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Article

Stress Management and Innovation: a Thermodynamic View

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Abstract

The article attempts to identify a thermodynamic origin and expression of stress in a business organization. Moreover it derives thermodynamically on the non-replaceable role of leadership in enabling employees to cope with their experienced stress. Last but not the least it thermodynamically identifies three specific innovation culture models: adhocracy model, facilitative model, and bureaucratic model, each having unique and significant managerial implications.

Introduction

The evidence in literature of studies conducted in various organizational contexts highlighting the negative impact of occupational stress on employees resulting in poor mental health and psychosomatic disease is piling up. [1] One may understand occupational stress as negative environmental factors or stressors, such as work overload, role conflict, etc., associated with a particular task. In the words of Kahn and Quinn (1970), it may include any work role aspects displaying 'noxious' characteristics. [2] Thus not only occupational stress brings down individual performance, but it also affects organizational performance. Individuals, however, cannot remain immune to stress in the organizational contexts thanks to the globalized market scenario prevalent in current times. Enhanced competition and the need for speed in product differentiation and process optimization has never been felt so strongly as now. Innovation in the areas of product, process, cost reduction, quick turnover etc., is now more of a necessity so to enjoy a sustainable competitive advantage. Hence it becomes imperative on the part of the top management and leadership to understand the nature of stress formation, stress reduction, and the

correlation of stress to that of innovation in order to maintain a productive workforce that can keep the organization competitively afloat. Despite many analyses on the nature and solution of the research problem stated above in the management literature, there is little initiative on the part of social scientists and management professionals alike to provide a thermodynamic interpretation and solution to the same. Through this article we attempt to fill the gap. In this direction, the three specific purposes of this article are as follows:

1. Identify the nature of expression of stress in organization.
2. Propose a strategy to manage stress.
3. Investigate the role of stress in directing the nature of innovation.

The science of thermodynamics, the science applicable to any system in the universe, will be used to facilitate these objectives.

Thermodynamic Analysis of Stress

Proceeding on to a thermodynamic analysis of the influence of organizational characteristics on stress formation in employees, we will use the first law of thermodynamics to derive relevant conclusions that shall help us in appreciating the phenomenon better.

Specifically, the first law of thermodynamics otherwise known as the law of conservation of energy stipulates that there exists a function U, defined as the energy of the system of the organization, such that any energetic changes that pass through the boundary of the system, such as organization expansion or work produced, will equal the chance in the energy of the system ΔU between two time intervals:

$$\Delta U = U_2 - U_1 \qquad \text{eq. 1}$$

where U_1 and U_2 are the internal energy states of the organization at an initial time, e.g. day one, and a final time, e.g. day two, respectively. In this context, the basic first law of thermodynamics for a system, defined by a certain number of particles, when an amount of heat dQ is added to the system, in the organizational case the daily rhythmic heat input of the Sun, will cause the system to do an amount of work dW:

$$dU = dQ - dW \qquad \text{eq. 2}$$

It should also be noted that derivatives of heat and work take the form of what are called 'inexact differentials', whereas internal energy is an 'exact differential'. Here, however, for the sake of simplicity, we will ignore these mathematical details, and attempt to present a generalized picture. In this direction, the above first law equation can be rearranged into the form:

$$(dU + dW) - dQ = 0 \qquad \text{eq. 3}$$

In most generalized cases, wherein the organization is modeled as a heat engine, the infinitesimal amounts of work *dW* done by or on the system take the form of pressure volume boundary work:

$$dW = PdV \qquad \text{eq. 4}$$

where *P*, as a first approximation, represents the atmospheric pressure, and the volume change *dV* represents the organization's daily expansion outward into the market place. For the sake of convenience, the important quantity shown in brackets in eq. 3, with substitution of equation 4, can be defined as what is called the enthalpy *dH* or 'heat content' of the system:

$$dH = dU + PdV \qquad \text{eq. 5}$$

This assignment was made in 1909 by Dutch physicist Heike Kamerlingh-Onnes who gave *H* the name enthalpy, from the Greek εν (*en*) 'in' and θαλπος (*thalpos*) 'to heat', which combined define the word *enthalpos*, to warm within. In chemical terms, enthalpy reflects the number and kinds of chemical bonds in the reactants and products. In human chemical terms, modeling people as reactive entities in the changing dynamics of the organization between time one (bonds of the people reactants) and time two (bonds of the human products), the enthalpy represents the change in the heat content of the structure of the organization during the course of, for example, one quarter.

