the aim to generate a hierarchical and dynamic network of interconnected processes and metrics.

The main theory of FCM is presented in an explanatory and clear way for the readers, analyzing them theoretically and mathematically, and a detailed reference is made in the most recent applications and trends of FCM in various scientific fields such as medicine, engineering, information technology, social and political sciences, business etc.

The Operations Management theory is analyzed in detail and the state of the art in Business Process Management (BPM) is particularly highlighted in terms of the components consisting this very important entity in the field of business administration.

The proposed FCM Modeler Tool is presented in detail in its operating mode using real examples in order to fully understand the purpose of the particular tool. Next, similar Fuzzy Cognitive Maps creation and processing tools are presented so that the reader will be able to get a more complete picture of the FCM design process.

The FCM Modeler Tool is used in a case study modeling real processes and then introducing experiments and results showing the impact that strategic changes, an organization may have on the status of process performance.

Contents

1 Introduction

1.1 Thesis's Objectives

The objective of this thesis is to fully clarify the basic notions concerning Fuzzy Cognitive Maps (FCMs) and their application in the field of Operations Management rendering them a supporting tool to simulating strategic models with imprecise relationships while quantifying the impact of strategic changes to the overall process performance system. This thesis aims - through this elaborate analysis of Business Process Management (BPM) to establish process-based maps in order to implement the integration of hierarchical Fuzzy Cognitive Maps into business process performance measurement change activities. Finally, this paper discusses experiments with the proposed mechanism of FCM Modeler Tool, and presents valuable comments on its usability.

The innovative FCM Modeler Tool is applied on a case study with real organization processes from different business domains, aiming at the study and prediction of the consequences caused by strategic changes in the business process performance measurement.

1.2 Structure of the Thesis

In Chapter 2, the Basic theories of Fuzzy Cognitive Maps are presented. Fundamental mathematical theories of Fuzzy Cognitive Maps are presented and analyzed in this chapter in order for the Fuzzy Cognitive Maps to be more comprehensive. An algorithm is presented and used to demonstrate the usefulness of the FCM approach in modeling complex systems. In addition to, methods for FCMs constructing is presented and the process of synthesizing different FCMs is described step by step. Finally FCMs is proposed for modeling and controlling complex systems like the process of Modeling Supervisors of Complex Systems and the Fuzzy Cognitive Map's application in Decision Analysis.

In Chapter 3 various cases of application of FCMs on different scientific sectors are going to be studied. Starting from the medical sector, the application of FCMs will be extensively analyzed in Information Technology (IT) as a Business domain, in engineering, computer vision, production systems and other scientific fields such as political and social sciences, agriculture etc.

In Chapter 4 an extensive reference is made to the FCM Modeler Tool with which FCM can be created and processed. Information on the user interface of the tool and its various functions such as the node linking process is presented with the aid of an ERP System from a business. Other features such as simulating, the final reports the program exports after simulating process, and the tool software information are also presented. In the second part of the chapter, various other FCM creation and processing tools are also presented.

In Chapter 5 the Operations Management entity is presented, considered to be the heart of the creation of wealth for businesses. The state of the art in Business Process Management (BPM) is presented in detail. The main definitions and components that consist BPM are presented, starting from process analysis and, then, on various other entities such as Business Process Languages, Business Process Modeling, Business Process Reengineering Workflow Management, Knowledge Management etc.

In Chapter 6, the use of FCM Modeler Tool is presented in order to support the Balanced Scorecard framework and to advance the decision making process, exploiting its predictive modeling capabilities in process performance measurement. A Case Study consisting of realistic sets of processes is presented to analyze the impact that various changes have in this particular process-based system. Simulation experiments and results are provided in order to ease the complexity of deriving expert decisions concerning the process based planning for the process performance improvement. The final Fuzzy Cognitive Maps are presented in the Appendix A, Appendix B.

Finally, in Chapter 7 conclusions are presented, including the limitations faced during the implementation of this thesis and, finally, the future proposals that have to be made.

2 Basic Theories of Fuzzy Cognitive Maps

2.1 Introduction

Fuzzy Cognitive Maps (FCM) consist a soft computing technique following an approach that is considered to be rather similar to both human reasoning and to the corresponding human decision-making process (Groumpos & Karagiannis, Mathematical Modeling of Decision Making Support Systems Using Fuzzy Cognitive Maps, 2013). Fuzzy Cognitive Maps theories have been lately proven to be able to offer realistic and useful tools for addressing a long series of social issues. Fundamental mathematical theories of FCM appear to have been developed in previously made researches. This chapter provides the space for their extensive analysis so that FCM theory becomes much more comprehensive for the reader. The usefulness of the FCM approach in modeling complex systems is represented by an algorithm used to demonstrate it (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010). All relevant methods of Constructing Fuzzy Cognitive Maps the process of Assigning Numerical Weights and Linguistic variables for the Fuzzy Cognitive Map Weights is included, are elaborately described. Further than that one of the main concerns of this study is to present a fundamental approach of Fuzzy Cognitive Maps as a modeling technique (Bart Kosko) as well as to gradually describe the process of achieving synthesis of various, usually different Fuzzy Cognitive Maps. Last but not least, the Neural Network Nature of Fuzzy Cognitive Maps is also thoroughly studied in this introductory chapter.

The present chapter closes with the proposition of Fuzzy Cognitive Maps for purposes of modeling and controlling more complex systems like the process of Modeling Supervisors of Complex Systems and the Decision Making Analysis Systems.

2.2 Literature Review

Many readers of this scientific Thesis may be wondering about what exactly is Fuzzy Cognitive Map (FCM). It is a legitimate question that those who have not previously dealt with this scientific field. In order to explain the concept of Fuzzy Cognitive Maps, we must first explain one by one the three words that compose them.

The last two words (Cognitive Maps) indicate the origin of Fuzzy Cognitive Maps which define a new scientific field. The first reference to cognitive maps took place in the distant year 1948 by Edward Tolman but dare from 1976 onwards was their complete development. More specific Cognitive Maps formal theory introduced by R. Axelrod and the Fuzzy Sets theory introduced by L.A. Zadeh who states (Zadeh, 1965) that “a fuzzy subset A of a universe of discourse U is characterized by a membership function associate with each element y of U a number μ(χ) in the interval [0,1], representing the grade of membership of y in A”.

$$\mu_A: U \rightarrow [0,1]$$

Axelrod states in (Axelrod, 1976) that Cognitive Maps are signed digraphs designed to capture the causal assertions of a person with respect to a certain domain and then use it in order to analyze the effects of alternative e.g. policies, decisions, etc. upon certain goals”. Cognitive Maps are an excellent way to represent concepts in a certain domain and their cause-effect relationships. People are easily able to produce them and manipulate them in order to achieve certain results. Furthermore, Cognitive Maps are closer to the way people evaluate complex situations. Cognitive Maps have been used in many different fields such as education, geography, urban planning, geography, psychology, architecture, landscape architecture and management. At that time many scientists began to publish many articles which refer to the causal relationship that have different concepts between them. These concepts are often called ‘factors’ or otherwise ‘nodes’.

The third word Fuzzy was added in 1986 by Bart Kosko who through a great article developed the notion of fuzziness to cognitive maps (Kosko, Fuzzy Cognitive Maps, 1986). So as perceived Bart Kosko is the first scientist who developed the theory of Fuzzy Cognitive Maps (FCM). He introduced the notion of a fuzzy weight which means the relationship between the two concepts also called ‘nodes’ can take values in the interval [-1,1]. For the above reasons Bart Kosko is considered the father of fuzzy cognitive maps (Glykas, Fuzzy Cognitive Maps: Advances In Theory, Methodologies, Tools and Applications, 2010).

One may simply argue that Fuzzy Cognitive Maps consist a symbolic representation for describing and modeling a complex system. (Kosko, Fuzzy Cognitive Maps, 1986) (Dickerson & Kosko, 1994) (Hagiwara, 1992) (Craiger, Goodman, Weiss, & Butler, 1996). They consist of concept nodes and weighted arcs being graphically illustrated as a signed weighted graph with feedback. Weighted arcs that link concept nodes are clear representations of causal relationships present among concepts. What is worth mentioning is that the concept of a FCM clearly represents key factors and characteristics of a modeled complex system and generally stands for: inputs, outputs, states, events, goals, variables, and trends of the complex system each time modeled. Our graphic display clearly represents the mutual influence among concepts and its degree. Fuzzy Cognitive Maps may thus easily be characterized as a symbolic representation for describing and modeling complex systems. Fuzzy Cognitive Maps prove to be extremely useful in decision-making processes or operations research. As a result one has to mention that the main purpose of this chapter is no other than the mathematical analysis, construction and application of such maps in two examples of dynamic and complex systems (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010).

2.3 Mathematical Representation of FCMs

As it has been already noted, FCM describe a system's behavior in terms of concepts. Each concept represents a variable, an entity, a characteristic of a system or a state. Kosko in (Kosko, Fuzzy Cognitive Maps, 1986) has defined concept C_1 that represents certain causal relationships in FCM as:

$$C_\mathrm{i} = (Q_i \cup {\sim}Q_i) \cap M_i$$

Where one assumes the following:

- Q_i consists a quantity fuzzy set
- $\sim Q_i$ consists the dis-quantity fuzzy set
- $\sim Q_i$ consists the negation of Q_i.
- Each Q_i and $\sim Q_i$ partitions the whole set C_i.
- Double negation $\sim\sim Q_i$ equals to Q_i so the $\sim Q_i$ corresponds to Q^c_i being the complement of Q_i

It is essential to note that negation doesn't mean antonym. For this reason, if a dis-quantity fuzzy set $\sim Q_i$ doesn't correspond to the complement of Q_i, one calls it as an anti-quantity fuzzy set in order to express clearly the subtle meaning in the dis-quantity fuzzy set. The variable M_i is a modifier fuzzy set that modifies Q_i or $\sim Q_i$ concretely. The modifier fuzzy set fuzzily intersects the fuzzy union of a quantity fuzzy set, and a dis-quantity fuzzy set.

It is useful to point out both the positive and negative causal relationships the way suggested by Kosko (Kosko, Fuzzy Cognitive Maps, 1986). The following definitions exist:

- First Definition: C_i causes C_j iff $(Q_i \cap M_i) \subset (Q_j \cap M_j)$ and $(\sim Q_i \cap M_i) \subset (\sim Q_j \cap M_j)$
- Second Definition: C_i causally decreases C_j iff $(Q_i \cap M_i) \subset (\sim Q_j \cap M_j)$ and $(\sim Q_i \cap M_i) \subset (Q_j \cap M_j)$

The symbol “⊂” represents fuzzy set inclusion (this is a logical implication).

A rather simple FCM of five (5) concepts and six (6) weighed arcs, illustrating graphically existent interdependencies of the model or causalities existing among certain concepts, concerning a typical freeway condition at rush hour (Khan, Khor, & Chong, 2004). Concept variables along with their causal relations always consist the basic elements of a FCM. The notations C_1 (Bad Weather), C_2 (Freeway Congestion), C_3 (Driver Frustration), C_4 (Road Accident) and C_5 (Driver Risk Awareness) are the concept variables and are represented by nodes. Causal variables depict concept variables at the origin of the arrows. Unlike the effect variables they appear to illustrate the concept - variables in the endpoints of the arrows. In this respect, following Figure 2.1, node C_1, appears as the causal variable “Bad Weather” and for this reason node C_2 consists the variable effect “Freeway Congestion”. Each concept is by a number A_i representing both value and result of the actual value of the system during transformation process. These values appear in the interval [0,1]. Existent causality between concepts allows varying degrees and cannot be limited to binary format. As a result, the values of interconnections weights belong to the interval [-1,1]. Nodes are able to bear different concepts while interconnection weights represent all causal relationships existing among concepts. Through FCM we have managed to present the causal relationship among concepts through interconnection weights. Fuzzy weights express causal relationships. FCM structure and layout nodes directly appear to depend upon system knowledge. Each node is nothing else but a separate key – factor for the system. There are three types of concept relationships:

- Those expressing positive causality between two concepts ($W_{ij}>0$)
- Those expressing negative causality ($W_{ij}<0$)
- Those expressing no relationship ($W_{ij}=0$)

The variable W_{ij} signals the value indicating the degree of influence among concept C_i and concept C_j. In the same way the variable indicates the direction affecting concepts C_i and C_j. It indicates the cases when concept C_i causes concept C_j and vice versa.

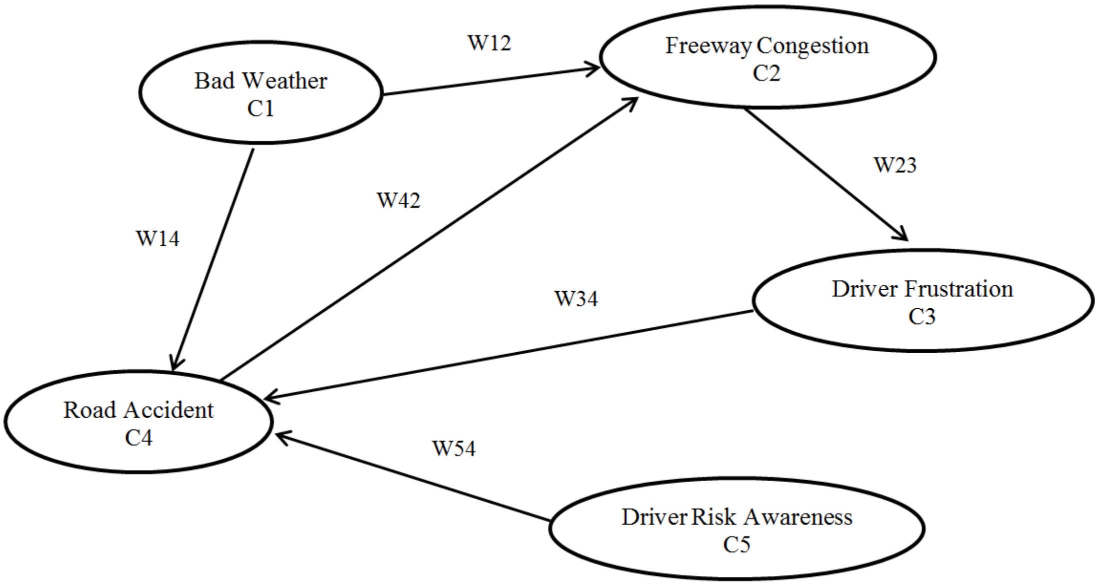


Figure 2.1 A simple FCM (Khan, Khor, & Chong, 2004)

Below is a method of calculating the value of concept at each step:

$$A_i^t = f\,(\,k_1 \sum_{\substack{j=1 \\ j\neq i}}^{n} A_j^{t-1}\, W_{ji} + \; k_2\, A_i^{t-1})$$

Equation (1)

- k_1 represents influence of interconnected concepts while creating concept A_i value.
- k_2 represents the proportion of the contribution of the previous value of the concept in the computation of the new value.

In the formulation above, each concept connects to itself with a weight, so it is true that Wii = k_2.

It can be assumed that the influence of the previous value of each concept is rather high, directly affecting any new value. So the relationship that follows is assumed: k_1 == 1. If we include each concept's value in the calculation process it can probably result in a smooth variation of the concept when recalculating values. Number A_i for each concept C_i is provided by the equation that follows here:

$$A_i^t = f\,(\sum_{\substack{j=1 \\ j\neq i}}^{n} A_j^{t-1}\,W_{ji} + A_i^{t-1})$$

Equation (2)

By setting values k_1 and k_2 equal to 1 the above equation (2) is the result:

- Number A^t_i is the value of concept C_i at that time t
- Number A^{t-1}_i is the value of concept C_i at that time t-1
- Number A^{t-1}_j is the value of concept C_j at that time t-1
- Weight W_{ji} of the interconnection from concept C_j to concept C_i
- Function f consists a threshold function and the values of the result may be found in the interval [0,1].

Values of each concept change based equation (2). The whole process described above is called a running cycle of the FCM model and is the fundamental process that makes the Fuzzy Cognitive Map.

We find two kinds of threshold functions to be used in the Fuzzy Cognitive Map framework.

$$f(x) = \frac{1}{1+e^{-\lambda x}}$$

The above equation, represent the sigmoid function. The number λ represent the steepness of the continuous function f. Where the events are negative values, then they belong to the interval [-1,1]. We use the function that follows:

$$f(x) = \tanh(x)$$

At this point let us assume that we have a cognitive map which consists of n concepts. This is represented mathematically by a 1xn state vector A. It may also be illustrated mathematically by an nxn weight matrix W with each element of the matrix W to represent the value of weight W_{ij} between concept C_i and concept C_j. It is also noted that the diagonal of the matrix is zero since it is equal to zero as it is considered that no concept causes itself. So the number $W_{ii} = 0$ appears.

The Equation (2), explained in a previous analysis, may be transformed in the following compact form, thus computing the new state vector A^t. The new vector A^t depends on the previous state of A and from the multiplication of the previous, at that time t-1 state vector A^{t-1} by the weight matrix W

$$A^t = f(A^{t-1}\,W + A^{t-1})$$

Equation (3)

This is also an expression of the previous equation:

$$A^t = f(A^{t-1}\, W^{new})$$

Equation (4)

The new weight matrix W^{new} that results from equation (4) appears to be a weight table with all its diagonal elements being equal to unit. In simple words, each concept is itself affected with a weight $W_{ii} = 1$. (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010).

2.4 Methods for Constructing Fuzzy Cognitive Maps

Human knowledge and experience have certainly been fundamental elements for the development of a Fuzzy Cognitive Map. As a result this kind of map has been based on the expert's experience on a rather complex system. Based on the given knowledge one decides on the number of concepts being appropriate and on what kind of concept must be used in each case. Concepts or nodes represent factors: their type is determined by experts. They are the ones selecting the factors of Fuzzy Cognitive Map representing actions, values or simple events. They are the ones being aware of which elements of a FCM affect one another and when each concept influences another in a negative degree. Specific rules suggested may well determine whether two events should be negatively impacted. Such a method is analyzed below, in the next paragraph.

2.4.1 Assigning Numerical Weights

The construction of an accurate model complexity is in need of the assistance of already experienced experts. We have noted above that they are the ones to decide the content of the events to be used in a FCM model. They also decide on the degree of the causal relationship between concepts. By this way they have created similar Fuzzy Cognitive Maps containing events. These events occur to be among the different links and weighted interconnections. They must all be combined into one FCM. The equation indicates the sum of different weighted matrixes.

$$W = f\left(\sum_{1}^{N} W_k\right)$$

- Number W is the overall matrix

- Number W_k is the individual weight matrix, developed by each one of the N experts.
- Function f is a threshold function. In particular it is a sigmoid function that transforms the sum of weights in the interval [-1,1].

Each expert has a subjective knowledge of a very complex system. As a result their contributions on constructing FCMs may be multiplied by a nonnegative 'credibility' weight b_k before we proceed with the combination with other expert's opinions. The above conclusion is described in the following mathematical equation.

$$W = f\left(\sum_{1}^{N} b_k W_k\right)$$

- The number b_k is the credibility weight for the k_{th} expert
- The number W_k is the matrix of the k_{th} expert's Fuzzy Cognitive Map
- Finally, N is the number of the experts

Nevertheless a case of an expert to consider at its own discretion exists, that is, the need to set an extremely low or zero credibility weight in case the expert's choice differs from another expert's choice. One may conclude that it is necessary to discover a certain mechanism that would indicate what and in what manner credibility weights may be probably assigned to each expert.

This is the reason for which a new algorithm has been created in order to set weights for each interconnection and credibility weights selected by the experts. At the creation of the map by every expert all corresponding weights are collected and compared by the following algorithm. This algorithm mainly uses the average of the interconnection weights. The algorithm operation is based mainly on the examination of weight values that put experts in a complex system. If the number of weight value with the same sign appears less than π*N then it will not be clear for the experts whether there is positive or negative causality between two concepts. As a result they are asked to reassign weights. In another case the process continues and the weights selected are based on the proposed weights. Furthermore, if the weights' values selected by experts to enter to the system, is not close enough to the average weight then, this weight is only partially taken into account. Below we may find the steps of the algorithm (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010).

Algorithm 1	
Step	Algorithm Process
1	For all the ^{N} experts, set credibility weight b_k =1
2	For i,j = 1 to n
3	For each interconnection (C_i to C_j) examine the N weights $W^k{}_{ij}$ that each k_{th} of the N experts has assigned.
4	IF there are weights $W^k{}_{ij}$ with different sign and the number of weights with the same sign in less than π*N THEN ask experts to reassign weights for this particular interconnection and go to Step 3 ELSE take into account the weights of the greater group with the same sign and consider that there are no other weights and penalize the experts who chose "wrong" sighed weight with a new credibility weight $b_k = \mu_1 * b_k$
5	For the weights of the greater group with the same sign find their average value $W_{ij}^{ave} = \frac{(\sum_{k=1}^{N} b_k W_k)}{N}$
6	IF $\left\|W_{ij}^{ave} - W_{ij}^{k}\right\| \geq \omega_1$ THEN consider that there is no weight $W^k{}_{ij}$, penalize the k_{th} expert $b_k = \mu_2 * b_k$ and go to step 5
7	IF there have not examined all the ^{nxn} interconnection go to step 2 ELSE construct the new weight matrix W which has elements the weights $W^{ave}{}_{ij}$ END

Table 2.1 Steps of the Algorithm 1 (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010)

This is an example of the algorithm:

- Example 1.

There are six experts that constructed six individual FCMs and have suggested the following weights for the interconnection from Concept C_i to concept C_j:

W_{ij} = [-0.5, 0.6, 0.66, 0.7, 0.65, 0.25]

In the given example the required number of weights with the same sign is studied, that is π=0,8 and ω=0,2 and μ_1= μ_2=0,9. Step 3 of the algorithm previously tested has shown that, the majority of experts have assigned positive weights to the interconnection. As a result the first expert has been penalized with credibility weight $b_1 = \mu_1 * b_1 = 0.9 b_1$ and the corresponding weight is dropping out. Continuing the process to Step 4 of the algorithm, the average weight is computing $W^{ave}_{ij} = 0.572$, compared with other weights. When one considers the sixth step of the algorithm, the weight that has been recommended by the sixth expert (0.25) is excluded in the calculation and the particular expert appears penalized. All other weight values calculate the new average weight. In the instance used the selected weight is of value $W^{ave}_{ij} = 0.652$. In order to construct an integrated FCM, one is advised to apply the procedure described above (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010).

2.4.2 Assigning Linguistic Variables for FCM Weights

Another method of constructing Fuzzy Cognitive Maps, based on fuzzy logic will be explained in this subchapter. Any expert who uses linguistic notions may decide on the influence of a concept on the other as a “negative” or “positive” one. Then he or she describes the degree of influence by a linguistic variable like “strong”, “weak” etc. (Lin & Lee, 1996)

A concept’s influence on another is represented by linguistic variables that take values in the universe U = [-1,1]. Its term set T (influence) might be:

T (influence) = {negatively very strong, negatively strong, negatively medium, negatively weak, zero, positively weak, positively medium, positively strong, positively very strong}

The semantic rule is defined as follows below and these terms are characterized by the fuzzy sets whose membership functions are shown in

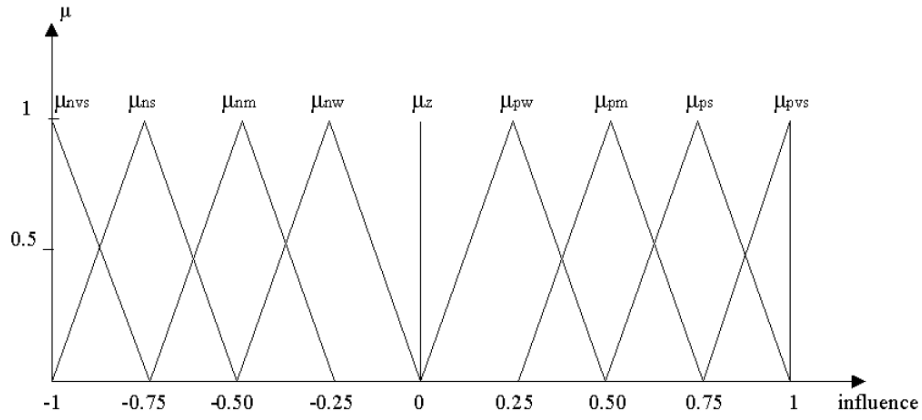


Figure 2.2.

Figure 2.2 Terms of the linguistic variable influence (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010)

- **M(negatively very strong)** = the fuzzy set for "an influence below to -75%" with membership function μ_{nvs}
- **M(negatively strong)** = the fuzzy set for "an influence close to -75%" with membership function μ_{ns}
- **M(negatively medium)** = the fuzzy set for "an influence close to -50%" with membership function μ_{nm}
- **M(negatively weak)** = the fuzzy set for "an influence close to -25%" with membership function μ_{nw}
- **M(zero)** = the fuzzy set for "an influence close to 0" with membership function μ_z
- **M(positively weak)** = the fuzzy set for "an influence close to 25%" with membership function μ_{pw}
- **M(positively medium)** = the fuzzy set for "an influence close to 50%" with membership function μ_{pm}
- **M(positively strong)** = the fuzzy set for "an influence close to 75%" with membership function μ_{ps}
- **M(positively very strong)** = the fuzzy set for "an influence above to 75%" with membership function μ_{pvs}

A similar methodology can be used to assign values to concepts. The experts are also asked to describe the measurement of each concept using once linguistic notions. Measurement of a concept is also interpreted as a linguistic variable with values in the interval [-1,1]. Its term set **T(Measurement) = T(Influence)**. A new semantic rule $\mathbf{M_2}$ (analogous to **M**) is also defined and these terms are characterized by the fuzzy sets whose membership functions $\boldsymbol{\mu_2}$ are analogous to membership function $\boldsymbol{\mu}$.

After the linguistic variables' combination describing each interconnection, the overall linguistic variable follows. A numerical weight for each of the interconnections will be the outcome of the defuzzifier, where the Center of Gravity (CoG) method is being used to produce this crisp weight (Nie & Linkens, 1995).

In practice, stakeholders may provide their expert estimates based on past data analysis, statistical analysis, of trends, best practices etc. The exact definition method of the expert linguistic variables is of little concern to this research approach. The definition of fuzzy membership functions allows rich interpretation of such variables. As an example, assume that three experts propose different linguistic weights for the same interconnection W_{ij} **(**Figure 2.1) from concept C_i = "Bad Weather" to concept C_j = "Freeway Congestion" as follows: (a) positively weak (b) positively strong (c) positively very strong (Xirogiannis, Glykas, & Staikouras, Fuzzy Cognitive Maps in Banking Business Process Performance Measurement, 2010).

- The linguistic variable "positively weak" with a membership function μ_{pw} has a **GoG = 0.216**
- The linguistic variable "positively strong" with a membership function μ_{ps} has a **GoG = 0.65**
- The linguistic variable "positively very strong" with a membership function μ_{pvs} has a **GoG = 0.783**
- So the defuzzified linguistic variables produce a weight
$$W_{ij} = \frac{GoG_A + GoG_B + GoG_C}{3} = 0.549$$

2.4.1 Synthesizing different Fuzzy Cognitive Maps

Suppose we have created a number of Fuzzy Cognitive Maps. Below there is an equation showing how to perform the combination of these maps in one augmented FCM with a weight matrix W representing the entire system. It is noteworthy that doing this presupposes depends on the segmental FCM's concepts. More specific, if there are no common concepts among different maps, then, the combined matrix W is constructed according to the following equation. In this case on may assume that there exist K different FCM matrices with weight matrices W_i. The table's dimensions are determined by the number of distinct concepts. For instance, in case the number of the distinct concepts is n, the table will be nxn dimensions:

$$W = \begin{bmatrix} W_1 & & & \\ & W_2 & \underline{0} & \\ & \underline{0} & \ddots & \\ & & & Wk \end{bmatrix}$$

Equation (5)

- Example 2

In this case one assumes the existence of two FCMs. The first map is named F_1 and includes concepts C_1, C_2, C_3 and F_2 includes concepts C_4, C_5, C_6. Weighted matrices for F_1 and F_2 are depicted as follows:

$$W_1 = \begin{bmatrix} 0 & 0 & W_{13} \\ W_{21} & 0 & 0 \\ W_{31} & W_{32} & 0 \end{bmatrix} \ and \ W_2 = \begin{bmatrix} 0 & W_{45} & W_{46} \\ W_{54} & 0 & W_{56} \\ 0 & W_{65} & 0 \end{bmatrix}$$

The augmented weight matrix is going to be:

$$W = \begin{bmatrix} W_1 & 0 \\ 0 & W_2 \end{bmatrix} = \begin{bmatrix} 0 & 0 & W_{13} & 0 & 0 & 0 \\ W_{21} & 0 & 0 & 0 & 0 & 0 \\ W_{31} & W_{32} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & W_{45} & W_{46} \\ 0 & 0 & 0 & W_{54} & 0 & W_{56} \\ 0 & 0 & 0 & 0 & W_{65} & 0 \end{bmatrix}$$

The equation that follows depicts the case when common concepts exist among the distinct FCM. In this case, there is going to be an overlapping between certain diagonal elements-matrix of matrix W in equation 5. In the phase that follows the segmental FCM with common concepts computes new weights among interconnections. If there are more than one common concept, then two or more weights for this interconnection are suggested. In such a case the value of the new weight takes the average of the previous values. Below we find the new equation created according to the abovementioned.

- Example 3

In this case we assume that there are two FCMs. The first map is named F_1 with concepts C_1, C_2, C_3 and F_2 with concepts C_2, C_3, C_4, C_5. Weighted matrices for F_1 and F_2 are shown below:

$$W_1 = \begin{bmatrix} 0 & 0 & W_{13} \\ W_{21} & 0 & 0 \\ W_{31} & W_{32} & 0 \end{bmatrix} \; and \; W_2 = \begin{bmatrix} 0 & W_{23} & W_{24} & 0 \\ W_{32} & 0 & W_{34} & W_{35} \\ W_{42} & W_{43} & 0 & 0 \\ W_{52} & W_{53} & W_{54} & 0 \end{bmatrix}$$

The augmented weight matrix is going to be:

$$W = \begin{bmatrix} 0 & 0 & W_{13} & 0 & 0 \\ W_{21} & 0 & W_{23} & W_{24} & 0 \\ W_{31} & W_{32}^{ave} & 0 & W_{34} & W_{35} \\ 0 & W_{42} & W_{43} & 0 & 0 \\ 0 & W_{52} & W_{53} & W_{54} & 0 \end{bmatrix}$$

2.4.2 The Neural Network Nature of Fuzzy Cognitive Maps

Both the mode of creating and nature of FCM use the features of fuzzy logic and neural networks. FCM's methodology construction leads to a controversial model since the human factor is considered to be utterly influential. This is why Differential Hebbian is developed, according to which learning law adjusts the weights of the interconnection between concepts. It seems to grow a positive edge between two concepts in case they both increase or correspondingly decrease. Also it grows a negative edge if values of concepts move to opposite directions.

It is worth noting that the fundamental difference between Fuzzy Cognitive Maps and Neural Networks is in that all the concepts of the FCM have strong semantic defined by the modeling of the concept. On the contrary the input / nor output nodes of the Neural Network have a weak semantic and are representing only by mathematical relations. Certainly one expects appropriate learning rules to exist, giving FCMs useful characteristics like the fault tolerant capability, ability to generalize adaptivity to situations and, also, learn arbitrary non-linear mappings. (Papageorgiou, Spyridonos, Ravazoula, Stylios, Groumpos, & Nikiforidis, 2006) (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010).

2.4.1 Supervisors of Complex Systems and FCMs

A phenomenon that is fairly as often as possible observed is that most organizations worldwide are organized with no centre-focused control infrastructures. In most cases it comes because of their local interconnections. For this reason, another methodology was created for Fuzzy Cognitive Maps for the modeling of the supervisor of the complex system. It is displayed in Figure 2.3 An FCM-Supervisor of a complex system Figure 2.3 and shows the structure of the hierarchy to FCM. The plant lies in the lower level of the structure. The plant is controlled through conventional controllers. These particular controllers perform common tasks, reflecting the model of the plant amid typical operation conditions utilizing conventional control techniques. It merits saying that the supervisor was built as a FCM. The first endeavor to model a supervisor of one “scale” complex system using the concept of FCM was made close to 2000 (Stylios & Groumpos, The Challenge of modeling Supervisory Systems using Fuzzy Cognitive Maps, 1998) (Groumpos & Stylios, 2000). Because of a large amount of information, it is important to express and transfer this specific information in the following way: from the lower level of the structure to the top. In our case it is called a FCM-Supervisor. FCM will interact using Equation 2. The concepts of FCM are going to have new values that are to be transmitted to the conventional controllers of the system. So the procedure will follow the opposite direction and, as a result, changes will occur in the value of specific elements (one or more) of the overall system.

Another feature of FCM considered to be very useful is the ability to await for and redesign a system, enabling the user to calculate and predict the outcome in case parameters change. The human factor is of fundamental importance in the operation of FCM. It is very substantial for the human planner to have an in-depth knowledge on the operation of crucial aspects of the overall system. Then, the expert can utilize the suitable concepts to depict through FCMs precisely what he wants.

The FCM-Supervisor incorporates concepts able to depict failure mode variables, design variables or the irregular operation of some components of the system along with failure effects variables or even the seriousness of the effect. Further than that, it includes concepts for strategic planning and decision analysis.

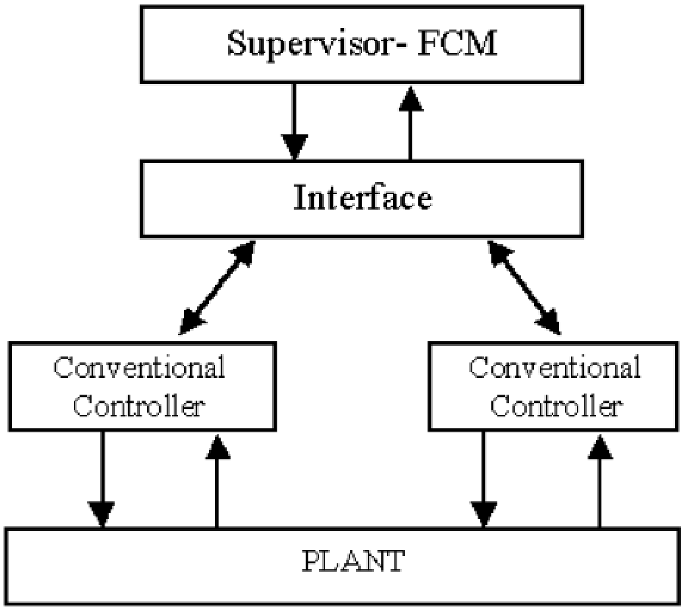


Figure 2.3 An FCM-Supervisor of a complex system (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010)

2.4.2 Decision Analysis and Fuzzy Cognitive Maps

Decision analysis is usually based on a various diverse methodologies going for choosing among specific alternatives. The aftereffect of each given decision is constantly measured in view of costs, benefits or the utility. On the off chance we choose to examine each value of the output-result then we will see that the different numbers of these specific values are normally found to vary considerably.

The Decision Trees (DT) consist an application of the so-called decision analysis methodology. There is a significant number of others machine learning techniques compared to the Decision Trees like Neural Networks (D'alche-Buc, Zwierski, & Nadal, 1994) or Bayesian Networks (Janssens, Wets, Brijs, Vanhoof, Arentze, & Timmermans, 2006). As mentioned in previous subchapter, if we are to spot the fundamental difference between Neural Networks and FCMs we should accentuate the way that all nodes of the FCM graph seem to have significant semantic that is completely defined by the modeling of the concept, whereas the nor input/nor output nodes of the neural network have a weak semantic, only defined by mathematical relations (Xirogiannis, Glykas, & Staikouras, Fuzzy Cognitive Maps in Banking Business Process Performance Measurement, 2010). Amid the last decade newly appearing literature demonstrates the blend of Decision Trees and Fuzzy

Cognitive Maps (Podgorelec, Kokol, Tiglic, & Rosman, 2002) (Papageorgiou, Stylios, & Groumpos, Unsupervised learning techniques for fine-tuning Fuzzy Cognitive Map causal links, 2006). In this subchapter a technique from Dr. Groumpos (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010) that combines a FCM model with a Decision Tree (DT) in Decision Analysis is presented. The derivative model is prepared by means of an algorithm to achieve better accuracy. One is to say that for this situation the Nonlinear Hebbian Learning (NHL) algorithm has been adopted. The Decision Tree-Fuzzy Cognitive Map's (DT-FCM) function shows up in Figure 2.4. In the case at hand a lot of input data and after the quantitative data had been utilized for stimulating a Decision Tree (DT). Using the knowledge of expertise qualitative data are used to shape the Fuzzy Cognitive Map (FCM) model. FCMs and, more specifically, their flexibility appear to incorporate certain strict decision tests. This flexibility gets from fuzzy IF – THEN rules, regarding the assigning weight directions and values. The FCM model that is constructed gets training by the supervised NHL algorithm, going for teaching a fruitful decision. This specific methodology may be utilized for the accompanying three different circumstances, depending each time on the sort of the initial input data:

1. In the instance of the quantitative initial data, the Decision Tree generators have been used. At that point, an inductive algorithm creates the fuzzy rules. These fuzzy rules mean to update the development of the FCM model.
2. Assuming the availability of the expert's knowledge, through the unsupervised NHL algorithm, the Fuzzy Cognitive Map (FCM) model is intended to compute the objected output concept. This exact concept seems, by all accounts, to be responsible for the particular decision line.

