Governance Knowledge Management and Decision Support Using Fuzzy Governance Maps

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Abstract. Business process management systems incorporate the possibility of monitoring the behaviour of a company, by observing their business process indicators. Depending on the process executed, and the order of their performances, certain KPIs can be modified to render the company more competitive. This paper proposes the creation of a model-based fuzzy logic that can represent the relation between KPIs and the business processes of the companies. The use of this graph enables business experts to simulate the evolution of the business according to the decisions taken in the governance process, thereby helping in governance activities.

Keywords: Governance · Business process · Decisions · Fuzzy logic · Modelling knowledge

1 Introduction

The IT Governance Institute (2001) defines enterprise governance as the "set of responsibilities and practices exercised by the Board and Executive management Team (BET) with the goal of providing strategic direction, ensuring that objectives are achieved, ascertaining that risks are managed appropriately and verifying that the enterprise's resources are used responsibly" [1].

At management level, the BET must make decisions in order to maintain and follow the agreed business strategy, thus the right direction. The BET members that make the decisions at a specific moment must take into account the available knowledge concerning the current business processes. Performing the decision-making process implies analysing a great quantity of knowledge represented across a wide set of variables. The use of these variables in the decision-making process will improve the competitiveness of the company, which is determined by the correctness of the decided actions. The attainment of the proposed

objectives in an organisation therefore implies three main activities: observing the current and heterogeneous information used and produced as process indicators in the processes of the companies; ascertaining the activities or processes that can be performed to improve the observed indicators; and making the best decision according to both aspects. Framed within this scenario, we propose a methodology to model business BET knowledge, by using fuzzy logic. Our proposal facilitates a mechanism to achieve the predicted business evolution after the execution of a set of actions. The obtained predictions help the BET make better reasoned decisions, since the team are aware of how these decisions will affect the business.

In process orientation, business processes are the main instrument for the organisation of the operations of an enterprise [2]. This implies that the overall organisation can be seen as a set of business processes, working together to achieve the objectives of the company. At organisation level, from the point of view of process orientation, lets the characterization of the operation of an enterprise using business processes [3]. Organizations can incorporate various types of business processes, and they are influenced by the business strategy that defines the objectives and goals of the organisation, but they are also influenced by the stakeholders and the information systems that support them.

Each business process can contribute towards achieving one or more business goals. In order to gain information about the business process efficiency according to the desired business goals, activities represented in controlling mechanism are performed, and KPIs of business processes are determined [3].

Certain variables can be part of the decision-making process, but others are affected by external actions in an indirect way. For example, a company can change the price of a product (variable directly determined in a decision-making process) but cannot determine the number of products sold (variable affected by the execution of other actions). However, a company normally has a set of mechanisms that can help: for example, when the price is decreased or an advertising campaign is deployed, more products will probably be sold. Some actions cannot modify these variables directly, but they can stimulate the KPIs in the desired direction.

Decision-making processes for directly determined variables have been studied previously [4]. However, to the best of our knowledge, the problem has not been extended to include variables affected by the execution of other actions.

The degree to which a business process directly or inversely affects a set of KPIs forms part of the expert knowledge of the business. Since the decision about which process should be executed is a human and manual task, the BET of the enterprise uses these indicators, typically shown on dashboards, to decide which actions to take to improve the KPIs in the future. The relation between the actions and how they can affect the variables is not always clear, since it depends on the background of the particular decision-maker whether to perform a determined action. Taking into account every item of information can be a complex task, for example if not every item of department information is included, then some profess-KPI relations can be lost. Errors can therefore be produced or decisions can fail to follow the strategy defined in the organisation.

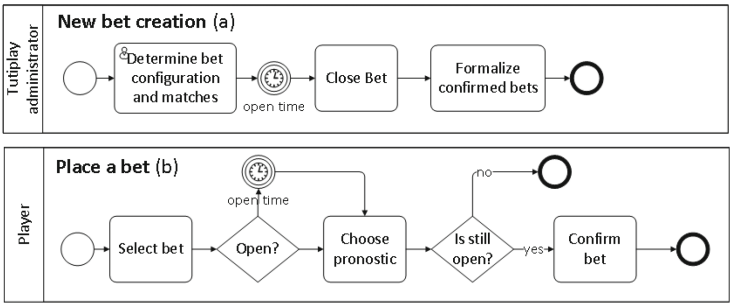

Fig. 1. Tutiplay business process for users

In order to model the indicator and action relations, in this paper we propose the creation of a model-based fuzzy logic graph that can represent the relation between KPIs and the professes of the companies, called Fuzzy Governance Maps (FGM). These FGMs help the BET in the decision-making processes, completed with a framework to simulate the various scenarios in a what-if analysis [5] supported by a tool.