In addition to these expressions, being that amounts of heat *dQ* are difficult to measure, a common substitution is to use the second law of thermodynamics, which equates amounts of heat to the product of the temperature *T* of the system and what is called the entropy *dS* of the system:

$$dQ = TdS \qquad \text{eq. 6}$$

Using this new identity, with substation of eq. 5 and 6 into eq. 3 we have:

$$0 = dH - TdS \qquad \text{eq. 7}$$

This new expression defines what is called an organization or system at equilibrium. For the sake of convenience, we can assign the value to the right of the equality sign in eq. 7 the new name of Gibbs free energy, symbol *G*:

$$dG = dH - TdS \qquad \text{eq. 8}$$

which is named in honor of American engineer Willard Gibbs who pioneered the application of this logic for chemical systems in 1876. In this expression, it is known that due to internal irregular variations of work done by the particles (or humans) of the system or organization as

the system expands and contract each day due to solar heating that the quantity of the entropy of the system *dS* will vary, tending to increase until the system reaches equilibrium, a final dead or non-active state defined by eq. 7. Subsequently, because this entropy variation exists, the value of the free energy of the system *dG* gives an indication of whether or not the organization or system will favorably or spontaneous evolve through its quarter. The rule that indicates favorable quarterly evolution in an organization is given by the expression:

$$dG < 0 \qquad \text{eq. 9}$$

This means that the organization has high potential and is slated to release productive energy in the form of externally-released utilizable work. With these basic equation definitions in place, we will set forth the following human descriptors for each variable:

Symbol	Description
W	Work done on or by the organizational members. The nature of 'work done' is explained later in the article.
H	Stress within the organization developed in the workers and in the connective bond between the individual workers.
T	Resources available to per member of the organization; in accordance with the generic definition of temperature as the average kinetic energy per particle in a physical system (as in Byrant, 2007 in Chen, 2009) [3].
U	Internal energy of the organization which can be understood as stress in the group in absence of organizational intervention.

The potential source of stressors having an organizational source can be grouped into the following factors: task demands, role demands, interpersonal demands, organizational structure, organizational leadership, and organizational life stage. [4] We hypothesize that organizational structure is a function of organizational life stage which can be defined as the 'spent time of an organization in the environment'. Thus, organizational structure can be seen as dynamic and hence can be argued as evolving as a function of exposed and anticipated environmental constraints and demands. Moving further, organizational structure can be interpreted as an architecture that provides the right position for the managers, leaders, and workforce; a place for all with all in right place. So organizational leadership, organizational culture, and organizational life stage are interrelated concepts that we can group under a single dimension: *leadership* – for the purpose of this analysis. Similarly the factors of task demands and role demands can be grouped under a single dimension of *role expectation* that is defined as how others believe one must function given a situation. Therefore under the condition of $\Delta W = 0$, i.e. null organizational intervention condition, it is argued that two dimensions contribute to stress on the employees: role expectation and interpersonal demands. In this direction, herein we will define the internal

energy of an organization as a 'natural self inclination of the organizational actors towards maintaining interpersonal conformity and goal conformity without external aid'.
The simple interpretation of eq. 8 shall be that the change in organizational intervention, or work done, exhibited on a work team shall manifest as change in stress levels of the group members which is defined as a 'dynamic condition in which an individual is confronted with an opportunity, constraint, or demand related to which he or she desires and for which the outcome is perceived to be both important and uncertain'. [3] As can be observed, the definition is silent about the negativity of stress although stress is typically discussed in a negative context. This is because stress also has a positive aspect to an extent [5] for it contributes to enhancement of individual and consequently the group performance since it stimulates the body and improves its ability to react. So for the purpose of this article we shall differentiate stress, or enthalpy *H*, into performance enhancing stress or *positive stress* and performance diminishing stress or *negative stress*.

Thermodynamic Analysis of Innovation from Stress

We will now proceed to identify the nature through which stress manifests in an organization in order to devise an effective management strategy for promoting coping among employees. Investigating deeper, work function *W* used in equations 2-4, is defined thermodynamically as:

$$dW = P(V_2 - V_1) \qquad \text{eq. 10}$$

where *P* is the pressure (a constant value), and $V_2 - V_1$ the change in volume, of the system, respectively. Extrapolating again using the above variables and redefining them in the organizational context, we argue that:

Symbol	Description
P	Relates to the pressure of the involvement of the leaders or top management with the organizational actors.
V	Relates to the volume of targets that have to be achieved.

In this context, the work done by the employees can be understood to be directly proportional to the involvement of the leader with them and the volume of targets that have to be achieved by them.