3. With the outputs-results of both the quantitative and qualitative data, the initial information/data are separated with each data sort to be utilized for the creation of DT and FCM. Both DTs and FCMs are developed separately. At that point, the fuzzy rules induced from the inductive learning re-structure and the FCM model is the ones upgrading it. In this specific FCM model case the training algorithm helps the FCM model with the mean to achieve the correct decision.

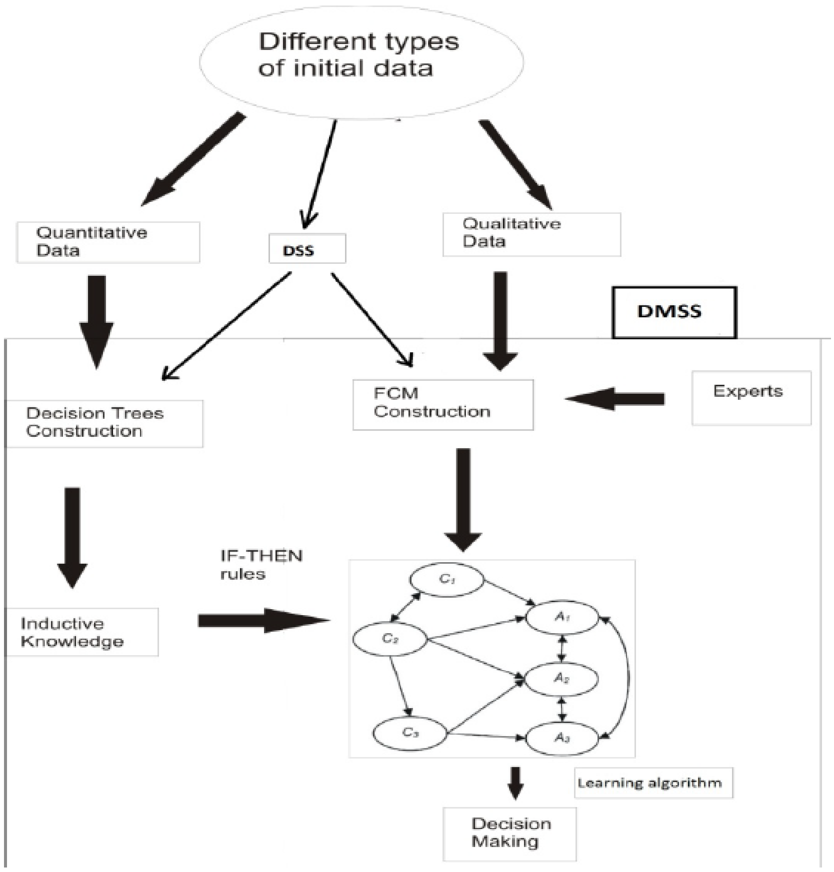


Figure 2.4 The decision making system constructed by Decision Trees (DTs) and Fuzzy Cognitive Maps (FCMs) (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010)

Three crucial advantages get from this technique. To start with, the association rules originating from the decision trees may simply and straightforwardly interpreted. Further than that, the decision trees that have been introduced in the initial Fuzzy Cognitive Map model intend to enhance both operation and structure. In simple terms, expecting that we have a developed rule saying: variable 1 (or input variable) has feature A. Consequently, variable 2 (or output variable) has feature B. Secondly, it is merits specifying that the methodology introducing DT rules into a FCM may likewise aid weight assignment through the new cause and effect relationships between the FCM concepts. Thirdly, it has been demonstrated that the technique at hand has been ended up being more functional than the best Decision Tree (DT) inductive learning technique or the FCM decision tool (Groumpos P. P., Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems, 2010) (Groumpos & Karagiannis, Mathematical Modeling of Decision Making Support Systems Using Fuzzy Cognitive Maps, 2013).

3 Applications on Fuzzy Cognitive Maps

3.1 Introduction

According to the points already made in the introductory chapter, Fuzzy Cognitive Maps are diagrams utilized as causal representations. Specifically, one may contend that the diagrams are the causal representations between knowledge and data and they represent events relationships. Maps of this sort may leverage knowledge and experience to modeling methods, in terms of describing particular domains using the existing concept and existence relationships among them. Each of the concepts represents a state, a variable, an input or an output and these are collected by asking human experts who are the ones to decide which variable is the most appropriate for a particular complex system. The dynamic characteristics that FCMs have and the learning methodologies make them essential for modeling, analysis, prediction and decision making tasks as they seem to improve performance of many various systems (Papageorgiou E. I., Review study on Fuzzy Cognitive Maps and their applications during the last decade, 2011). Fuzzy Cognitive Maps constitute a particularly convenient, simple and powerful tool, used in numerous areas of application. In the chapter at hand, various cases of application of Fuzzy Cognitive Maps are going to be carefully studied. Starting from the Medical Domain, the application of Fuzzy Cognitive Maps will be extensively studied in Information Technology (IT), in general Business Management applications and a comprehensive report will turn out to be beneficially used regarding maps in Business Performance Measurement, Banking Management and other types of Business Risk Management. The FCM application studies in the scientific field of Production Systems, Engineering and Computer Vision will also follow. Further than that there are going to be examples of FCM’s application in the field of Political and Social Sciences. A thorough study is also presented highlighting applications of FCMs to Environment and Agriculture issues.

3.2 Healthcare and Medical Decision Making

Medical decision support systems can unquestionably provide assistance in crucial clinical judgments, especially for medical professionals lacking experience. Fuzzy Cognitive Maps (FCMs) constitutes an innovative computing technique for modeling complex systems. It is essential to say that these systems follow an approach, similar to human reasoning and additionally to human decision making process and, for this specific reason they are of a unique importance. Human experience and knowledge can be both represented by Fuzzy Cognitive Maps, presenting concepts to represent the essential elements and the existence cause and effect relationships that existing among the concepts as far as modeling the conduct of any system. One significant characteristic of medical decision complex systems is that they comprise of related and non-related components and also subsystems where various factors must be thought about. These might be conflicting, complementary and competitive (Stylios, Georgopoulos, Malandraki, & Chouliara, 2008). In the given subchapter the application of Fuzzy Cognitive Maps in the Healthcare and Medical Decision Making field will be contemplated and the way the previously mentioned factors influence each other and define the overall clinical decision with an alternate degree will be well understood.

One may note that there is no great variety of studies in view of Fuzzy Cognitive Maps as a reference on the medical decision systems. Nevertheless, in recent years, FCMs have found essential applicability in the medical diagnosis and the decision support.

Radiotherapy is the application of ionizing radiation for curing patients suffering from cancer. The point of radiation therapy is to outline and perform a sort of treatment plan on how to deliver an exactly measured dose of radiation to the characterized tumor volume. At the same time, it is important to produce as a little radiation as possible to the encompassing healthy tissue. A decision making system for radiation therapy in light of human knowledge and experience was produced by Papageorgiou (Papageorgiou, Stylios, & Groumpos, 2003) (Papageorgiou E. , 2010). The very specific system consisted of a two- level hierarchical structure where an FCM in each level was made, developing an advanced decision making system. The lowest level FCM modeled the treatment planning, considering all factors and treatment variables alongside their impacts and influences (CTST-FCM). The initials said (CTST) mean Clinical Treatment Simulation Tool. The upper level FCM modeled the methodology of the treatment execution and computed the optimal last dose for radiation treatment. In case of the upper level, FCM both supervised and assessed the overall radiation therapy process. Before the treatment execution, the two level integrated form for supervising the procedure gives off an impression of being a realistic approach to the decision making process in radiation therapy domain. The focal thought of this specific technique is to combine distinctive data driven methods to extricate all available knowledge from information/data and generate causal paths through fuzzy rules through the definition of new linguistic weights (Papageorgiou E. , 2010).

Another fundamental investigation on the application of Fuzzy Cognitive Maps in medical terms is a learning approach and a FCM based grading tool namely FCM-GT for characterizing different sorts of tumors malignancy (Papageorgiou, Spyridonos, Ravazoula, Stylios, Groumpos, & Nikiforidis, 2006) (Papageorgiou, et al., 2008). At last, essential studies still exist, concerning the utilization of Fuzzy Cognitive Maps for pattern recognition and diverse classification approaches (Papakostas, Boutalis, Koulouriotis, & Mertzios, 2008) (Boutalis, Kottas, & Chrystodoulou, 2009), which comprises a vital case in the approach of FCM connected to autism categorization (Papageorgiou & Oikonomou, Particle Swarm Optimization Approach for Fuzzy Cognitive Maps Applied to Autism Classification, 2013).

Chrisostomos Stylios et al. (2008) have published a research for Medical Decision Support Systems (MDSS) that may give assistance in critical clinical judgments, especially for inexperienced medical professionals. As we know from previous subchapter FCMs may successfully represent both knowledge and human experience, introducing concepts to represent the essential components and the cause and effect relationships among the concepts to model any system’s behavior. Medical Decision Systems consist certain perplexing systems able to be decomposed to non-related and related sub-systems and components, where many variables and factors must be contemplated. They influence each other and decide the overall clinical decision at a different degree. This particular research applies FCMs to MDSS and proper FCM architectures are suggested and created as well as the corresponding examples from two medical disciplines i.e. speech and language pathology and additionally, obstetrics are described (Stylios, Georgopoulos, Malandraki, & Chouliara, 2008). In order to model medical decision making, Papageorgiou and Iakovidis suggest a novel approach in view of cognitive maps and the intuitionistic fuzzy logic. The new model, called intuitionistic fuzzy cognitive map (iFCM), extends the current fuzzy cognitive map (FCM) by considering the expert’s hesistancy in the determination of the causal relations between concepts of a particular domain.

Furthermore, a modification in the formulation of another new model makes it even less sensitive than the earliest model to missing input data. The simplification of this supposed approach suggests its appropriateness for an assortment of medical decision-making tasks (Iakovidis & Papageorgiou, 2011).

In the medical field -and specifically for medical decision support tasks- there are as yet other FCM based decision frameworks and methodologies including an approach for the pneumonia seriousness appraisal (Papageorgiou, Papandrianos, Karagianni, Kyriazopoulos, & Sfyras, 24-27 August 2009) and a model for the administration of urinary tract infections (Papageorgiou, Papadimitriou, & Karkanis, Management uncomplicated urinary tract infections using fuzzy cognitive maps, November 5-7, 2009). Froelich and Deja, (2009), suggested an FCM approach for mining wordly medical data (Froelich & Wakulicz-Deja, 2009). Rodin et al. has build-up a fuzzy impact graph to model the cell conduct in biology systems through the intercellular biochemical pathway (Rodin, Querrec, Ballet, Battaile, Desmeulles, & Jean -Francois Abgrall, 2009). Later this model can be integrated in agents speaking to cells. Results show that notwithstanding singular variations, the average behavior of MAPK pathway in a cells group is near to results gotten by standard differential equations. The model was connected in multiple myeloma cells signaling.

Kannappan et al. have just suggested the soft computing technique of Fuzzy Cognitive Maps for modeling and foreseeing autistic spectrum disorder. By this approach the hebbian algorithm on non-linear units is utilized for training FCMs for the autistic disorder forecast issue. The investigated approach fills in as a guide in deciding prognosis and in planning the fitting therapies to kids with special needs (Kannappan, Tamilarasi, & Papageorgiou, 2011).

In the research work of Dr. Papageorgiou (2011), a novel structure for the development of augmented Fuzzy Cognitive Maps in light of Fuzzy Rule-Extraction methods for decision in medical informatics is examined. In particular, the issue of designing augmented Fuzzy Cognitive Maps joining knowledge from experts and knowledge from various sort of data in the form of the fuzzy rules produced from rule-based knowledge disclosure methods is investigated (Papageorgiou E. I., A new methodology for Decision in Medical Informatics using fuzzy cognitive map based on fuzzy rule-extraction techniques, 2011).

3.3 Information Technology (IT)

Information Technology (IT) certainly constitutes a major component for enterprises investing billions of dollars in IT projects (Salmeron J. L., Fuzzy Cognitive Maps-Based IT Projects Risks Scenarios, 2010). In the mid-1980s articles started to concentrate on Strategic Planning of Information Systems (SISP) and to contend elaborately on the crucial significance of Information Technology (IT) in current organizations. From that point forward, countless models were exhibited as a means to analyze IT from a strategic perspective and propose new IT projects (Kardaras & Karakostas, 1999).

In the field of Information Technology (IT) project management, a FCM-based methodology helps at success modeling. Current frameworks and tools utilized for identifying, classifying and assessing the specific indicators of success in IT projects show a few constraints. These could be overpowered by the employment of FCMs for mapping success, modeling Critical Success Factors (CSFs) observations and relations amongst them (Rodriguez-Repiso, Setchi, & Salmeron, 2007). Rodriguez-Repiso et al. (2007) exhibited the applicability of the FCM methodology through a contextual analysis in light of a new project idea, the Mobile Payment System (MPS) project, identified with the quick developing world of the mobile telecommunications.

Salmeron (2010) has proposed the usage of Fuzzy Cognitive Maps, as far as better management of the IT risks. As indicated by this approach the applied endeavors to search for the right IT implementation ought to be accompanied by systems for managing the various implementation risks. The basic point is to attempt to diminish the risk of presumptive implementation failure. This very approach dissects Information Technology implementation risks and additionally the current relationships between using Fuzzy Cognitive Maps (FCMs). This mentions the objective fact of the most important risks conceivable and off all, the decision on which has the a biggest effect on the IT projects (Salmeron J. L., Fuzzy Cognitive Maps-Based IT Projects Risks Scenarios, 2010).

Xiangwei et al. (2009) analyzed and condensed normal software's usability quality character framework with the expectation to discover the software's usability malfunction and improve various problems (Lai, Zhou, & Zhang, 2009). They utilized FCM to depict the software quality character relationship and give a completed training arithmetic, semantic pruning arithmetic, syntax pruning arithmetic, and quality relationship analysis arithmetic to the technique.

Chytas et al. propose an approach portraying a model for software reliability prediction. The output is a “forward-looking” model supporting analyzers to forecast and manage software reliability. In spite of the availability of different approaches created in the field of software reliability, these are still issues requiring further research with a specific end goal to succeed with regards to support the decision making process and meliorating software quality. In this research at hand the utilization of Fuzzy Cognitive Maps (FCMs) is presented, as an approach to modeling of software reliability. Fuzzy Cognitive Maps catch data in the relationships between concepts, are dynamic, express concealed relationships, and are combinable and tunable. Preliminary experiments demonstrate that the proposed system shapes a sound support for the process of software reliability modeling (Chytas, Glykas, & Valiris, Software Reliability Modelling Using Fuzzy Cognitive Maps, 2010).

Furfaro et al. (2010) proposed a novel method for both the identification and interpretation of sites that yield the high potential of cryovolcanic activity in Titan and introduced the theory of FCMs to investigate remotely gathered data in planetary exploration (Furfaro, Kargel, Lunine, Fink, & Bishop, 2010).

3.4 Telecommunications

In telecommunications, Fuzzy Cognitive Maps connected for distributed wireless P2P networks (Li, Ji, Zheng, Li, & Yu, 2009). Peer-to-peer (P2P) technologies have raised extraordinary research interest because of a noteworthy number of effective applications in wired networks. Well known commercial applications, for example, Skype and Napster have pulled in millions of users around-the world. A novel team-driven peer selection plan in light of Fuzzy Cognitive Maps, at the same time considering different selection criteria in wireless P2P networks, has been recommended. The primary influential factors and their complex relationships for peer selection in wireless P2P networks have been researched.

3.5 Business Management

3.5.1 Business Analysis and Process Performance Measurement

Glykas et al. (2011) describes a sort of a methodology for the development of a specific proactive balanced scorecard (PBSCM). The balanced scorecard jumps out at be amongst the most famous approaches created in the given domain of performance measurement. The research at hand addresses the problems of the balanced scorecard through using soft computing characteristics of Fuzzy Cognitive Maps (FCMs). While utilizing FCMs, the proposed methodology seems to create a dynamic network of interconnected Key Performance Indicators (KPIs). Additionally, it both simulates each KPI with imprecise relationships and quantifies the impact of each KPI to other KPIs going for adjusting objectives of performance (Chytas, Glykas, & Valiris, A proactive balanced scorecard, 2011).

Glykas (2013) suggests a research elaborating Fuzzy Cognitive Maps' (FCMs) application on Strategy Maps (SMs). The constraints of Balanced Scorecards (BSCs) and SMs are as a rule right of the bat discussed and dissected. The requirement for simulated scenario based SMs is also talked about alongside the utilization of FCMs as one of the best alternatives introduced. A software tool for the development, simulation and finally analysis of FCM based SMs is shown to. The effectiveness of the subsequent software tool and FCM theory in Strategic Maps (SMs) are appeared as experimented in two particular case studies in the field of Banking (Glykas, Fuzzy Cognitive Strategic Maps in Business Process Performance Measurement, 2013).

Xirogiannis et al. (2004) depict at their approach the Business Process Reengineering (BPR) that had a noteworthy effect on both managers and academics. Regardless of the talk encompassing BPR articulated mechanisms, supporting reasoning on the impact of the redesign activities to the performance of one specific business model is as yet rising. This research describes a significant endeavor to develop and operate such a reasoning system as a novel supplement to Performance Driven Change (PDC) works. This new approach suggests the use of the fuzzy causal characteristics of fuzzy cognitive maps (FCMs) as the provided fundamental methodology as a means to produce a hierarchical and dynamic network of interconnected performance indicators. With the utilization of FCMs, the recommended mechanism goes for at simulating the operational efficiency of complex process models that have “fuzzy” relationships to evaluate the effect of performance-driven reengineering activities. The research at hand additionally builds up generic maps complementing the strategic planning and business analysis stages of run of the mill redesign projects going for implementing the integration of hierarchical Fuzzy Cognitive Maps (FCMs) into PDC exercises. At last, this specific research talks about experiments made with the suggested mechanism and remarks on its plausible ease of use (Xirogiannis & Glykas, Fuzzy Cognitive Maps in Business Analysis and Performance-Driven Change, 2004) .

3.5.2 Banking Sector

Typical financial plans comprise chiefly of quantitative assessments of certain key financial indicators. Clearly a qualitative supplement of typical financial plans may contribute altogether strategic planning at financial sector enterprises (and vice versa).

Xirogiannis et al. (2010) proposed Fuzzy Cognitive Maps as a novel supplement for strategic-level financial planning at the banking domain. It comprises a decision system and financial targets composition stages of regular financial strategy formulation projects, through the support of the cognitive modeling of Profit and Loss (P&L) analysis and also “intelligent” reasoning of the expected effect of strategic change activities to the financial related status of a regular financial sector enterprise. This mechanism utilizes the fuzzy causal characteristics of FCMs as another new modeling technique for building up a causal representation of the dynamic financial principles keeping in mind the end goal to develop hierarchical network of interconnected financial performance indicators. The suggested mechanism goes for simulating the efficiency of complex hierarchical financial models with “fuzzy” (imprecise) relationships while measuring the impact of strategic changes to the overall P&L status. The FCM hierarchies additionally integrate stimuli of the external environment (e.g. sector characteristics, national economy, market opportunities, and so on), likely to drive the strategic positioning of a run of a mill bank yet their impact to the P&L performance might not be quantified correctly. Fuzzy reasoning capabilities improve usefulness of FCM mechanism extensively while in the meantime diminish the effort of identifying exact P&L measurements during a strategy formulation activity. This approach exhibits a comprehensive mechanism for strategic-level financial planning in light of scenario building and ex-ante impact evaluation. The model proposed objectives the principle beneficiaries and stakeholders of strategy formulation projects (bank administration, planning and budgeting managers, client facing division managers, interval auditors, and so on.) helping them to reason successfully about the status of financial maturity metrics, provided the (actual or the hypothetical) implementation of strategic changes (Xirogiannis, Glykas, & Staikouras, Fuzzy Cognitive Maps in Banking Business Process Performance Measurement, 2010).

3.5.3 Risk Management

One of the principle challenges in the areas of Risk Analysis and Management (RAM) is to identify the relationships among risk factors and risks. Lazzerini et al. (2010), proposed expanded Fuzzy Cognitive Maps (E-FCMs) to examine the relationships between risk factors and risks (Lazzerini & Lusine, 2010). The primary contrasts between E-FCMs and regular FCMs are the accompanying: E-FCMs have non-linear membership functions, conditional weights, and time delay weights. In this way E-FCMs give off an impression of being extremely suitable for risk analysis since each component of E-FCMs is a great deal more instructive and ready to fit to the needs of Risk Analysis. Especially, the work investigated the Software Project Management (SPM) and talks about risk analysis of SPM applying E-FCMs.

The Operative Risk incorporates an extraordinary amount of risk factors. Their modeling is troublesome for two reasons: initially, the data identified with the factor is much of the time of qualitative sort and, also, the rare quantity of information because of discrete character of the occasions that make it hard to model the risk utilizing formal statistical tools. Hurtado (2010) concentrates on his research, on modeling operative loss exposure of the Allowances and Retirement Funds with the utilization of Fuzzy Expert System, assessing environmental and managerial variables. This framework allows to get a qualification about the possibility that the organization causes in operative losses. The mechanism can be exceptionally useful and valuable either when the quantitative data is constrained because of the discrete character of the risk events or where the data about the risk factors are related to expert’s knowledge: consequently modeling utilizing statistical tools is evaluated to be a difficult one (Hurtado, 2010)

More remote than the previously mentioned case, Fuzzy Cognitive Maps (FCMs) have an immediate application on different instances of risk management like the forecasting risk effect on Enterprise Resource Planning (ERP) maintenance. Enterprise Resource Planning (ERP) is a standout amongst the most well-known systems implemented by organizations around the globe. Be that as it may, ERP adoption success is not ensured. Fruitful adoption of an ERP system additionally relies upon appropriate system maintenance. The use of Fuzzy Cognitive Maps in this case helps to predict risk consequences for ERP maintenance objectives and simulate distinct scenarios (Salmeron & Lopez, Forecasting Risk Impact on ERP Maintenance with Augmented Fuzzy Cognitive Maps, 2012).

3.5.4 General Applications of FCMs in Business Sector

As some of the above finds, FCMs have found broadened applicability in the business domain. They are to be utilized for product planning, for examination and decision support as introduced above in the previous subsection. In this subchapter some intriguing applications are going to be presented that are deserving of reference.

Jetter et al. (2006) utilized the concept of fuzzy front end for ideation, concept development and concept assessment of new product development. This concept helped different problems managers who confronted trouble in early product development, and in addition to systematic approaches to deal with manage them (Jetter A. , July 2006). This particular approach helped in identification of market needs and technology potentials, recognition and exploitation of idea sources, early stage evaluation of ideas and product concepts and in addition effective management styles.

Yaman and Polat suggested the utilization of fuzzy cognitive maps (FCMs) as a methodology for supporting the decision-making process in effect-based planning. With sufficient consideration of the problem highlights and the existent limitations administering the technique being used, a FCM is produced to model effect-based operations (EBOs) (Yaman & Polat, 2009). In the mentioned study, the model was connected to an illustrative scenario including military planning. Wei et al (2008) have been examining the utilization of fuzzy cognitive time maps for modeling and assessing trust dynamics in the virtual enterprises (Wei, Lu, & Yanchun, 2008). Bueno and Salmeron (2008) have proposed a tool for fuzzy modeling Enterprise

Resource Planning choosing (Bueno & Salmeron, 2008), while Salmeron (2009) has suggested the augmented fuzzy cognitive maps for modeling LMS Critical Success Factors (CSF) (Salmeron J. L., 2009)

Kim alongside coworkers (2008) has built up a quantitative approach, utilizing FCMs and Gas, with a specific end goal to assess forward-backward analysis of RFID supply chain (Kim, Kim, Hong, & Kwon, 2008). Trappey et al. (2010) utilize FCMs to model and assess performance of RFID-enabled switch logistics operations (Trappey, Trappey, & Wub, 2010). The Radio frequency identification (RFID) conforming to the EPC global (2004) Network architecture, i.e., a hardware (and software) coordinated cross platform IT framework has been embraced to better empower information collection and transmission in revrse logistic management. Inference analysis utilizing genetic algorithms adds to the performance prediction and decision support for enhancing reverse logistic efficiency (Trappey, Trappey, & Wub, 2010). The research mentioned has given a guideline to forecast future logistic operation and moreover build a decision support model for managing a performance mechanism based on the forecast.

Buyukozkan et al. (2009) suggested a semantic method of analyzing Collaborative Planning, Forecasting and Replenishment (CPFR) supporting factors utilizing FCM approach (Buyukozkan, Feyzioglu, & Vardaloglu, 2009)

Fuzzy Cognitive Maps, being an illustrative causative portrayal of modeling and manipulation of complex systems, might be utilized to model the dynamic conduct of the explored systems. All things considered, because of imperfections in articulation and architecture, the conventional FCMs and majority of their pertinent expansions are not applicable to categorization problems. To tackle such an issue, Song et al. (2011) present an approach specifically expanding the model by translating the reasoning system of traditional FCMs to set of fuzzy “if-then” rules. More distant than that, this suggested approach fully considers the contribution of the inputs to the activation of the fuzzy rules and evaluates the causalities utilizing common subset hood. This seems to work in conjunction with volume defuzzification in a gradient descent-learning framework. This particular approach upgrades the capability of the traditional FCMs to automatically identify membership functions and quantify causalities. The work efficiently broadens the use of the conventional FCMs into classification problems, while in the meantime keeping the ability for forecast and approximation (Song, Miao, Wuyts, Shen, & D'Hondt, 2011).

3.6 Production Systems

Fuzzy Cognitive Maps can give an extremely interesting solution to manage the problem of evaluating factors considered to influence the operator's reliability, ready to be researched for human reliability in production systems (Bertolini & Bevilacqua, 2010). Bertolini and Bevilacqua (2010) researched the human reliability in production systems going about as an outstanding means to examine a productions process and get valuable indications on the results to be dictated by the variety of at least one variable in the system studied.

Lo Storto et al. (2010) proposed a methodological structure to investigate the cognitive processes implemented by individuals of a software development team to manage questionable circumstances at the phase of product requirements definition (Lo Storto, April 2010). Fuzzy Cognitive Maps were utilized in the framework as a part of the system to evoke cognitive schemes and built up a measure of individual uncertainty tolerance. More distant than that, Fuzzy Cognitive Maps have been utilized to design game-based learning mechanisms, as it has the excellent ability of concept representation and reasoning (Luo, Wei, & Zhang, October, 2009). A novel game-based learning model consists of a teacher sub-model, a learner sub-model and am arrangement of learning systems has been developed.

3.7 Engineering

In this field, Fuzzy Cognitive Maps have discovered a genuine number of uses, particularly with regards to in charge and forecast. All the more particularly, FCMs have been utilized to model and bolster a plant control system, to build a mechanism for failure modes and impact analysis, to tweak fuzzy logic controllers and to model the supervisor of a control system and so on. Stylios and Groumpos (2004) have investigated the FCM for modeling complex systems and controlling supervisory control systems (Stylios & Groumpos, Modeling Complex Systems using Fuzzy Cognitive Maps, 2004). Papageorgiou et al. implemented learning approaches in light of non-linear Hebbian rule in order to train FCMs that model the industrial process control issues (Papageorgiou, Stylios, & Groumpos, Unsupervised learning techniques for fine-tuning Fuzzy Cognitive Map causal links, 2006).

As of late, a combination of a cognitive map and a fuzzy inference engine was proposed, as a cognitive-fuzzy model, targeting online fuzzy logic controller (FLC) design and self-fine-tuning (Gonzalez, Aguilar, & Castillo, 2009). The suggested model that has been not the same as past proposed Fuzzy Cognitive Maps (FCMs) is that it displays a hierarchical architecture. As per this, the Fuzzy Cognitive Map process, officially available in a plant, and control target information on knowledge representation to create a total FLC architecture and parameters depiction. Simulation comes about show model interpretability, recommending that the model is scalable and offers powerful capacity to generate near optimal controller.

In 2010 Aguilar suggest in his research a Dynamical Fuzzy Cognitive Map (DFCM) where its casual relationships depend on fuzzy rules, in a way that the structure of the map changes during the execution phase (that is the runtime). This research goes for the modification of the relationships' values between the concepts through of fuzzy rules gotten from the concept states speaking to the system modeled by the map. The suggested DFCM is ideal to assemble supervision systems for multiagent systems (MAS), keeping in mind the end goal to examine the behavior of the agents community when they fail, utilizing a considerable resources, and so forth. DFCM has been utilized to construct a supervision system for a faults management system in view of multiagent systems (Jose, Dynamic Fuzzy Cognitive Maps for the Supervision of Multiagent Systems, 2010).

At 2010, Kottas et al. (Kottas, Boutalis, & Christodoulou, Fuzzy Cognitive Networks: Adaptive Network Estimation and Control Paradigms, 2010) have introduced their fundamental theoretical results identified with the presence and uniqueness of equilibrium points in FCN, adaptive weight estimation in view of system operation data, fuzzy rule storage system and utilization of whole framework to control unknown plants. The results have been approved utilizing well known control benchmarks. A similar research group, at that year, utilized FCN to develop a maximum power point tracker (MPPT), that may work in cooperation with a fuzzy MPPT controller (Kottas, Karlis, & Boutalis, Fuzzy Cognitive Networks for Maximum Power Point Tracking in Photovoltaic Arrays, 2010). The suggested plot outflanks other existing MPPT schemes of the literature giving great maximum power operation of any PV array under various conditions, for example, changing insolation and temperature.

Jetter et al. propose a novel method for scenario building, in view of Fuzzy Cognitive Maps, consolidating intuitive, cognitive mapping, methods and techniques with formal, quantitative examination. This technique helps scenario planners to incorporate qualitative and partial knowledge of various individual and conquer data processing limitations. The achievability of the suggested approach is examined with two scenario studies on solar photovoltaic panels (Jetter & Schweinfort, 2011).

Beeson et al. (2010) suggested a factored approach to mobile robot map-building that handles qualitatively distinctive sorts of unpredictability by consolidating the strengths of topological and metrical approaches (Beeson, Modayil, & Kuipers, 2010). This mechanism depends on a computational model of the human cognitive map and allows robust navigation and communication inside few distinctive spatial ontologies.

In Baykasoglu et al. Extended Great Delude Algorithm (EGDA) research it has been considered without precedent for literature as a training algorithm for Fuzzy Cognitive Maps. The algorithm's performance has been tried with two problems. The primary problem is chosen from the literature being an "industrial process control problem". The proposed algorithm has given promising results on this problem. In the second issue specified a simulation model of a job shop is created and utilized for examining causal relationship between the control/performance factors through Fuzzy Cognitive Map (FCM) (Baykasoglou, Durmusoglou, & Kaplanoglu, 2011).

3.8 Computer Vision

With computer vision being another developing area, there are demanding solutions for solving various problems. Information to be processed seen by all accounts, to be fairly bi-dimensional (2D) images that have been caught from the tri-dimensional (3D) scene. The objects in 3D are by and large made out of related parts that have joined from the entire object. Luckily, the relations in 3D are preserved in 2D. In this manner, there are specific necessary ingredients to build a structure under the FCMs paradigm. Fuzzy Cognitive Maps have been successfully utilized as a part of a few territories of computer vision including: image change detection, or pattern recognition, or stereo vision matching (Pajares, Guijarro, Herrera, Ruz, & De La Cruz, 2010). Pajares (2010) built up a general mechanism of FCMs as far as 2D images and described the performance of three applications in the three specified areas of computer vision.

3.9 Political and Social Sciences

Fuzzy Cognitive Maps has been developed as a kind of technique for modeling political and strategic issues states and supporting the decision-making process in perspective of an up and coming crisis. Andreou et al. has suggested the utilization of the Genetically Evolved Certainty Neuron Fuzzy Cognitive Map (GECNFCM) as an extension of CNFCMs. The general point was to defeat the principle weakness of the last mentioned, specifically the recalculation of the relating weights. Another strategy is embraced for every concept each time (Andreou, Mateou, & Zombanakis, 2003). That particular novel technique combined CNFCMs with genetic algorithms (Gas). Its advantage lies in their ability to offer the ideal solution without a problem-solving strategy once the prerequisites are characterized. Utilizing a numerous scenario analysis the value of the hybrid technique has been shown with regards to a model reflecting the political and strategic complexity of the Cyprus issue, and also the unpredictability involved in it. Afterward, this specific research group utilizing the provided mechanism, in order to analyze and depict the unstable framework prevailing in Cyprus, while this many-sided political issue remains yet unsettled (Andreou, Mateou, & Zombanakis, 2003).

An Ambient Intelligence (AmI) System, incorporating parts both of psychology and social sciences, might be considered as a distributed cognitive framework made by a gathering out of intelligent entities, fit for modifying their behaviors by considering the user’s cognitive status in a given time. Acampora’s research group has presented a novel methodology of AmI systems’ design, take advantage of multi agent paradigm and a novel extention of FCMs theory benefiting on the theory of Timed Automata keeping in mind the end goal to make an accumulation of dynamical intelligent agents utilizing cognitive computing for the meaning of action’s patterns that can augment environmental parameters like, for example, the user’s comfort or energy saving (Acampora & Loia, 2009).

Carvalho had already talked about issues of structure in the research, the pertinent semantics and the possible utilization of Fuzzy Cognitive Maps, as tools for both modeling and simulating complex systems (such as social, economic and political), while elucidating issues that have been repeated in published Fuzzy Cognitive Map (FCM) papers (Carvalho, 2010).

3.10 Environment and Agriculture

Fuzzy Cognitive Maps have many particular applications in the environment and agriculture domain. More specific, Fuzzy Cognitive Maps have been applied in the field of environmental management and ecology in order to model a generic shallow lake ecosystem by augmenting the individual cognitive maps (Tan & Ozesmi, 2006), evaluating local knowledge utilization in agroforestry management (Isaac, Dawoe, & Sieciechowicz, 2009), modeling of interactions among sustainability elements of an agro-ecosystem utilizing local knowledge (Ramsey & Norbury, 2009), forecasting modeling a New Zealand dryland ecosystem to anticipate pest management outcomes (Rajaram & Das, 2010), semi-quantitative scenario utilizing an occasion from Brazil (Kok, 2009). As of late, van Vliet et al., (2010) utilized Fuzzy Cognitive Maps as a communication and learning tool for connecting stakeholders and modelers in scenario examinations (van Vliet, Kok, & Veldkamp, 2010). In their study they tried to show the potential use of a profoundly participatory scenario development mechanism including a blend of qualitative, semi-quantitative and quantitative techniques. Giordano, et al. (2010) suggested a framework in view of a Fuzzy Cognitive Map in order to support the exportation and the analysis of stakeholders' perceptions of drought, and additionally the analysis of the potential conflicts which may take place (Giordano & Vurro, 2010). At that year Kafetzis et al. (2010) examined two particular case studies worried about water use and water use policy (Kafetzis, McRoberts, & Mouratiadou, 2010). One of them is a certain research concerning public participation in the Water Framework Directive (WFD) of the European Union (EU) (Mouratiadou & Moran, 2007) concentrating on information gathered in the Pinios River basin which is located in Greece. The other one depends on beforehand unpublished research by the authors on trans-boundary river problems in the Maritza river. This river has the peculiarity of being shared among Bulgaria, Greece and Turkey. Fuzzy Cognitive Maps (FCMs) have been used as an expository methodology helping the effect of the underlying factors which connect the two investigations to be more justifiable. Both analysis and documentation of such stakeholders' models is going to perhaps offer bits of knowledge in the use and restrictions of local knowledge and management, while in the meantime giving an approach creating fitting strategies for both process-oriented problem solving and decision making environmental pollution context.