The paper is organized as follows: Sect. 2 introduces an illustrative example in a real scenario; Sect. 3 shows the relation between business strategy and business processes, and how the governance helps the BET to maintain the correct direction; Sect. 4 explains the elements and structure of an FGM; Sect. 5 introduces how to use FGMs to evaluate a what-if analysis; Sect. 6 analyses an overview of related work found in the literature; and finally, conclusions are drawn and future work is proposed.

2 A Real-World Example

A real-world example is used to illustrate our proposal. It is a collaborative platform to play a football pool called Tutiplay [6]. This is a platform oriented towards allowing a set of people (usually friends) to place a betting ticket together. In each bet, each person fills in an independent row and permits the Tutiplay platform to collect every row together in one betting ticket, and formalizes the bet using the corresponding administration. In the case of economic reward, the platform also collects the winnings and divides the quantity between the participants. More than one bet can be opened for placing at the same time.

Figure 1 shows two business process models implemented to support the platform. The first model "New bet creation (a)" shows how a bet is managed by the person who administers the platform, from the creation to the close and final formalization of the bets. The second model "Place a bet (b)" shows the steps that a player must follow to place a specific bet.

The business objective of the platform is to formalize as many bets as possible in order to maximize profits, but also maximize the number of active users. To optimize these variables, Fig. 2 shows processes that allow the BET to perform certain strategies in order to ensure the proposed goal.

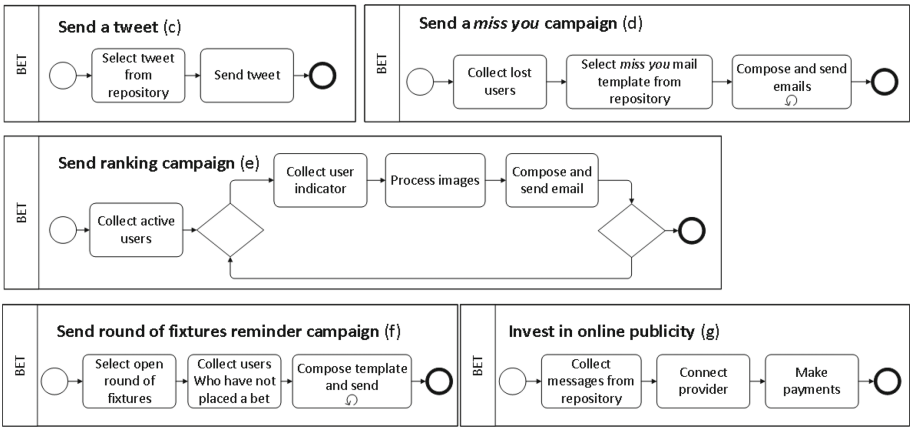

Fig. 2. Tutiplay business process for BET members

Table 1. BET strategy process

Business process	Consists of	Strategy aim
Send tweet (c)	Select a generic tweet from a repository and send it to make some noise and to connect players and followers	Increase the forecasts by making noise to followers
Execute a "miss you" campaign (d)	Send a emails to every lost user, inviting them to use the platform again	Decrease the number of lost users through the number of active users by increasing user reactivation
Execute a ranking campaign (e)	Send an individual email to every user, including indicators of the evolution of the player	Gain more bets and decrease the number of lost users
Execute a reminder campaign (f)	For a determinate round of fixtures, send an email to players that have not yet placed a bet, when the deadline is near.	Increase the number of bets for a determinate round of fixtures
Invest in online publicity (g)	Spend money on social networks, to enroll new users to the platform	Increase the number of users

Table 1 shows a small explanation regarding the business processes available for the BET and shown in Fig. 2, with the business aim that each one follows.

The correct direction of the company is based on the business strategy defined: The BET observes the evolution of the system using a dashboard, and when necessary or desired, they can decide to perform any action, that implies executing some process.

