A Physics-Based Enterprise Modeling Approach for Risks and Opportunities Management

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Abstract. Management Science tries to enable managers and decision-makers to take the desired solutions to guide systems toward their objectives. This requires identifying the different dimensions of the system. Organizations and enterprises are complex systems associated with uncertainties in dynamic business contexts, that interact with their environments. Due to pressures such as collaborations with their customers, suppliers, their environment, the seek for innovations, etc., the performance may be changed by internal and external risks and opportunities that push and pull the enterprises like forces. Thanks to Physics of Decision (PoD), by identifying these pressures according to the organization's features and objectives, unstable conditions due to the forces, can be detected and identified as risks and opportunities. This article attempts to present a time-dependent dynamic framework, based on a physical approach to identify risks and opportunities seen as forces applied on Organizations and Enterprises.

Keywords: Management Science, Enterprise Modeling (EM), Risk, Opportunity, Physics, Theory, Organizations, Enterprises

1 Introduction

Organizations and Enterprises must get enough awareness, take systematic approaches for identifying and interpreting risks and opportunities as early as possible, and implement appropriate strategies to manage them throughout the evolution of collaboration [1]. This paper focuses on aspects encountered in the practice of Enterprise Modeling (EA) to deal with decision making and management. In this specific context, risks and opportunities may be seen as forces for Organizations and Enterprises that push or pull them in the performance framework of their KPIs (Key Performance Indicators). These forces lead the system into uncertainty over time. Therefore, a time-dependent perspective could be useful to investigate these forces. The characterization of a collaborative situation requires describing several points of view. To clearly describe these points of view, this article directly refers to dynamic system modeling which is defined as creating time-dependent models for physical systems [2]. In particular, we are concerned with dynamic phenomena and physical rules for identifying and modeling forces of enterprises. Managing a dynamic system requires the specification of its *objectives* within a time interval. According to these *objectives*, the manager of the system will take some *decisions* to reach them. Since each system is emerged in *characteristics* (which may be environment or internal characteristics) and has its own *nature* (which relate to the specific attributes of the organization), according to the *decisions* made by the manager to reach the *objectives*, some risks and opportunities will appear which may affect the system. These risks and opportunities (known as *forces* [3]) unless *conditions* met, are considered as potentialities. As soon as conditions are satisfied, these potentialities become actualities and will impact on the *performance* of the system. Figure 1 shows a brief view of such systems [3], [5] which is discussed in detail in the following.

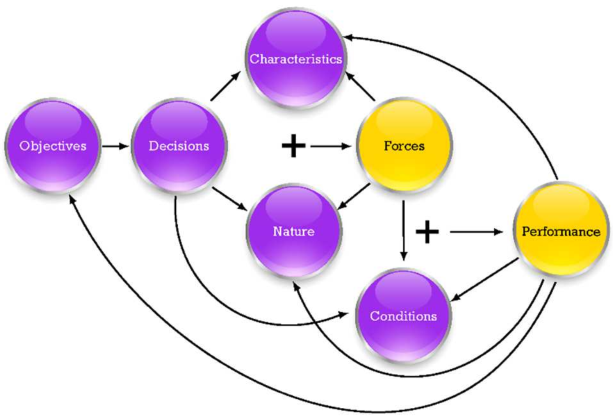

Fig. 1. Dynamic viewpoint of Organizations or Enterprises.

This model presents the concepts of the enterprise and the relationships between them. There are generally two classes of concepts in this model. First class refers to concepts that can be changed to get closer to the *Objectives* of the system (purple circles in Fig. 1). The second class of concepts (yellow circles in Fig. 1) is the consequences of interactions between concepts of first-class. Due to the *Characteristics* and *Nature* of the system and *Decisions* made to achieve the *Objectives* of the system, some *Forces* will be created. The last concept, *Performance*, comes from the potential *Forces* (risks and opportunities) that the required *Conditions* trigger to actually change the performance of the organization within the KPIs framework. A detailed definition of the concepts and their relationships is given in section 3.1. The paper's discussion is centered around the following questions:

1) How could an organization or an enterprise be considered as a time-dependent dynamic system?

2) How Physics of Decision can help to define the Attributes, *KPIs* and Objectives of a system based on the dynamic enterprise model for identifying and modeling of risks and opportunities?

This article is organized according to the following structure: Section 2 is dedicated to existing research works and scientific contributions. Section 3 describes the physics-based theory that aims to consider an organization or an enterprise as a time-dependent dynamic system. Section 4 details hypothesis and expectations of that theoretical vision. Finally, section 5 concludes this research work and gives some perspectives for future works.