In agriculture domain, Fuzzy Cognitive Maps (FCMs) used to represent knowledge and evaluate the cotton yield prediction in accuracy farming through the connection of the defining parameters in Cotton Crop Production in Central Greece as a reason for a decision support system. The management of the yield in cotton production has adequate interacting parameters and Fuzzy Cognitive Maps (FCMs) are used for this sort of problem. The constructed FCM model comprises of nodes that stand for the principle factors influencing cotton production linked by directed edges that demonstrate the cause-effect relationships amongst factors and cotton yield. Moreover, weather factors and conditions were contemplated by classifying springs as dry-wet and warm-cool (Papageorgiou, Markinos, & Gemtos, Soft Computing Technique of Fuzzy Cognitive Maps to Connect Yield Defining Parameters with Yield in Cotton Crop Production in Central Greece as a Basis for a Decision Support System for Precision Agriculture Application, 2010).

It is well known that the Common Agricultural Policy (CAP) of European Union (EU) perceives that agriculture is multifunctional and that its multifunctional nature ought to be advanced. Under this specific desire, Ortolani et al. (2010) utilize Fuzzy Cognitive Maps (FCMs) in their approach as a means to analyze the farmers' concepts of environmental management measures and cluster analysis is performed seeking to model agents' behavior in a formal and structured way, and in addition giving extra useful information to the investigator (Ortolani, McRoberts, Dendoncker, & Rounsevell, 2010).

4 Fuzzy Cognitive Map Tools

4.1 Introduction

This chapter will detail the FCM Modeler Tool with which Fuzzy Cognitive Maps can be created and edited. It consists of several parts that make the construction of FCM easier for the user. This tool is also used in the Case Study of this thesis in Chapter 6. The following chapter also shows some basic FCM creation and processing tools.

In more detail, the first part of the chapter begins with the basic principles governing FCM theory, followed by a description of cognitive map design with the assistance of the FCM Modeler Tool. The components of this tool are then studied starting from the user interface. Here is a detailed description of the node linking process with the help of an example of selecting the most suitable ERP System from a business. Then, the simulation process, the final reports that the program produces after it, and the basic software information we are studying are outlined.

The second part of the chapter includes a number of several other basic FCM creation and processing tools. Each tool is typically used for a particular science such as medicine, the business sector, environment, etc.

4.2 The FCM Modeler Tool

4.2.1 Fuzzy Cognitive Maps and the FCM Modeler Tool

Computers are being characterized by a strict way of thinking. They can work exclusively under the 0 or 1, true or false, mode of thinking. By and large they think in a “fuzzy” way. They depend on imprecise or vague (fuzzy) expressions like “expensive”, “much”, “little” or “big”.

As have been extensively noted on Chapter 2 in the mid-80s, Bart Kosko has presented for the first time the theory of Fuzzy Cognitive Maps (FCMs) (Kosko, Fuzzy Cognitive Maps, 1986). As has been repeatedly mention, FCMs are signed, directed graphs with feedback, modeling the world as an accumulation of concepts and casual relations between concepts. The contrast between FCMs and “conventional” Cognitive Maps is that the concepts and/or their relationships can be fuzzy in Fuzzy Cognitive Maps.

Without getting too deep into mathematical details (for more details see Chapter 2), we may express the accompanying tasks.

Fuzzy Cognitive Maps (FCMs) can have weight values in the fuzzy bipolar interval [-1,..,1]. "Bipolarity" is used in order to represent a positive or negative relationship between two concepts. Concept Ci causally increases Cj in case weight value is greater than zero and causally decreases Cj in case weight value is less than zero. In case the weight value equals to zero, concept Ci has no causal effect on Cj. Simple FCMs for the most part used in business decision making applications and can take trivalent weight values [-1,0,1]. On the other hand, in more complicated FCMs, word weight like strong, medium, or weak, can also be utilized. Each of these words certainly comprises a fuzzy set.

Contingent upon the number of concept nodes a Weight Matrix (WM) is constructed. In a FCM that consists of n concept nodes we will have one nxn Weight Matrix where W stands for the weights between each related concept. Once more, in the case of simple FCMs, the value of W will either be 0 in the case of no relationship between the concepts, or 1 or –1, depending on the relationship between the concepts.

WM=

	C1	C2	C3	…….	Cn
C1	W11	W12	W13	…….	W1n
C2	W21	W22	W23	…….	W2n
C3	W31	W32	W33	…….	W3n
. . .	. . .	. . .	. . .	…….	. . .
Cn	Wn1	Wn2	Wn3	…….	Wnn

Table 4.1 Sample of Weight Matrix

As previously discussed in the introductory chapter of this thesis, when FCM begins to model the system, concepts may take their initial values and then the system is simulated. At each specific step, the value of each concept is determined by the influence of the interconnected concepts on their corresponding weights (Glykas, Fuzzy Cognitive Strategic Maps in Business Process Performance Measurement, 2013):

$$a_i^{t+1} = f(\sum_{j=1, j\neq i}^{n} W_{ji} a_j^t)$$

Where:

- a_i^{t+1} appears as the value of concept C_i at step *t+1*
- a_j^t is the value of the interconnected concept C_j at step *t*
- W_{ji} is the weighted arc from C_j to C_i
- $f: R \rightarrow V$ consists a threshold function, normalizing activations.

The concept node uses a bounded signal function Si in order to map a real causal activation value to a number in [0,1] or in [-1,1]. In the literature identified three threshold functions (Kosko, Fuzzy Engineering, 1997). These are the ones described below:

1. Bivalent Function

$$S_i(x_i) = 0, x_i \leq 0$$
$$S_i(x_i) = 1, x_i > 0$$

2. Trivalent Function

$$S_i(x_i) = 1, x_i \geq 0.5$$
$$S_i(x_i) = -1, x_i \leq -0.5$$
$$S_i(x_i) = 0, -0.5 < x_i < 0.5$$

3. Logistic

$$S_i(x_i) = \frac{1}{1 + e^{-cx_i}}$$

Where c = 5.

The state value of a concept in an FCM not influenced by another concept, but rather a “start” node will have a standard state value and ought not to be changed by the dynamic of the system. Depended on the above, an FCM algorithm can be depicted, as follows:

Steps	Algorithm Process
1	Get node values
2	Get weight values
3	Construct a weight matrix
4	Multiply node values by the weight matrix
5	Normalize the result

6	Acquire a new state of state values
7	If there is a node that is not affected by any other nodes, then keep its initial value unchanged
8	Repeat steps 4 to 7 until the system comes into equilibrium

Table 4.2 The Algorithm Processes step by step

The primary target of the FCM Modeler development is the establishment of a model of business performance and effectiveness criteria, specifically supplementing existing quality models. These particular models customized and demonstrated in the Financial Sector and demonstrate their applicability, in a more broad manner, in the Service Sector.

They reflect the business strategy, human aspects, and technology and it has been agreed that they are represented as Fuzzy Cognitive Maps (FCMs). This computer-based business performance metric tool is developed based on the Fuzzy Cognitive Maps (FCMs). A general perspective of the Financial Sector "World" can be found in the accompanying Figure 4.1. Each model forms its own "little world", impacting or being affected by other "little worlds". One task will be to locate the weighted relationships of the concepts inside each "little world" and then the relationship between each "little world". Now, we will be able to ask "what-if" questions that bring a dynamic change into the behavior of every concept and lead us to farther business performance measures.

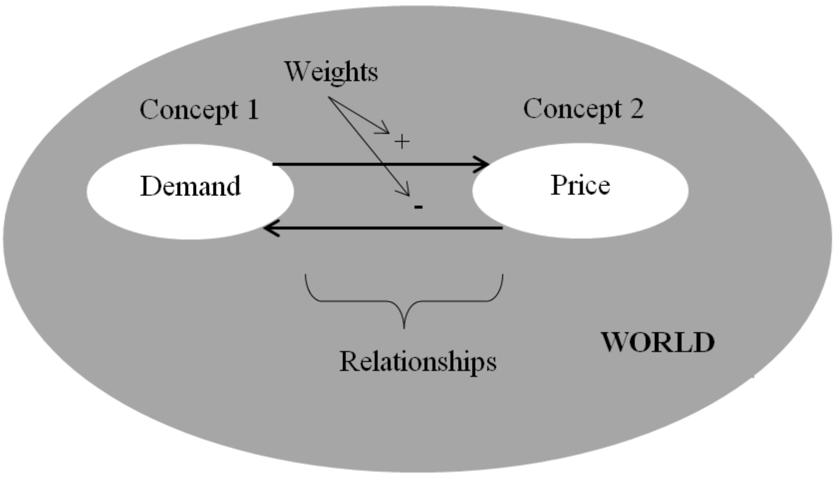


Figure 4.1 Basic Constructs of FCMs

4.2.2 Designing Fuzzy Cognitive Maps with FCM Modeler Tool

Concepts may represent a decision variable or a business metric in a specific domain. As the concepts constituting the distinctive model classifications are derived, the relationships between these specific concepts must be obviously defined. A relationship is presented by a line connecting concepts (Glykas, Fuzzy Cognitive Strategic Maps in Business Process Performance Measurement, 2013).

The direction of the relationship that shows which concept influences the other, is indicated by the direction of the arrow on this line. This is depicted in Figure 4.2.

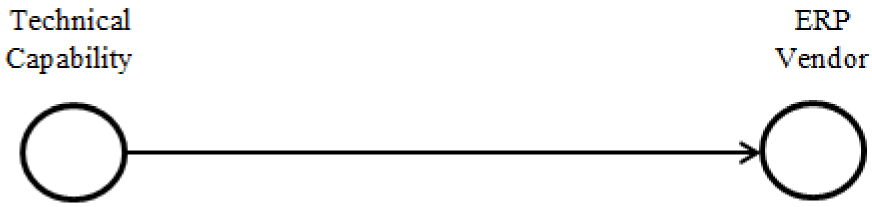


Figure 4.2 Example of FCM Concepts and Links

Hence, in Figure 4.2, the “Technical Capability” concept by one means or another affects the “ERP Vendor” concept.

The constructed Fuzzy Cognitive Maps (FCMs) using the method above don’t contain any information with the exception from the way that there are relationships between the abstract concepts.

The following step to be taken is enriching the maps with numerical values, assigned to the concepts with the mean to signify their state at a certain time. The concept’s state might be changed in light of the FCM Modeler Tool algorithm presented above. FCM Modeler Tool concept states have three particular values, namely:-1,0,1 as a means to empower business domain experts to express their negative (-1), neutral , do not know (0), or positive (1) belief about the state of a specific concept. This is obviously illustrated in Figure 4.3.

Figure 4.3 FCM node values example

Figure 4.3 demonstrates that, at this specific point in time, the user accept unequivocally that his or her organization is investing in technology and that ERP vendor importance is neither high nor low. The subject of what will be the following conditions of the two nodes will be addressed once the relationship existing between concepts is defined. As we probably are aware of, there are two sorts of relationships in Fuzzy Cognitive Maps (FCMs). The same is valid of the FCM Modeler Tool we are studying in this chapter. If there should arise an occurence of positive causal relationships, the value of the effect concept increases when state value of the cause concept increases too and the value of the effect concept decreases when state value of the cause value likewise decreases. In negative causal relationships, the value of the effect concept increases when the state value of the cause concept decreases and the value of the effect concept decreases when the state value of the cause concept increases.

The graph in Figure 4.4 shows schematically the assignment of relationship weights to our example.

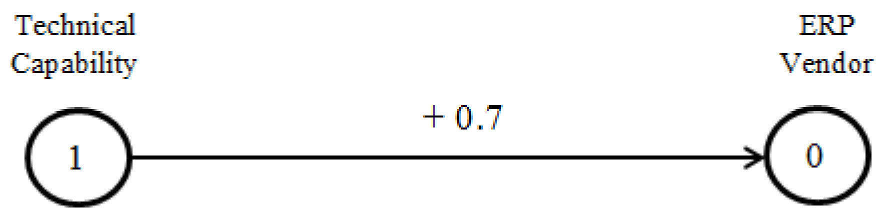


Figure 4.4 Positive Causal Relationship Example

Figure 4.4 demonstrates that Technical Capability and the positive causal relationship bring about increased ERP Vendor, i.e. the following state value of ERP Vendor will become one (1).

The degree of belief or certainty that a relationship exists is numerically signified with a number in the bipolar interval of [-1,…,1]. The negative values in that range signify a negative causal relationship, while the positive values mean a positive causal relationship.

The value of zero (0) indicates that there is no relationship between the cause and effect concepts. On account of a zero relationship, it is not necessary for the user to draw an arrowed line representing the relationship.

The calculation of the next state of an effect node is performed by including the multiplications and of the nodes of the cause nodes by the weights of the causal relationships. For instance, if the concepts in Figure 4.5 “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, the calculation formula of the next state of ERP Vendor is:

Value of Technical Capability state * 0.5 + Value of Reputation * 0.2 + Value of Ongoing Service * 0.3 = **Value of ERP Vendor**

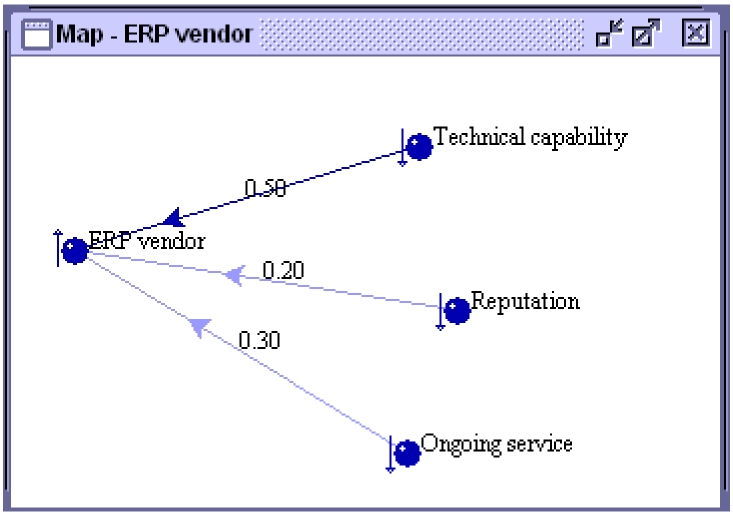


Figure 4.5 The "ERP Vendor" Map Weights

4.2.3 FCM Modeler Tool Interface

Class FCM Application is the core of the modeling. It is a subclass of the Java class Applet**.** The display area for the graph as shown in Figure 4.6 allows users both the creation and modification of FCMs with an assortment of mouse commands (see Table 4.3). Concept nodes are likewise made with default values of one for the current and initial values, zero for the initial and current values of the external input, and finally "N" for the name. These can be changed utilizing the concept configuration dialog (or properties) box as portrayed in Figure 4.7.

The new User Interface including all basic elements of a Windows based application (see Figure 4.6). To be more specific:

- A Menu Bar including various of drop-down menus that embody all of the application's functionalities
- A Tool Bar including the most vital functionalities of the application.
- The "Repository View" window
- The "Project View" window

- The "Business Case View" window

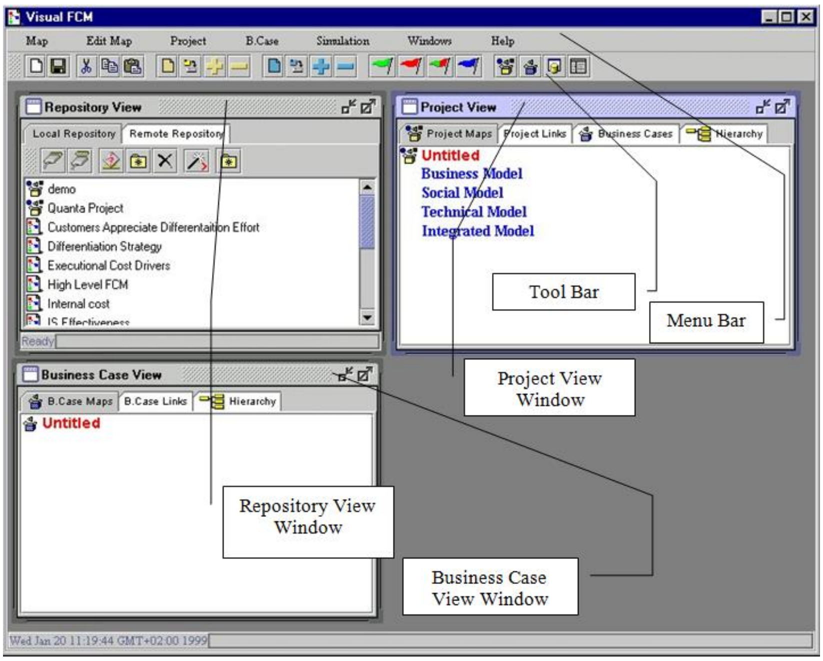


Figure 4.6 FCM Modeler tool User Interface picture

Target	Action	Effect
FCM Window	Double Click	New Node
Node	Delete	Delete Node
Node	Alt + Click	Open Properties Dialog Box
Node	Shift + Drag	Move Node
Inactive node	Click + Drag	Draws a Weighted Arrow
Edge	Delete	Delete Edge
Edge	Drag	Change Edge Weight

Table 4.3 Mouse Commands

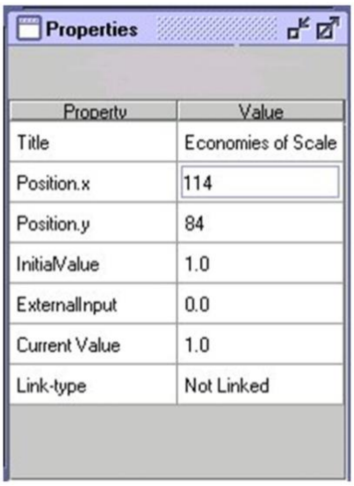


Figure 4.7 The Properties Window

The interface indicated so far is sufficient to construct and modify a Fuzzy Cognitive Map (FCM). More is expected to operate the state simulation. The interface specification for the buttons panel which is provided from user interface of FCM Modeler Tool is given in Table 4.4.

The User Interface picture of Figure 4.6 likewise includes adds of the platform, for example, particular capabilities of the title bar, e.g., system control boxes, and in addition a menu bar uncovering the full features of the FCM modeling tool. The menu specification is provided in Table 4.4.

Menu Item	Effect
File	
Open	Opens system file dialog box to open a previously open FCM.
Learn	Opens a system standard file dialog box to open a data file of concept names and state vectors.
Save	Saves the current FCM under the existing name. If no name has been specified, Save As.., is opened.
Save As	Opens a system file dialog box to save the current FCM model
Exit	Terminates the application.
Threshold	
Bivalent	Selects the Bivalent threshold function
Trivalent	Selects the Trivalent threshold function
Logistic	Selects the Logistic threshold function
Help	
About	Opens a dialog box with information descriptive of the application

Table 4.4 Menu Items in FCM Modeler Tool Interface

The FCM application is developed in the programming language Java. It is likewise expected that with minor changes, the application will be implanted into an HTML file and will be published on the Web. Now it merits specifying that the user interface module of this tool consists of two sub-modules: a) the FCM Design sub-module and b) the FCM Manipulation sub-Module. The module and its sub-modules are obviously shown in Figure 4.8.

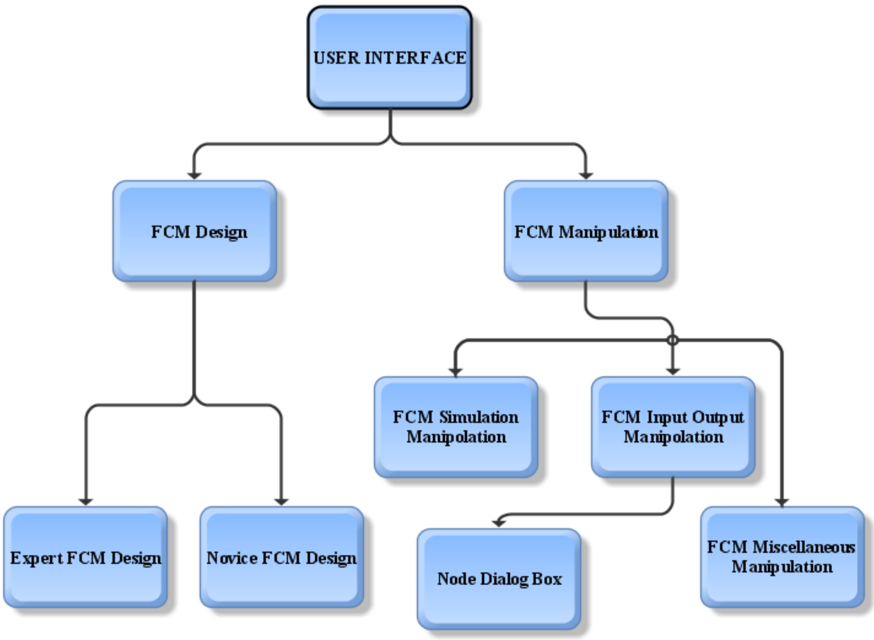


Figure 4.8 User Interface Diagram

4.2.3.1 The Repository View Window

What we call the "Repository View" window consists the place where contents of the repositories are visually presented to the user. A repository may include both Fuzzy Cognitive Maps (FCMs) and Projects.

The repository View may have various repositories where FCMs and Projects can be saved and the default installation includes two repositories. The first is the Local Repository which contains a local MS Access database and is stored in the local drive during the installation process. The second one is the Remote Repository containing the same database in MS SQL Server format and is stored in a remote server. A user may have access to the Remote Repository just on the off chance that he or she is authorized to do as such. The Repository View Window is demonstrated as follows.

4.2.3.2 The Project View Window

The "Project View" window is the place where a user can build a project (i.e. to apply node linking in a number of FCMs). The first time a user opens the application he or she is presented with an empty project structure (i.e. Business Models, Social

Models, Technical Models, and Integrated Models). The "Project View" window is presented in Figure 4.6.

The "Project Maps" tab includes four directories, comprising the Project structure. In each directory a user can add FCMs taken from the repository. The particular FCMs that have been added into a Project can be opened from the "Project View" window. This is the place where node linking is applied and it is going to be descriped later. All in all, two FCMs can be linked just in the event that they have been added to a Project. The "Project Links" tab will contain all maps that are linked to a project and in addition the concept node they are likewise linked with. The "Business Case" tab will contain all the business cases that have been made for a specific project. Generally speaking, a Business Case is a part of a Project or the whole Project that can be simulated and the "Hierarchy" tab contains a graphical representation of the Project Hierarchy.

4.2.3.3 The Business Case View Window

The "Business Case View" window includes a piece of a Project that might be simulated. In other words a Business Case will contain various Fuzzy Cognitive Maps (FCMs) taken from a Project and their corresponding node links.

The "B.Case" tab will include all the FCMs that have been added from the "Project View" window and they can be opened from that point.

4.2.3.4 New FCM Window

Keeping in mind the end goal to construct a new FCM either the “New Map” menu item must be selected or the New FCM toolbar item must be selected. In the two cases an untitled FCM window will open and a user can begin creating the FCM.

4.2.4 Node Linking

In the previous subchapter, the fundamental parts that make up the User Interface (UI) were examined. The node linking methodology will be presented in this point. The Node Linking Module is the area where two or more nodes (concepts) and FCMs will be linked together.

4.2.4.1 Nodes and Edges

The class Edge is extremely simple as it keeps up properties for its source and target nodes alongside the edge weight. Some simple accessor techniques are given to control public access to these properties. EdgeView is predominantly concerned with keeping up the visual state of the edge. An edge color property is included, as are properties for the screen coordinates and some values useful in improving rendering performance. EdgeView is in position to compute a new edge weight value from a provided arrowhead location and in addition the inverse operation. A draw technique accepts a Graphics instance and draws the edge on it when invoked. The FCM area has no further requirements for edges. That's there is no reason to additionally specialize these two classes.

Nodes have all the earmarks of being more complicated. They contain a Vector instance whose components are the edges originating with the node. This is adequate, but a Vector object containing references to the nodes giving inputs to the host node is added to simplify navigation backwards through the graph, e.g., to notify influencing nodes of the impending deletion of the host node. It is worth noting that initial and current state values are properties. Initial and current external influence properties are added to implement a fixed external influence on the node, i.e., when "clamping" a concept to represent a fixed policy originating outside the map's area. The Class NodeView carries out visual services analogous to those offered by EdgeView to Edge. Once more, with the possible exception of the external influence properties, Fuzzy Cognitive Maps (FCMs) do not require any exceptional techniques or properties, so Node and NodeView are not additionally specialized. The accompanying Figure 4.9 shows a basic seven-node linking example.

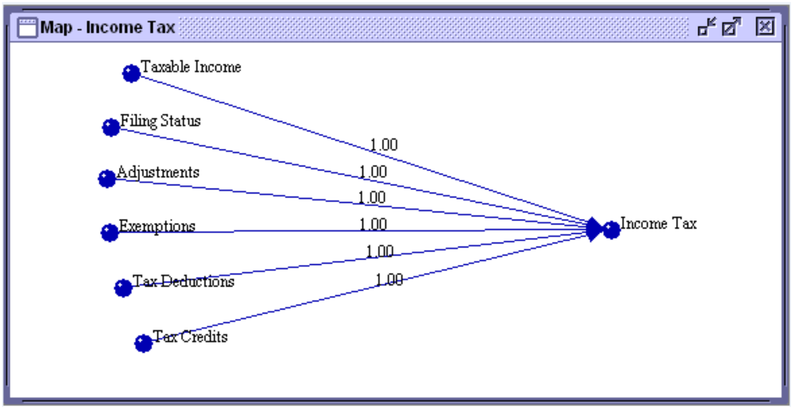


Figure 4.9 A Simple FCM

4.2.5 FCM Hierarchies

The motivation purpose behind the Fuzzy Cognitive Map (FCM) hierarchy is to make a genuine level hierarchy. A noteworthy input to the FCM Hierarchy is the node linking information contained in a FCM.

Recalling from the node linking dialog box a Source FCM has links with higher level and lower level target FCMs. At the point when a Fuzzy Cognitive Maps (FCM) has been chosen to be placed the FCM hierarchy, the system searches to find its higher level and lower level target FCMs. The higher level and lower level target level FCMs are getting to be source FCMs and the system searches every one for their higher and lower level target FCMs until the Hierarchy has been formed. The FCM Hierarchy Algorithm is depicted underneath:

Get the FCM that has to be place in the hierarchy

Level = 2

Place the FCM in Level

Place higher level FCMs in Level=Level-1

Place lower level FCMS in Level=Level+1

For i=1 to the number of FCMs in Level=1

If the FCM has higher level FCMs shift it and all FCMs below one Level down and place the higher level FCMs in Level=1

Next

Repeat until the none of the FCMs in Level=1 have higher level FCMs

Level = 0

Level = Level +1

For i=1 to the number of FCMs in the current Level

Place all the lower Level FCMs of the ith FCM one Level below

Next

Repeat until none of the current Level FCMs has lower Level FCMs

For i=Levels of FCMs to 2

For j=1 to the number of FCMs in the current Level

If the jth FCM appears again in the jth-1 Level then discard it from this level

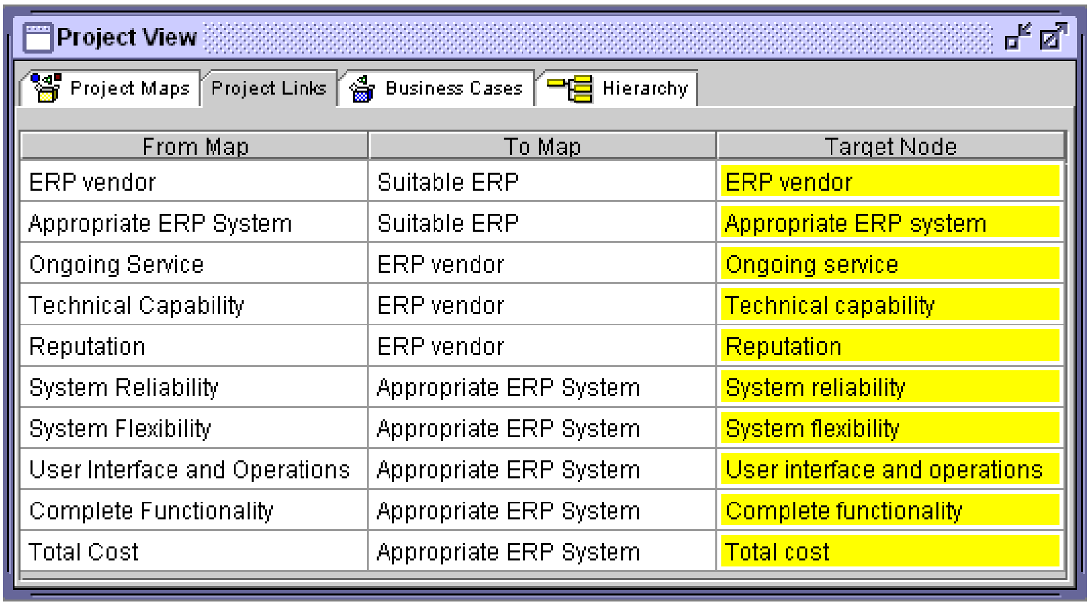
Next

Next

The FCM Modeler Toll utilization includes four different map categories:

1. **Business Category** including all concepts having a relating to core business activities.
2. **Social Category** including all human resources related and external stimuli concepts.
3. **Technical Category** including all infrastructure related concepts with emphasis on technology infrastructure.
4. **Integrated Category** including basically concepts falling under more than one of the above three categories, likewise, top-most concepts.

The hierarchical decomposition of different process, metrics or whatever else that can be described from Fuzzy Cognitive Maps produces a group of dynamically interconnected hierarchical maps. To make this more justifiable we show a real-world example of one firm, where the objectives of ERP selection to support the business goals and strategies of an enterprise are used (Wei, Chien, & Wang, 2005)(see Figure 4.10).



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 4.10 Project Links Window

Each map examines farther the relationships among concepts at the same hierarchical level. Also, dynamic nature of the approach permits easy reconfiguration. At present the mechanism integrates more than 250 concepts, forming a hierarchy of more than 10 maps. The specific dynamic interface of the mechanism gives its' user to utilize a sub-set of these concepts by setting the value of the redundant ones and/or the value of their weights to zero. Concepts and weight arcs have been obtained as follows in the Figure 4.11.

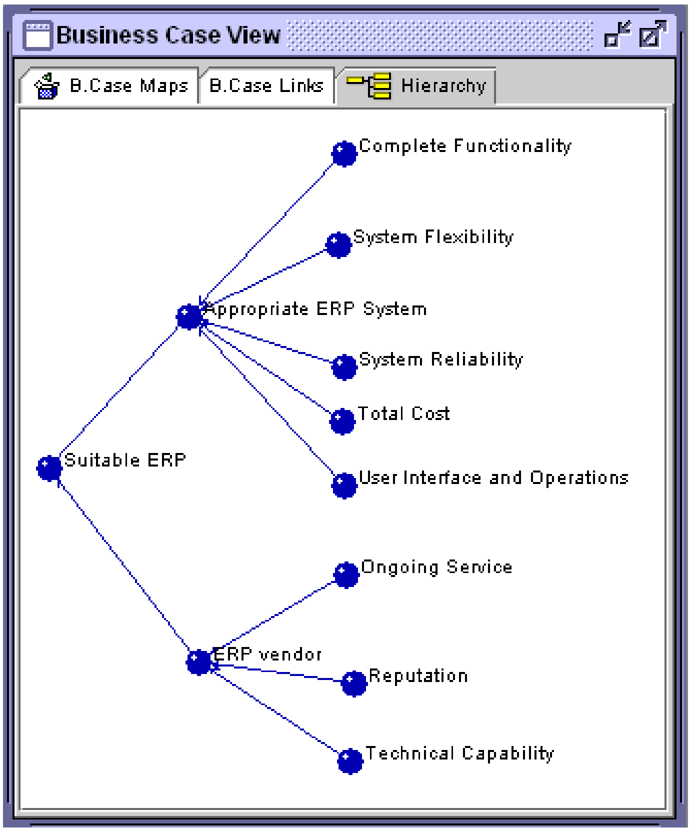


Figure 4.11 Sample Map Hierarchy

To be more understandable, a run of the mill case of the interconnection mechanism is now commented briefly. Consider now the maps “Suitable ERP” and “ERP Vendor”. Linking a concept, defined into two maps, generates a hierarchy. Figure 4.12 presents the system interface for the generation of the hierarchical relationship between maps “Suitable ERP” and “ERP Vendor”. Map “Suitable ERP” decomposes further concept “ERP vendor” by using this concept as the link to map “ERP vendor”.

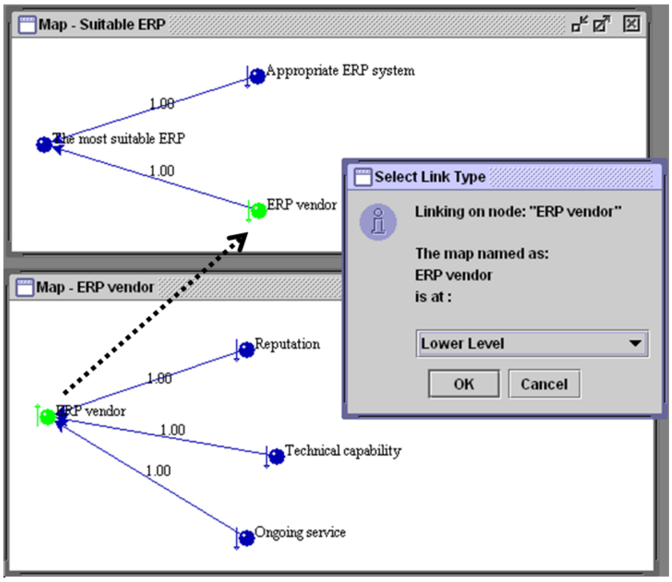


Figure 4.12 Interconnection mechanism

The implementation can decompose financial concepts might be decomposed by the implementation to their constituent parts (sub-concepts) on demand and let the user reason about lower level hierarchies of Fuzzy Cognitive Maps (FCM) before it passes values to the higher-level hierarchies. The proposed mechanism additionally enables the user to determine the degree of FCM decomposition during the map traversal. This process is presented in Figure 4.13.

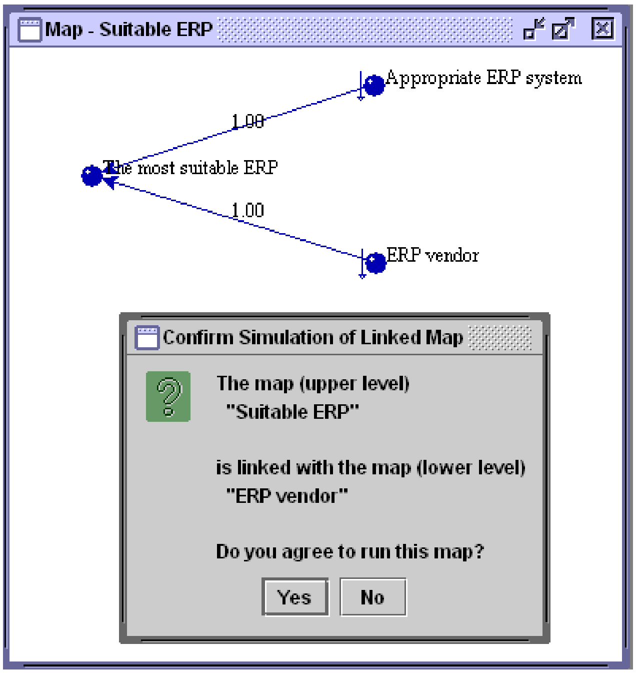


Figure 4.13 User-defined Map Decomposition

Rather than sitting tight for a lower level FCM to traverse its nodes and pass its' value to higher level map hierarchies, the user may assign specifically an external value to nodes linking hierarchies. Practically speaking, the simulation is done as in case there are no links to any other maps.

4.2.6 Simulation Module

The simulation module is the place where the FCM algorithm will be applied on a Fuzzy Cognitive Maps (FCM). The simulation Module will be depicted considering that a simulation of a project and its result depends completely on whether a user has gone through FCM Hierarchy process or not. It must be said that earlier the simulation the user has to choose which FCM in a project he or she wants to simulate. The FCM algorithm that has been described in previous subchapter is a vital part of the Node Linking Module.

The "Simulation Menu" of the FCM Modeler Tool is demonstrated as follows. It includes the "Run" menu item which runs a simulation of the active FCM, the "Pause" menu item which pauses the present simulation and the "Step" menu item which runs a simulation of the active FCM in a step by step mode, so a user can monitor the simulation. The "Reset" menu item when selected brings up the initial values of an FCM as they have been saved into a Business Case.