In thermodynamics, another variable which is important is what is called heat capacity or the relative 'capacity' of a given body to absorb heat. In general, the smaller the temperature change of a body caused by the transfer of a given quantity of heat, the greater its capacity. The measure of the heat capacity for a body at the conditions of constant pressure, which characterize the conditions of the surface of the earth (1 atm), can be defined by the following expression:

$$C_P = \frac{1}{m}\left(\frac{dH}{dT}\right)_P \qquad \text{eq. 11}$$

where C_p is the isobaric specific heat and m is the number of particles or amount of mass of the system. Extrapolating using eq. 11 in the organizational context, although the relation between atmospheric pressure, being the weight of the molecules of the atmosphere pushing down on surface of the earth, and pressure within the organization, being the weight of the people of the surrounding community pushing inward on the company to produce, is elusive, we will argue that the constant pressure condition (eq. 11) is experienced by the group when they perceive that the leadership style exhibited remains unchanged in accordance with the constraints and demands experienced by them. More clearly, the leader remains uninvolved with the group, is immune to its needs and experiences and reduces his or her role to just being a reporting point. In short, the leader is just a position and not a person.

Hence, in accordance with eq. 11, in such a condition, there is a proliferation of stress on account of increasing load of work. Without the aid and approval of an authority, organizational members may find themselves frozen in a particular role that may require additional or different skills for coping thus leading to role conflict which in turn may end in a failure in meeting role expectation that may in turn lead to negative stress as defined before. This leads to a deterioration of organizational performance on a whole. A counter argument can be given to the above stated premise, on the basis of similarity of work type and volume, i.e. the workers shall not feel stressed out if the work type and volume remain unchanged (since role ambiguity nullifies). This is in accordance with the scientific management principle propagated by Taylor (1911). [6] However, the non-sustainable nature of scientific management in ensuring organizational performance and the need of motivation in determining the same, as established by The Hawthorne Studies by Mayo (1933) [7], leads credential to our earlier analysis that in absence of participation and motivation from the leader, the members of the work teams experience negative stress eventually.

Utilizing a different approach, the heat capacity for a structure when measured at constant volume, but with variable pressure, is defined by the expression:

$$C_V = \frac{1}{m}\left(\frac{dU}{dT}\right)_V \qquad \text{eq. 12}$$

Although it is difficult to say if this the isochoric heat expression is applicable to a human organization, we might postulate that, when the employees perceive that the volume of targets is constant, i.e. the rate of inflow of work equals the rate of completion of the same; the stress resulting out of change in participation or influence of the leader on the group is manifested as a change in its internal energy (eq. 12).

Following up from our definition of 'internal energy' in organizational context, we can state that it promotes a change in role expectation or interpersonal demands between the employees or both. Change in role expectation may occur due to alteration in the nature of the assigned tasks or due to boredom induced by similarity or lack of assigned tasks. Alteration in the nature of assigned task usually leads to role ambiguity which calls for a directive style of leading in order to ease the cognitive load (and eventually stress) on the employee. However the remedy for boredom includes job redesign, skill development, and task redistribution in addition to emotional support which calls for a participative style of leadership. This is in accordance with the path or goal theory [8].

Participatory leadership is also an answer to the change in interpersonal demands, such as competition for recognition by the leader, career enhancement, etc., of employees. It helps members in believing the equitable nature of status hierarchy which in turn shall promote group cohesiveness. On a whole the change in internal energy in the organization reshuffles the organization bringing about new coping mechanisms which may in turn change the nature of response given by the organization to the environmental demands. In long run this may end up in changing the organizational culture.

Having discussed the role of leadership in managing stress, we shall now proceed to analyze the effect of stress on employee innovation. Modern organizations are expected to adhere to four important performance standards: innovation, flexibility, quality, and efficiency in order to tide over competition. [9] Hence, the importance of innovation being established, we now utilize the combined law of thermodynamics (eq. 8) to derive three strategies for deducing and understanding the typologies of employee innovation. Using eq. 8, the combined law of thermodynamics, which is the first and second law combined into one expression, can be defined using the capital delta symbol Δ meaning change or the difference between in the variable between two given times, as follows:

$$\Delta G = \Delta H - T\Delta S \qquad \text{eq. 13}$$

where ΔG is the change in free energy, ΔH the change in enthalpy, T the temperature, and ΔS the change in entropy of the system, respectively.

Subsequently, according to the rules of chemical thermodynamics, ΔG is negative for a spontaneous change and positive for non-spontaneous or facilitated change. From eq. 13, it is evident that ΔG = ΔH when TΔS = 0. It means that free energy is the entire heat of the system in absence of energy loss due to entropy change or disorderliness. Thus, at an approximation, organizationally speaking, free energy can be viewed as profit earned by an organization (G) after one subtracts the resources spent (T) and the resources lost on account of experimentation which has its source in employee freedom (S) from that of stress (H) in the system that

originated due to influence of (or work done by) organizational intervention (in according with eq. 1).