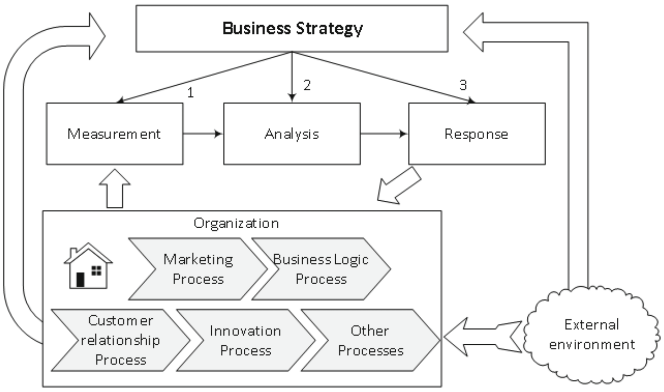

Fig. 3. Performance management process

The problem involves ascertaining which process or processes can improve the competitiveness of the company, and how they can affect the other KPIs. Our proposal includes obtaining this information by simulating the different options that the decision can produce.

3 Business Process and Business Strategy

The existing relation between certain types of processes and the capacity to modify the goals of an organisation was detected by Smith et al. [7], and depicted in Fig. 3. The alignment between the processes of an organisation, and the goals to be achieved implies performing three steps. The first (1) consists of taking measurements, which are taken from the KPIs observed from the processes defined as relevant for the organisation. (2) It is then necessary to make an analysis of these measurements in order to (3) perform possible actions that will affect the goals of the organisation. As mentioned earlier, measurement, analysis and response actions are oriented towards improving the business strategy defined, which is affected by the evolution and the status of the organisation itself, and by the external environment.

The principal aspects started above can be implemented and automated in an easy way by using BPMSs. BPMSs represent a software that supports the implementation, coordination, and monitoring of the business process execution.

The main aspect supported by BPMSs involves the handling of the business processes of the organisation. This aspect is represented in Fig. 3 in the box labelled as *Organization*. Furthermore, the *External Environment*, including the relationship with *Stakeholders*, manages input knowledge obtained from external information systems and other important sources.

In order to obtain measurements from the status of the business (edge 1 of Fig. 3), the Business Activity Monitoring (BAM) or Process Performance Measurement (PPM) tools are employed. These tools allow the expert to evaluate

the defined KPIs that permit the status of the business to be ascertained at each moment. These tools require intervention from IT personnel in order to be automated. The visualization and monitoring of the status of the business by means of observations of the KPIs can easily be created through using the dashboards of these tools.

However, the following aspects cannot be automated: the first aspect is to define the business strategy or the specific KPIs to measure, since this is the responsibility of the BET and it depends on the strategies that the organisation wants to follow. This step is guided by the target markets that the company wants to cover, and the product and services offered.

Once the BET obtains the status of the business by evaluating the KPIs that can be observed on a dashboard (edge 1 in Fig. 3), the team must decide whether the status of the business is correct based on the business strategy defined (edge 2 in Fig. 3), and they must also decide whether to act (edge 3 in Fig. 3). A response can involve doing nothing, or performing a set of actions in order to archive the objectives defined as strategy. Here is where the contributions of this paper take place, by helping to model action-reaction knowledge in the process governance, and by contributing a method for the computation of this knowledge in order to make better reasoned decisions that steer the computing in the right direction to achieve its business goals.

4 Fuzzy Governance Maps (FGM)

In order to model the expert knowledge represented in Table 1, which is needed to help in the governance decision points, we propose the use of Fuzzy Governance Maps (FGMs). The use of FGMs contributes towards the effort for more intelligent governance control methods and for the development of systems that help in the governance decision process. FGM representation is a formal method that allows the BET to describe the expected behaviour of the organisation itself, and how the environment will evolve by means of the simultaneous use of stimulations of business processes and KPIs. This method is an extension of Fuzzy Cognitive Maps (FCMs) by Kosko [8], with a set of new elements for the expression of the complete semantics. As FCMs, the success of the construction of FGMs is strongly dependent on the degree of expertise held by those involved in the FCM construction [9].

A FGM is composed of $\langle IN, BPN, CE, SE \rangle$, Indicator Nodes (IN), Business Process Nodes (BPN), Causality Edges (CE), and Stimulation Edges (SE).

Indicator Nodes (IN) model the set of indicators that represents the status of the organisation: this is the set of KPIs typically included on a dashboard for the visualization of the status of the business, such as "*number of users*" or "*profits*". On the other hand, *BPN* models the business processes or actions that a BET has available for execution, such as "*send a tweet*", or "*invest in online publicity*" processes. Every *IN* is defined by using the name of the indicator.

