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Modeling Organizational Design - Applying A Formalism Model From Theoretical Physics

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Abstract

Modern organizations are exposed to diverse external environment influences. Currently accepted concepts of organizational design take into account structure, its interaction with strategy, processes, people, etc. Organization design and planning aims to align this key organizational design variables. At the higher conceptual level, however, completely satisfactory formulation for this alignment doesn't exist. We develop an approach originating from the application of concepts of theoretical physics to social systems. Under this approach, the allocation of organizational resources is analyzed in terms of social entropy, social free energy and social temperature. This allows us to formalize the dynamic relationship between organizational design variables. In this paper we relate this model to Galbraith's Star Model and we also suggest improvements in the procedure of the complex analytical method in organizational design.

Keywords: adaptation, organizational design, Galbraith's Star Model, model variables, resources, social entropy, social free energy, social temperature

1. Introduction

Modern organizations are exposed to external environment influences and variability of environment requires permanent organizational adaptation. Adaptations to environmental situations can be either short-term, or a long term, radical option.

To provide short-term responses to unexpected external processes and situations that test opportunities or involve threats (the well known SWOT framework), each organization needs to hold a certain amount of resources in reserve. The necessary reactions sometimes require new types of response to resources engagement. These new responses are most frequently made possible through new organizational competencies and capabilities, created through a numerous very fast learning processes [13]. Levels of learning success are especially important for collective organizational learning [1]. Resource reserves and related capabilities, which can be deployed in response to environmental challenges, represent so-called *organizational potential*, and but it is not considered as indispensable potential.

A second type of organizational adaptation is long-term. This type of response mainly relates to organizational design. Changes in organizational design also involve changes to the structure, complexity, levels of formalization, and decision-making centralization.

Organizational theory on organizational adaptation that looks for answers in the existing or new structure, have an approach to problems that mostly involves qualitative considerations rather than formal, quantitative models.

Our aim is to provide a complementary formal framework, originating from physics, to apply restrictions and conditions to important variables, thus narrowing the area of appropriate solutions in organizational design. The proposed framework aims to supplement the set of approved models used in organizational design modeling.

For reasons of resources, diverse nature of organizational competences and the variety of organizational structures, our integrated approach deals with one complex task. Starting with existing knowledge on organizational design, the concept of social capital, the meta-theoretic approach and others, the paper is divided into several parts. In the second part we provide an overview of key notions and concepts of "our" approaches, in the third part we establish a measure of adaptation that relates the organizational state to environmental conditions and in the fourth part we consider possibilities for further application of this approach.

2. Process-Related Potentials

A prominent feature of the new organization model is the so-called *complex analytical method* [2]. This method is used in organizational evaluation and when designing new organizations. It considers several key organizational functions (planning, production, sales, etc.) and considers their impact on organizational units. The organizational potential both indispensable and real is determined for each business area and organizational unit. Organizational potential includes parameters of organizational stress governed by high capacity utilization levels combined with low costs. We perceive organizational potential to be composed mainly of purposeful resources and organizational capabilities (competencies).

There are several methods used to classify resources and the most popular of these is probably a categorization into human resources and material resources. The level at which an organization functions depends on how successfully the available resources are utilized. A satisfactory degree (level, creditworthiness) of organizational operation can be achieved depending on this level of utilization. Standard resource management procedures, such as assurance, capacity utilization, maintenance, renovation, can be implemented on an ad hoc basis or governed by certain rules. The latter option requires responsibilities to be well defined, instructions to be developed and control systems to work well.

One of the key criteria during organizational planning is the internal stress of organizational units, so called *narrow indispensable organizational potential* [2]. Organizational bottlenecks can be avoided by the creation of an organizational chart with a network of related "in-house" symbols representing organizational units, with their respective organizational potential added. *Real organizational potential* of certain units should approach the value for indispensable organizational potential. The burden on the various organizational units must be balanced out, which is an important design task (organizational planning).

3. Organizational Design

Efficient organizational design can compensate for very changeable conditions. Key variables with the greatest influence on organizational design are environment, strategy, size of organization and technology. In a simplified regime, these procedures can first be used to formulate the organizational strategy and then the structure. These procedures also analyze the assumed business processes.

Different theoretical schools have developed their own concepts and paradigms for applying theory to the process of organizational design. Recent approaches have emphasized the importance of human resources as well as motivation and compensation systems. Today, one of the most popular models for organizational design is the "Star model" (Figure 1.)

A few decades ago organizational design was primarily aimed at developing competitive advantage using structures based on functions, products, markets, and geographical arrangements. The high level of correlation between changes in strategy and structure was very well known.