2 Related Works

With the rising trend in globalization, all sectors encounter new challenges associated with increased competitiveness, high levels of uncertainty and risks [4]. Risks and opportunities management has become the main part of the organizations and enterprises' activities. Organizations and enterprises include components that interact together in a dynamic environment. Enterprise models include "concepts that are suited to support the conjoint analysis and design of information system and action system" [6]. Enterprise Modeling (EM) and Enterprise Engineering (EE) "provide methods and techniques for an aligned development of all parts of an enterprise" [7]. Risks considered in enterprise modelling literature are mainly related to mainstream requirements such as security, privacy, compliance and capability [8]. In the other side, opportunity is some enterprise capabilities which could be modeled as a specialized type of intentional actor so that their socio-technical characteristics can be specified and analyzed [9].

As this article deals with risks and opportunities modeling, SWOT has definitely to be mentioned: the SWOT analysis is an essential and indispensable approach for identification and modeling of risks and opportunities. The SWOT Analysis is mainly dedicated to the classification of (i) attributes of the considered system (Strengths and Weaknesses) and (ii) external potentialities (Opportunities and Threats) [10]. Similarly, PESTEL analysis is an interesting approach to identifying risks and opportunities. One interesting connection between SWOT and PESTEL is that the external Opportunities and Threats (basically opportunities and risks) could be identified by investigating the PESTEL sectors. A formalized vision of concepts and relationships between them could be present like Danger/Risk/Consequence chain which can well describe risk-related collaborative contexts [11].

Managing dynamic systems requires trying to reach objectives. These objectives can be of various types but mostly they can be represented by a combination of target values of Key Performance Indicators (KPIs). There may be several ways to achieve them, which means several decisions to take to escape risks or seize opportunities. In that perspective, risks and opportunities must be manageable and thus modeled. Dynamic risks and opportunities modeling have different and complex phases such as identifying, assessing and analyzing. These phases based on the potentiality management metamodel, try to enable decision-makers to manage the trajectory of a considered system

with regards to its performance towards its associated objectives and also to support the definition of these performance objectives [12]. The dynamic system changes over time, and therefore, data also changes. Dynamic Risk Analysis (DRA) is one of the most practical approaches for risk analysis that helps provide safer operations of complex process systems.[13].
Activity Based Costing (ABC) system calculate the costs of individual activities and assign costs to cost objects such as products and services based on activities undertaken to produce each product and service [14]. Balanced Scorecard (BSC) has the potential to provide planners with a way of expressing and testing a sophisticated model of cause-and-effect in the organization a model that provides managers with a basis on which to manage the drivers of desired outcomes [15]. Statistical Process Control (SPC) in Quality Management monitors the system's behaviors to track the changes in the system [16]. Based on the enterprise's processes, some simulation such as System Dynamic, Discrete Event Simulation and Multi-agent simulation are the most known tools. Besides, performance management often uses Multi Criteria Decision Making (MCDM) systems such as ANP, AHP, SAW, TOPSIS, and PROMETHEE to deal with the process of making decisions in the presence of multiple criteria [17]. Deep Learning (DL) provides advanced analytics tools for processing and analyzing big enterprise data to take better decisions in the uncertain situations of organizations and enterprises [18].

In conclusion, management science tools mentioned above help to identify risks and opportunities. Besides, some contributions defined chains to show the interactions between entities of the system over time. Due to changes, inter-actions, and objectives of systems, some mentioned approaches try to model these risks and opportunities based on the susceptibility of systems to internal and external characteristics. All in all, most of the risks and opportunities modeling consider the forces based on previous data of the system, and they forecast the future forces. In this approach, the model is dynamic and it can be adapted to unpredicted events that impact the system in any interval.

3 A physics-based theory

The objective of this section is to describe a theoretical framework to identify, assess and analyze the related risks and opportunities of organizations and enterprises considered as systems. This framework, based on physical laws, tries to identify and model risks and opportunities as forces to control a system trajectory which is affected by these forces.

3.1 Dynamic Organizations and Enterprises

Organizations and Enterprises can be described and implemented by some components called concepts. This section defines these concepts and their relationships. Physics of Decision (PoD) applies physical laws to such systems to manage them in a dynamic context. PoD tries to enable organizations and enterprises to identify and model negative potential events (known as risks), as well as positive potential events (known as opportunities). The mentioned systems consist of the following two classes:

First Class: Variable concepts to get closer to the system's goals (purple circles in Fig.1)
Objectives: Desirable values of some Key Performance Indicators (*KPIs*) which the system wants to achieve in a specified period (Δt).
Decisions: Actions that may be taken to reach the specified *Objectives* during Δt.
Characteristics: Danger or favorable conditions of the system (or out of the system) which can generate risks and opportunities (*Forces*) respectively.
Nature: Some of the system's attributes that may generate *Forces*.
Conditions: Some states of the system which can activate/deactivate the potential *Forces*.
Second Class: Resulting concepts of interactions between first-class concepts (yellow circles in Fig. 1)
Forces: Created risks and opportunities due to the *Characteristics* and *Nature* of the system and *Decisions* made to achieve the *Objectives* of the system.
Performance: Current level of *KPIs* at time *t*.