The **Bivalent** $S_i(x_i) = 0, x_i \leq 0$, $S_i(x_i) = 1, x_i > 0$, **Trivalent** $S_i(x_i) = 1, x_i \geq 0.5$, $S_i(x_i) = -1, x_i \leq -0.5$, $S_i(x_i) = 0, -0.5 < x_i < 0.5$ and **Logistic** $S_i(x_i) = \frac{1}{1+e^{-cx_i}}$ radio buttons have been elaborately explained in a previous subchapter and are used in order to select a threshold function by default set to Trivalent.

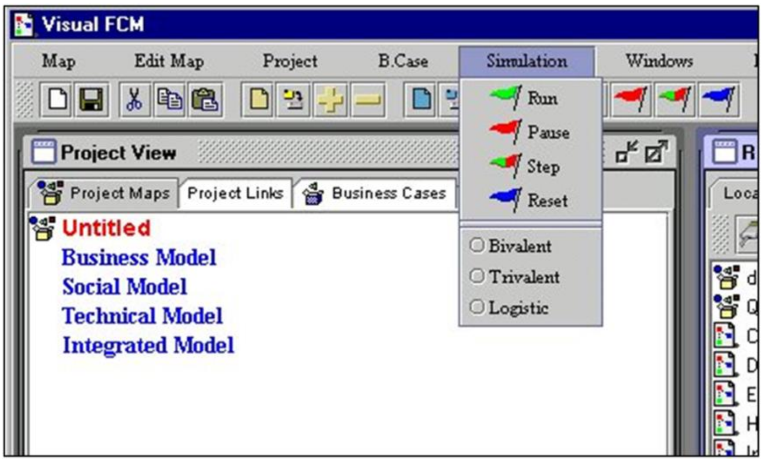


Figure 4.14 Simulation Window

4.2.6.1 FCM Design Principles for Successful Simulation

Before the presentation of more details about the simulation process (with or without hierarchy), it is important to make an examination of the FCM design principles for successful simulation. For proper FCM design that will prompt successful simulation we classify FCM nodes into three categories (Glykas, Fuzzy Cognitive Strategic Maps in Business Process Performance Measurement, 2013):

- **Cause**: Have only outgoing arrows
- **Intermediate:** Have incoming and outgoing arrows
- **Effect**: have only incoming arrows

Below are some basic rules in order to achieve a proper simulation process.

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 seems, by all accounts, to be 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”*

Keeping in mind the end goal to achieve proper synchronization between FCMs in different levels we need to ensure that only effect or intermediate nodes from a lower level FCM may be linked to cause or intermediate nodes of a higher level FCM. The most 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.

In FCM Modeler Tool only one node from FCMs at a lower level is allowed to be linked with a node 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 for this.

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

4.2.6.2 Simulation without FCM Hierarchy

At the point when a user needs to simulate an FCM, depended by other FCMs he or she will be informed on the existence of this dependency.

If a user decided to carry out the simulation without taking into consideration FCM dependencies then one may inform the simulation module to run a simulation excluding the dependencies.

4.2.6.3 Simulation with Hierarchy

Once more, for this case a user will be informed on the existence of FCM dependencies. The user will have to accept the node linking information and then carry on with the simulation.

The FCM Hierarchy Module informs the Simulation on FCM dependencies and the FCM simulation algorithm is not applied until a FCM without dependencies is reached. Below in Table 4.5 Algorithm with Hierarchy, a more general description (relative to the previous one) is presented as a means to show how the hierarchy algorithm works during simulation.

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	

Table 4.5 Algorithm with Hierarchy

At this point it is worth noting that as far as the number of iterations is concerned, lower level maps have iterated 8 times on average. The average number of iterations has been increased to 20 for all the middle and upper level maps. Only the top-most map has increased the average number of iterations to approximately 90 (depending on the initial concept and/or weight values) because of the volume map links. In practice, the actual process time was negligible on such a typical PC.

4.2.7 Reports

The reports are produced for the user to get information about a project and a simulation is automatically created in the "Reports" directory of the application. They include tables about each concept values before and after the simulation, hyperlinks, weight matrixes and graphs. The reports that are created are in HTML format and they can be viewed by any web browser (e.g. Netscape, Microsoft Internet Explorer) or by any word processing application that can open HTML files. The HTML document has links to the corresponding FCM images, being in a GIF format and stored in the same directory as the HTML document. Those reports are complete web pages and they are prepared to be deployed into the Internet. The aim of the report is to provide the user with a detailed, step-by-step description of a simulation already carried out. A detailed description of the reports follows. The following are some examples of Reports in two separated Figures.

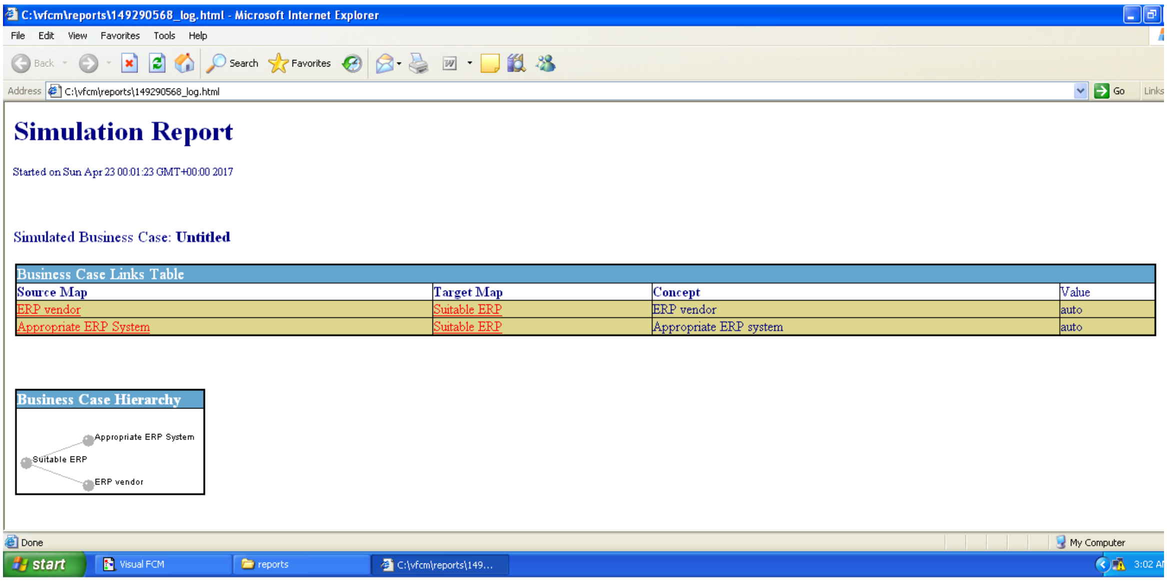


Figure 4.15 Simulation Report Window

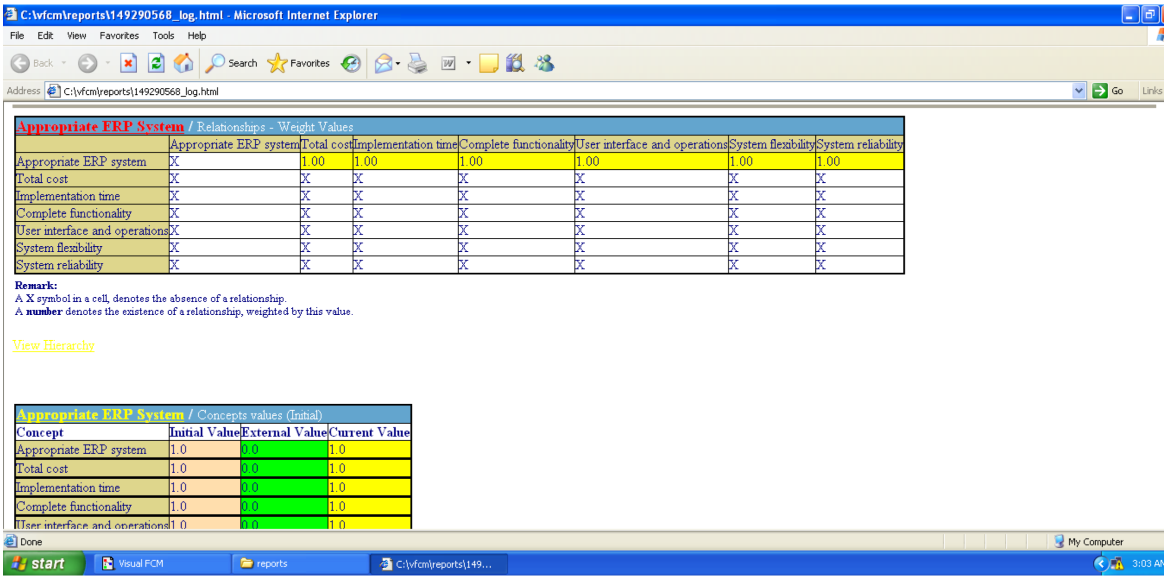


Figure 4.16 Simulation Report Window

4.2.8 FCM Modeler Tool's Software

The FCM Modeler Tool was developed in Java programming language. Using this programming language helps to permit deployment as either a standalone application or an embedded applet in an HTML page. The availability of development tools and WWW browser capabilities drive the choice of development kit (JDK) version JDK 1.1. The JDK itself includes a compiler, but no integrated development environment supporting such productivity features such as class browsers and graphical dialog box layout. The JDK 1.1 was preferred for the development kit version and Microsoft Visual J++ 1.1 as the development environment.

In spite of the fact that, the platform for this application is Microsoft Windows NT 4.0 and Windows 95, the software will not make use of any platform particular extensions.

As reference, the requirements that the system that the FCM Modeler Tool's software will have to operate, are the few features that almost all computer at present has. Specifically, the system in which this software will work ought to have the operating system of Windows, at least a Pentium 133 (Processor), RAM up to 32MB, up to 100MB free hard disk space, SVGA graphic card which permit 800x600 screen resolution, screen with high color (16 bit) and mouse reader. More distant than that the system needs to have Microsoft Open Database Connectivity (OBDC) drivers for Microsoft Access and Microsoft SQL Server which is typically contained in the Windows operating system installation.

4.3 Other FCM Tools

Aside from the Visual FCM Modeler tool that has been analyzed thoroughly in the previous subsection, there are likewise some other fundamental tools with which Fuzzy Cognitive Maps (FCMs) can be constructed. At this point, these tools will be mentioned used in specific scientific fields such as medicine, business, agriculture, environment, etc.

4.3.1 FCM Designer Tool

This is a tool in Spanish allowing the design of the structure of the maps (the definition of the concepts and the relationships between them). In this tool, the causal relationships between concepts can be the classical defined in Kosko's approaches (Kosko, Fuzzy Cognitive Maps, 1986), or we can establish specific causal relationships as per the problem modeled either static or dynamic. On account of dynamic causal relationships, these depend on logic rules, mathematical equations and fuzzy logic, among other things. Besides, the inference patterns from an offered input to a map can be followed. Moreover, by utilizing this tool, the evolution of a map during its runtime can be stopped, of such form to introduce new information to a map, proceed with a previous execution, and so on. The FCM Designer Tool is a flexible tool allowing to design, and later execute, the FCM (Jose & Contreras, The FCM Designer Tool, 2010). The tool suggested, requires an expert knowledge about the issue to study as a means to decide the type of dynamic relationships among the concepts, and knowledge about the tool and the language Java to program the particular relationships of the problem modeled (Jose & Contreras, The FCM Designer Tool, 2010).

4.3.2 Java FCM Tool (JFCM)

Java Fuzzy Cognitive Maps (JFCM) (JFCM - Java Fuzzy Cognitive Maps site, 2017) consists an open source library written by Dimitri De Franciscis, implementing fuzzy cognitive maps using the Java™ programming language. The proposed users of JFCM are students willing to learn FCMs, scientists who may experiment with new learning algorithms and FCM variants, application developers who need a simple, tested and extensible library and companies which developing applications in light of FCM technology. The JFCM library allows loading networks from XML files, thus increasing the library usability. The focal idea behind the library is to construct reusable modules that could be utilized when needing FCM solution in a given problem (De Franciscis, 2014).

4.3.3 FCM Wizard

The FCM Wizard is developed software from Leon et al. (Leon, Napoles, Rodriguez, Garcia, Bello, & Vanhoof, 2011). It comprises 20.000 source code lines (completely written in Java language) distributed in 115 Java source code lines. These archives are organized in 4 global packages (Map, Algorithms, Interface and Resources) and various sub-packages (e.g. Causality, Topology, Stability, Dataset, Handlers and Graphics). The most applicable packages are Algorithms and Interface: the first one contains several learning methods for adjusting the map parameters, through the second one incorporates graphical components. FCM Wizard is an object-oriented implementation with a simple to use and manage interface. It is organized in packages, including algorithms for computing causal relations, optimizing the network topology and improving the system convergence. One should say that these algorithms are principally oriented to the systems with prediction capability, albeit other scenarios could be modeled too.

4.3.4 Intelligent Expert System based on Cognitive Maps (ISEMK)

The Intelligent Expert System based in Cognitive Maps (ISEMK) consists computer software. It is a universal tool for modeling decision support systems, in view of Fuzzy Cognitive Maps (FCMs). This specific application has been developed with the utilization of Microsoft Visual C#2010. The implementation of Fuzzy Cognitive Map has been based on expert knowledge or historical data. It has the ability to do multi-step supervised learning based on gradient method or Markov model of gradient with the use of historical data and multi-step unsupervised learning based on Hebbian rule. This approach is population-based learning with the use of real-codec genetic algorithm and structure optimization genetic algorithm. It can also save and reveal the project with the examined FCM parameters using .xml files.

ISEMK software tool's operation happens by testing of learned FCMs based on historical data and it can do monitoring of learned FCMs operation, to export data of FCM analysis to .csv files and it can appropriate proper of done research (Piotrowska, 2012).

4.3.5 FCModeler

Fuzzy Cognitive Map Modeler or FCModeler consists a freely publicly available software package designed to empower the biologist to visualize and model metabolic and regulatory network maps in plants (Dickerson J. A., 2005). It has been developed by Dr. Julie A. Dickerson and Dr. Eve Wurtele with the cooperation of other colleagues from different University Departments (FCModeler site, 2017). The graphical display program is written in Java. The modeling software is at present implemented in Matlab with an XML interface between the packages (FCModeler site, 2017). FCModeler expects to aid the development and evaluation of hypotheses, and provide a modeling framework for evaluating a lot of data captured by high-throughput gene expression experiments. This software tool empowers biologists to capture relationships at different levels of detail, to integrate gene expression data, and model these relationships. The three-dimensional virtual environment selected provides exciting new opportunities for visualizing complex networks. The ability to link detailed physical models with representations of regulatory and metabolic flow will prompt new teaching methodologies in biology (Dickerson J. A., 2005).

4.3.6 Mental Modeler

Mental Modeler consists a modeling tool developed by Dr. Steven Gray and can make mental models of stakeholders explicit. Along these lines, provides a choice to incorporate distinctive sorts of knowledge into environmental decision-making, define hypotheses to be tested, and run scenarios to decide perceived results of proposed policies. In particular, the software has been designed to enable stakeholders to: build a qualitative conceptual model, develop scenarios and assess system change under conceivable conditions and revise their model in view of the model output. Mental Modeler is comprised of three fundamental User Interfaces (UI): the concept mapping interface that gives a space for model assembling and parameterizes model construction in the format required for FCM analysis, the matrix interface that permits the structural properties of the cognitive map (i.e. a representation of a mental model) to end up noticeably clear by looking at pairwise relationships and the scenario interface, enabling stakeholders to run and compare change inside the system - under different potential scenarios - and return to and revise their models in the concept mapping interface provided this new information (Gray, Gray, Cox, & Henly-Separd, 2013).

4.3.7 FCM Mapper

The software FCMapper has been developed by Bachhofer and Wildenberg (FCMappers net, 2017). It is freely available, in view of EXCEL and allows to calculate the basic FCM indices, conduct dynamical analysis and visualize the Fuzzy Cognitive Maps (Wildenberg, Bachhofer, Isak, & Skov, 2014). All the more particularly, it is based on Microsoft Excel and VBA (Visual Basic Applications). Through this tool users can calculate all indicators from the theory of graphs and to perform various simulation scenarios. The software seems to hold up under a great deal of favorable situations that are difficult to quantify human behavior and in addition when scientific data is fragmented or missing. Likewise, the tool proves to be exceptionally useful in more mind boggling cases where compromises instead of simple or correct answers are to be found. The fundamental functions of the program are recognized as follows: Calculation, Simulation and Visualization.

4.3.8 FCM Graphic User Interface (GUI)

The Graphic User Interface (GUI) is developed in English as a means to reach a higher number of users, particularly students and researchers from all around the globe. Moreover, MATLAB environment is preferred since it is broadly utilized by scientists from various fields like engineering, medicine, information technologies and social science disciplines. Along these lines, the created MATLAB code is divided into as meaningful small functions as possible going for an expanded readability and extensibility. Likewise, the developed MATLAB code will be distributed as an-open source software. The users may create and use the tool relating to their needs. The FCM-GUI consists of two fundamental windows. The first one is called "Design Simulation" and allows users to design and work on the user defined FCM, representing expert knowledge or the randomly delivered stable Fuzzy Cognitive Map (FCM), and, at that point, simulate these FCMs to examine diverse scenarios. The second window allows users to construct a FCM from a historical data by using the proposed algorithm (Yesil, Urbas, & Demirsoy, 2014)**.**

5 Operations Management

5.1 Introduction

Operations Management appears to be the heart of wealth creation for businesses and a vital core for the improvement of the living standards in every country around the world. The chapter at hand deals with the concept of Operations Management, analyzing the main parts and placing more emphasis on both its design and strategy. In the rest of the chapter, Business Process Management (BPM) is thoroughly analyzed aiming at the full comprehension of its importance in business management. Business Process Languages, Business Process Modeling, Business Process Reengineering and Workflow Management are only some of the issues examined in this chapter. Further than that, Knowledge Management, Business Process Intelligence and the concept of Information Technology (IT) have been also comprehensively described.

5.2 Definitions of Operations Management

Current usual organizations are consisted of the integration of various functions. The main goal of each organization is the maximization of its profits by providing reliable products and services customers. Operations Management (OM) is the entity enabling organizations to proceed with providing quality products and services by properly resource managing (Slack, Chambers, & Johnston, Operations Management, 2010). All the more particularly, Operations Management alludes to the design and control of the production procedure while business process redesigning alludes to the production of goods and/or services. Furthermore, it is an entity of extraordinary significance, straightforwardly relying on marketing, finance and human resources business domains (Chase, Jacobs, & Aquilano, 2007). The decisions made in the manufacturing and service operations fields include the accompanying parts (Krajewski, Ritzman, & Malhotra, 2013):

- Operations Strategy
- Product and process design,
- Quality management,
- Production and facility planning

- Inventory control.

Slack et al. present in their work five core functions of Operations Management being the following (Slack, Chambers, & Johnston, Operations Management, 2010):

- The Sales & Marketing, being in charge of conveying the organization's products and services to markets aiming at generating customer requests for service.
- The Product/Service Development function being responsible for creating new and modified products and services in order to generate future customer requests for service.
- The Operations' function, is responsible for fulfilling customer requests for service throughout the production and delivery products and services,
- The Accounting and Finance function, providing the information needed to aid economic decision making and managing the financial resources of the organization.
- The Human Resources function of recruiting and developing the organization's staff as well as looking after their welfare.

All operations change inputs into outputs. By this process they produce products and services. It is completely reasonable for all organizations to consist of operations as they are impossible to provide one or even more product/service. In simple words, operations are processes taking in a set of input resources used to transform something or are transformed themselves into outputs of products and services. One set of inputs to any operation's processes are transformed resources treated, transformed or converted in the process. Usually they appear to be a mixture of materials, information or customers and there are two basic types of transforming resources: the facilities and the staff. Outputs are all these products and services that occur after the processes function.

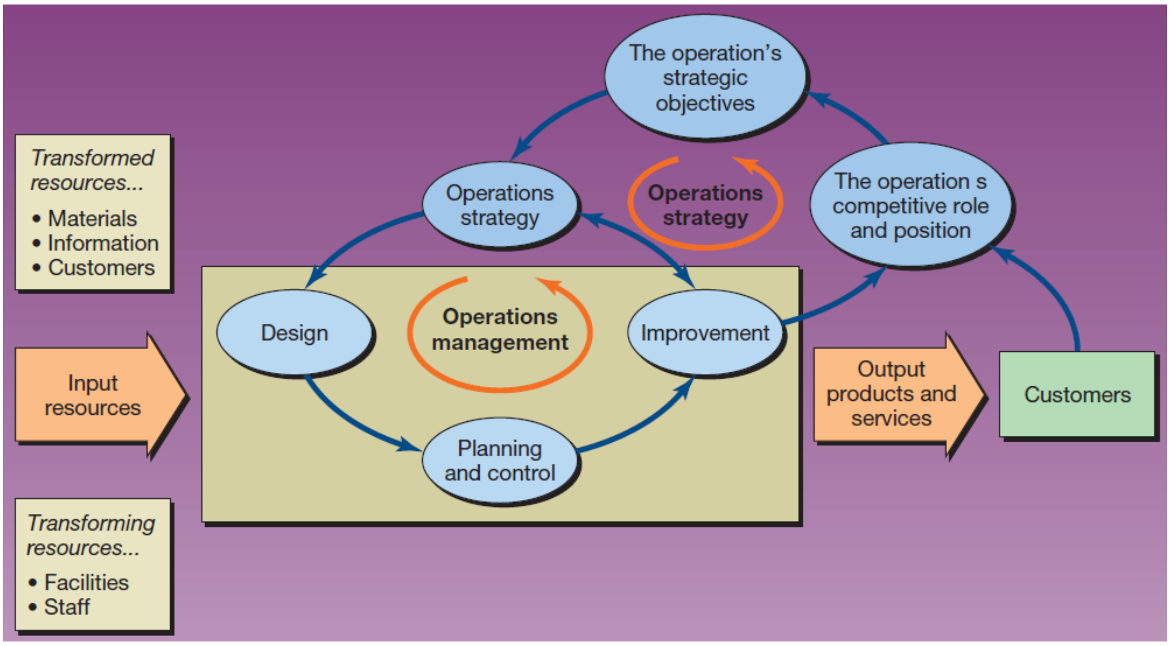


Figure 5.1 Operations Management (Slack, Chambers, & Johnston, Operations Management, 2010)

5.2.1 Operations Strategy

The Operations Strategy determines the methods by which operations executes corporate strategy and aids to build a customer-driven firm. Another one of its functions is to link long-term and short-term operations decisions to corporate strategy. It likewise builds up the capabilities required in the firm to be competitive. It is the core of managing processes. A company's inside processes need to be organized in order to be effective in a competitive environment. The operations strategy comprises a noteworthy field uniting these processes keeping in mind the end goal to form supply chains extending beyond the walls of the firm, enveloping both suppliers and customers. Clients always desire change, and therefore the company's operations strategy must be driven by the needs of its customers. Building up a customer-driven operations strategy, facilitates the firm's overall goals with its center processes. It is the thing that decides the markets that will be served by the firm and the responses the firm is going to make to changes in the environment. It gives the resources to build up the firm's core competencies and core processes, and identifies the strategy utilized by the firm in the environment of universal markets. In view of corporate strategy, a market analysis classifies the company's customers, identifies their needs, and asses competitor's strengths. This information is used to develop competitive priorities helping managers develop the services or products and the processes needed to be competitive in the marketplace. Competitive priorities are essential to the design of existing as well as new service or products, the processes delivering them, and the operations strategy that will develop the firm’s capabilities to fulfill them. Building up a firm’s operations strategy is a non-stop process as the firm’s capabilities to meet competitive needs are to be occasionally checked. Additionally, any gaps showing up as far as of performance must be tended to in the operations strategy process (Krajewski, Ritzman, & Malhotra, 2013).

Slack and Lewis (2011) have recommended in their research the presence of three levels of analysis in operations management so as to make a far reaching description of this definition. All the more particularly, the most obvious level is that of the business itself or, all the more particularly, the operations function of the business. In any case, any operation can likewise be seen as a major aspect of more noteworthy network of operations. It will have operations that supply it with the products and services it needs to make its own products and services. What’s more, unless it deals specifically with the end consumer, it will likewise supply customers who themselves may go ahead to supply their own customers. More distant than that, any operation may have a few suppliers and customers and might be in rivalry with others producing comparative services to those it produces itself. This accumulation of operations is known as the supply network. There will be also a network of processes. Some of these processes will be ‘operations’ processes in that they are within the operations function. Be that as it may, many processes in this internal network will be in the other elements of the business. Finance, marketing, sales, HRM and all the other functions’ processes will form part of (and ideally be incorporated with) the internal process network. Also, inside each process there will be a ‘network’ of individual resources (people & technology). At each level of analysis, functional managers must comprehend the capabilities of every component, and the connection between them. The idea we allude to is known as the hierarchy of operations (Slack & Lewis, Operations Strategy, 2011).

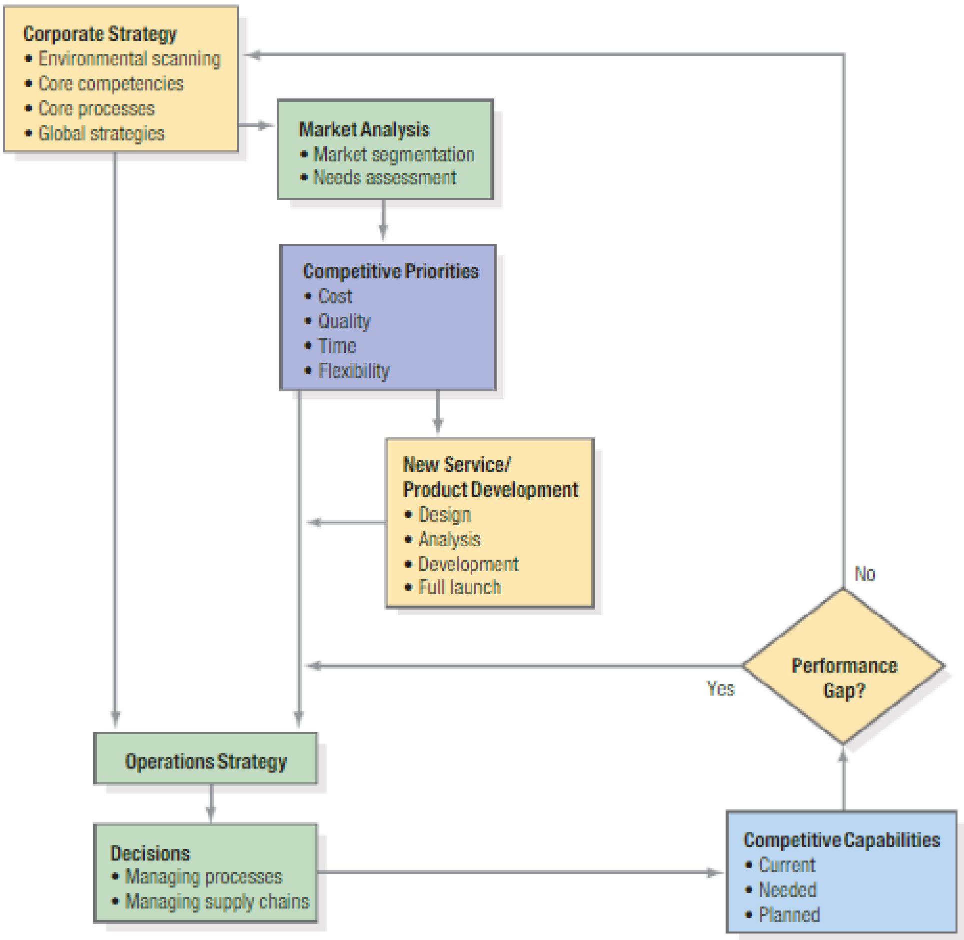


Figure 5.2 The Operations Strategy (Krajewski, Ritzman, & Malhotra, 2013)

In the next subchapter the Business Process Management (BPM), which is the fundamental element of Operations Management, will then be thoroughly studied.

5.3 Business Process Management

Lately, an undeniably more prominent number of organizations are giving careful consideration to Business Process Management (BPM). It is considered to rather remarkable that Gartner studies (Gartner, 2009) have been recognizing Business Process Management as the most essential business priority of CEOs on a worldwide level. Business Process Management is fundamentally a cross-discipline "theory in practice" subject for which many perspectives, definitions and views have been made. Because of its multi-disciplinary nature, it is regularly simple to discover business process research materials crosswise over many subject's databases (Ko, Lee, & Wah Lee, Business process management (BPM) standards: a survey, 2009).

As indicated to Van der Aalst et al. Business Process Management (BPM) incorporates methods techniques, and tools for the design process, enactment, management, and analysis of operational business processes (van der Aalst, ter Hofstede, & Weske, 2003). It is contended that "BPM offers organizations the likelihood to be more efficient, effective and capable for change compared to a functionally focused traditional hierarchical approach" (Ko, A Computer Scientist's Introductory Guide to Business Process Management (BPM), 2009). As mentioned in the previous paragraph BPM shows an assortment of perspectives and definitions that comprise it. In our endeavor to give a more far reaching and distinct definition, we could embrace the approach of Association of Business Process Management Professionals International (ABPMP). Business Process Management is a discipline approach for the identification, design, execution, document, measure, monitor, and control of both automated and non-automated business processes to achieve, consistent, targeted results aligned with the organization's strategic goals. Business Process Management includes the deliberate, collaborative and increasingly technology-aided definition, improvement, innovation and management of end-to-end business processes driving business results, creating value, and enabling an organization to meet its business objectives with much more agility. Business Process Management empowers an enterprise to align its business processes to its business strategy, prompting to effective overall company performance through improvements of specific work activities either within a particular department, over the enterprise, or among organizations (Association of BPM Professionals Int., 2017).

Zairi, in his individual approach, offers an explanatory approach expressing that BPM is a structural way to analyze and continually improve key activities like manufacturing, marketing, communications and other major elements of company's operation (Zairi, 1997). As per Smith et al. a process-manages enterprise makes coordinated course adjustments installs Six Sigma quality and decreases total expenses across the value chain. It pursues strategic initiatives with confidence, including mergers, consolidation, alliances, acquisitions, outsourcing and global expansion. Process management is the only way of achieving these objectives with transparency, management control and accountability. Process management finds what you do, and after that deals with the lifecycle of improvement and optimization, in a way that translates straightforwardly to operations. Regardless of whether one wishes to adopt industry best practices for efficiency or pursue competitive differentiation, process management will be required in any event (Smith & Fingar, 2003).

For rendering terminologies and features more reasonable van der Aalst et al. clarify in their approach the concept of the BPM Lifecycle illustrated in Figure 5.3. The BPM lifecycle portrays the different phases in support of operational business processes. In the design phase, processes are (re)designed. In the configuration phase, designs are executed by configuring a process aware information system, for instance a Workflow Management Systems that will be dissected in a following subchapter. After configuration, the enactment phase begins where the operational business processes are executed utilizing the system configured. In the diagnosis phase, the operational processes are investigated to identify problems and find things that can be improved (van der Aalst, ter Hofstede, & Weske, 2003).

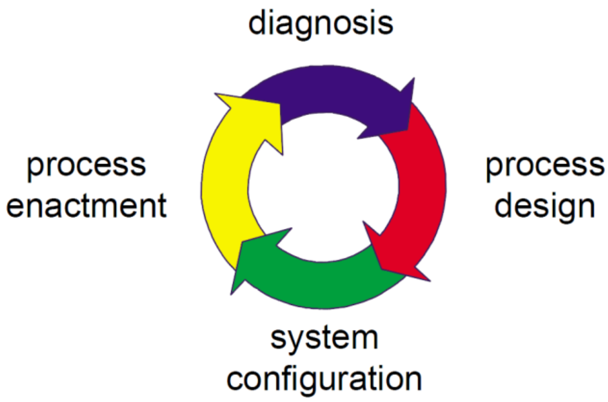


Figure 5.3 The BPM Lifecycle (van der Aalst, ter Hofstede, & Weske, 2003)

5.4 Business Processes

According to Glykas and Xirogiannis "a process can be seen as a structured series of activities designed to produce a specific business output e.g. a product, a service, etc., for a particular customer internal and/or external demand, etc." Such a definition suggests a solid accentuation on how the actual business is directed by the endeavor. Processes typically cross the organizational boundaries of a firm and occur crosswise or between organizational units. Processes are for the most part recognized regarding start–end points, interfaces, organizational units involved, served customers and so on. Normal cases of processes include: development of a new product, creation of a marketing plan, procurement of goods from a supplier, processing and payment of an insurance claim, and so on. (Xirogiannis & Glykas, Fuzzy Cognitive Maps in Business Analysis and Performance-Driven Change, 2004).

A prior definition of Hammer and Champy (Hammer & Champy, Reengineering the Corporation: A Manifesto for Business Revolution, 1993) characterized a business process as “a collection of activities that takes one or more kinds of input and creates an output of value for the customer. A business process always has a goal and is mainly affected by events occurring in the external world or in other processes”. This definition is strong because of its comprehensiveness, despite its generic form. It might effectively total up all conceivable realistic permutations of business process flows. As indicated by Davenport’s book a business process is defined “as a structured, measured set of activities designed to produce a specified output for a particular customer or market. It infers a strong accentuation on how work is done inside an organization, as opposed to a product concentrate’s emphasis on what. A process is, hence, a particular ordering of work activities crosswise over time and place that all have a starting, an end, and unmistakably identified inputs and outputs: a structure for action” (Davenport, Process Innovation: Reengineering Work Through Information Technology, 1993).

Despite the fact that the initial two definitions characterized the goals, temporal location, and the flow structured by a business process, there are likewise two other critical components as yet missing in their definitions: the actors of the specific work activities and the collaborative nature of these actors. As per Ould, a business process may be seen as (1) a containing deliberate activity, (2) done collaboratively by a group (of humans and/or machines), (3) regularly cross functional boundaries, (4) invariably driven by the outside world. This description of business process presents the elements of actors/roles and coordinated effort between the actors/roles involved (Ould, 1995).

As indicated by the above divisions Ryan Ko says that business processes would be a series or network of value-added activities, performed by their relevant roles or collaborators, to deliberately achieve the regular business goal (Ko, A Computer Scientist's Introductory Guide to Business Process Management (BPM), 2009).

He likewise proposes various perspectives as far as of the business processes division. R. Ko recommends the processes separation based on the Level Perspective and the Core Competency Perspective. The Level Perspective classifies business processes into levels like those of conventional organizational charts. This present Ko's view is for the most part affected by Robert N. Antony, characterizing three level of management activities (Antony, Planning and Control Systems: A Framework for Analysis, 1965) (Antony, Dearden, & Bedford, Management Control Systems, 1989):

1. Operational Control, which is the process of assuring that specific tasks are done effectively and efficiently.
2. Management control, being the process by managers which guarantee of the acquisition and effective utilization of resources in the accomplishment of the organization's objectives.
3. Strategic Planning, being the process of settling on the objectives of the organization, on changes in these goals, in the resources used to obtain these objectives, and on the policies administering the acquisition, utilize and disposition of these resources.

The other perspective recommended by the analyst is the Core Competency Perspective. This perspective of business process groups business processes by their functions, or all the more particularly, their "heart" competencies (Prahalad & Hamel, 1990). There are for the most part three groups:

1. Core Business Processes: the revenue –generating processes (e.g. the Software Development Department in IBM or Microsoft).
2. Management Business Processes: They incorporate the processes that guarantee efficiency, corporate compliance, and governance (e.g., Requests, notifications, etc.).
3. Support Business Processes: These are non-revenue-generating cost components, in any case significant to the satisfaction of business goals (e.g. the transportation business processes of a manufacturing company, the IT Department in a retail outlet chain).

5.5 Business Process Modeling

A business model could be said to be an abstract depiction of an actual or proposed process representing selected process elements thought to be critical to the purpose of the model and can be authorized by a human or machine. Effectively incorporating these models-systems into the enterprise regularly requires modeling even the manual organization processes into which these systems intervene. (Curtis, Kellner, & Over, 1992). In this way, Business Process Modeling is considered to be key factor of a firm's operation. Process modeling has been performed in respect to IT and organizational advancement in any event since the 70ties (Krogstie, 2013). Process modeling is an instrument for copying the complexity of process planning and control. The existing process models appear also significantly complexity themselves, though. Consequently, the design of process models regularly ends up being extremely problematic (Becker, Rosemann, & von Uthman, 2000). To build up process modeling as a one of a kind zone, scientists must identify reasonable boundaries that identify their work from modeling in different territories of information science. Process modeling is recognized from other sorts of modeling particularly in computer science on the grounds that many of the phenomena modeled must be authorized by a human rather than a machine (Curtis, Kellner, & Over, 1992).