Since profit is used for further investment, we can argue that ΔG can be used to represent organizational innovation, as used herein. To make innovation spontaneous to organization ΔG ought to negative (according to eq. 9), i.e. depletion in profit after investment of the same in innovative activities. Hence, based on the above premise we derive the table below:

Typology of Employee Innovation Culture Table

ΔG	**ΔH**	**TΔS**	**Remarks (Absolute values)**	**Strategies for competition**	**Parameters of innovation**
- ve	+ve	+ve	TΔS > ΔH (Adhocracy model)	Product portfolio expansion	Cost reduction
-ve	-ve	+ve	ΔH > TΔS (Facilitatory model)	Differentiation/Competition	Process innovation
-ve	-ve	-ve	ΔH > TΔS (Bureaucratic model)	Expertise	Reduction of turnover time

In this table, ve is short for an absolute value of energy in units of joules. Below we explain the various employee innovation cultures derived from thermodynamic interpretation as represented in this table.

Adhocracy model (of employee innovation):

In this type of innovation culture, stress on the employee is high (since ΔH = +ve) indicating high role ambiguity on account of lack of active involvement of leadership (as noted in eq. 11). An alternative view of 'lack of involvement' of leaders is in my opinion 'non-interference' of leaders who fully trust their employees' abilities in steering the organization and hence provide them with full freedom (since ΔS = +ve) to utilize the organizational resources according to their will and come up with something novel. The organization lacks a formal structure and control mechanism and is characterized by a high degree of informational flexibility. There is no formalized leadership and every employee is expected to be self-initiating type, creating a product as he or she wishes and thus contributing in expanding the product portfolio of such an organization. Such an organizational response is appropriate for a very dynamic environment where the sole fundamental competitive advantage is low cost of production of the products. According to Denison (1990) the culture of these organizations can be termed as adaptable. [10] The 3M company can be viewed to house such an innovation culture.

Facilitatory model (of employee innovation):

This innovation culture is characterized by low degree of stress (since ΔH = -ve) indicating clarity in role expectation due to the interest and participation of leaders in the employee affairs (unlike adhocracy model) and high degree of freedom (ΔS = +ve). We argue that the above

findings go along with market orientation culture of a firm which is characterized by the strategies of differentiation (focused customer bases and hence products) and competition orientation (low cost strategy or providing more value for money). [11] The leaders exhibit focussed control since they have to optimize the usage of resources in accordance with the mentioned strategies. Hence, employees are well informed about their roles and deliverables thus experiencing low levels of negative stress and innovation is highly process oriented (unlike product oriented innovation of adhocracy model). The culture of these types of organization is dominated by mission. [10]

Bureaucratic model (of employee innovation):

In the bureaucratic model of employee innovation that is characterized by low levels of stress (ΔH = -ve) as well as low degree of freedom (ΔS = -ve) granted to employees (as represented in the above table). It can be analyzed and derived that the above conditions result in a bureaucratic innovation culture. Here the low stress levels again indicate that the role expectations from the employees are clear yet the negative entropy indicates a restriction on their freedom. It implies a formalized organizational structure with a limited scope of action and span of influence for the employees. The limited scope of action further implies that no employee is completely involved from the beginning to end of process. The assembly line can be used as an example to understand this culture. Hence the only aspect the employees can innovate on is a judicious utilization of time to increase the rate of turnover. Expertise in the assigned 'sub-process' leading to enhanced rate of churning out of high quality products is the chief strategy adhered to.

The summary of the innovation models, with the underlying strategies and parameters of innovation is provided in above table.

CONCLUSION

In conclusion, we would like to recapitulate the chief findings from the above analysis and the potential learning for business organizations. Firstly, it is very clear that absence of leadership multiplies the volume of stress experienced by the employees (it can be observed in adhocracy model of innovation too). The above conclusion is in accordance with many reported studies on stress management. Thus leaders have an important role in bringing down the stress level of employees.

Secondly, the article threw light on the change in manifestation of organizational stress one can expect in different conditions. While the absence of leadership, irrespective of the work load, gives rise to negative stress, thus bringing about deteriorating organizational performance, the constant work flow condition, brings about a change in the organizational culture under the influence of different types of leadership based on the contextual requirement. Hence, leadership

is must to change culture of a workplace. This conclusion is in accordance with Schein (1990) who echoes the importance of leadership in constructing an organizational culture. [12]

Finally, the article identifies three types of employee innovation cultures possible by taking into account the stress experienced by the employees and the perceived degree of freedom granted to them by the organization, namely: adhocracy model, facilitatory model, and bureaucratic model. In each of these the potential parameter where innovation can be brought about is categorized by keeping an eyesight on the chief strategy that the firm of a given innovation culture must adhere to in order to remain competitive.

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