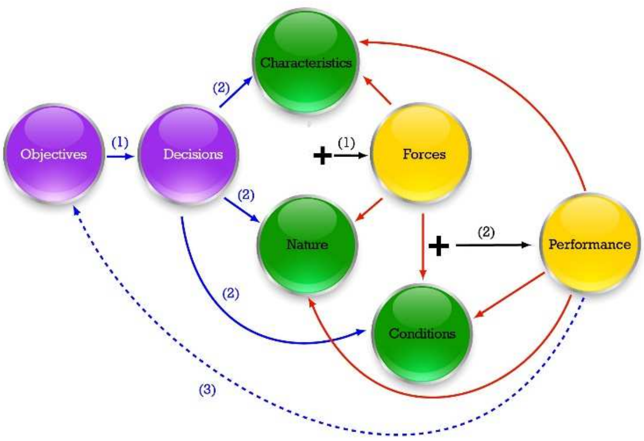

Fig. 2. Dynamic Organizations or Enterprises

Since the system is dynamic, interactions between concepts are considered interactive chains. According to Fig. 2, there are the following three types of chains in this viewpoint of the system.
Causal Chain (black arrows): This chain shows the results of first-class interactions which cause the changes in second-class. As can be seen in Figure 2, due to the *Characteristics* and the *Nature* of the system, and due also to the *Decisions* made to reach the *Objectives*, some *Forces* (risks and opportunities) are created **(1)**. Also, the system's *Performance* will be changed because of the existence of some potential *Forces* and the *Conditions* triggering them **(2)**.
Cascading Chain (red arrows): Red arrows show the effects of second-class concepts on some of the first-class concepts. In other words, *Forces* (risks and opportunities) and *Performance* may impact on *Characteristics*, *Nature*, and *Conditions* of the system. For example, the consequences of a collaboration with a new supplier (change in the

Performance) may create the *Characteristics* for an emerging *Force* due to the risk on the collaboration with another supplier.
Decision Chain (blue arrows): This chain shows that the manager can decide to change first-class concepts to reach the system's *Objectives*. According to the difference between the current level of *KPIs* (*Performance*) and the desired level of *KPIs* (*Objectives*), some *Decisions* will be taken to reach them **(1)**. The *Decisions* made to reach *Objectives* will be fulfilled by changing the features of the system which are *Characteristics*, *Nature,* and *Conditions* **(2)**. If the system's *Performance* is not desired, the manager may decide to change the system's *Objectives* to reach the desired *Performance*. In fact, the starting point for making *Decisions* is to dynamically compare the current level of *KPIs* (*Performance*) and the desired level of *KPIs* (*Objectives*) which system wants to improve during Δt **(3)**.

The dynamic viewpoint of organizations and enterprises takes into account the different dimensions of the network and allows monitoring them over time. Exploring the status of concepts over time helps to identify and model risks and opportunities. The question now is: *"How dynamic viewpoint of organizations and enterprises can help to define the Attributes, KPIs and Objectives of the system?"*. To answer this question, this paper presents a framework, based on two modeling spaces to formalize the status of the system over time.

3.2 Description and Performance Spaces

In general, dynamical systems are precise about the notions of *"system states"* and *"evolution of the system states over time"*. The system state at time *t* is an instantaneous description of the system which is sufficient to predict the future states of the system without recourse to states prior to *t*. The evolution of the system state refers to a sequence of states or continuous trajectory through the space of possible system states. The space of possible system states is called *"the state space of the dynamical system"*. Description space shows the location of the system's aspects at time *t*. According to concepts of Dynamic Collaborative Systems in section 3.1, some of these concepts are considered *"Attributes"* of the system. The *Attributes* of the system refer to the nature of the system and tangible concepts. The *Attributes* could be described by: *"Characteristics"*, *"Nature"* and *"Conditions"* of the system (green circles in Fig. 2). The proposed vision could be shown in a Description Space (DS) that the location of the system in this space, indicates the current status of the system in each *Attribute* in a specific time t (Fig. 3). The system state in Description Space will be represented with an **"m"** term vector called **D**escription **V**ector (**DV**), where m is the number of *Attributes* of the system. The *Attributes* of a system will be divided into two categories. The first category refers to attributes that cannot be changed too much and they are practically out of control (PESTEL). The second category indicates attributes that can change depending on the degree of liberty of the system. This category indicates the *control space* of the system. The *Control Space* is a subspace of the *Description Space* with refer to restriction of changing Attributes in any range (blue subspace in Description Space)
Dynamic interaction between concepts, changes the system's state over time. Evaluation of the system states is done by monitoring *KPIs*. The level of *KPIs* indicates the