Business Process Modeling is basically helpful (1) for the description of the process, (2) examination of process and (3) enactment of a process. In the event of the description of a process it merits saying that these descriptions can address humans. It is critical that they comprehend machines, creating a need for formality. Process might be measured and gaps amongst present and wanted performance are to be recognized. We can at last refer to the enactment of a process, as we could state this may happen for simulation purposes, or to offer support for process execution that can range from reacting to the execution of the activities of the process in order to driving the execution of the process. Just formal languages make process enactment possible (Sezenias, Farmakis, Karagiannis, Diagkou, & Glykas, 2013).

Another description of the advantages emerging from business process management should be made by Indulska et al. It investigates the impression of benefits gotten from business process modeling and separates them into 5 principle categories. The primary category manages Strategic advantages from Business Process (BP) modeling for strategic activities, for example, long-range planning, customer retention, product planning, mergers and acquisitions. The second category alludes to Organization benefits by BP modeling, all the more particularly for organization benefits as far as strategy execution, learning, cohesion and increased focus. The third category needs to do with managerial advantages from BP modeling: these are benefits given to management as far as improved decision making planning. The fourth one incorporates Operational advantages identified with the lessening of process costs, the increase of process productivity, the increase of process quality as well as improved customer service and/or reduced process execution time. At long last, the fifth ones is identified with IT Infrastructure benefits including BP modeling benefits that influence emphatically IT support of business agility, lessening of IT costs, diminished implementation time (Indulska, Green, Recker, & Rosemann, 2009).

There are a few classifications of processes in view of the field they have a pace with and the most suitable modeling technique is chosen. Probably the most well-known approaches identified with the process management are Process Innovation Workflow Management, Activity-based Costing, Supply Chain Management, Total Quality Management and Business Process Reengineering (Becker, Rosemann, & von Uthman, 2000).

Because of the way that business processes are complex, process designers will regularly provide diverse modeling views, each concentrating on one part of the process (Glykas, Effort Based Performance Measurement in Business Process Management, 2011). Curtis et al. recognized four general views, summarized underneath (Curtis, Kellner, & Over, 1992):

1. **The functional view**: it exhibits the functional dependencies between the process components (activities, sub-processes, and so forth.). These dependencies are normally epitomized in the way that some process components consume (need) data (resources) produced by others. Run of the mill notations utilized as a part of the functional view include event Process Chain Diagrams (ePCD), IDEF1-2, and so on.
2. **The dynamic (behavioral) view**: it gives sequencing and control process information on when certain activities are performed (timing, pre-conditions) and how they are performed, i.e. state transition diagrams, petri nets and so forth.
3. **The informational view**: it incorporates the description of entities produced, consumed or manipulated by the process. They include pure data, artifact, products, and so on.
4. **The organizational-structural view**: it depicts who plays out a given task or function, and where in the organization (functionally and physically).

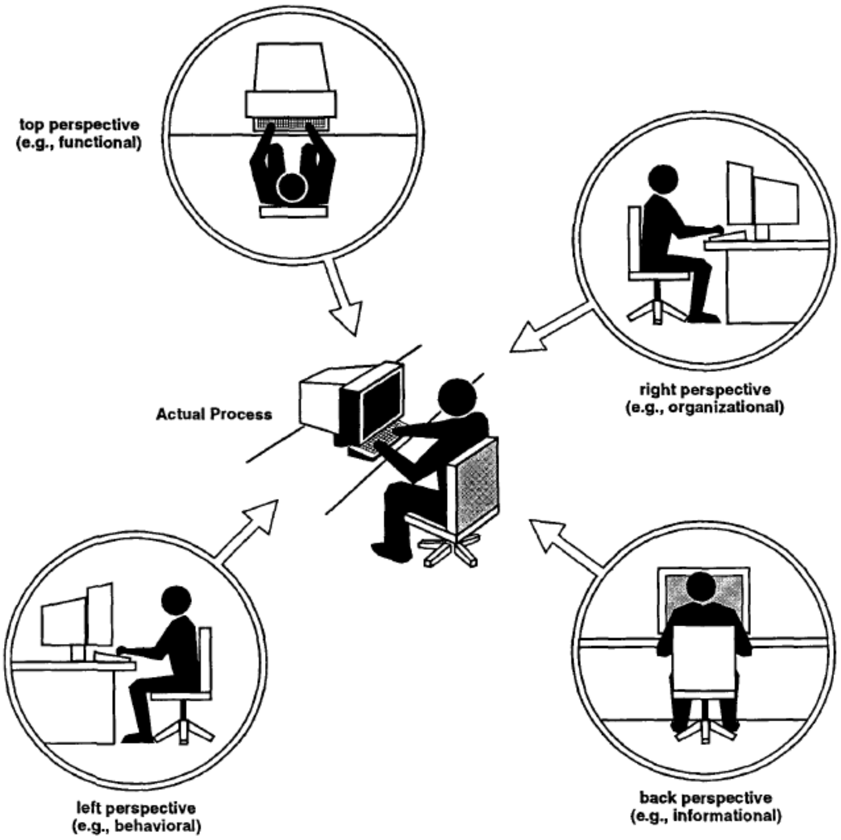


Figure 5.4 Four Modeling Perspectives (Curtis, Kellner, & Over, 1992)

Numerous different approaches from other scientists depended on these four perspectives (Zelm, Vernadat, & Kosanke, 1995) (Teng, Grover, & Fiedler, 1996). Krogstie in his approach made a review of modeling perspectives, in which he consolidates many research works supplementing with some extra perspectives the Curtis et al. approach (Curtis, Kellner, & Over, 1992) for best portraying process modeling highlights (Krogstie, 2013). As being normal with modeling methodologies, distinctive notations may likewise be fitting for different perspectives.

Another modeling view by Becker et al. assume in their work Guidelines of Modeling. This seems, by all accounts, to be a framework to structure factors for assessing process models. In particular, the point of this framework is the improvement of particular design proposals keeping in mind the end goal to expand the quality both of data-information models and data-information modeling (Becker, Rosemann, & von Uthman, 2000). A comparative methodology which includes rules on the most proficient method to utilize a business process modeling framework is introduced by Jeston & Nelis (Jeston & Nelis, 2014).

Georgakopoulos et al. (1995) expect the presence of two essential classifications of process modeling approaches situated in a workflow specification. The principal classification is the communication in light of methodologies expecting that the target of business process reengineering is the improvement of customer satisfaction. It decreases each action in a workflow to four in light of communication between a customer and a performer. The second classification is the activity based methodologies focusing on modeling the work as opposed to modeling different responsibilities among humans (Georgakopoulos, Hornick, & Sheth, 1995).

Another prominent audit in regards to business process modeling classification is the one by Aguilar-Saven (Aguilar-Saven, 2004). The author introduces the fundamental process modeling methods, grouping them, in light of two dimensions: the first one applies to two unique reasons for utilize and classifies the business process models in view of whether they are: (1) descriptive aiming at learning, (2) empowering decision support for process development-design, (3) empowering decision support for process execution, or (4) allowing information technology (IT) enactment support. The second one recognizes active and passive models. As an active one we consider a model enabling the user to connect with them (dynamic model), while passives are those that don't give this capability.

Business Process Modeling assumes a noteworthy part in the perception and comprehension of business processes. Components and capabilities of business process model show assume a huge part in depicting and understanding a business model. Vergidis et al. are the ones proposing a grouping scheme for processing models expected to order a scope of business processing models, continually as per their structural characteristics and their capabilities for both analysis and optimization. This approach proposes three sets to group business modeling techniques. The main set is the "Diagrammatic Models" including business process models that portray a business process utilizing a visual diagram. The second set is the "Mathematical Models" relating to models where all components are of a mathematical or formal underpinning. The third and last set is the "Business Process Languages" which contains software-based languages that help business process modeling and most of the times process execution (Vergidis, Tiwary, & Majeed, 2008).

It is fairly straightforward that there is a plenitude of business process modeling techniques and methodologies that might be embraced. A standout amongst the most fundamental things for partners is to recognize what sort of business process modeling technique is presumably appropriate for each situation.

5.6 Business Process Modeling Languages

As it has as of now been talked about in a past subchapter of this work, Business Process Models are very intricate and stakeholders ought to assign a similar significance to a model exhibited in graphical representations. For this situation there shouldn't be any scope for alternative interpretations. Clearly the utilization of a process modeling language for their determination is the best way to ensure that alternative interpretations are precluded (van der Aalst, ter Hofstede, & Weske, 2003). Business Process Modeling Language comprises another modeling technique utilized worldwide by businesses to model and execute a business process.

Beneath there is a gathering of these particular executable languages, the last pattern in business process modeling as of now producing a number of different semantic packages, with Business Process Modeling Language (BPML) and Business Process Execution Language for Web Services (BPEL) to be the most distinctive one (Vergidis, Tiwary, & Majeed, 2008).

Business Process Execution Language (BPEL) is a language upheld by companies like IBM, Microsoft, and BEA. BPEL is not a notational language, but rather it is an XML-based, and in that capacity, it acquires XML attributes like programmability, executability, and exportability.

Business Process Modeling Language (BPML) gives off an impression of being a result of the Business Process Modeling Initiative (www.bpmi.org). Additionally, it is a XML-based language that encodes the stream of a business process in an executable frame, dealing with the entire of business processes (e.g data management, operational semantics). The persistence and interchange of definitions crosswise over various systems and modeling tools is allowed because of the provision of a language structure (grammar) in an XML Shema format. BPML has been joined by Business Process Modeling Notation (BPMN), a graphical flowchart language that can speak to a business process in an intuitive visual frame. It is worth noting that BPMN gives a standard business process modeling notation for business partners, including also business analysts and technical developers who additionally manage and monitor these processes. BPMN permits the creation of Business Process Diagrams speaking to graphically every one of the activities and the request of the business processes and the flow controls performed (Plakoutsi, Papadogianni, & Glykas, 2013). There is below a simple example of a BPMN diagram presenting a book order fulfillment process (Harmon, 2007).

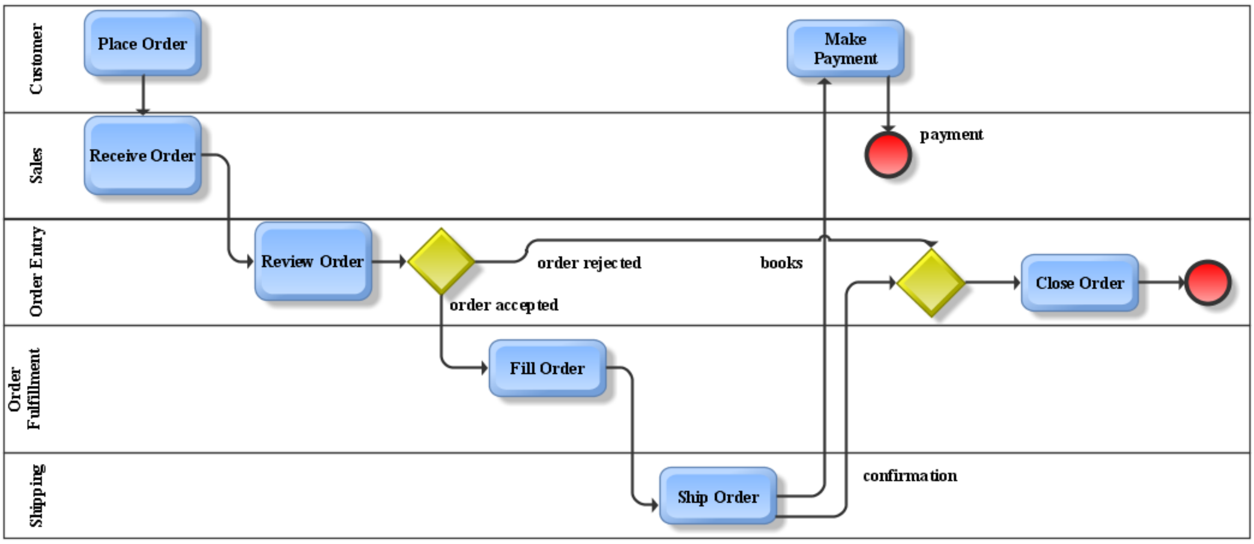


Figure 5.5 A Simple BPM Diagram

Yet Another Workflow Language (YAWL) is another Workflow graphical process language made by van der Aalst and ter Hofstede. YAWL is a Petri-net-based language worked with the essential focus to support an extensive variety of business process patters (van der Aalst, ter Hofstede, & Weske, 2003) (Vergidis, Tiwary, & Majeed, 2008).

JBoss Business Process Management (jBPM) execution language called jPDL comprises a novel approach to deal with business process modeling execution also. This new approach encourages normal transition from declarative input by the business analyst to the programming rationale that is required for implementing a business process. Along these lines, business process advancement is simplified, permitting even non-programmers to create business process utilizing visual tools. JBoss BPM engine is additionally in light of open source software, giving infrastructure to developers approaching an awesome assortment of supplementary software tools that they can without much of a stretch design and analyze business processes in a graphical domain (Vergidis, Tiwary, & Majeed, 2008).

An explanatory arrangement of the XML-based workflow languages is given by Plakoutsi et al. As indicated by this approach the workflow languages are being partitioned into four categories. These are the accompanying:

1. Web service based languages
2. Grib based languages
3. Petri net based languages
4. Agent based languages

5.7 Business Process Reengineering

Undoubtedly the field of Business Process Reengineering (BPR) comprises an essential element of Business Process Management (BPM). Michael Hammer is the originator of this concept after his article in (1990) Harvard Review. As per the approach talked about, Hammer underpins that “the reengineering in business operations consists a method for breaking away from outdated rules and fundamental assumptions to underlie operations” (Hammer, Reengineering Work: Don't Automate, Obliterate, 1990).

There are plenty of definitions for Business Process Reengineering (BPR). Hammer and Champy (1993) characterized reengineering as the fundamental rethinking and radical redesign of business processes so as to achieve dramatic improvements in critical, contemporary measures of performance, for example, cost, speed, quality and service (Hammer & Champy, Reengineering the Corporation: A Manifesto for Business Revolution, 1993). Guha et al. (1993) support in their work that BPR tries to redesign work processes with a specific end goal to accomplish quick performance improvement by radical organizational changes and by enhancing productivity and competitiveness (Guha, Kettinger, & Teng, 1993). Another definition was given by Ozcelic who in his approach exhibits the Business Process Reengineering (BPR). According to this researcher, it is a radical redesign of processes for earning critical improvements as far as cost, quality, and service (Ozcelik, 2013).

There is a noteworthy scope of methodologies for BPR. Hammer and Champy propose particular reengineering principles that streamline work processing, improve quality, speed, time management and profitability. These principles are seven and are recorder underneath (Hammer & Champy, Reengineering the Corporation: A Manifesto for Business Revolution, 1993):

- Organizing around results and outcomes.
- Identifying all processes incorporated into an organization and sort them to accomplish urgent redesign.
- Integrating information-processing work into genuine work producing the information.
- Treating geographically dispersed resources as if they were centralized.
- Linking parallel activities in the workflow as opposed to incorporating their results.
- Putting the decision point where work is performed and incorporate control with the process.
- Capturing information once and at the source.

Glykas and Valiris (1999) introduce in their approach an overview of existing work in the area of BPR keeping in mind the end goal to highlight distinctive classifications of BPR methodologies in view of literature with their emphasis on the redesign process and the general BPR principles rising up out of them. Authors have noticed the contrast between reengineering and redesign. As per the above definitions reengineering is synonymous to radical change, on the contrary process improvement to incremental change. Both reengineering and process improvement might be incorporated into the definition of redesign. Authors presenting a BPR methodology called Agent Relationship Morphism Analysis (ARMA) going past the boundaries of the current BPR methodologies taking an all-encompassing perspective of the organization (Valiris & Glykas, 1999).

5.8 Workflow Management

In the previous subchapter the concept of Business Process Management (BPM) has been extensively studied, considered as an extension of classical Workflow Management (WFM) systems and approaches (van der Aalst W. , 2004). Distinctive definitions of Workflow are formulated from time to time. Havey characterizes Workflow as “a flow of work, including the exchanged enrichment of information” (Havey, 2005). The Workflow Management Coalition (WfMC) characterizes “workflow as automation of a business process during which documents, information and/or tasks pass from one participant to another for action, as indicated by a set of procedural rules" (Lawrence, 1997). Georgakopoulos et al. (1995) define the workflow as a gathering of tasks organized to accomplish some business process (e.g. processing insurance claims, processing purchase orders over the phone, provisioning telephone service). A task can be performed by at least one software systems, a team of humans, or a mix of these and it can be the giving input commands during computer interaction, generating or mailing a bill or laying a cable, a basic file or database updating (Georgakopoulos, Hornick, & Sheth, 1995). A Workflow Management System (WFMS) is characterized as a system defining, creating and managing workflows by using software, running on at least one workflow engines, capable to interpret the process definition, interact with workflow participants and, where required, summon the utilization of IT tools and applications (Lawrence, 1997).

Through a slightly unique view, Georgakopoulos et al. (1995) gives another definition and, all the more particularly, sets the workflow as firmly identified with reengineering and automating business and information processes in an organization. A workflow applies to business process tasks at a conceptual level essential for understanding, evaluating and potentially redesigning the business process. Then again workflows may catch information process tasks at a level describing the process prerequisites for both information system functionality and human skills. The discrepancy between these workflow viewpoints is not generally clear. The term workflow is utilized for describing either, or both, of the business and information systems views. Workflow Management (WFM) characterizing workflows by depicting those attitudes of a process being important to controlling and coordinating the execution of its tasks. Besides, WFM comprises a technology giving fast (re)design and (re)implementation of processes required by a business and/or information systems change (Georgakopoulos, Hornick, & Sheth, 1995). Different concepts attributed to the term workflow have been illustrated in Figure 5.6**.**

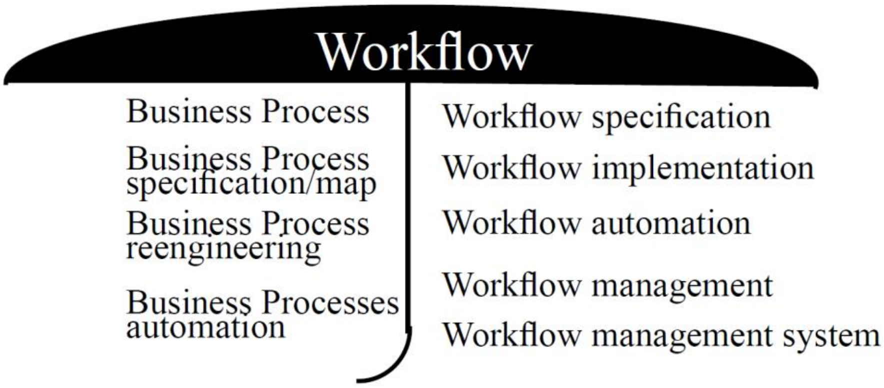


Figure 5.6 The Workflow Concept (Georgakopoulos, Hornick, & Sheth, 1995)

The following Figure 5.7 illustrates the reason for which WFM is considered to be a subset of BPM. The diagnosis stage of BPM Lifecycle is not included in WFM and that is the basic difference between them (van der Aalst, ter Hofstede, & Weske, 2003).

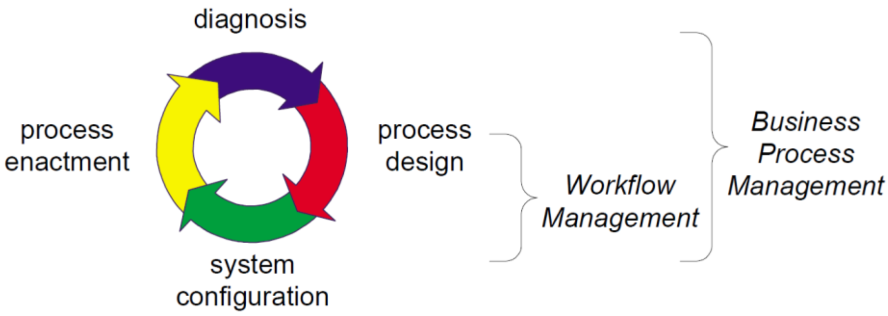


Figure 5.7 BPM and WFM (van der Aalst, ter Hofstede, & Weske, 2003)

Workflow Management Systems (WfMSs) are used to run every-day different applications in differential domains. A workflow separates the different activities of a given organizational process into an arrangement of well-defined tasks. The tasks take after the organization's policies going for accomplishing certain objectives. Among these policies, security policies are significant for guaranteeing that the organization adheres to its own security targets. Be that as it may, numerous workflows are managing with diverse sorts of data starting from different sources. Once the data is recovered for a specific workflow case, the organization, through its WfMS, is in charge of keeping up data privacy according to organization's secrecy policy. Wellcrafted workflow get to control mechanisms unquestionably help the organization for accomplishing such security objectives by relegating tasks to authorized (human) resources only (Alhaqbani, Adams, Fidge, & ter Hofstede, 2013). Authors suggest examples and one of them is illustrated in Figure 5.8.

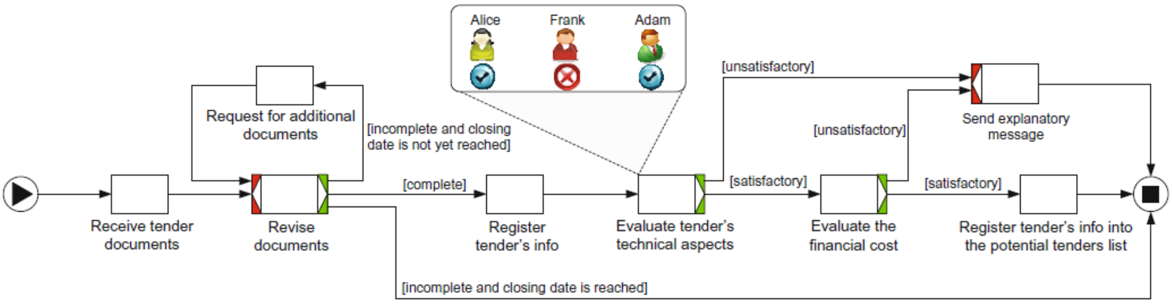


Figure 5.8 Tender evaluation workflow model (Alhaqbani, Adams, Fidge, & ter Hofstede, 2013)

In this case YAWL notation is utilized as a part of request to highlight the privacy and the conflict-of-interest suggestions coming about because of neglecting the subject of workflow. All the more particularly, this example alluded to contract tenders assessed in few steps as illustrated in Figure 5.8. The process begins by accepting the tenderer's documents and putting them through technical and final assessments. These tasks are allocated to the organization's available resources to accomplish the organization's security authorization policy. In any case, one may recognize a security threat coming about because of not considering the subject of the workflow in the authorization process. Expecting that the ACME company has presented a tender document to a government agency, the agency's authorization policy, either of Adam, Alice or Frank may perform technical assessment for any particular submitted tender. In the event that we additionally expect that someone, named Frank is an investor in ACME distributed the technical evaluation task for ACME's tender. This makes an irreconcilable situation that may compromise Frank's actions in a way that does not serve the organization's best interests. This happens on the grounds that the organization cannot express an authorization restriction excluding those Human Resources (HR) being in a conflict-of- interest in firm. Rather, the company's identify ought to be utilized as the workflow's system "subject" with the goal that the organization can without much of a stretch make an authorization restriction to secure against any conflicts of interest (Alhaqbani, Adams, Fidge, & ter Hofstede, 2013).

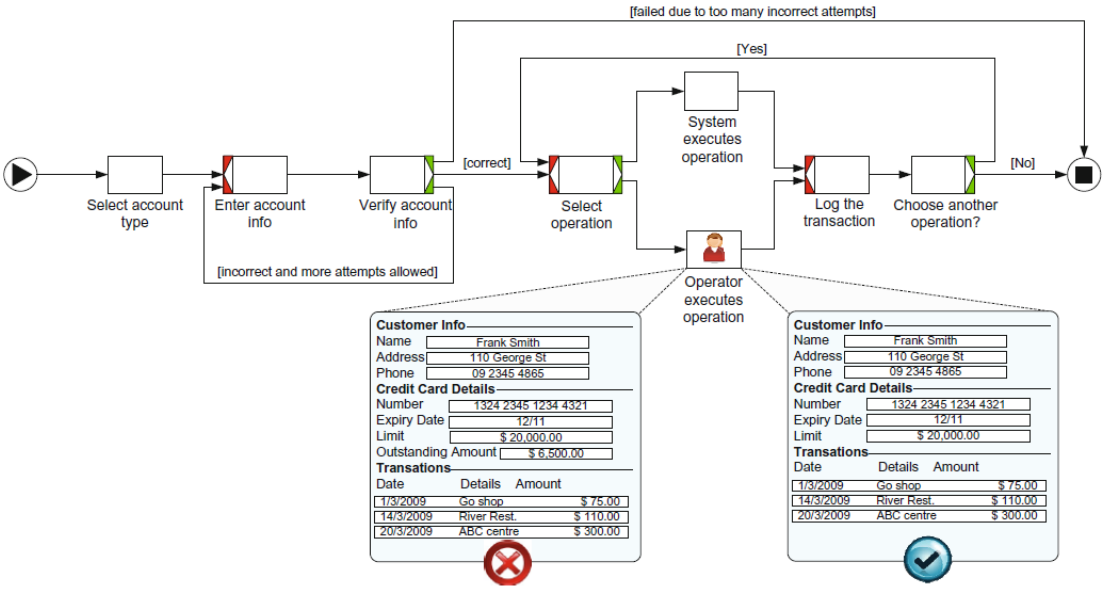


Figure 5.9 Phone Bankng Workflow model (Alhaqbani, Adams, Fidge, & ter Hofstede, 2013)

Authors appear to propose another similar illustration related with phone banking. This specific service is extremely valuable in the banking sector, giving generous advantages. Figure 5.9 appears to represent a phone banking workflow model getting and processing client request. Requests are being processed, automatically by the system or manually by an administrator. In this specific case, the customer has no power over what can be seen of his bank account's information by the workflow-authorized operator. This is because of information access control managed by the bank's security policy without thought of the customer's protection wishes. For instance, a customer's privacy desire to conceal his credit card balance from a bank operator can't be implemented in current WfMSs. In any case, stretching out the WfMS to perceive the subject of the workflow would allow a WfMS to recover and enforce the customer's privacy policy. Something like this can be accomplished by concealing the client's private credit card balance from forms visible to authorized resources. In Figure 5.9 distinctive data is uncovered to the operator relying upon the customer's privacy settings.

5.9 Knowledge Management

A sign of the new economy is the ability of organizations for acknowledging economic value from their accumulation of knowledge assets and also their assets of affiliation, production, information and distribution (Gold, Malhotra, & Segars, 2001). Knowledge is data consolidated with experience, context, reflection and interpretation. It is a high esteem type of information that is prepared to apply to choices and actions. While knowledge and information might be hard to recognize now and again, both are more profitable and include more human participation than the crude data on which we have lavished computerization during the previous forty years. Given the significance of such an advantage, it is not surprising that organizations wherever are focusing to knowledge investigating what it is and how to make, transfer and utilize it all the more efficiently (Davenport, De Long, & Beers, Successful Knowledge Management Projects, 1998).

Knowledge Management (KM) is a developing field that has summoned consideration and support from the modern industrial community. Numerous organizations as of now participate in knowledge management to keeping in mind the end goal to use knowledge both inside their organization and outwardly to their shareholders and clients. Knowledge management includes the creation of significance worth an organization’s intangible resources (Rubenstein-Montano, et al., 2001).

Operational knowledge sharing adds value to the organization. Numerous scientists have connected organizational knowledge creation to business strategy and in the organizational performance. The majority of these analysts move in the connection between business processes and knowledge creation, catch and retrieval while others like have made frameworks that asses and measure knowledge and readiness and captures in organizations (Sezenias, Farmakis, Karagiannis, Diagkou, & Glykas, 2013). Kock et al. (2009) led an investigation of an expansive number of finished Business Process Reengineering (BPR) projects and have concluded that communication flow in the business process amongst the process members and external stakeholders is the most basic factor for success. They likewise presumed that communication flow is firmly combined with process model quality and its connection with the reality and real time execution (Kock, Verville, Danesh-Pajou, & DeLuca, 2009).

Wiig (1997) exhibit in his approach the basic objectives of Knowledge Management (KM) which are (1) to make -the knowledge management- the firm act as cleverly as attainable to secure its viability and general success, (2) to generally understand the best value of its knowledge assets. To achieve these objectives, ahead in position organizations, build, deploy, transform, organize and utilize knowledge assets successfully. As it were, the general reason for KM is to amplify the firms's knowledge-related efficacy and returns from its knowledge assets and to renew them continually. Knowledge Management is to understand, concentrate on, and manage methodical, unambiguous and consider knowledge building, renewal, and application that is, manage effective knowledge processes (EKP). In a 1989 study, a few Fortune 50 CEOs agreed that knowledge is a central factor behind all the firm's activities. They likewise concurred that enterprise viability hinges straightforwardly in the antagonistic quality of knowledge asset and their fruitful application to create and deliver products and services (Wigg, 1997).

Another idea is that the "body of knowledge" inside the enterprise is equivalent to a living being with every one of its flows and functions that energize, motivate, and revive the enterprise and make it workable for it to function. Its wellbeing straightforwardly influences our capacity to operate successfully and effectively. This makes it feasible for everybody to "act intelligently" as required. It is the part of knowledge management to keep the assortment of knowledge alive and energetic to secure the firm's prosperity and long term viability. As clear as these thoughts may be, to achieve these targets by and by –across all the firm's activity domains- is a long way in simple. It turns out to be considerably more mind boggling when management chosen to methodically integrate and deal with the vital KM-related activities. Every enterprise has a tendency to be unique and alternative options for managing knowledge are numerous. Besides, since Knowledge Management is still generally new, the availability of standarized or off-the shelf approaches is constrained. Thusly, customized approaches are regularly formulated to provide the enterprise with the best and most relevant solutions and this adds to the complexity. By and by, established strategies, practice models and technical options are presently getting to plainly accessible to ease the difficulty of pursuing Knowledge Management (KM) once management guides the concentration is toward that path.

From a managerial view orderly Knowledge Management (KM) includes four domains of accentuation. They focus on:

1. Top-down monitoring and facilitation of knowledge-related (KR) activities
2. Creation and maintenance of knowledge infrastructure
3. Renewing, organizing, and transferring knowledge assets
4. Leveraging (utilizing) knowledge assets to realize their value

The domains are illustrated in Figure 5.10 which additionally shows some applicable knowledge related practices and activities (Wigg, 1997).

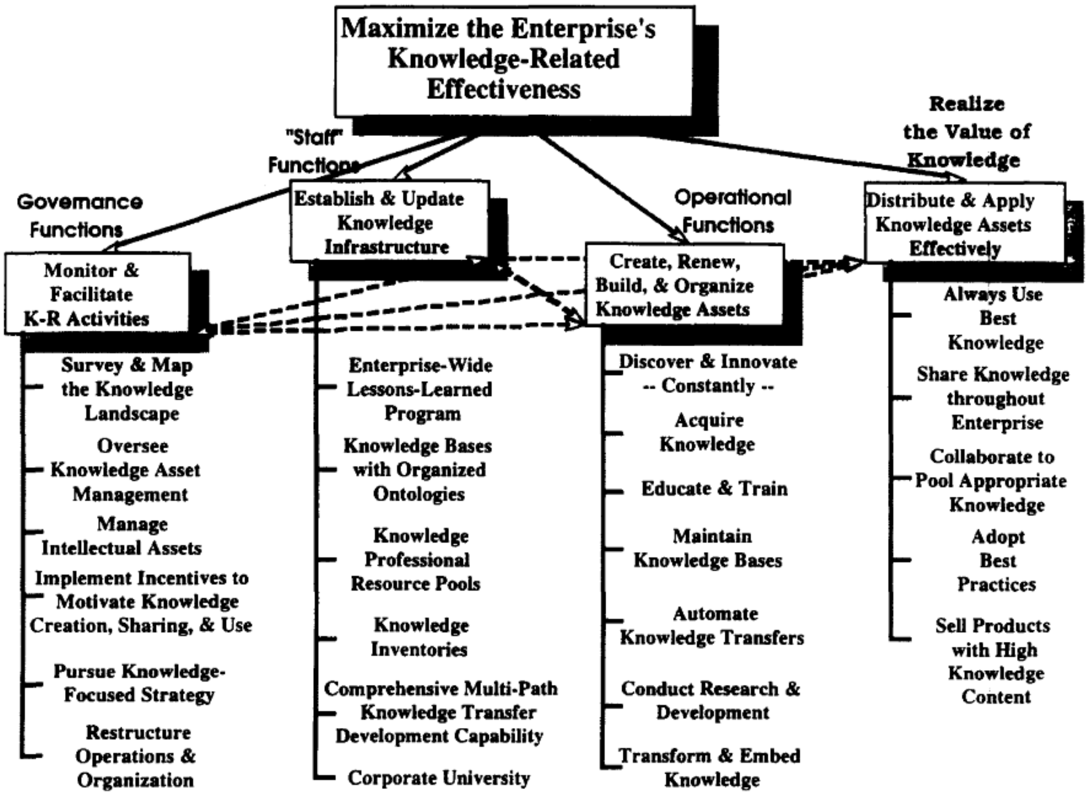


Figure 5.10 The Knowledge Management Areas (Wigg, 1997)

Successful and effective Knowledge Management (KM) is neither panacea nor bromide. It is one of numerous elements of good management. Sound planning, insightful marketing, high quality products and services, regard for clients, the effecting organizing of work and the thoughtful management of an organization's resources are not reduced is significance by the affirmation that knowledge is basic to progress and should be managed. At the edge, however when a business confronts contenders that perform well on those various dimensions the distinction amongst success and failure may well turn on how adequately its knowledge is managed from it (Davenport, De Long, & Beers, Successful Knowledge Management Projects, 1998).

5.10 *Business Process Intelligence*

It is a fact that Process design and automation technologies are in effect progressively utilized by both customary and recently formed, internet-based enterprises as a means to improve the quality and efficiency of their managerial and production processes, to manage e-commerce exchanges, and to quickly and reliably deliver services to business and individual clients (Grigori, Casati, Castellanos, Dayal, Sayat, & Shan, 2004). Business Process Intelligence (BPI) is a rising domain that is getting increasingly famous for enterprises. The need to improve business process effectiveness, to respond rapidly changes and to meet regulatory compliance is among the primary drivers of Business Process Intelligence (BPI). Business Process Intelligence alludes to the application of Business Intelligence strategies and techniques to business processes and involves an extensive scope of use territories crossing from process monitoring and analysis to process discovery, prediction, optimization and conformance checking (Castellanos, De Medeiros, Mendling, Weber, & Weijters, 2009). As indicated by Grigori et al. (2004) BPI identifies with an arrangement of integrated tools that can support business and IT users in the managing process execution quality area (Grigori, Casati, Castellanos, Dayal, Sayat, & Shan, 2004).

A comparative approach to Business Process Intelligence concept was given by Felden et al. (2010). This research has characterized the Business Process Intelligence (BPI) as the analytic process of identifying, defining, modeling and improving value making business processes for supporting the tactic and strategic management. The same researches feel that different elements likewise exist, connected to BPI business process design and redesign, made by the tactical and strategic level of management, and concentrating on both structured and unstructured data, originating from both internal and external information-data sources (Felden, Chamoni, & Linden, 2010).

As per Grigori et al. Business Process Intelligence (BPI) relates to the application of Business Intelligence (BI) techniques and methodologies to business processes (Grigori, Casati, Castellanos, Dayal, Sayat, & Shan, 2004). The purpose of Business Intelligence is to support better business decision making process. The data source of Business Intelligence is a purported data warehouse i.e. a special data base where an organization stores imperative important and historical data. More often than not the data is gathered from various information frameworks and systems as utilized as a part of an organization. Important notions like data analysis and data mining can be performed utilizing this data sources. The main target is to make clear translation of the data to valuable business information that can bolster the decision making process which takes part in an organization. In the event that the data warehouse likewise includes information about the processes inside an organization it is known as a process data warehouse and this can be utilized as source for Business Process Intelligence analysis (Casati, Castellanos, Dayal, & Salazar, 2007) (Castellanos, De Medeiros, Mendling, Weber, & Weijters, 2009). As indicated, BPI is a rising field, that is rapidly picking up enthusiasm because of the increasing pressure companies are confronting to enlarge the efficiency of their business processes and to rapidly react to market changes as a means to be competitive in this extremely dynamic Internet domain (Castellanos, De Medeiros, Mendling, Weber, & Weijters, 2009).