Now, new variables have been incorporated into a "success formula" for organizational planning, which follows a process approach to interpreting businesses and acknowledges the importance of the human factor. This means that information system, planning processes, budgeting, performance measurement, education and training, should all be designed along with the traditional variables to form a coherent entity. Star model variables are interconnected and each small change in one factor induces changes in others.

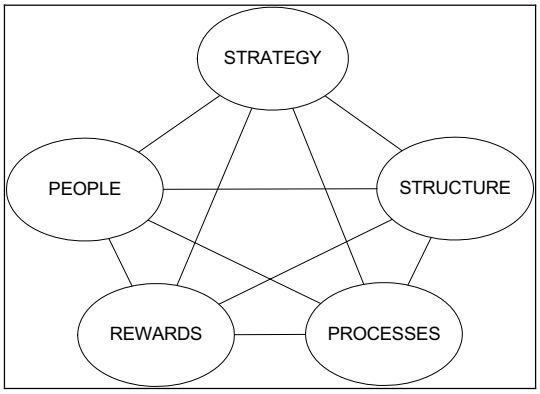

Figure 1. The Star Model [6].

Organizational forms, which have been established mostly under the influence of specific environment conditions, can be divided into two classes, mechanistic and organic [3]. This formulation makes a distinction between decision-making and formalization. In organic structures, decision-making is decentralized, communication is less formal, hierarchical development is poor, and so on. Mechanistic structures are more rigid, with vertical communication and a large number of strict rules [5]. In dynamic environments characterized by relatively big changes, an organic form of organization is the only one that provides the essential level of adaptation.

Significant influences such as changes in the environment lead to changes in resources deployment, most often to unpredictable and acceptable changes. When designing organizational structure and processes, resource planning needs to be undertaken at an early stage to utilize environmental opportunities and threats.

Minzberg hypothesized that «effective structuring requires a consistency among the design parameters and contingency factors» [10]. By situation or contingency factors he means organizational size, technology, power relations, and external environment. We will focus on the environmental factor.

An issue not given enough emphasis in conceptual considerations of organization theory is formalism, more precisely models that could provide information on the interrelatedness of and interactions between variables, rules governing changes to these variables etc. We believe further that by applying an equation taken from a physical model to organizational systems we can provide a modest contribution towards a greater degree of precision in these considerations.

4. Social Capital

Along with strategic management concepts such as core competencies, organizational capabilities, intangible resources, which are important in the context of organizational resources utilization, we would emphasize the idea of social capital [7].

Social capital is the actual or potential resources of collective action based on the norms of trust and related norms in a social network [14]. It can be observed in practice in collectives with a wide variety of characteristics, e.g. families, companies or nations.
It is generated by constant activities, which are required both to establish it and secure its preservation. Social capital is to be differentiated from economic and cultural capitals, although these forms are in part mutually convertible.

A closely related notion is social trust. Social capital functions as a framework enabling agents in a system to perform resource transfers through actions that are highly delocalized in time. This delocalization is made possible by the broad acceptance of social norms of trust, where misalignments in resource transfers are considered temporary ones.

5. Meta-theoretic Approach

Of the various approaches to predicting the necessary, or sometimes optimal conditions for an organization, we concentrate here on applying a formalistic approach taken from theoretical physics. This approach is chosen based on the similarity between the dynamics of some organizations and of some physical models. The physical models are usually conceptually simple, but rich in terms of dynamics. This means that they have an optimum combination of a small number of parameters and a large number of described characteristics. However, there is no general prescription linking the organizational and physical situations, and thus additional criteria should be used when selecting the physical model.

We concentrate in particular on the thermodynamics. This approach utilizes a fundamental characteristic of thermodynamics formalism – that it extracts the maximum predictive information from a given, relatively small set of aggregated variables. In this sense the approach is useful for characterizing systems where detailed micro-level understanding is missing.

The key variables of our model, their significance in terms of the physical system and how we can interpret them in relation to the characteristics of the organizational system, are shown in a short table. We presume that similarities between physical system variables also apply in the domain of social (organizational) system for analogous variables.

Variables	System in Physics	Organizational (Social) System[1]
Tempera-ture, Social temp.	For ideal gas-measure of average energy	Measure of intensity of performing regular activities
Entropy, Social entropy	Measure of number of states available in physical system	Measure of number of possible states
Free energy, Social free energy	Thermodynamic potential the changes of which give the maximal amount of work extractable from the system in a quasi-equilibrium process	The largest amount of resources that could be engaged in an organization without violating the stability of its structure

Table 1. Variables in the physical system and in the organizational system.

There is a history of using the concept of entropy in relation to social systems, particularly in information theory (transfer of information). Entropy is defined as the measure of probable distribution of certain states in a system. Entropy suggests an amount of uncertainty associated with a certain distribution of probabilities. Insofar as great uncertainty regarding an outcome also represents a great surprise when it is realized, it could be said that entropy provides also a measurement of information [9]. Entropy as a general systemic quantity has a wide history of being used both in physical models and in the broader, social context, as in [11], [12]. However, entropy does not incorporate interactions with other systems, or with the environment.