system states that are formulated with some *Attributes*. In some cases, the *KPIs* are simple and could be directly calculated with the *Attributes*. In other words, sometimes the *KPIs* are exactly derived from the *Attributes* (they even are sometimes directly some *Attributes*). These cases imply that the values of *Attributes* within the Description Space show the level of *KPI* in Performance Space (PS) too. Obviously, the major *KPIs* are a combination of Attributes and are formulated with them.

System state in Performance Space is represented with a **"n"** term vector called **P**erformance **V**ector (**PV**), where n is the number of considered *KPIs* for the system. Each *KPI* comes from one or more *Attributes*. In other words, *KPIs* in a dynamic system are functions of *Attributes* and time, so $f_i(A_1, A_2, \ldots, A_j, \ldots, A_m, t) = K_i^t$.

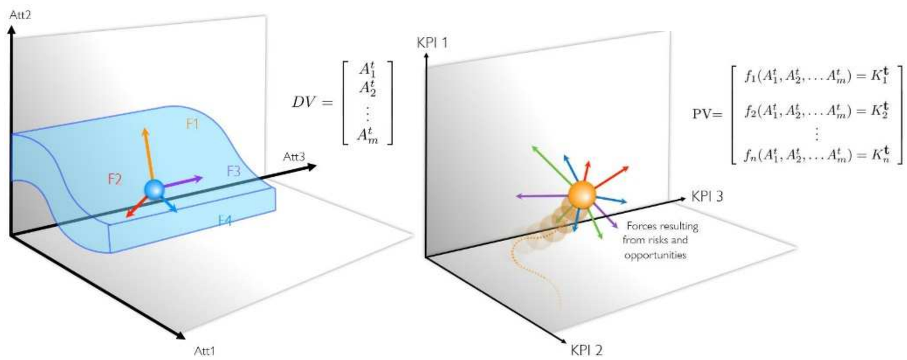

Fig. 3. Description Space (left), Performance Space (right)

Note: *For sure the scales of axes of Description and Performance Spaces are not the same. These spaces just represent the level of each Attribute(left), KPI (right) at time t.*

4 Hypotheses and expectations

According to the dynamic viewpoint of organizations and enterprises, and the presented spaces for monitoring the status of the system, the PoD approach, based on physics laws in these vector spaces, tries to identify and model the risks and opportunities with the following steps:

4.1 Context Definition

First step is characterizing the current state of the system and the optimal state(s) of the system to be achieved by the PoD strategy. According to Dynamic Collaborative Systems (fig. 2), the system's manager specifies the *Objectives* of the system within a specified Δt (It can be weekly, monthly, seasonally or, yearly period).

In this stage, the *Performance* of the system at time t_0 (current state) will be compared to considered *Objectives* (optimal state(s)) which is shown by arrow **(3)** in fig. 2. This comparison indicates the difference between the status of *KPIs* (as well as *Attributes*) in two *Description* space and *Performance* space (Fig. 3) at t_0 and favorable levels of them after Δt (K^*). The *Objectives* are the favorable level of *KPIs* after specified Δt.

This favorable level of KPIs is shown by OBJ vector. In the other words, OBJ vector indicate the part(s) of *Performance Space* which is desired space (It can be a point, sphere, volume or plate) after Δt. For example, $O_1^{\Delta t} = K_1^*$ means that the *Objective* for KPI_1 is reaching to K_1^* after Δt.

$$\text{PV}=\begin{bmatrix} f_1(A_1, A_2, \ldots A_m, \mathbf{t}) = K_1^{\mathbf{t}} \\ f_2(A_1, A_2, \ldots A_m, \mathbf{t}) = K_2^{\mathbf{t}} \\ \vdots \\ f_n(A_1, A_2, \ldots A_m, \mathbf{t}) = K_n^{\mathbf{t}} \end{bmatrix} \Rightarrow OBJ = \begin{bmatrix} O_1^{\Delta t} = K_1^* \\ O_2^{\Delta t} = K_2^* \\ \vdots \\ O_n^{\Delta t} = K_n^* \end{bmatrix}$$

In conclusion, context definition step for modeling will be done by answering the following questions: I) Which *KPIs* are intended for improvement (K^*)? II) After how much time will the system reach K^* (Δt)? III) Which range of *KPIs* is desirable (Which part of *PS* are target zones)?