Normally event logs include information about start and completion of activities and additionally the resources that executed them. As a rule, related data (such as the values-estimations of data fields connected to tasks) is recorded to. The Business Process Intelligence (BPI) exploits this process information by giving the way to for analyzing it to provide organizations a superior comprehension of how their particular business processes are really executed. It supplies bolster in the disclosure of glitches and bottlenecks and aids identifying their causes. In this way, BPI frequently triggers process improvement or the reengineering efforts. Business Process Intelligence not just fills in as a tool in order to improve the business processes performance additionally encourages changes by encouraging the decision-making process. What’s more, BPI is utilized to monitor the operational business process’s alignment, with strategic business targets and to give the visibility that regulatory compliance requires. Besides, BPI is not confined to the examination of historical data, but rather can also be utilized to optimize future endeavor for instance foreseeing future problems and malfunctions (Castellanos, De Medeiros, Mendling, Weber, & Weijters, 2009).

5.11 Information Technology

There is a number approaches that connect Information Technology (IT) to business strategy, enterprise performance, technology or human resources, industrial engineering, process reengineering and numerous other relative areas. Notions like Business Process Management (BPM), Workflow Management (WfM), and Business Process Reengineering (BPR) have been IT-related disciplines with a background marked by around three decades (Ko, A Computer Scientist's Introductory Guide to Business Process Management (BPM), 2009).

In a previous subchapter, we altogether examined the significance of processes into a business or organization. Information Technology is more than an accumulation of tools for automating or mechanizing processes. It can in a general sense reshape the way business is done and empower the process design (Attaran, 2004). Information Technology (IT) and Business Process (BP) design are common accomplices, yet industrial engineers have never completely exploited their relationship (Davenport & Short, The New Industrial Engineering: Information Technology and Business Process Redesign, 1990).

The expression “reengineering” first showed up in the Information Technology (IT) field and has evolved into an extensive change process. The point of this radical improvement approach is quick and substantial gains in organizational performance by redesigning the center business process. The term of Information Technology (IT) has been utilized to eliminate communication barriers between the corporate functions, to enable line workers and to fuel process reengineering. Much of the time, IT has been utilized to speed up office work instead of to transform it. Top executives assume IT an intense source of competitive advantage (Attaran, 2004). Whenever BPR and IT are combined they have the potential to create more coordinative, flexible, team-oriented, and communication-based work capability (Whitman, 1996).

Hammer and Champy assume IT as the key empowering influence of BPR (Hammer & Champy, Reengineering the Corporation: A Manifesto for Business Revolution, 1993). Davenport and Short, content that BPR requires taking a boarder perspective of both IT and business action, and of the connections between them. Information Technology (IT) capabilities should bolster business processes which ought to be as far as the capabilities IT can provide. The same authors believe that IT’s promise and its ultimate effect is to be the most powerful and capable tool for reducing the expenses of coordination (Davenport & Short, The New Industrial Engineering: Information Technology and Business Process Redesign, 1990). In Figure 5.11 the recursive relationship between the Information Technology (IT) Capabilities and Business Process Redesign (BPR) is illustrated.

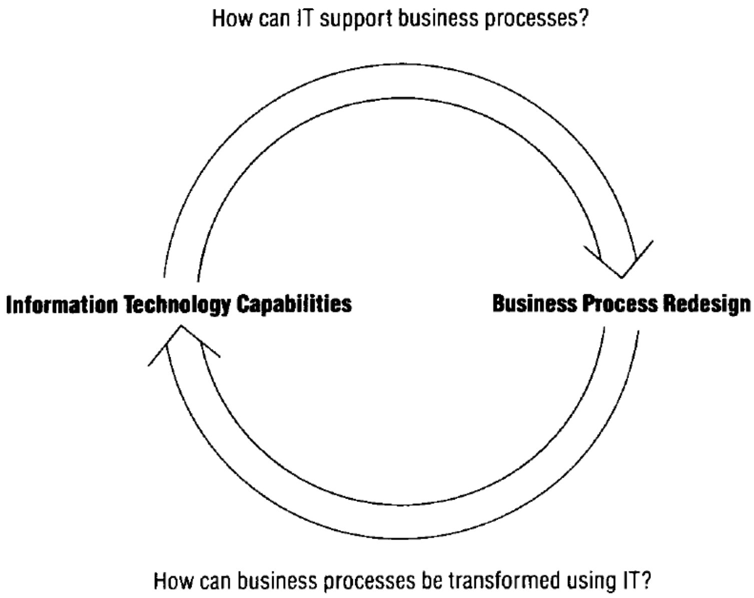


Figure 5.11 The IT and BPR relationship (Davenport & Short, The New Industrial Engineering: Information Technology and Business Process Redesign, 1990)

Davenport and Short assume that Information Technology (IT) which includes the capabilities offered by PCs, software applications, and telecommunications. Business Process Redesign (BPR) incorporates the analysis and the design procedure of workflows and processes inside and between the organizations. These are two imperative business tools. Cooperating, these tools can possibly make another kind of industrial engineering, changing the way the discipline is applied and the particular skills necessary to practice it. They likewise propose a pattern that includes five stages to reengineering processes. These particular five steps are the developing of business vision and process mission targets, identifying the redesigning processes, understanding and measuring the current process, identifying the IT levers, and finally designing and building an archetype of the new process (Davenport & Short, The New Industrial Engineering: Information Technology and Business Process Redesign, 1990).

It has been contented that innovative uses of IT would definitely lead many enterprises to grow new, coordination-intensive structures, empowering them to coordinate their actions and activities in ways that were not possible some time recently. Such coordination-intensive structures may prompt key favorable circumstances to strategic advantages (Teng, Grover, & Fielder, 1994).

5.12 Process Performance Measurement

Inside current competitive business domain, firms should continually improve the quality of their particular products and services to remain in front of the competition. Amid the previous couple of years numerous organizational endeavors have been attempted by modern firms, wherein the notion of a process-centered company has gotten considerable attention. In this specific circumstance, evaluating process performance is fundamental since it empowers individuals and groups to evaluate where they stand in comparison to their competitors. Moreover, assessing process performance gives the chance of recognizing conflicts and problems and taking correction action before these problems raise (Kueng, 2000). It has been broadly detailed that there has been a revolution in performance measurement in the most recent decades. The colossal enthusiasm in measurement has showed itself in practitioner conferences, publications and additionally in academic research (Neely, 1999).

There are many researches which demonstrate that numerous businesses utilize the balanced measurement with a specific end goal to be more effective regarding management than different antagonists-opponents. For this advantage to be acknowledged, it is crucial for organizations to implement an effective performance measurement system that "enables informed decisions to be made and actions to be made in light of the fact that it quantifies the efficiency and effectiveness of past actions through acquisition, collation, sorting, analysis, interpretation, and dissemination of proper data" (Neely, 1999).

For a long time frameworks have been utilized by organizations to characterize the measures that they should use to evaluate their performance. Without a doubt a standout amongst the most broadly perceived performance measurement frameworks of today is the Balanced Scorecard (BS), proposed by Kaplan and Norton (Kaplan & Norton, The Balanced Scorecard: Measures That Drive Performance, 1992) (Kaplan

& Norton, The Balanced Scorecard: Translating Strategy into Action, 1996) (Kennerley & Neely, 2002). The Balanced Scorecard (BS) firstly identifies and secondly integrates four distinctive ways of looking at performance (internal business, financial, customer, and innovation and learning perspectives). The researches identify the need to guarantee that financial performance, the drivers of it (customer and the internal operational performance), and the drivers of the on-going improvement and future performance, are given equivalent weighting. The balanced reflects a considerable lot of the attributes of other various measurement frameworks however more explicitly connects measurement to the organization's strategy. The researches assert that it ought to be conceivable to deduce an organization's strategy by reviewing the measures on its Balanced Scorecard (BS). Kaplan and Norton content that the full potential of the balanced scorecard may be acknowledged if an organization connects its measures plainly, identifying the particular drivers of performance (Kaplan & Norton, Linking the Balanced Scorecard to Strategy, 1996). Despite the fact that not designed as performance measurement frameworks, the European Foundation for Quality Management's (EFQM) Business Excellence Model and its US equivalent the Malcolm Baldrige Quality Award take a boarder perspective of performance, addressing many of the territories of performance not considered by the balanced scorecard. The Business Excellence Model is an expansive management model that explicitly highlights the enablers of performance improvement and demonstrates result areas that ought to be measured (Kennerley & Neely, 2002).

Keegan, Eiler and Jones (1989) suggested a performance measurement matrix reflecting the requirement for balanced measurement. It classifies measures as being "cost" or "non-cost", and "internal" or "external" reflecting the requirement for more balance of measures over these dimensions. That is a basic framework and it does not reflect the greater part of the attributes of measures that are progressively viewed as necessary, the matrix ought to have the capacity to accommodate any measure of performance. This fact enables an organization to plan its measures and identify where there is a need for measurement focus adjustment. The performance measurement matrix is presented in Figure 5.12.

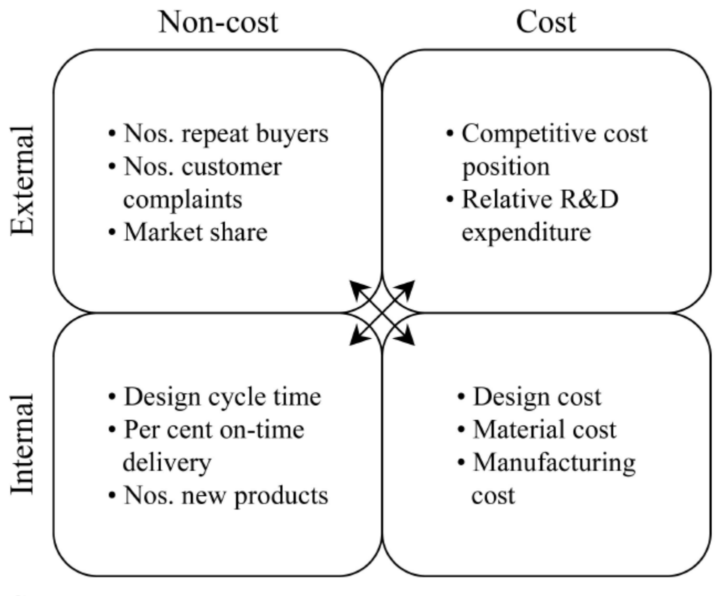


Figure 5.12 A Performance Measurement Matrix

The SMART (Strategic Measurement and Reporting Technique) pyramid created by Wang Laboratories (Lynch & Kelvin, 1991) likewise underpins the need to incorporate internally and externally focused measures of performance. This technique includes the thought of cascading measures down the organization with a goal that measures at department and "work-center" level reflect the corporate vision additionally internal and external business unit targets.

Other than the approaches said, different management tools and instruments are being used nowadays, Glykas propose a technique-methodology and toolset that depends on business analysis of relationships between ratios that define and measure Key Performance Indicators (KPI) in qualitative and quantitative terms and identify the particular relationships that exist between them. These ratios enable firms to achieve a performance assessment tool for continuous improvement in their endeavor to react and adapt rapidly to the turbulent markets. The performance measurement tool is called ADJUST and is utilized for (1) planning diverse reorganization scenarios for the achieving accomplishment of desired performance results, (2) for evaluating real time performance and finally (3) reporting deviations from desired and planned performance. So as to monitor and evaluate the real time performance, the ADJUST software tool provides interfaces to three distinctive kinds of management tool classes-categories, in particular (1) Process Management Tools (PMT) that need to do with business models, cycle time, primitive cost, and so on. (2) Human

Resource Management (HRM) tools that allude to job descriptions, performance measures, and so on. (3) Workflow Management (WFM) tools that is connected with transactions, business rules, workflow models, and so on. The ADJUST business analysis engine depends on employee effort analysis and provides meta-analysis of data which are analyzed in both PMT and HRM tools. Data like activity sequencing, cycle times, primitive costing, and so forth, from PMT tools are fully analyzed in ADJUST tool in order to evaluate the rate of high-business and low value added activities, concentration analysis, the mission-non mission activities, and so on. Knowledge Management components are integrated to job descriptions and related with performance measures and finally workflow elements. Also, data of job descriptions and performance measurement that are provided by HRM tools are analyzed further as far as cost to manage, principal agent analysis and so on. On account of WFM tools the ADJUST system gives don't just meta-analysis of workflow processes or transactions and document flows but in addition dynamic monitoring of their "real time" performance (Glykas, Effort Based Performance Measurement in Business Process Management, 2011).

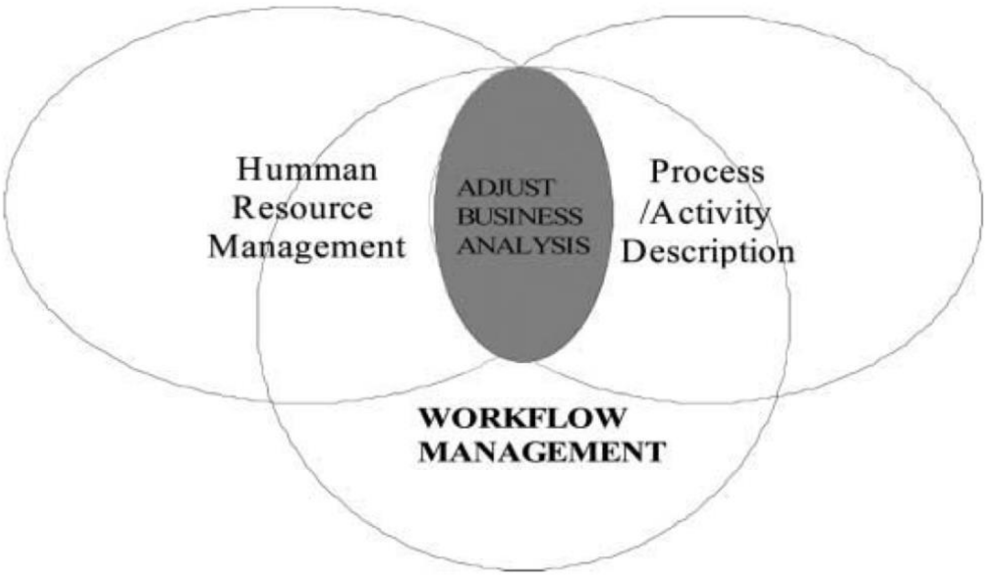


Figure 5.13The ADJUST Business Analysis (Glykas, Effort Based Performance Measurement in Business Process Management, 2011)

6 Case Study

6.1 Introduction

It is a fact that the strategic role of Performance Measurement systems in Operations Management has been widely stressed in management literature. These systems provide managers with useful tools to understand how well their organization is performing and to evaluate them in deciding what they should do next. Balanced Scorecard is a well-known framework which can make easier the exploring of the trade-offs among measures. In this chapter the utilize of FCM Modeler Tool is proposed in order to support the Balanced Scorecard framework and to advance the decision making process, exploiting its predictive modeling capabilities in the process performance measurement. The reason of Balanced Scorecard utilizing is to link in a balance way both financial and operational measures (Glykas, Fuzzy cognitive maps in business process performance measurement, 2013).

A Case Study presents a set of realistic processes in order to analyze the influence that various changes have in a particular system. The main purpose of this chapter is to drive strategic change activities for continuous improvement rather than limit itself to qualitative simulations, presenting a Case Study that based on the process performance measurement predictions. This mechanism eases significantly the complexity of deriving expert decisions concerning the process based planning.

6.2 Literature Review

6.2.1 Business Process Performance Measurement

It is a fact that in our days organizations are operating in a consistently evolving condition. In that changing environment, the need for sufficient design, implementation and utilization of performance measurement systems is greater than any time in recent memory. As indicated by to Eccles (2011) it will be increasingly important for all significant business to assess and alter their performance measures as a means to adapt to the rapidly changing and profoundly competitive business environment. An average performance measurement system depends on three stage processes which are the design, the implementation and the use. Failing to implement any of these particular stages will come about into a non-resistant performance measurement system. When endeavoring to improve organizational performance by utilizing performance measurement systems, an important point is the choice of suitable measures (Chytas, Glykas, & Valiris, A proactive balanced scorecard, 2011).

As mention in the previous chapter several authors have perceived that a great deal must be done as means to identify the relationships that exist among measures. Kaplan when met by de Wall (2003) contented that cause and effect relationships ought to be tested further. By-the-by, in almost all cases, organizations disregard the vital interdependencies and trade-offs among measures. Besides, criticism that exists in respect to performance measurement frameworks and their static nature and ought to be dynamic and modified as circumstances change. While trying to depict and test cause and effect relationships Kaplan and Norton (2001) suggested the utilization of strategic maps (Kaplan & Norton, Transforming the Balanced Scorecard from Performance Measurement of Strategic Management, 2001). In any case, the causal relationships that strategy maps claim to model are not generally linear and one-way, but rather for the most part a fuzzy mess of interactions and interdependencies.

Kellen (2003) contends that in the range of executive management only 6 in 10 executives put confidence in the data exhibited to them. He brings up that one of the fundamental factors that forestall measurement is the fuzzy mission targets. By the same token, Xirogiannis et al. (2008) clarify that in a performance measurement system an expansive number of multidimensional factors can influence performance (Xirogiannis, Chytas, Glykas, & Valiris, 2008). Integrating those multidimensional effects into a solitary unit must be done through subjective, individual or group judgment. It is difficult to have an objective measurement and scale framework for each unique dimension of measurement that can encourage objective value trade-off between various measures. They contend that techniques and methodologies, which are suited to fuzzy paradigms, ought to be considered.

6.2.2 The Staff Productivity Measure

As a principle purpose of this Case Study we identify the examination of the influence of processes, sub-processes and metrics on Staff Productivity measurement. Productivity comprises a basic performance measure for the economies, industries, firms, and processes. Improving productivity comprises a noteworthy pattern in Operations Management as firms confront pressures for improving their processes and supplying chains as means to compete with their regional and foreign competitors. We could say that the concept of “Productivity is the value of outputs (services and products) produced divided by the values of input resources (wages, the cost of equipment and so on) that utilized” (Krajewski, Ritzman, & Malhotra, 2013):

$$Productivity = \frac{Output}{Input}$$

There is a great number of measures. For instance value of output can be measures by client pays or essentially by the number of units produced or clients served. The input value may be evaluated by their cost or, basically, by the number of working hours. Managers as a role pick a few sensible measures and monitor trends to spot ranges that need improvement. For example, a manager in an insurance firm might measure office productivity as the particular number of insurance policies processed per worker, per week etc. This case unmistakably reflects labor productivity as a list of the output per person or per hour worked (Krajewski, Ritzman, & Malhotra, 2013). Another case is the measure of Staff Productivity in regards to annual sales’ orders for a specific firm process (e.g. operating warehousing). This might be the number of sales per order fulfilled divided by the number of FTEs performing the process “operate warehousing”. Similar measures may be used for machine productivity, where the denominator represents the number of machines.

Accounting for several inputs at the same time is likewise possible. Multifaceted productivity is an indicator of the output given by more than one of the resources utilized in production. It might be the value of the output divided by the sum of the materials, the labor, and the overhead costs (Krajewski, Ritzman, & Malhotra, 2013).

6.2.3 The Full Time Equivalent Metric

At this point it is necessary to define the FTE unit of measure used as metric in many cases for the Staff Productivity measure. More specific, a Full Time Equivalent (FTE) is a unit of measure of employed persons or students in a way that makes them comparable in spite of the fact that they may work or study for a different number of hours per week. FTE is frequently utilized to measure a worker’s or student’s involvement in a project or even to track cost decreases in a given organization. Thus, full-time person is thought to be one FTE, while a part-time worker/student receives a score in proportion to the hours working or studying. For example, a part-time worker, being employed for 20 hours a week when full-time work consists of 40 hours counts as 0.5 FTE (Eurostat, 2017).

6.3 The Balanced Scorecard

As mentioned in the introduction of this chapter, the aim of this Case Study is to link in a balance way both financial and operational measures. We can't forget the financial measures and improve only the operational. For this simple reason the Balanced Scorecard methodology is adopted in this particular research.

The Balanced Scorecard (BSC) is one of the best known Performance Measurement System (PMS) that mentioned in previous chapter (Kaplan & Norton, Using the Balanced Scorecard as a Strategic Management System, 1996). The Balanced Scorecard incorporates financial measures that tell the results of actions officially taken. It complements the financial measures with operational measures on customer satisfaction, internal processes, and the organization's innovation and improvement activities. It comprises of four distinctive perspectives. Firstly, the **Customer Perspective** shows how customers see our company. Discover by measuring lead times, quality, performance, service, and costs. This Perspective depicts how customers create value through customers, seeing how they view performance turns into a noteworthy aspect of performance measurement. Secondly, the **Internal Business Perspective** presents what must your company excel at? Decide the processes and competencies that are the most crucial, and determines measures, such as cycle time, quality, employee skills, and productivity, to track them. Thirdly, the **Learning and Growth Perspective** presents the essential actions that a firm must do as means to continue to improve and create value. Monitor your capacity to launch new products, create more value for clients, and improve the operating efficiencies. This Perspective identifies the infrastructure that the organization must build in order to create long-term growth and improvement. Learning and growth come from three principal sources, (a) People, (b) Systems, (c) Organizational procedures. Fourthly, the **Financial Perspective** depict how has your firm done by its shareholders. It incorporates financial performance measures which determine whether a company's strategy, implementation and execution are contributing to main concern improvement. Measure cash flow, the quarterly sales growth, the operating income by division, the increased market share by segment and the return in equity are some of the "survival" measures of this perspective (Kaplan & Norton, The balanced Scorecard: Measures That Drive Performance, 2005).

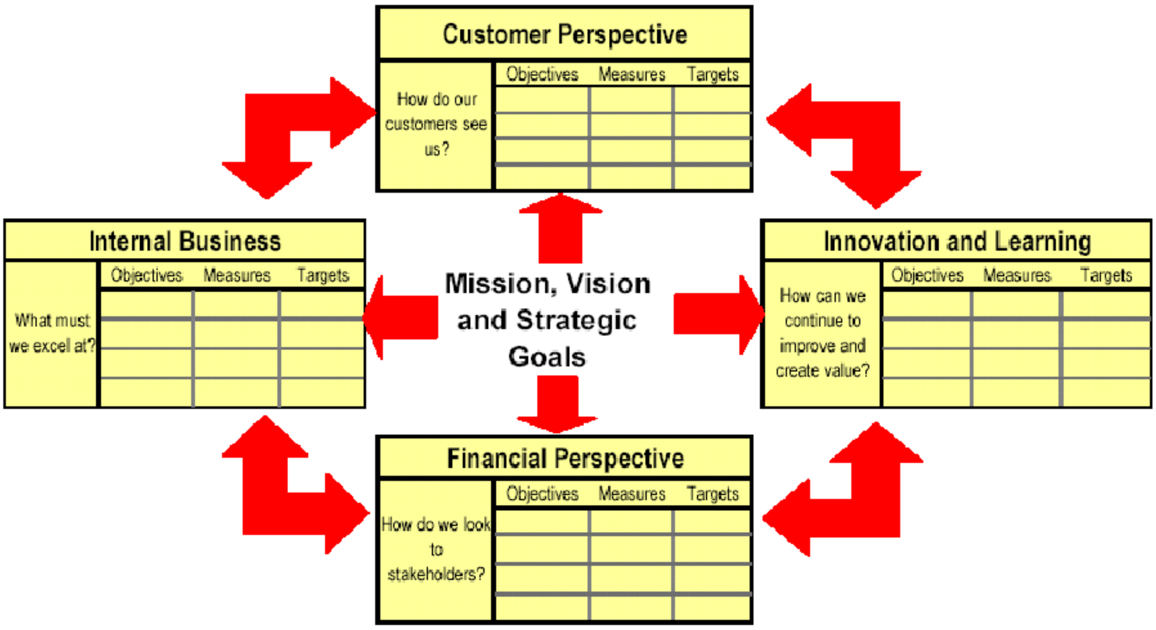


Figure 6.1 The Balanced Scorecard (Kaplan & Norton)

6.4 Need for Fuzziness in Balanced Scorecard Methodology

The Balanced Scorecard briefly described previously, is one of the most popular framework in the area of performance measurement that examined in this case study. This methodology is a balanced approach which needs to do with financial and/or non-financial measures and includes few measures in a multi-dimensional structure. Regardless of its reputation Balanced Scorecard is connected with several issues that need additionally research (Glykas, Fuzzy Cognitive Strategic Maps in Business Process Performance Measurement, 2013). More specific cause and effect consider to be one-way in nature. Measures in the Balanced Scorecard are set in a cause and effect chain rather a systematic approach. Besides, trade-offs among measures and additionally among the four perspectives are ignored. Overlooking the trade-offs among measures and among the four perspectives is fairly not an efficient approach. Notwithstanding to measures are similarly weighted which implies that all the measures in Balanced Scorecard are given a similar weighting. That is not occurs as a general rule. A few measures may be more significant and have greater impact compared to others. Weighting the measures among each other is a critical process on decision-making. It is very imperative to specify that designing techniques utilized for the development of the Balanced Scorecard are fairly poor in showing the dynamics of a system. There is nonattendance of feedback loops among measure concepts. At last predictions which are related with the future state of a market and values that business objectives and mission goals can reach dependably contain the issue of uncertainty.

These reasons that specified in the underneath paragraph, contain by themselves characteristics of vagueness or fuzziness as more than one cause node can be linked to the same effect node with different levels of influence.

6.5 The Proactive Balanced Scorecard Methodology (PBSCM)

In this point of this thesis it will be examined a methodology by Chytas et al. (2011) that allows the adoption of Fuzzy Cognitive Maps (FCMs) in the Balanced Scorecard basic theory principles (Chytas, Glykas, & Valiris, A proactive balanced scorecard, 2011).

According to Kaplan and Norton (Kaplan & Norton, 2004) the Balanced Scorecard has addressed the first concept by showing how to measure strategic objectives in numerous perspectives. It additionally introduced the early ideas in regards to the second part how to manage the strategy. Afterward, Kaplan and Norton have given a more comprehensive approach for how to manage the strategy and broadly expound on strategy maps, utilizing linked targets in strategy maps to depict and visualize the strategy. So as indicated by the above theory, the following equations emerge:

{Breakthrough Results}		*{Breakthrough Results}*		*{Breakthrough Results}*
=		=		=
{Describe the Strategy}	→	*{Strategy Maps}*	→	*{Simulate the Strategy}*
+		+		+
{Manage the Strategy}	↘	*{Balanced Scorecard}*	→	*{Describe the Strategy}*
		+		+
		{Strategy-Focused Organization}	→	*{Manage the Strategy}*

Table 6.1 Equations 1, 2, 3

By consolidating the new component "Simulate the Strategy" in the above equation we expect to beat every-one of the constraints identified in the literature review of previous subchapter and view performance measurement and in particularly the Balanced Scorecard inside the systemic approach. As a means to address this new "component", the utilization of Fuzzy Cognitive Maps (FCMs) is proposed. As it was described previously, FCMs are fuzzy signed directed graphs with feedback loops, in which the set of objects is modeled by the nodes and the set of the causal relationships is modeled by directed arcs. FCMs combine the beneficial strengths of cognitive maps with fuzzy logic. By representing human knowledge in a shape more representative of the natural human language than traditional concept mapping techniques, FCMs ease knowledge engineering and increment knowledge-source concurrence. The various characteristics and the structure of FCMs enable us to re-write the past 3 equations as follows:

{Breakthrough Results}		***{Breakthrough Results}***
=		***=***
{Simulate the Strategy}	→	***{FCMs}***
+		***+***
{Describe the Strategy}	→	***{FCMs}***
+		***+***
{Manage the Strategy}	↘	***{Balanced Scorecard}***
		+
		{Strategy-Focused Organization}

Table 6.2 Equation 4

In the above conclusive equation in the first instance (Simulate), the simulation characteristics of the FCM theory is utilized. The FCM approach includes forward-chaining (what-if analysis). The forward-chaining furnishes business domain experts with the capability to reason about the map they have developed (nodes relationships and weights) and inspect diverse scenarios. In the second case (Describe), the representation capabilities of the FCMs theory is utilized. FCMs are shown as causal-loop diagrams. This is extremely suitable for communicating strategy and additionally investigating the interrelationships among measures and in turn objectives (Chytas, Glykas, & Valiris, A proactive balanced scorecard, 2011).

The methodology for the development of a Proactive Balanced Scorecard is depicted in the Figure 6.2 below. PBSCM is capable of illustrating non-linear interactions and feedback loops using FCMs as a causal-loop diagram and performing what-if scenarios through the use of FCMs simulation.

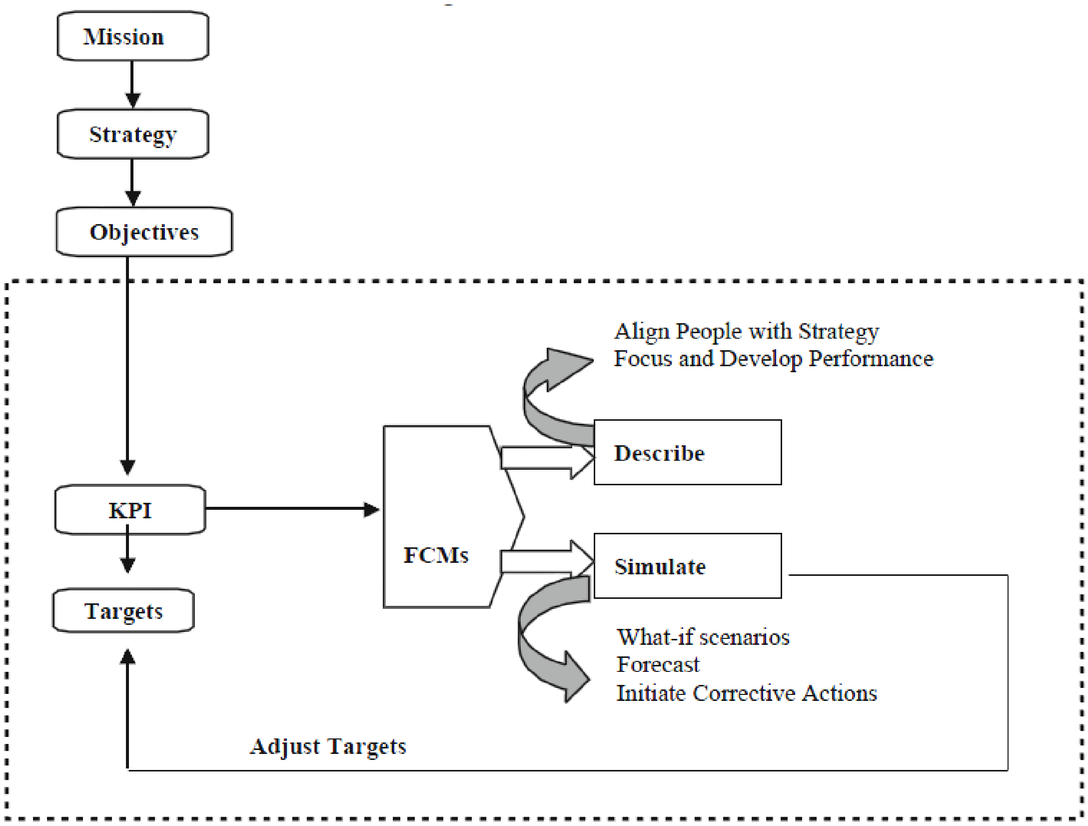


Figure 6.2 The PBSCM (Chytas, Glykas, & Valiris, A proactive balanced scorecard, 2011)

6.6 FCM-Based Decision Modeling

6.6.1 FCM as a Supplement Tool to Achieve Process Efficiency

The PBSCM experiences a progression of stages that include: (1) inputs to be provided, and (2) outcomes (results) to be generated. Business domain experts and/or professionals of Performance Measurement/Balanced Scorecard are people with particular business expertise that contribute towards providing the business knowledge for the PBSCM. The accompanying table indicates the stages of a PBSCM together with the inputs and outcomes of each following stage:

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

Table 6.3 Inputs and Outcomes of the PBSCM

At this point six steps are proposed in order to take place efficient FCM modeling through the Proactive Balanced Scorecard Methodology (PBSCM).

- Step 1: Establishing the Mission, Vision, Strategic Objectives, Perspectives and Critical Success Factors (CSF).
- Step 2: Identify Key Performance Indicators (KPI)
- Step 3: Establish Targets
- Step 4: Define relationships among the identified KPIs
- Step 5: Assign Linguistic Variables to Weights and Concepts (KPIs)
- Step 6: Continuous Improvement

6.7 Using the FCM Modeler Tool

6.7.1 APQC and the Process Classification Framework (PCF)

The American Productivity & Quality Center (APQC) is a non-profit authority which is concentrated on organization transforming giving solutions in organizations in various distinctive business domains such as, benchmarking, process performance improvement, best practices, and knowledge management. APQC has more than 500 member organizations worldwide in all existing industries (APQC, 2017).

The Process Classification Framework (PCF) of APQC (Productivity and Quality with Performance Measures and Metrics), is a list that organizations utilize to characterize and define work processes exhaustively and without redundancies. Past being only a list, the PCF fills in as a tool to support benchmarking, to manage content, and to perform other imperative performance activities. Process Classification Framework (PCF) is a categorization of business processes that enables organizations to equitably track and examine in contrast their performance internally and externally with organizations from any industry. It additionally shapes the basis for an assortment of projects identified with business processes. The PFC makes a typical language by sketching out the majority of the processes practiced by most organizations, classifying them, and aligning them as indicated by a hierarchical numbering framework-system.

The processes and metrics that will be utilized in this particular Case Study come from the Process Classification Framework (PCF) of APQC. More specific, 15 maps are constructed in order to create a successful and comprehensible example for the readers. Each map is also a set of processes that individually affect the final result that will arise after the simulation process.

6.7.2 The Strategic Goal of this Case Study

As mentioned at the beginning of the chapter, the main strategic objective of this Case Study is to monitor the process efficiency of an organization in order to ensure the desirable results for the Staff Productivity metric. Therefore, according to the Process Classification Framework (PCF) mentioned above, all those processes that directly affect productivity are selected. Based on this, we created eight maps each presenting a specific process, which in turn includes other sub-processes and metrics related to Staff Productivity. In the following Figure 6.3 we present these eight maps which correspond to one of the four Balanced Scorecard's Perspectives according to their attributes. At the center of the Figure 6.3 there is the main map of "Staff Productivity" (upper level), also being the Strategic Goal of our case.

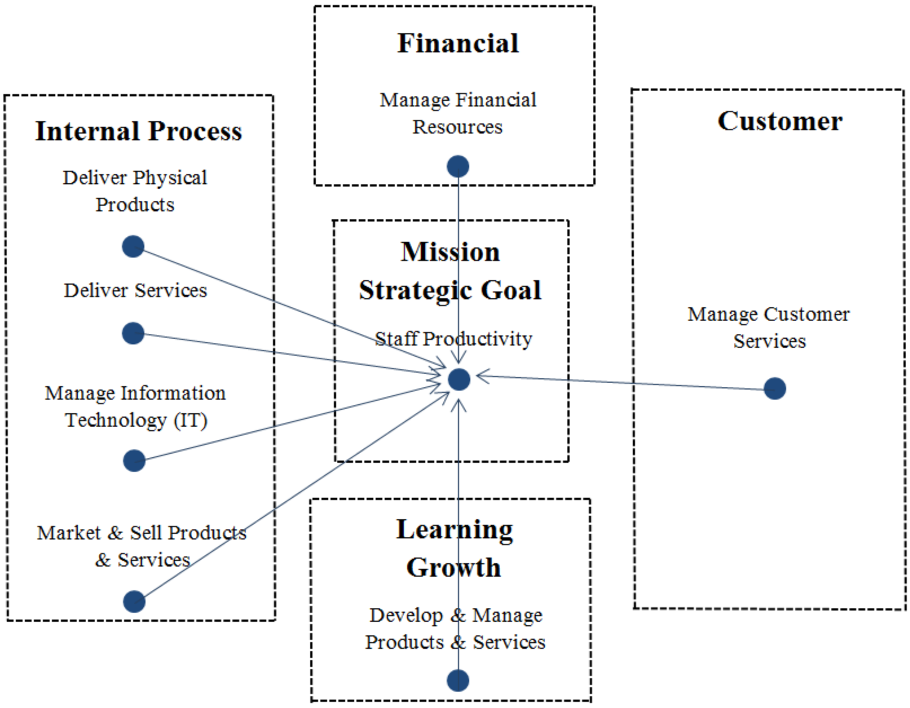


Figure 6.3 Relationships among Case Study's FCMs (Balanced Scorecard Perspectives)

Each of these maps may have a very large number of processes and metrics. This results in the separation of each map into smaller ones that will be lower in hierarchy. This particular process takes a lot of space and time. For this reason, in our case we will analyze how a specific process (map) of the above seven, affects our strategic goal of monitoring the Staff Productivity which is the upper level map of this process-based FCM network. This will make our description more effective and comprehensible to the reader.