The *INs* relate by means of the *Causality edges(CE)*. These edges can have a direct (+) relationship in the case when they increase/decrease in the same

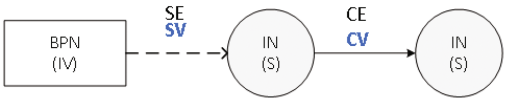

Fig. 4. Abstract FGM

direction; these edges have a indirect (−) relationship when the second indicator increases/decreases in the opposite direction to the first. Another characteristic of *CE* is the velocity of causality, which represents the speed with which the second indicator is affected once the first one has changed.

It is frequently too complex to define the velocity of action-reaction between two values with accuracy, for this reason we propose the use of fuzzy logic, and we have defined five fuzzy sets, denoted as "very slow", "slow", "normal", "quick", and "very quick". Considering *IN* and *CE*, an *FGM* can be seen as a FCM considering time relationships [10].

On the other hand, *BPN* represents the set of actions in terms of business processes that can be executed by the BET.

As mentioned in Sect. 1, the business processes do not always have the capacity of modifying the indicator nodes directly, since the behaviour of these indicators depends on external factors, however, these processes can stimulate certain variables. In order to model this concept, FGMs are composed of *Stimulation Edges (SE)*. An *SE* relates a *BPN* with an *IN*, and represents that the *IN* is stimulated by the execution of a *BPN* process. In order to facilitate the modelling, four fuzzy sets have been defined, whose ranges are:

- *Greatly increase*: The execution of the business processes greatly increases the associated indicator
- *Increase*: The execution increases the associated indicator
- *Decrease*: The execution of the business process decreases the indicator
- *Greatly decrease*: The execution of the business process greatly decreases the indicator

On the other hand, the velocity at which the indicator is influenced can be modelled by using the same five fuzzy sets defined above.

Figure 4 shows how these elements are represented graphically. Formally, FGMs consist of a finite non-empty set of n *BPN* and m *IN* nodes, a finite non-empty set of o *SE* edges, and a finite set of p *CE* edges.

$BPN = \langle name, IV \rangle$ represents a business process node, and is composed of a name to represent the business process, and a set of q input variables (IV) that need to be instantiated.

$IN = \langle I, S \rangle$ represents an indicator node, and is composed of the name of the indicator (I), and a Scope (S), which represents where the indicator can be applied. The scope models the actuation ambit of *IN*, and therefore the indicator refers to a determinate ambit.

SE represents a stimulation edge between a business process node (BPN) and an indicator (I), $SE = \{se_{ij}\}$ where $i \in BPN, j \in IN$.

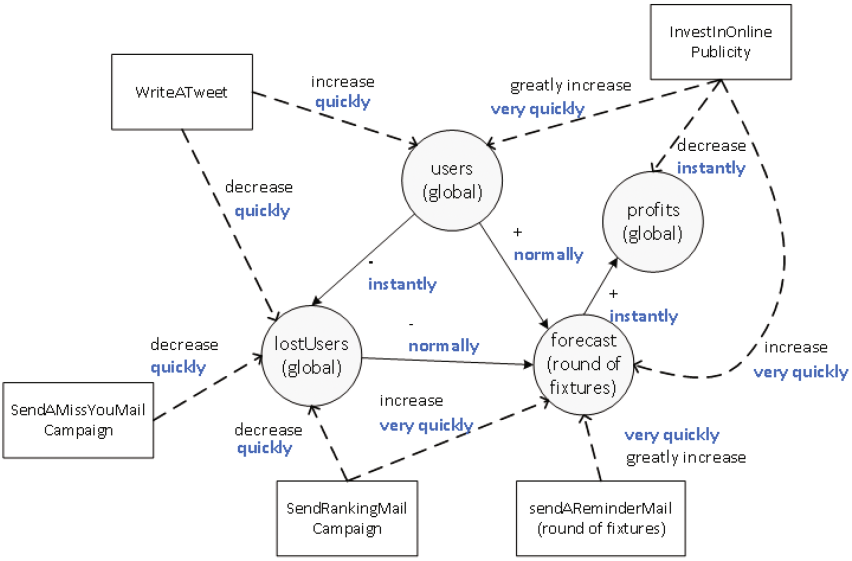

Fig. 5. FGM sample

$SE = \langle SF, SV \rangle$ is composed of a stimulation function (SF) and a stimulation velocity (SV), defined using discrete values $SV \in$ [VS, S, N, Q, VQ], which represent "very slowly", "slowly", "normally", "quickly" and "very quickly" stimulation velocities, respectively.