Socio-economic discussions incorporating quantities of thermodynamic origin include free energy [8]. It has been interpreted as broadly as profit within economic processes, common happiness or common benefit, or used without a specific meaning. Specifically, it is a measure of the possible social actions in relatively stationary social system states. Stationary

[1]In both systems it is assumed that there is one boundary, and thus that free (social) energy does not depend on external parameters.

implies a state describable using time-independent quantities. This measure of iso-structural social action provides information about what activities can occur in a given social system without significantly changing the system structure. For completeness, the introduction of social free energy also implies the introduction of social temperature as well as social entropy. Social temperature is an analogue of the average of resources in the organization, and social entropy the number of modes of operations in the organization. Here it relates to standard routine activities performed every day in organizational units, and for which indispensable organizational potential is needed.

Before proceeding, let us briefly compare social free energy with an organization's potential and social capital. In order to construct an operational notion of social free energy, we need to connect it with other quantities, particularly through time-evolution of these quantities. An organization's potential is the amount of resources needed in relatively large (or, at least unbounded) quantities to adapt an organization to observed, significant environment change. In this sense, an organization's potential is not restricted to resources that do not change structure. Regarding social free energy and social capital, social free energy places emphasis on whether resources are exploited in constant, predicted, regular dynamics formed by standard of living. In this sense, the type of resources contributing to it is of secondary importance. By contrast, in social capital the type of resources is emphasized, while its use in preserving the social system state is of secondary importance.

6. Measure of Adaptation

We define measure of adaptation formally in an a *posteriori* way, by measuring the flow of resources in different categories, and combining these flows in a defined way. Let us assume that, as a consequence of an uncharacterized process in the environment, quantity dF of resources is transferred in order to suppress that process's undesirable influences. In this sense, the transfer of dF resources prevents structural changes (deformation), changes at the level of strategy, and enables a short-term response and time-localized consideration of the environmental triggering process and related subsequent intra-organization processes. Such a consideration is not always possible.

Transfer dF is related to the temporary change in intensity of other, predicted operations in the organization. Let these changes be defined as SdT. In this sense, they are changes in intensity of existing internal processes and activities rather than changes in structure.

We use the following measure to estimate the level of adaptation:

$$M \equiv \left| \frac{\mathrm{d}F}{S\mathrm{d}T} \right|. \qquad (1)$$

It is to be expected that processes that do not change the structure will be expressed as relatively small, ideally infinitesimal amounts, included in the above formula as differentials.

Intuitively, in a non-adapted organization, the response to environmental influence will be an improvised one, and it is to be expected that on average, resources employed for the response will originate in both classes of resources, i.e. from what would in an optimized organization be considered social free energy (F), and from exploited resources ($T \cdot S$). If that is the case the ratio in (1) will be a fixed quantity, independent of the precise amount of dF and SdT. Conversely, in well-adapted organizations the response will presumably be implemented using social free energy. If that is the case, the numerator in (1) is considerably larger than de-numerator and (1) will attain a relatively large value!

It is at present beyond the scope of the approach to state which range of M refers to the adapted state, and which to non-adapted organizations. This will be addressed once M has been determined for a series of organizations and for a sufficiently large number of types of possible processes. In general valid: the larger the M, the higher the level of adaptation. Conclusions on the results of adaptation level state as well as for the organizational parts, units.

For responses to environmental influencing processes, it is convenient to add the **Pfr** attribute for organizational units to organizational design (Figure 2.). Formally, (1) can be determined after a set of operations takes place. However, if the organization is modeled relatively reliably, then different scenarios can be used to estimate the measure of adaptation (1).

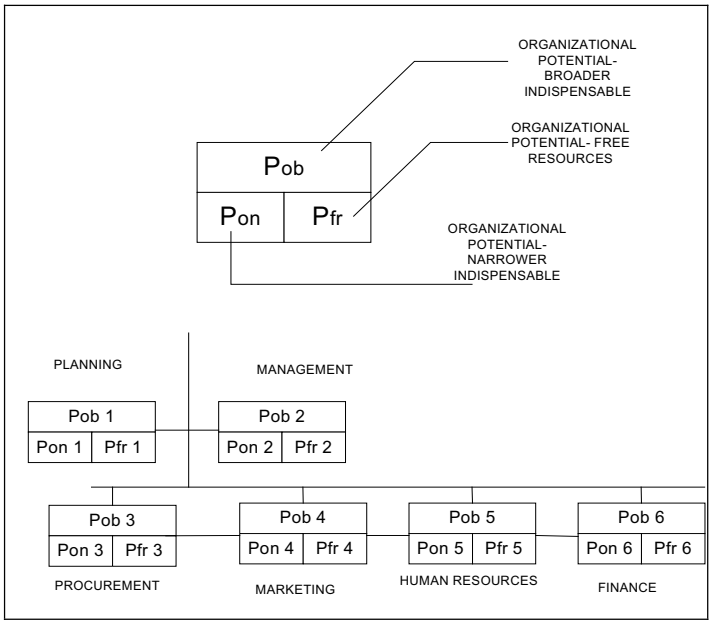

Figure 2. Organizational chart: organizational potentials and organizational design.