More specifically, a scenario consisting of seven maps was created, each separately influencing the "Deliver Physical Products" concept, based on its gravity. This particular concept is one of the other seven concepts mentioned above that directly affects the Staff Productivity metric. The "Deliver Physical Products" map was divided into more maps according to the content of the processes and metrics that they include, in order to generate a hierarchical and dynamic network of interconnected processes and metrics.

Below follows the map design process based on the Proactive Balanced Scorecard methodology (Chytas, Glykas, & Valiris, A proactive balanced scorecard, 2011).

6.7.3 The PBSC Methodology in our Case Study

Having as basic framework, the Proactive Balanced Scorecard Methodology's (PBSCM) six steps for modeling Fuzzy Cognitive Maps (FCMs), we generated the set of skeleton maps for our case, which are based in the "Deliver Physical Products" map.

1. **Establishing the Mission, Vision, Strategic Objectives, Perspectives and CSF:** The basic mission and hypothetical organization's strategy of this Case Study is to monitor the efficiency of particular processes in order to improve the "Staff Productivity" of a company through process changes.
2. **Identify Key Performance Indicators (KPIs):** The particular metrics of this Case Study come from the Process Classification Framework (PCF) which is related with various business domains (Appendix A, Appendix B).
3. **Establish Targets:** The intermediate target of this Case Study is to utilize the FCM Modeler Tool in order to consider the possibility of a change in the efficiency of the "Deliver Physical Products" process if changes are made in various other processes such as the "Plan & Acquire Necessary Resources" process, "Procure Materials & Services" process, "Order Materials & Services" process, etc.
4. **Define relationships among identified KPI:** The relationships among the processes and metrics are determined according to the Process Classification Framework (PCF). This framework provides a detailed description about process categorization.
5. **Assign Linguistic Variables to Weights and Concepts:** The linguistic variables of weights among concepts are defined according to our judgment about the influence of each relationship. The same methodology is followed for the concept's values that are assigned according to concept's measurement (concept values).

6. **Continuous Improvement:** The primary objective of this methodology is to improve the performance of specific processes in order to achieve our strategic goal of measuring Staff Productivity. To achieve this, we must take into account the results that the FCM Modeler Tool will give us and take the appropriate set of improvement actions.

6.7.4 Map Categories

At this point, we should recall the four (4) types of maps using the FCM Modeler Tool (for more details see Chapter 4). The **Business Category** includes all concepts relating to core business activities. Second the **Social Category** includes all human resources related concepts. The **Technical Category** includes all infrastructure related concepts with emphasis on technology infrastructure. Finally the **Integrated Category** includes essentially concepts which fall under more than one of the above three categories, also, top-most concepts.

In this particular example which is related with the "Deliver Physical Products" process, two categories of maps are used, Business and Integrated Categories:

- **Business Category**
  - **Record Receipt of Goods:** This type of map includes Full Time Equivalent (FTE) metrics per Million Barrel of Oil Equivalent (BOE), per Thousand Gross Operated Producing Wells etc.
  - **Order Materials & Services:** This type of map includes indicators which are related with purchase information.
  - **Procure Materials & Services:** This type of map includes dollar metrics and indicators which are related with active suppliers.
  - **Plan & Acquire Necessary Resources:** This type of map includes FTEs and dollar metrics.
  - **Produce/Manufacture/Deliver Products:** This type of map includes dollar metrics and metrics based on percentages.
  - **Manage Logistics & Warehousing:** This type of map includes metrics which have to do with sales information.
- **Integrated Category**
  - **Deliver Physical Products:** This type of map includes all of the previous indicators which are integrated in it.

6.7.5 Hierarchies

As have been mentioned in previous chapters, this tool provides its user, many map design choices. One of these is the creation of Hierarchy among different types of maps. Map Hierarchy utilization, is vital in our example in order to examine the particular concepts which may be decomposed further to conform with specialized analysis of a specific process measurement. The hierarchical decomposition of concepts develops a set of dynamically interconnected hierarchical maps. In the following Figure 6.4, the final hierarchical map of our example is presented. It consists of seven maps which include specific processes that are categorized according to the Process Classification Framework (PCF) of APQC research team.

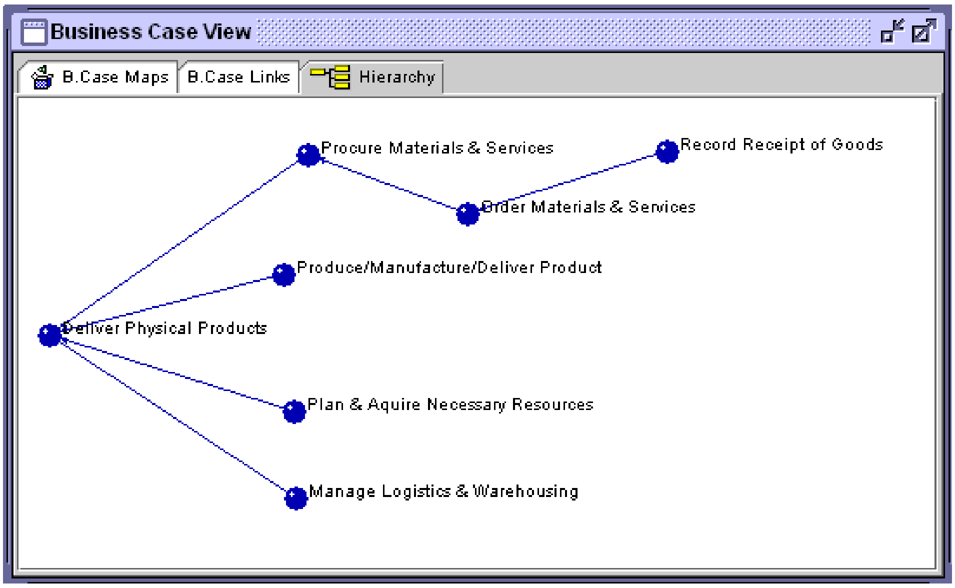


Figure 6.4 Map Hierarchy

6.7.6 Map Linking and Decomposition

At this point the node linking process of maps is presented in detailed and the function of the used Algorithm will be examined in Figure 6.5.

Consider now maps “Deliver Physical Products” and “Plan & Acquire Necessary Resources” (to be presented fully in Appendix A). Linking a concept, which is defined into two maps, generates a hierarchy. Figure 6.5 presents the system interface for the generation of the hierarchical relationship between maps “Deliver Physical Products” and “Plan & Acquire Necessary Resources”. The “Deliver Physical Products” map decomposes further concept “Procure Materials & Services” by using this concept as the link to map “Plan & Acquire Necessary Resources”

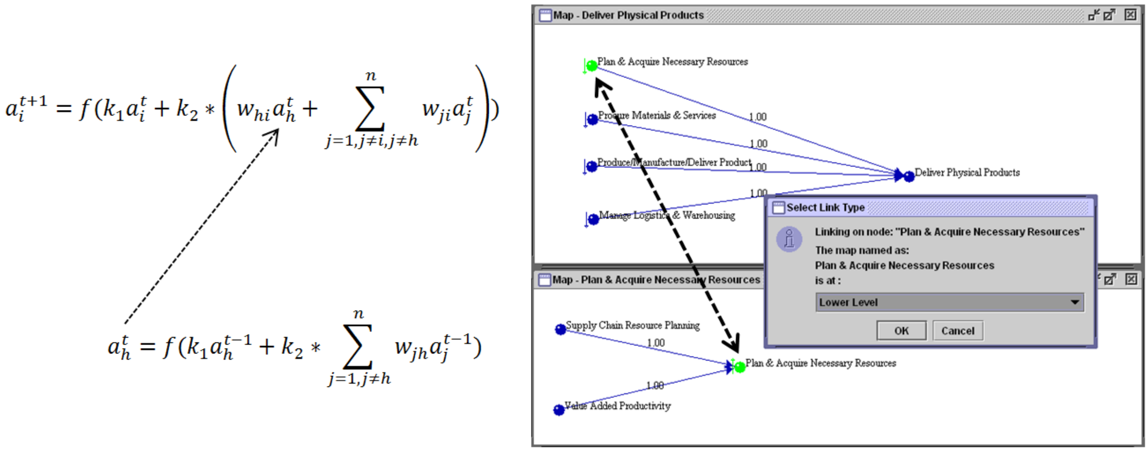


Figure 6.5 The interconnection mechanism

Figure 6.5 also presents how Algorithm is decomposed to integrate hierarchical connections. The proposed framework can portray the process modeling following either a holistic or a scalable approach. This is analogous to seeing a company or an organization either as a single main event or as an ongoing activity of setting successive financial/operational targets to selected company/organization processes. This specific proposed mechanism can adapt both approaches. Essentially, the implementation can decompose operational concepts to their component parts (sub-concepts) on demand and let the user reason about lower level hierarchies. The proposed mechanism likewise allows the user identify the level-degree of FCM decomposition during the map traversal Figure 6.6**.** Rather than waiting for a lower level FCM to traverse its nodes/concepts and pass its value to higher level map hierarchies, the user may assign directly an external value to nodes-concepts which link hierarchies. Practically, the simulation is completed as if there are no links with other maps.

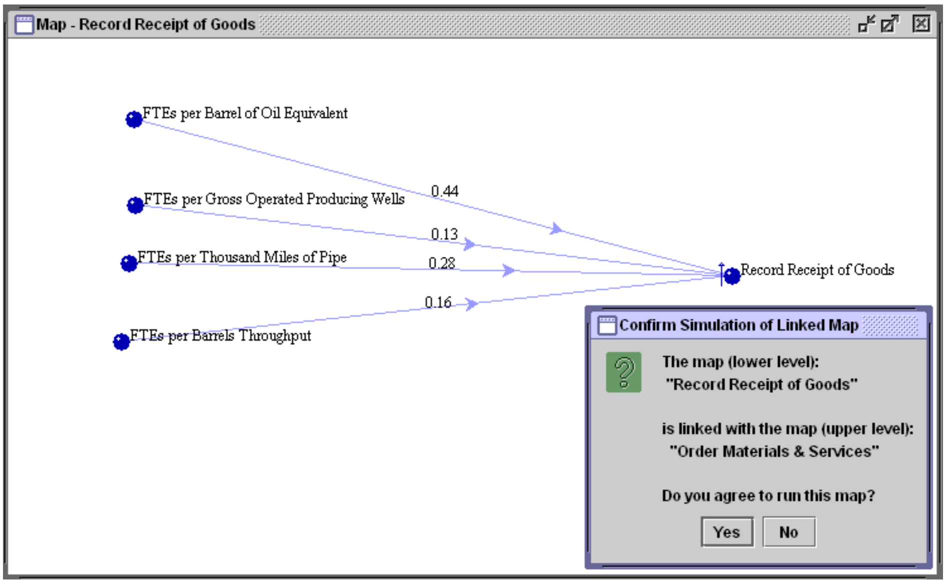


Figure 6.6 User-defined map decomposition

The following table summarized the available variations of the proposed FCM algorithm, which encode the dynamic map decomposition and the user-defined decomposition bound.

Map decomposition	FCM algorithm hierarchical calculations	
	Higher Level hierarchy	Lower Level Hierarchy
Unrestricted	$a_i^{t+1} = f(k_1 a_i^t + k_2 * \left(w_{hi} a_h^t + \sum_{j=1, j\neq i, j\neq h}^{n} w_{ji} a_j^t\right))$	$a_h^t = f(k_1 a_h^{t-1} + k_2 * \sum_{j=1, j\neq h}^{n} w_{jh} a_j^{t-1})$
User Defined, no external value assigned	$a_i^{t+1} = f(k_1 a_i^t + k_2 * \left(w_{hi} a_h^t + \sum_{j=1, j\neq i, j\neq h}^{n} w_{ji} a_j^t\right))$	$a_h^t = f(k_1 a_h^{t-1})$
User-defined, external value assigned	$a_i^{t+1} = f(k_1 a_i^t + k_2 * \left(w_{hi} a_h^t + \sum_{j=1, j\neq i, j\neq h}^{n} w_{ji} a_j^t\right))$	$a_h^t \in [-1, .., 1]$

Table 6.4 The variations of the proposed algorithm (Xirogiannis, Glykas, & Staikouras, Fuzzy Cognitive Maps in Banking Business Process Performance Measurement, 2010)

Also the current implementation allows easy customization of the function f and easy re-configuration of the formula A_i^{t+1} to adapt to the particular characteristics and particularities of individual enterprises. Additionally, generation of scenarios for the same skeleton FCM is achieved. Lastly, the user can accomplish automatic loop simulation until a user-defined equilibrium point has been reached. Alternately, step-by-step simulation (with graphical output of partial results) is also attainable to provide a justification for the partial results.

6.8 Experiments and Results

Experiments were conducted by utilizing metrics and process planning scenarios from a hypothetical company, operating in various business domains. The basic objective of this company is to monitor the process efficiency in order to ensure the desirable results for the Staff Productivity metric.

More specifically, in our case we will study the "Deliver Physical Products" node (map) which was divided into lower hierarchy maps (processes) based on the content of the processes it contains.

Based on our objective of measuring the impact of specific events on our basic process (Deliver Physical Products), we will select specific nodes (processes/metrics) in order to increase their influence through assigning external input values to these particular nodes. More specifically the following table presents in detail the change actions, and the external input value that will take each node for the first case.

Change Action	**Associated Node**	**Kind of Node**	**External Input**
Increase Record of Receipt Goods	Record Receipt of Goods	Process	0,57
Increase Order Materials & Services	Order Materials & Services	Process	0,35
Increase Procure Materials & Services	Procure Materials & Services	Metric (FTEs)	0,57
Increase Total Purchase Value	Total Purchase Value	Metric (Dollars)	0,34
Increase Supply Chain Resource Planning	Supply Chain Resource Planning	Metric (FTEs)	0,85
Increase Value Added Productivity	Value Added Productivity	Metric (Dollars)	0,67
Increase Manage Logistics & Warehousing	Manage Logistics & Warehousing	Process	0,87
Increase Operate Warehousing	Operate Warehousing	Process	0,75

Table 6.5 External Inputs (First Case)

Objective Node	Current Value Before External Inputs	Current Value After External Inputs	Rate of Increase/Decrease
Deliver Physical Products	0.993002 (positively very-very high)	0.993034 (positively very-very high)	**+ 0.0022%**

Table 6.6 Concept Value Changes (First Case)

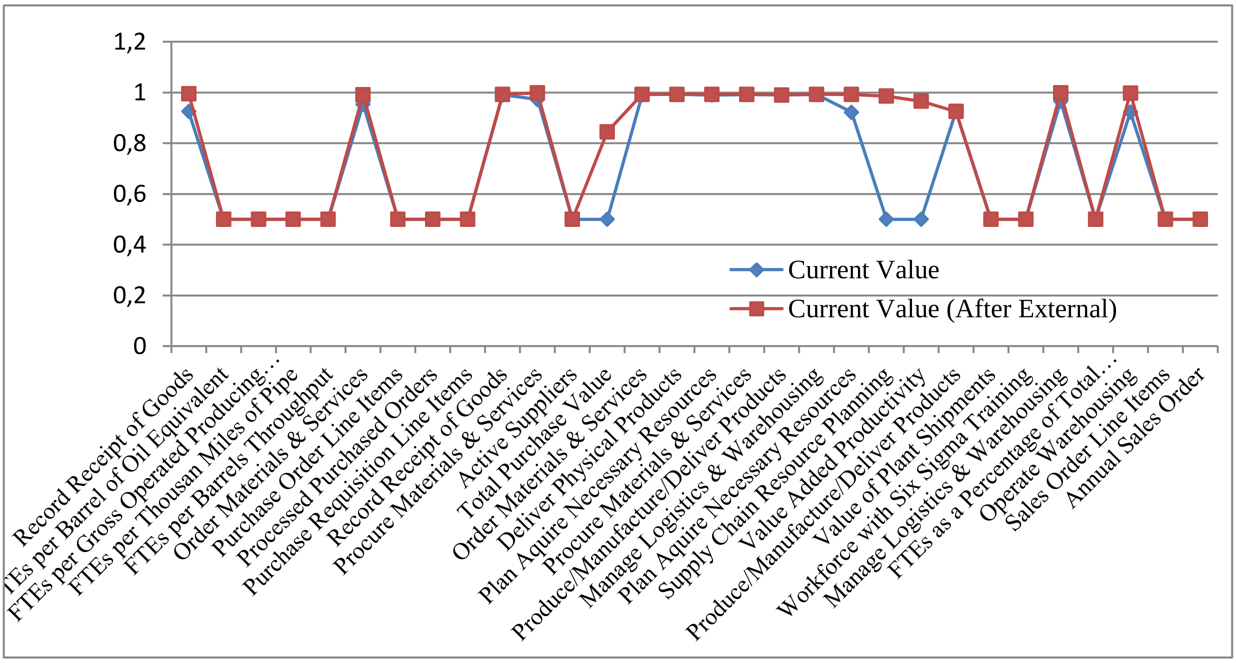


Figure 6.7 Processes Performance (1st Case)

As we can see (Figure 6.7) from the changes we have made to the efficiency of specific processes and metrics, almost all of them will remain virtually unchanged in terms of their efficiency. However, these eight interventions we have made will have more impact on: “Total Purchase Value” metric which increases by 34.55%, “Plan & Acquire Necessary Resources” process which increases 6.95%, “Supply Chain Resource Planning” metric which increases 48.59% and “Value Added Productivity” which increases 46.61%.

At this point we will add some additional external inputs in various concepts (nodes) to examine the reaction of the objective concept value “Deliver Physical Products” after these changes. Note that in this second case we calculate the simulation results that derived from the additional external input values as well as the external input values of the first case we examined earlier. The additional external input values are displayed in the following table with blue light color.

Change Action	Associated Node	Kind of Node	External Input
Increase Record Receipt of Goods	Record Receipt of Goods	Process	0,57
Increase FTEs per Barrel of Oil Equivalent	FTEs per Barrel of Oil Equivalent	Metric (FTEs)	0,8
Increase Order Materials & Services	Order Materials & Services	Process	0,35
Increase Processed Purchased Orders	Processed Purchased Orders	Metric (Purchase Orders)	0,32
Increase Procure Materials & Services	Procure Materials & Services	Process	0,57
Increase Active Suppliers	Active Suppliers	Metric (Active Suppliers)	0,54
Increase Total Purchase Value	Total Purchase Value	Metric (Dollars)	0,34
Increase Plan Acquire Necessary Resources	Plan Acquire Necessary Resources	Process	0,71
Increase Supply Chain Resource Planning	Supply Chain Resource Planning	Metric (FTEs)	0,85
Increase Value Added Productivity	Value Added Productivity	Metric (Dollars)	0,67
Increase Produce/Manufacture/Deliver Products	Produce/Manufacture/Deliver Products	Process	0,48
Increase Workforce with Six Sigma Training	Workforce with Six Sigma Training	Metric (Percent)	0,37
Increase Manage Logistics & Warehousing	Manage Logistics & Warehousing	Process	0,87
Increase Operate Warehousing	Operate Warehousing	Process	0,75
Increase Annual Sales Order	Annual Sales Order	Dollars	0,28

Table 6.7 External Inputs (Second Case)

Objective Node	Current Value Before External Inputs	Current Value After External Inputs	Rate of Increase/Decrease
Deliver Physical Products	0.993002 (positively very-very high)	0.993073 (positively very-very high)	+ 0.0071%

Table 6.8 Concept Value Changes (Second Case)

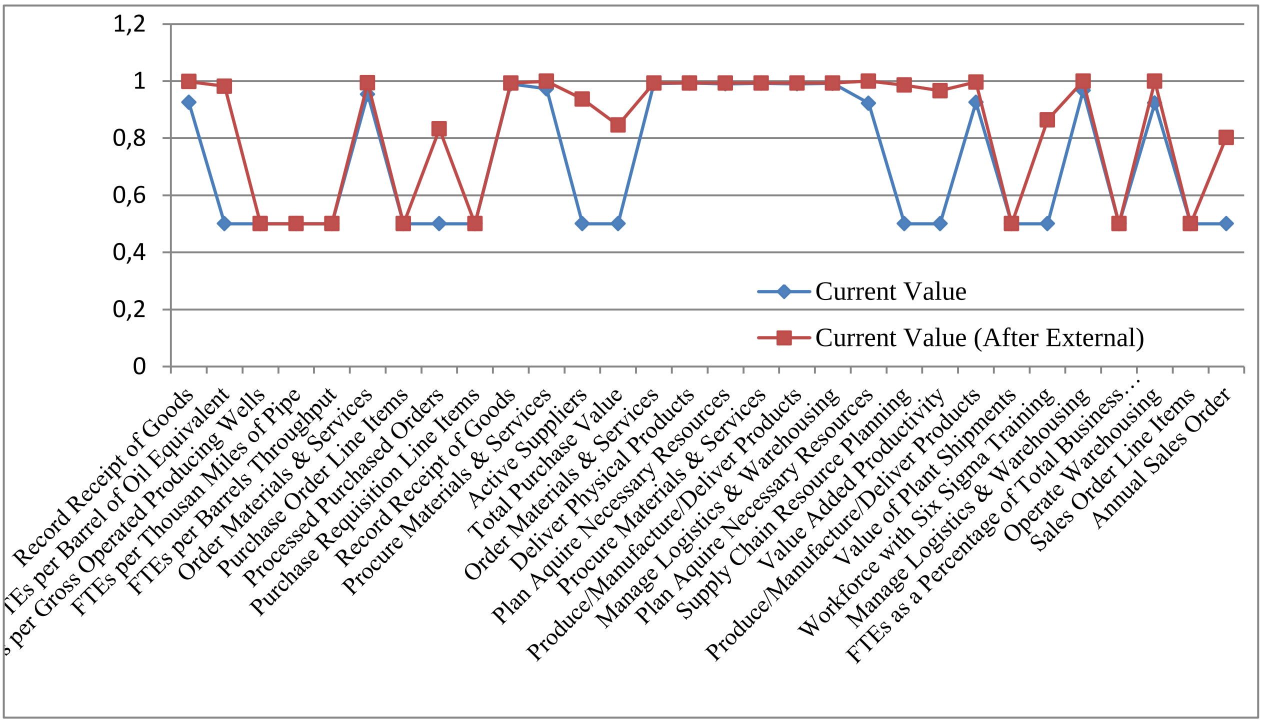


Figure 6.8 Processes Performance (2nd Case)

Based on the second graph, we notice that the seven additional external inputs had a greater impact on the following new concepts: “FTEs per Barrel of Oil Equivalent” which increases 48.20%, “Processed Purchased Orders” which increases 33.20%, “Active Suppliers” metric which increases 43.7%, “Workforce with Six Sigma Training” which increases 36.41% and “Annual Sales Orders” which increases 30.21%.

Obviously, adding more prices to different processes will result in an increase in terms of the process efficiency of our objective node. But our specific goal is to investigate the rate of increase of our target concept and then the system’s response to these particular changes. The above interventions resulted in an increase in our “intermediate” strategic node “Deliver Physical Products” by 0.0049% compared with the previous state. The strong influence of the external inputs from the previous two cases, are also best illustrated in the comparative graph below.

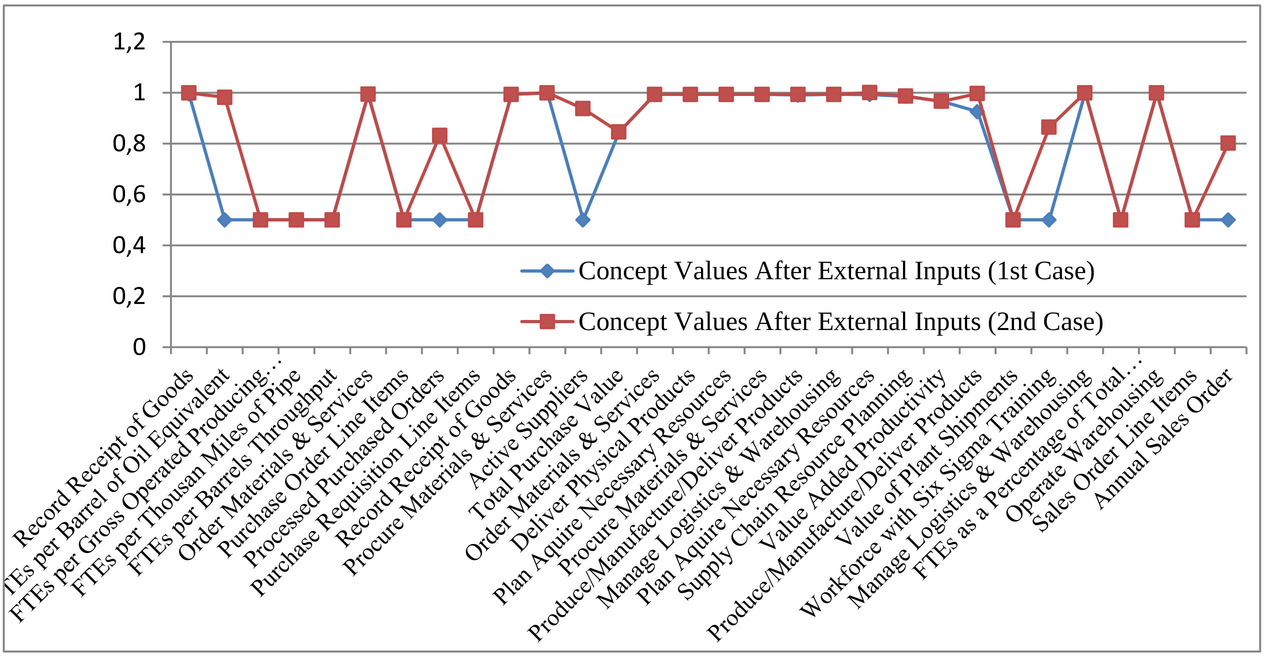


Figure 6.9 Processes Performance (Combination of Two Cases)

It is obvious that, therefore, that the changes occurring in performance of various nodes (processes or metrics), affect in a different way each of the process/metric of the network.

As far as our strategic goal (Deliver Physical Products) is concerned, we observe from the simulation results that the specific interventions in the efficiency of these processes/metrics resulted in an increase of 0.0049%.

The sample calculations above indicate that the user of FCM Modeler Tool has the ability to increase a process performance based on the increase or reduction of various nodes (concepts) values. They can choose objective processes/metrics (concepts) in order to see the rate of influence that they have in other target concepts.

Following the same methodology, we are gradually ascending to the upper level of the map hierarchy where the main objective concept of Staff Productivity is placed. We must not ignore that the choice of all processes and metrics that make up all maps of this Case Study, are chosen based on Staff Productivity metric. We recall that this particular second hypothetical simulation scenario consists of eight maps which are the following: “Staff Productivity” (upper level map) which is our target map and the main part of our strategic goal, “Develop & Manage Products & Services”, “Market & Sell Products & Services”, “Deliver Physical Products”, “Deliver Services”, “Manage Customer Service”, “Manage Information Technology”, “Manage Financial

Resources”. In order to familiarize space and time, these eight completed maps are in the Appendix B and not all of the lower hierarchy maps that make up each of them.

6.9 Benefits Arising from FCM Modeler Tool utilization

Undeniably FCM Modeler Tool is an innovative modeling method for decision based problems. It suggests a qualitative approach to strategic-level operating planning, which limits the utilization of crisp arithmetic values while offering sufficient trend-based decision support. Additionally, the utilization of the fuzzy linguistic variables expands the understanding of concept/weight significance without compromising considerably their arithmetic interpretation. In this manner, the proposed trend-based decision support tool may suit better in strategic-level exercises, which ask for less numerical examinations and more qualitative answers. This mechanism gives reasonably great approximations of the impact of various strategic change activities to the process based model. This specific mechanism tends to under estimate somewhat the impact of strategic changes to financial concepts (metrics) which have various complex constituent sub-concepts or concepts, which have several hierarchical dependencies. At the point when various complex financial performance factors are involved, it might be safer to assume a conservative financial improvement scenario like this specific mechanism. The hierarchical (or partial) traversal of operational metrics improved the circulated monitoring of strategic change activities throughout different hierarchical levels of the organization and then stipulated targeted communication of the associated operational or financial status.

7 Conclusions

7.1 Limitations

The main restriction we faced during working on the thesis was time. We only had 9 months to conduct a thorough research and update the FCM Modeler Tool we used in this work to work properly.

The user interface of the tool does not have the automations corresponding newer tools have. This has resulted in a difficulty in assigning prices to the concepts and weights of the maps. However, the tool works normally and provides all the desired results by its user.

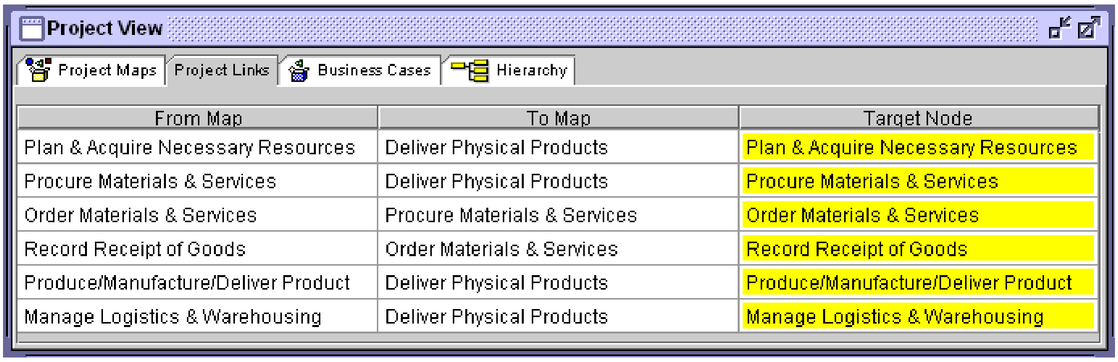
Also, the case study was carried out on actual processes and metrics, but it was not applied in a real organization context that would make sure that the example would be absolutely realistic.

7.2 Future Work

Future Work that could be implemented involves using the program on processes and metrics in an existing organization. This will make the tool more popular for forecasting and measuring business performance.

Future Work also focuses on improving the FCM Modeler Tool, in particular its user interface and its compatibility with newer computer software. Automating it and redesigning its software will make the tool more user-friendly and will, therefore, greatly facilitate its implementation in both the professional and the educational sectors.

Appendix A



From Map	To Map	Target Node
Plan & Acquire Necessary Resources	Deliver Physical Products	Plan & Acquire Necessary Resources
Procure Materials & Services	Deliver Physical Products	Procure Materials & Services
Order Materials & Services	Procure Materials & Services	Order Materials & Services
Record Receipt of Goods	Order Materials & Services	Record Receipt of Goods
Produce/Manufacture/Deliver Product	Deliver Physical Products	Produce/Manufacture/Deliver Product
Manage Logistics & Warehousing	Deliver Physical Products	Manage Logistics & Warehousing