4.2 Identification of Risks and Opportunities

Figure 2 indicates that some *Forces* will be appeared based on *Decisions* made to reach *Objectives*. These Forces (risks and opportunities) unless their conditions met are only considered as potentialities. As soon as the *Conditions* are activated, these potentialities become actualities and will impact on the *Performance* of the system (Causal Chain in fig. 2, arrows **(1), (2)**). Furthermore, sections 3.1 and 3.2, considered the *Attributes* and *KPIs* of the system in Attribute Space and Performance Space respectively. This step, based on the Context Definition step and specifying the K^*s and Δt, the PoD approach will identify the risks and opportunities. To identify risks and opportunities, PoD will determine the susceptible areas of *Performance Space*. These areas indicate identified risks and opportunities according to desired *KPIs* (K^*). To address this aim, after determining K^*s and time to reach them (questions I, II of step 1), the desired spaces in *Performance Space* will be specified (question III of step 1). In other words, out of target spaces in PS (Fig. 4) refer to the identified risks (negative unforeseen level of *KPIs* in step 1) and opportunities (positive unforeseen level of *KPIs* in step 1).

4.3 Modeling Risks and Opportunities

The final step of PoD is modeling the forces. After characterizing the status of the system and its objectives (step 1), the susceptible (sub)spaces will be determined in *Performance Space* (step 2). Now, the last step is analyzing the identified risks and opportunities to avoid the risks and catch the opportunities by modeling. As mentioned in Description Space (section 3.2), there are some restrictions for varying the *Attributes* which called the *control space* of the system. For example, a limited budget for hiring new employees for an organization (internal characteristics) or tax rate for an enterprise (external characteristics). According to these limitations and the degree of liberty for system, the Favorable and Danger zone (Fig.4) will be changed. The modeling will assess the identified risks and opportunities for the system and also possible ways (Blue dash lines on Fig. 4) for reaching the target zone in *Performance Space* by staying away from the Danger zone and approaching the Favorable zone by calculating the sum of the forces entering the system.

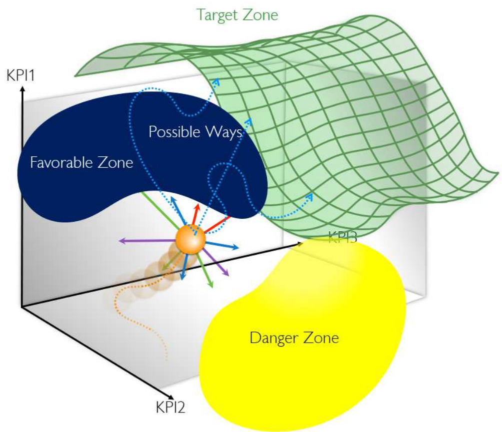

Fig. 4. Identification and modeling of Risks and Opportunities

5 Conclusion and future works

The current article tries to define different dimensions of organizations and enterprises with dynamic concepts. The article presents two spaces to track the status of them. Finally, a new perspective of management science, Physics of Decision tries to identify and model risks and opportunities in the presented dynamic spaces.

The future works would use time-dependent simulation like System Dynamic to develop the proposed approach for Enterprise Modeling, which focuses on:

The development of collaborative networks such as new organizations and enterprises with new innovations and processes made the business environment complicated. The result of this complexity is intense competition between systems for managing risks and opportunities. The PoD approach with a global vision of managing forces could be cover this diversity.

According to the complex relationship between risks (opportunities) factors, managing these forces is difficult. PoD's fundamental is based on physics laws (algebraic law of vectors, heat transfer, electrical fields, etc.) as well as mathematics equations (algebraic structure such as ring, field, groups). The relationships between *Attributes* and *KPIs* is a mathematic function from *Description Space* to *Performance Space*. Therefore, physics and mathematics laws could be useful for the deduction of interconnection rules and the simplification of these complexities.

The door is open to the definition of a global methodology, based on an experimental approach, for the inference of applied forces in the performance space and the exploitation of these forces to conduct decision making. Due to the simplicity of PoD approach, most of the existence techniques in the literature (or a combination of them) for risks and opportunity modeling could be used and assess.

Identifying Favorable and Danger zones in Description Space (Fig.6) using Artificial Intelligence techniques. This powerful tool could be used in the PoD approach.

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