CE represents the set of causality relations between indicators. $CE = \{ce_{ij}\}$, $i, j \in IN$, is composed of a type of causality relation (C) and a causality velocity (CV): $CE = \langle C, CV \rangle$.

Figure 5 shows an example of an FGM for the sample shown in Sect. 2. This FGM has been designed by the BET of Tutiplay^{TM} and collects their beliefs about the operation of the enterprise.

The set of *INs* that defines the status of the enterprise for the example are:

- *users*: Number of users registered on the platform, with at least one bet placed within the last month
- *lostUsers*: Number of users registered on the platform, that have not placed a bet in the last month
- *forecast*: Number of bets per round of fixtures
- *profits*: Profits obtained by the platform

The BET considers that *forecast* and *profits* has a direct casual relation, since if the number of *forecast* is increased, the *profits* are instantly increased. They also consider the another situation, in the case where *forecast* is decreased, *profits* are instantly decreased. There is a direct casual relation between *users* and *forecast*, and an inverse casual relation between *lostUsers* and *forecast*, since in the case where *lostUsers* is increased, *forecast* is decreased (and vice versa). Finally, the

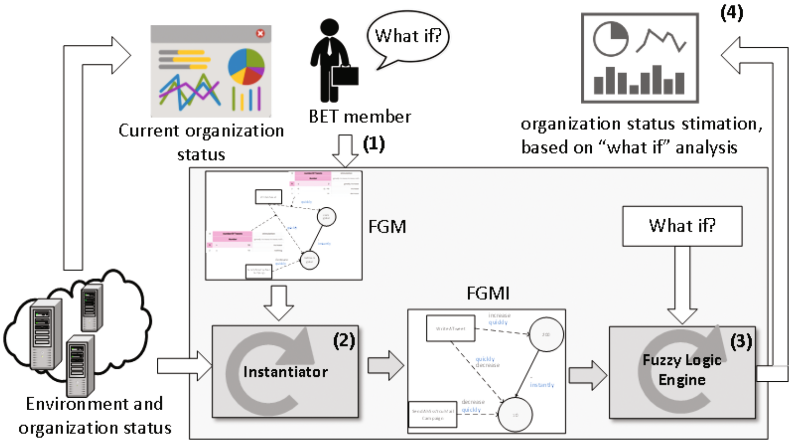

Fig. 6. Evaluation process

BET defines is an inverse casual relation between *users* and *lostUsers*, since in the case where *users* is increased, then *lostUsers* can decrease (and vice versa).

On the other hand, the processes that the BET can use to exert influence over the business, are described in Fig. 2. In this sample, the BET has modelled that the execution of the process "WriteATweet" can quickly stimulate the *users* and *lostUsers* indicator. The execution of the process "InvestInOnlinePublicity" stimulates the *users*, *profits* and *forecast* indicators. The process "SendAMissYouMailCampaign" stimulates the *lostUsers* indicator, "SendRankingMailCampaign" stimulates *lostUsers* and *forecast* indicators, and "sendAReminderMail" stimulates the indicator *forecast* for a specific round of fixtures. The degree to which these indicators are stimulated can be seen in Fig. 5.

5 Framework and Evaluation

This section describes the evaluation process of the FGM. The process is graphically shown in Fig. 6. In the case BET detects some unusual behaviour by observing the dashboard, they can decide either act in an effort to fix the problem, or they could simply remain informed as to the evolution of the organisation.

The evaluation process starts when a BET member needs to make a what-if analysis (1 of Fig. 6). The module "Instantiator" (2 of Fig. 6) explores the environment and organisational status by collecting indicators either defined by using the Process Instance Query Language (PIQL) [11], or from Business Activity Monitoring (BAM) [12] or Process Performance Measurement (PPM) [13] tools (external sources), and instances the FGM by calculating the final value for indicators and stimulation edges in order to create a Fuzzy Governance Map Instance (FGMI). An FGMI is an FGM, where the values of the *IN* are known.