Figure A.1 Deliver Physical Products Map Links

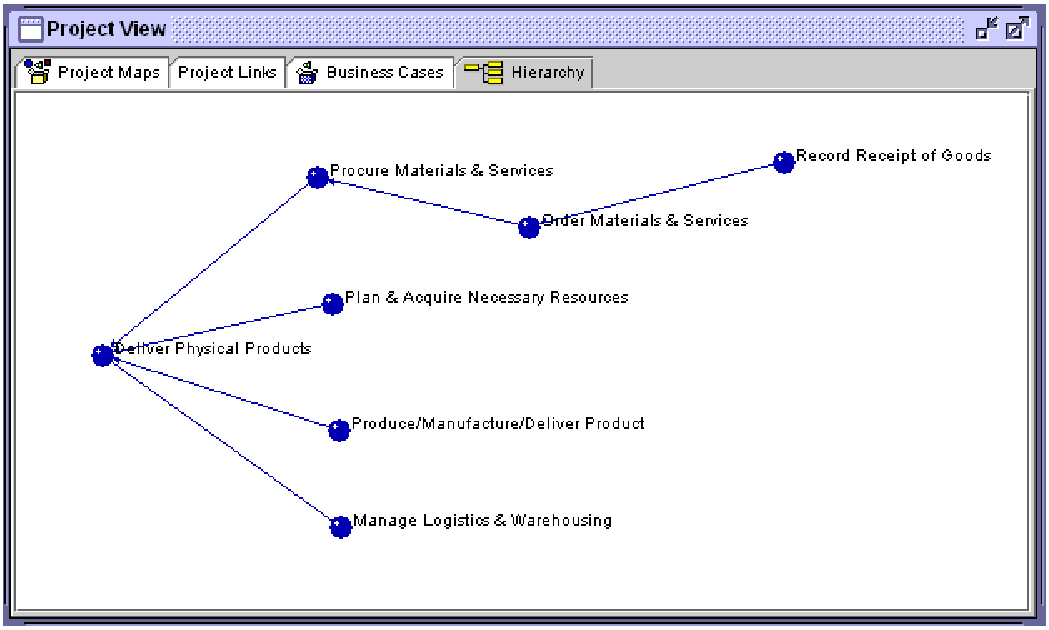


Figure A.2 Deliver Physical Products Hierarchy

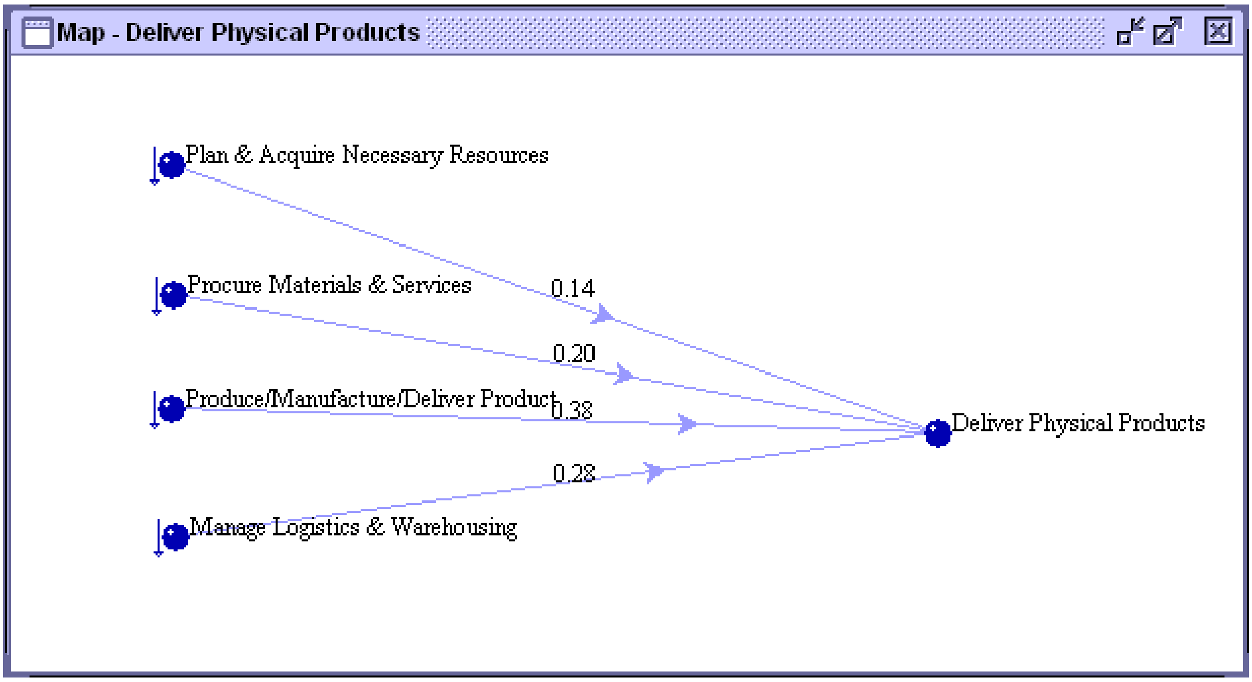


Figure A.3 Deliver Physical Products Map

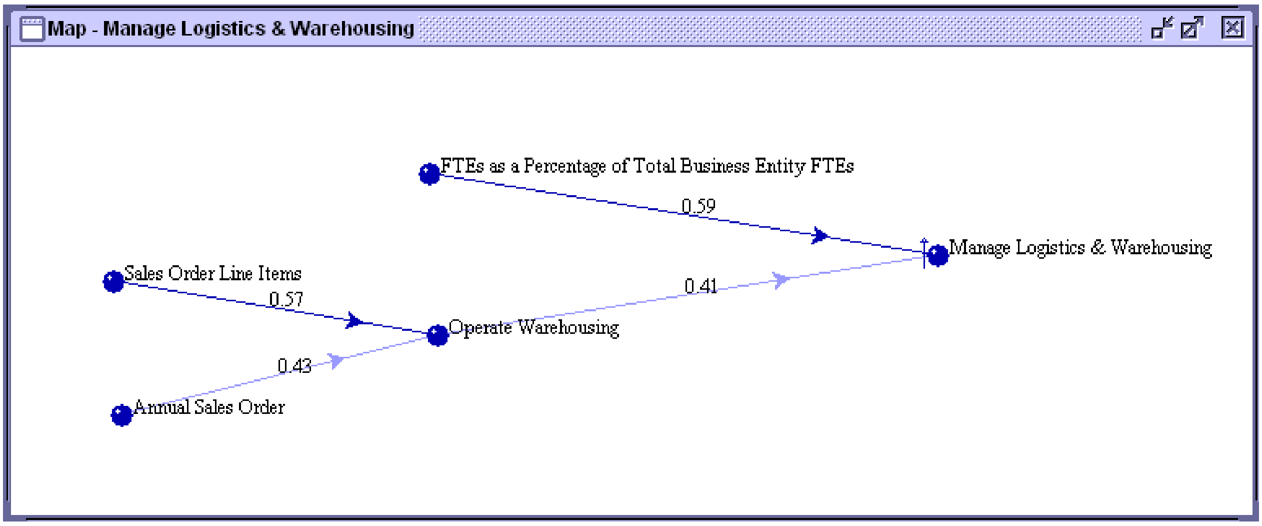


Figure A.4 Manage Logistics & Warehousing Map

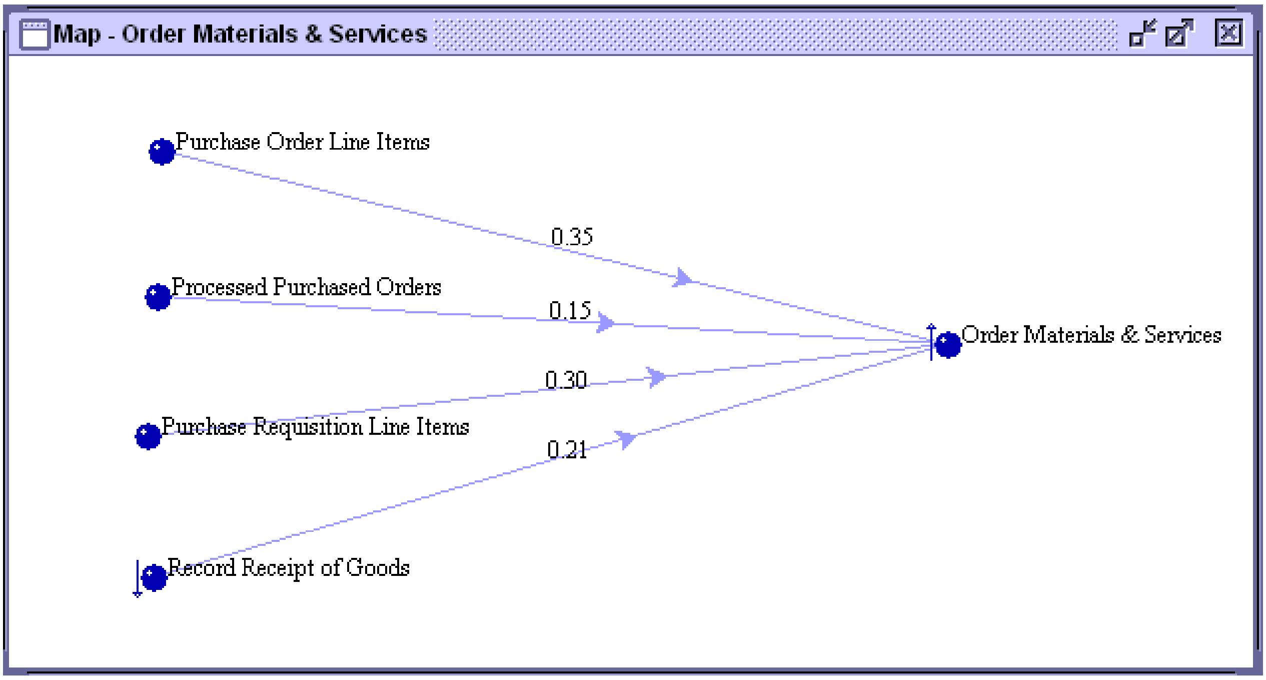


Figure A.5 Order Materials & Services Map

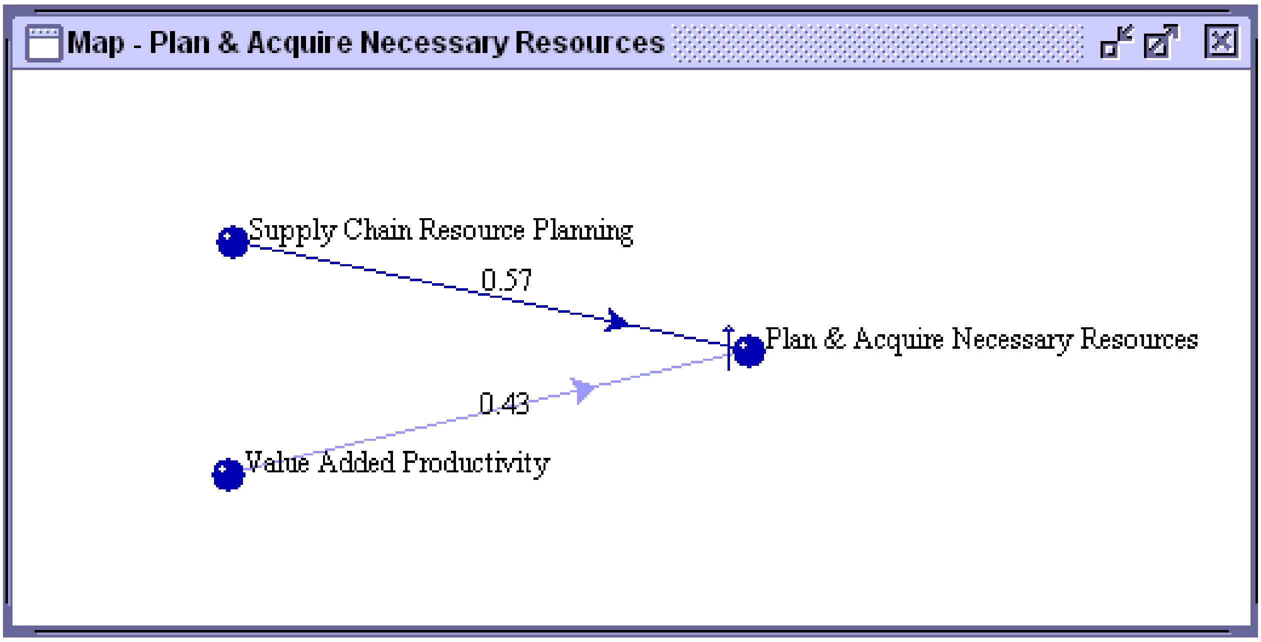


Figure A.6 Plan & Acquire Necessary Resources Map

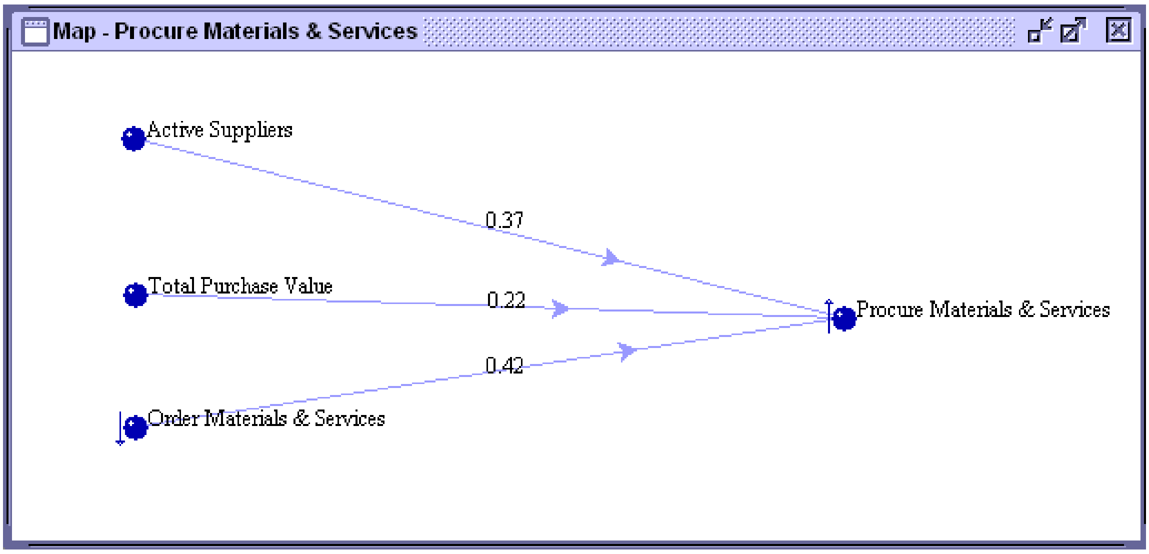


Figure A.7 Procure Materials Map

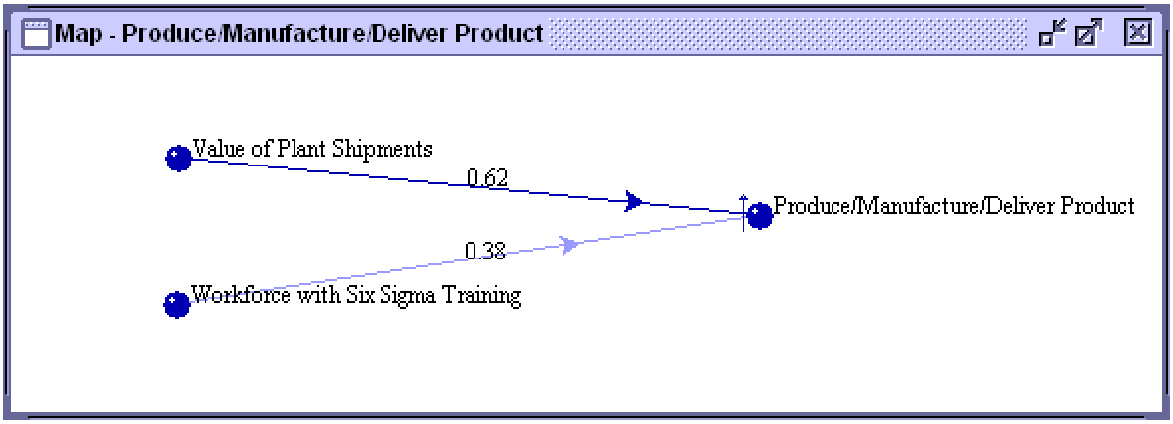


Figure A.8 Produce/Manufacture/Deliver Map

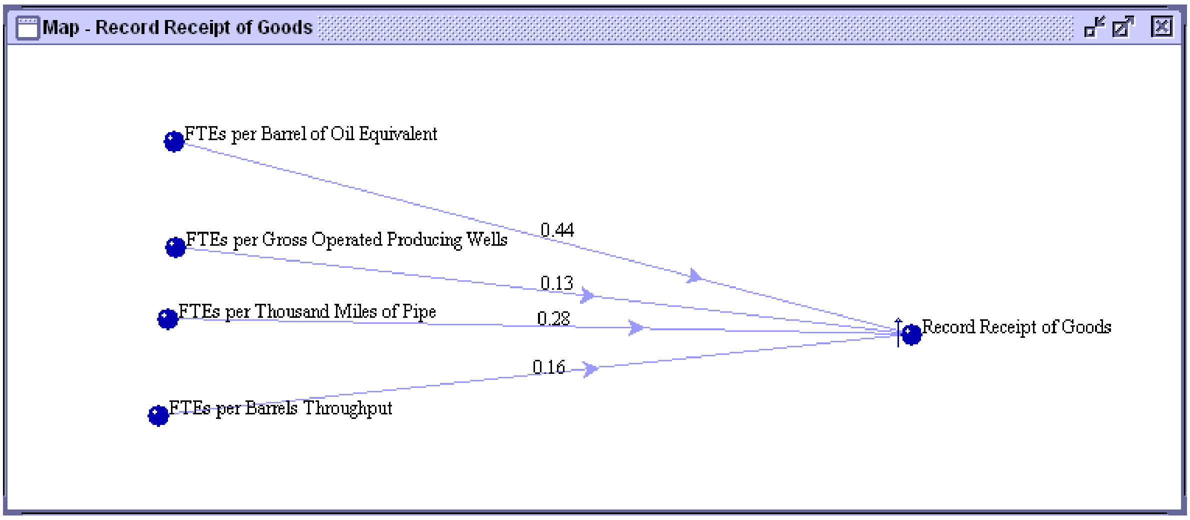
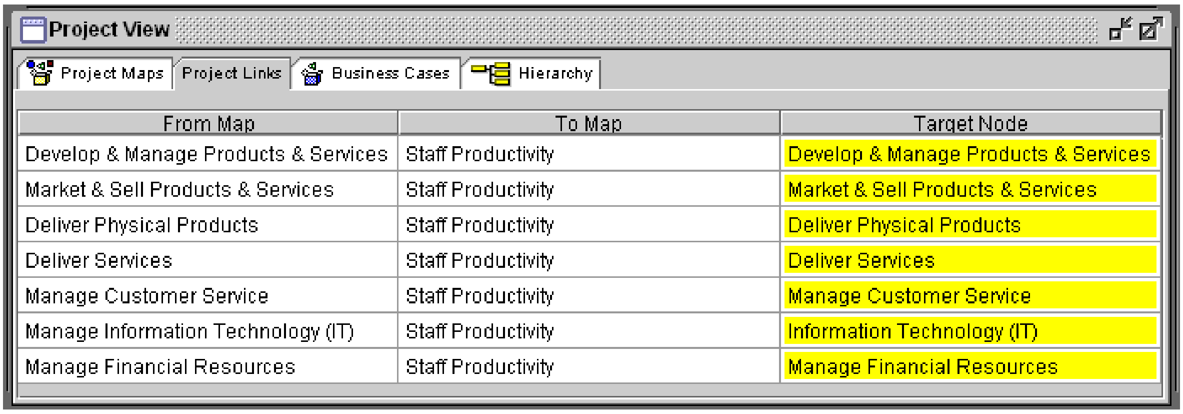


Figure A.9 Record Receipt of Goods Map

Appendix B



From Map	To Map	Target Node
Develop & Manage Products & Services	Staff Productivity	Develop & Manage Products & Services
Market & Sell Products & Services	Staff Productivity	Market & Sell Products & Services
Deliver Physical Products	Staff Productivity	Deliver Physical Products
Deliver Services	Staff Productivity	Deliver Services
Manage Customer Service	Staff Productivity	Manage Customer Service
Manage Information Technology (IT)	Staff Productivity	Information Technology (IT)
Manage Financial Resources	Staff Productivity	Manage Financial Resources

Figure B.1 Staff Productivity Map Links

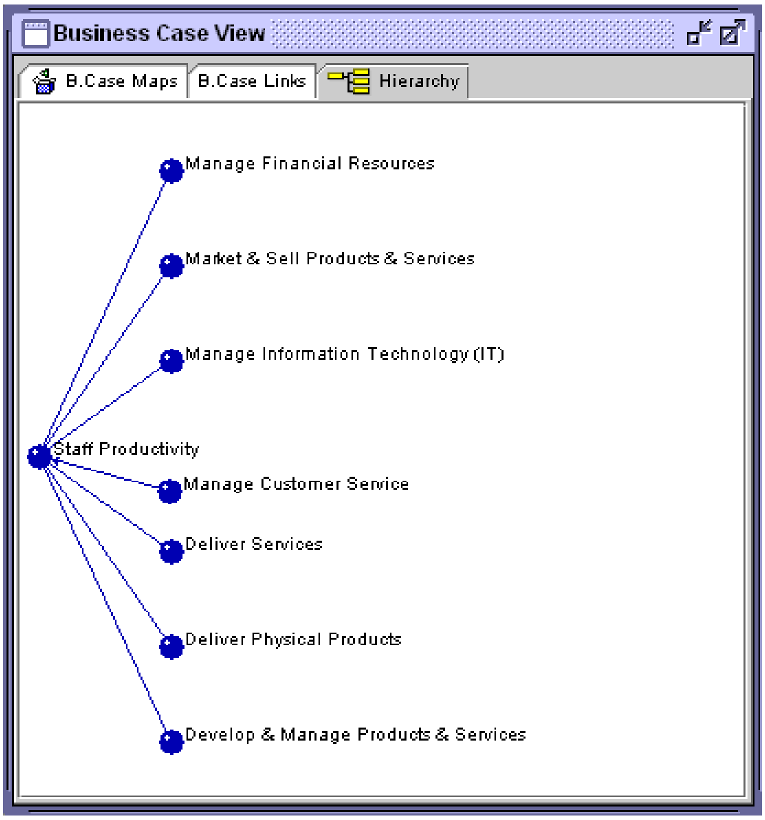


Figure B.2 Staff Productivity Hierarchy

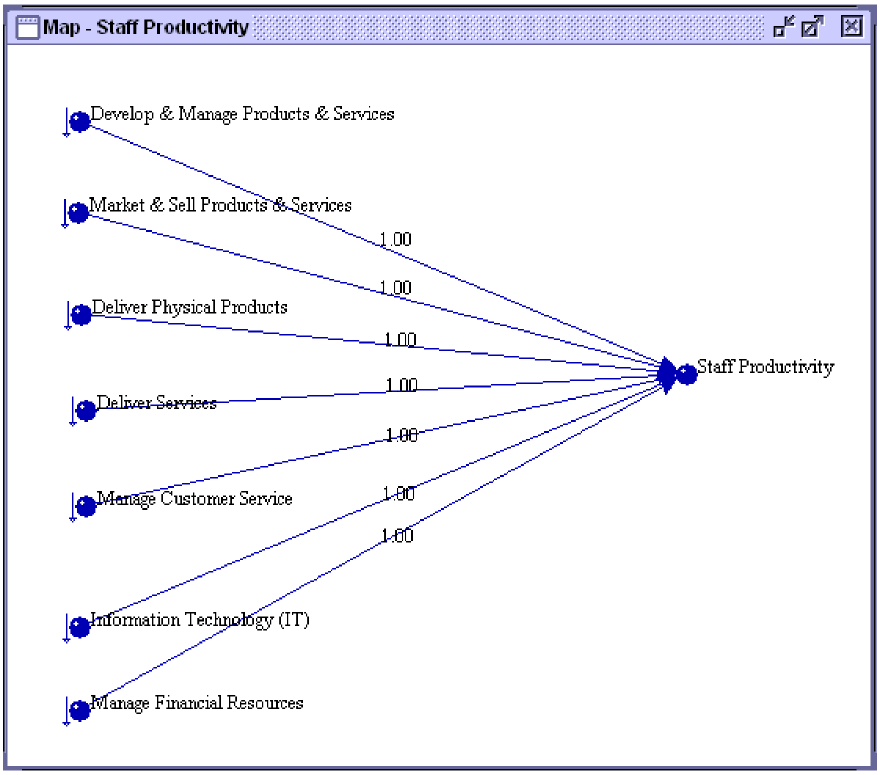


Figure B.3 Staff Productivity Map

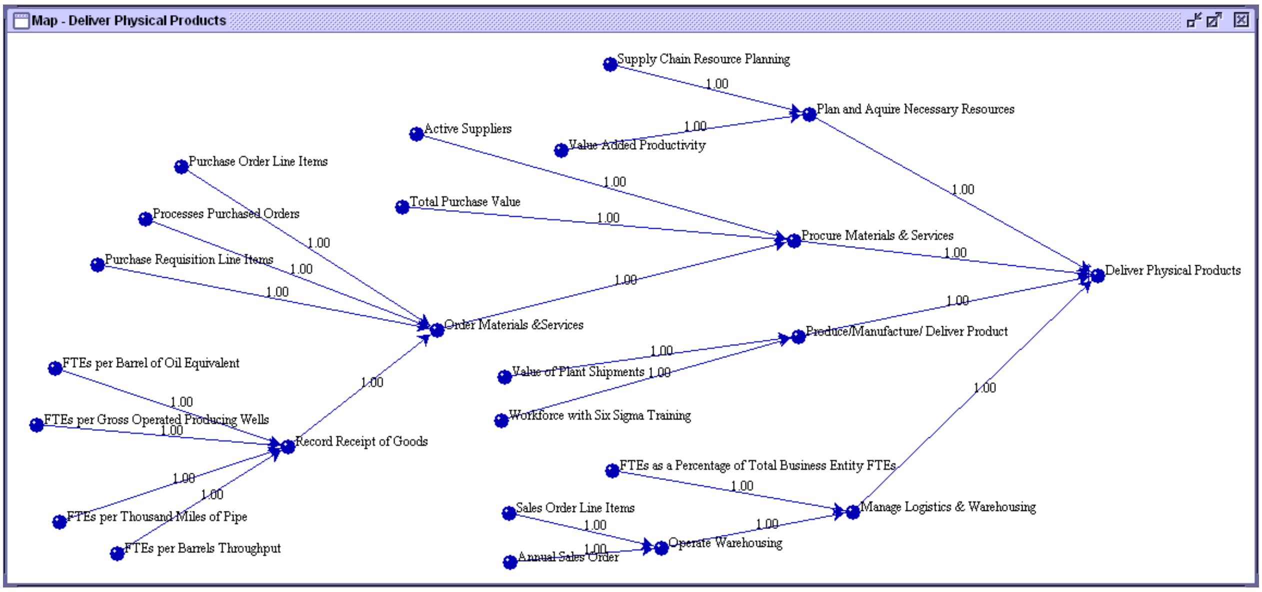


Figure B.4 Deliver Physical Products Map

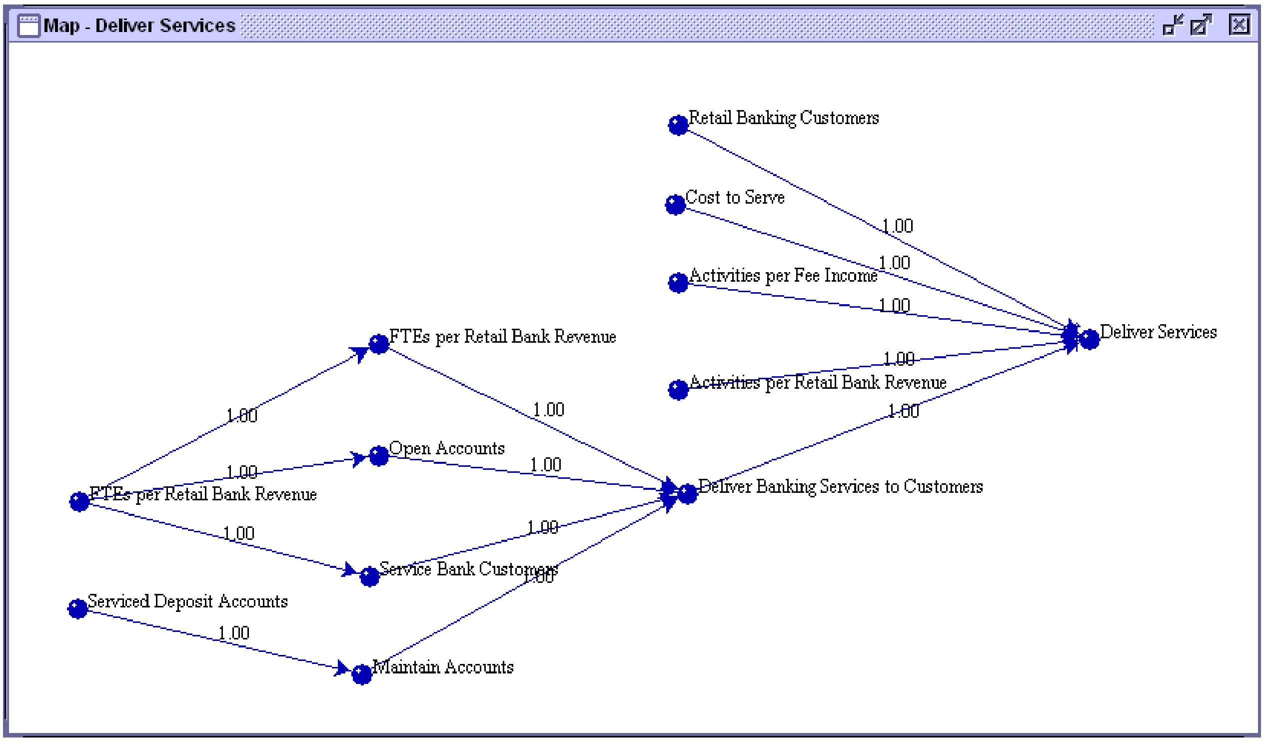


Figure B.5 Deliver Services Map

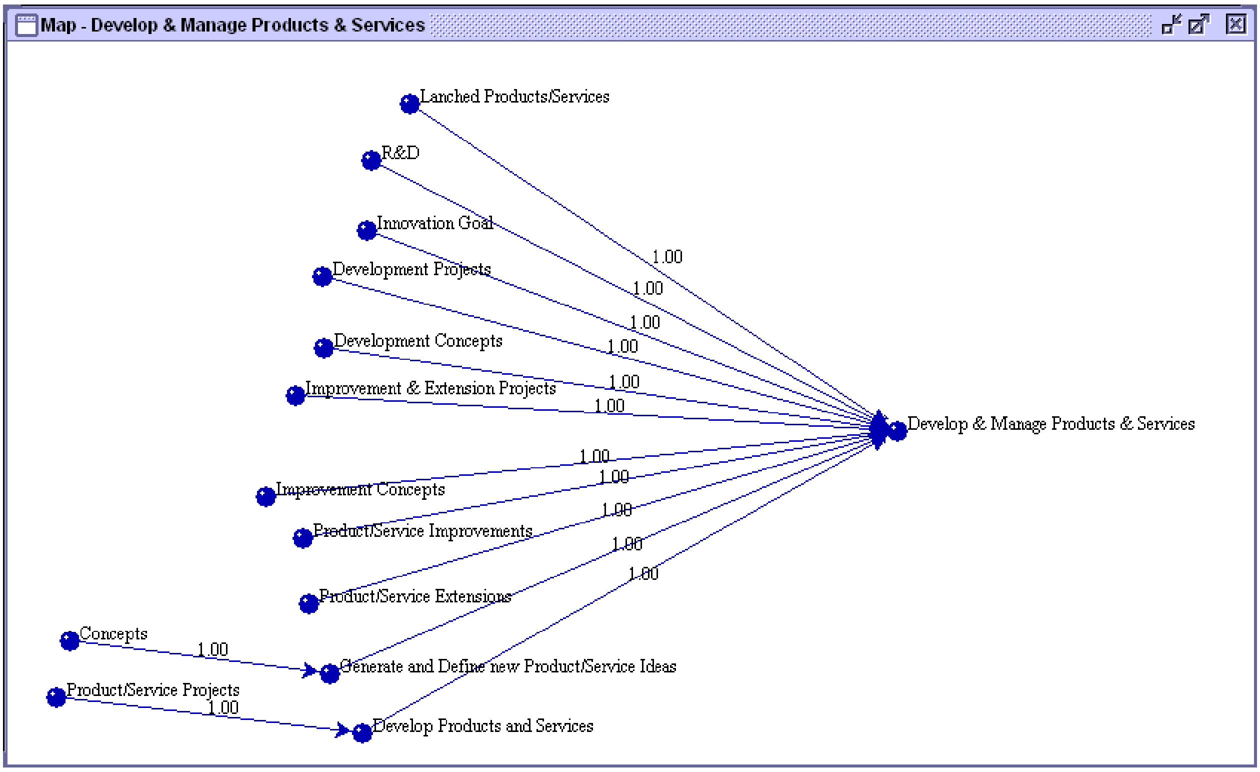


Figure B.6 Develop & Manage Products & Services Map

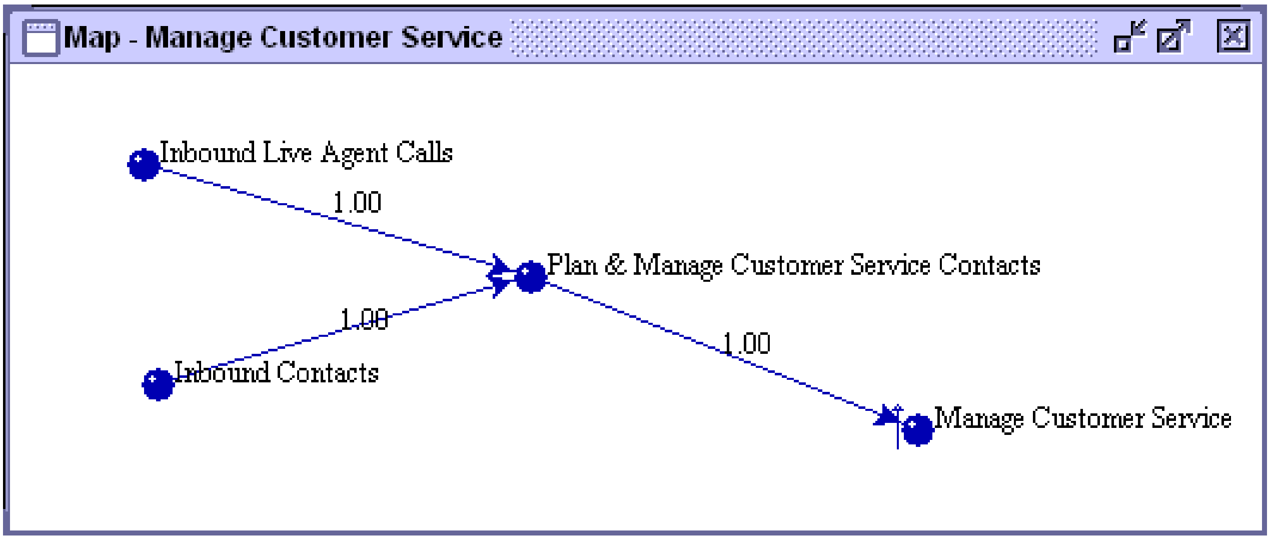


Figure B.7 Manage Customer Service Map

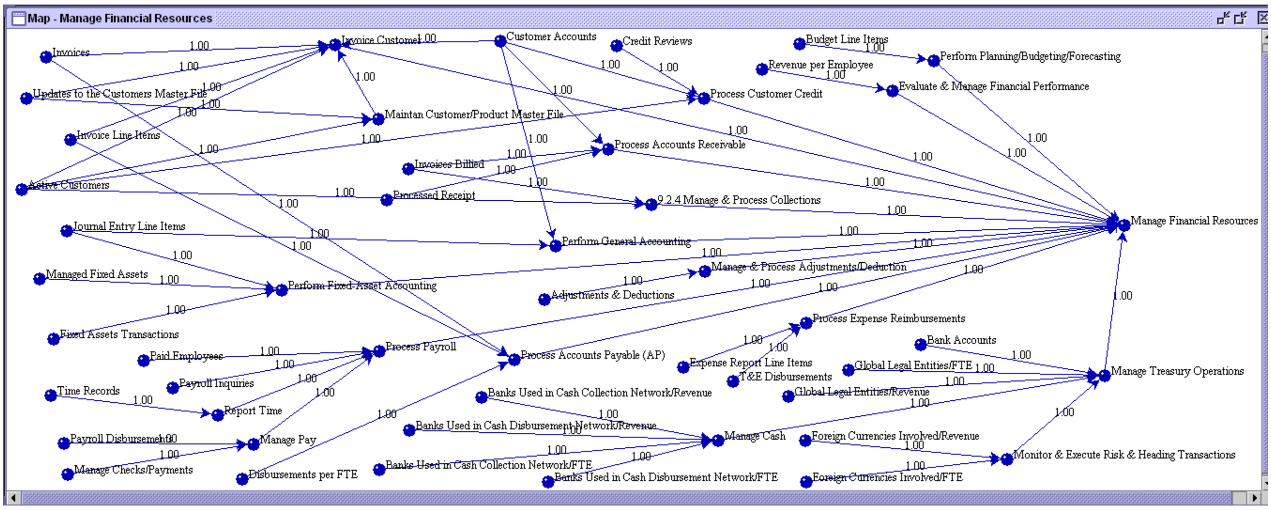


Figure B.8 Manage Financial Resources Map

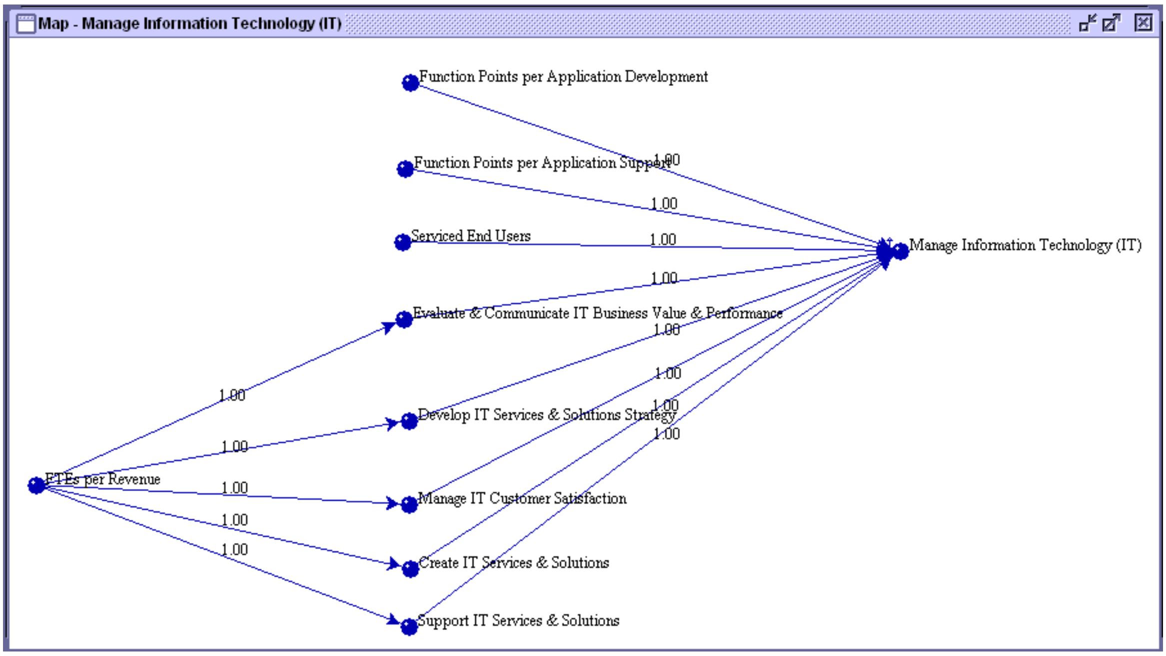


Figure B.9 Manage Information Technology (IT) Map

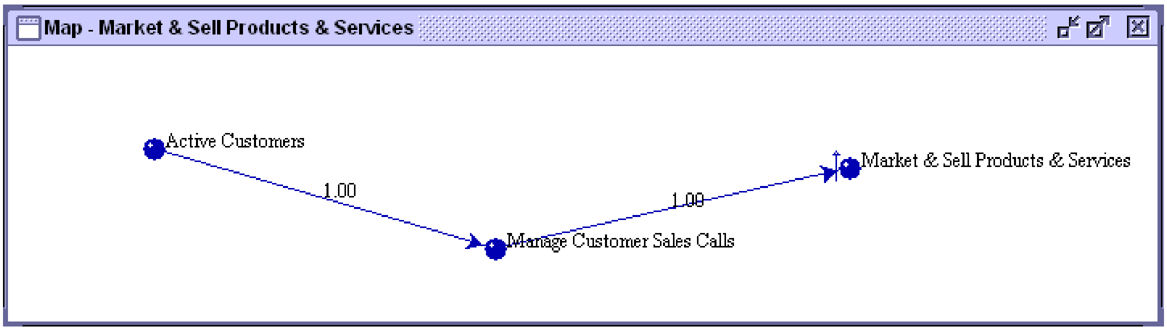


Figure B.10 Market & Sell Products & Services Map

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