Before we conclude, a note should be made regarding the duration of the processes underlying the transfers utilized for (1). We distinguish three time periods – short-term, long-term and intermediate processes. Long-term processes include strategic (and structural) changes. Correspondingly, long-term predictions include (or at least assume with non-trivial probability) significant changes to all types of resources and their aggregations. In the long-term all resources are to be used, and over that term there is no need to define free energy in relation to iso-structural processes. Conversely, in short-term processes free energy is crucial to enable the organization to function properly. We expect that in adapted organizations the short-term dynamics of free energy will absorb the consequences of environment influences.

A discussion on organizational efficiency is significant here. Due to resource costs, independently of rates of engagement, one can argue that the estimate of the indicator of efficiency (E_i) is approximately the following one:

$$E_i \sim |SdT/(dF+SdT)|. \qquad (2)$$

From expression (2) it is obvious that for relatively large changes in free energy, there are on the other hand also tendencies to low efficiency.

In that sense, the expression (2) relates relatively large efficiency with small changes in F, i.e. small values of dF. That is in order, as relatively large efficiency requires sufficient adaptation. When the system is adapted, then there are no sudden, unexpected changes in the environment which would require relatively large amounts of dF, so large Ei are related to small dF. Because of that, an appropriate rate of dF, within the «bottom-upper» limits should be determined for real organizations in defined strategic environments. This task should be facilitated by the differentiated approach toward organizational units design. An useful approach to this issues is given also by concepts of crises management as well as of *sustaining operational resiliency* [4].

Regarding expressions (1) and (2), it is to be noted that these expressions are indicator of dynamics otherwise existing in the system, thus being dependent quantities because of what they cannot be used to infer ranges of other quantities (dF, dT, S, etc.).

Presently, there are no case studies which we could use for inference of possible range of values which dF can obtain (it can be positive or negative, relatively small or not), so that points to be one of the tasks in future.

7. Conclusions And Projections

7.1. Conclusions

In organizational design, when the amount and level of essential resources are to be determined, it is important to make available (in addition to indispensable organizational potential), certain resources and organizational capabilities for situations requiring adaptation to challenges arising from the environment. The amount of organizational potential reserved and the circumstances for its utilization are well defined by formalistic approaches originating in thermodynamics, and can also be applied to organizations as social systems. The key concept in this model is social free energy.

Social free energy is a concept used to quantify the ability of a system to adapt to its environment over a relatively short time without structural changes. Its quantification requires a well-defined, sometimes idealized, context, in order to trace the deployment of resources and link it to the regular and irregular elements in environmental dynamics.

The choice of organizational structure between a mechanistic and organic type has an influence on the level of resources that can be engaged in terms of the free energy segment and the social temperature (regular) segment. If an organization is characterized with a higher level of formalization, resources used for every-day process and activities cannot in the short term be successfully transformed to provide an adequate response to environmental challenges. Therefore, organizations with a mechanistic structure may be supposed to be handicapped in terms of releasing and transforming resources for free energy actions. This mechanism has an influence on how adaptability is determined.

Principles of organizational efficiency require fewer resources to be available for the free social energy segment, which places limitations on this variable. Limitations are very important and should be respected together with the results of applying the formula for adaptiveness. Both these conclusions are important in connection with successful responses to challenges from the environment.

In particular, social free energy and social capital emphasis different topics – the former emphasizing the connection with irregularities in environment dynamics while the latter emphasizes the social character of the resources. They are similar in that both types of resources can be observed dynamically, after a set of events has been analyzed over a defined time span.

7.2. Projections

The example of social free energy points to the fact that an interdisciplinary approach is needed. This gives rise to further issues such as the need to form a basic set of accepted premises, minimum language used and methodology exploited which can be understood by all participants in the analysis. Whilst this may in practice be tedious, the overall objective of quantitatively based understanding and short-term prediction for organizations should be sufficient motivation for overcoming these barriers.

The basic premises in the SFE approach are that elements' characteristics are on the whole well defined aggregated quantities and that the aggregated quantities constantly satisfy the constitutive equations.

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