Once the FGMI is obtained, it is used as the input of the Fuzzy Logic Engine module (3 of Fig. 6). This module takes the FGMI and activates the

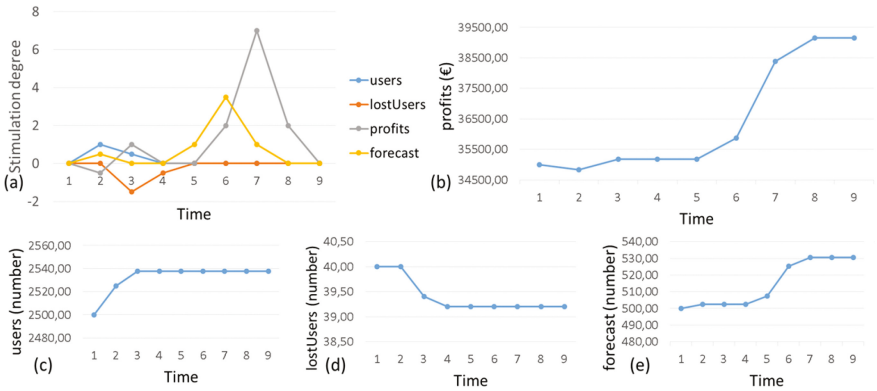

Fig. 7. Sample of estimated dashboard

actions according to the "what if" question. An FGMI is a Fuzzy cognitive map that must be instantiated in order to obtain a Fuzzy Governance Map Instance (FGMI). Once this is obtained, it can be computed by using fuzzy logic [14].

The proposal has been evaluated from an FGMI and by using simulation tools for the "Fuzzy logic engine" module. This FGMI has been mapped in the simulation tool and time relationships have been considered by introducing intermediate nodes [10]. The simulation tool has the capacity to modify the value of the nodes and propagate the results in order to obtain the degree of stimulation of each indicator. The specific evolution of each indicator can then be obtained by using these stimulation degrees and an application function.

Figure 7 shows an example of the estimated output of the dashboard obtained by using the FGM presented as a sample (Fig. 5) to simulate the evolution of the organisation from the status (*users=2500, lostUsers=40, profits=35000, forecast=[f:500]*) and the question "*what if we invest money in online publicity?*".

Plot (a) of Fig. 7 shows the stimulation degree. The remaining plots describe the evolution of each indicator. FGM predicts that organisation will start with a loss of profits, but the action will greatly increase profits in the long-term.

6 Related Work

For many years, organisations have invested large quantities of time and money to ensure business process compliance (BPC) with policies, regulations, and legislation. A systematic selection and characterization of the literature that focuses on BPC was published in [15]. Other studies have expounded on how it is possible to utilize tactical information, knowledge and experience concerning business activities for the BPC. In previous work [16], the organisation goals are modelled using User Requirements Notation (URN) [17].

In order to react to changes in the BPC, the various techniques could be categorized in the bibliography:

1. Rule-based techniques [18] or Business Rules Management Systems (BRMS) to automate the modelling, deploying, and execution of the business rules.
2. Business Process Intelligence techniques (BPI) integrate BPMS and Business Intelligence systems [19]. Shollo [20] proposes applying "hard facts" provided by BI in the IT governance context, as a foundation for rendering arguments more convincing during decision-making discussions.
3. Goal-Oriented techniques, which extend URN to include the validation business processes by considering performance issues as compliance [21].

Many previous studies use hybrid techniques to improve the results, but from our point of view, techniques listed above provide insufficient support when dealing with the business goal models and business process execution in an integrated and efficient manner. For this reason, our research addresses these issues.

7 Conclusions and Future Work

This paper proposes a formal method to model expert knowledge through the use of Fuzzy Governance Maps (FGM). A FGM allows the Board and Executive Team (BET) to understand how the business works, and how actions can directly or indirectly affect the KPIs that define the status of the business. By computing the FGM defined by the BET, the evolution of the business according to the decisions taken in the governance process can be attained, tat is, we can ascertain what will probably happens on performing certain actions. If the evolution of the business is known according to which actions are performed, then decision-making regarding these actions becomes easier, and this help towards achieving the company's objectives.

As future work, we propose that information about regarding past instances be incorporated. By using this information, we will be able to validate the FGM designed by the BET and also to propose new stimulation relations. Furthermore, we consider the possibility of introducing dynamic stimulation edges, since the degree of stimulation sometimes depends on external factors.

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