A comparison between organizational behavior and scientific laws

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Abstract
The authors explore the impact of process change through the lens of scientific law. We seek to establish conceptual links between truths found in the physical sciences and truths found in managerial sciences in order to understand the complexities involved in process change.

Keywords: Business Process Reengineering, Physics, Organizational Change

INTRODUCTION

Radical and disruptive change in any organization is difficult, but at times is desired or simply necessary for firms to compete. Business Process Reengineering (BPR), the radical redesigning of a company's business processes, focuses on reinventing the way firms operate to meet the demands of a modern economy (Hammer 1994). Several companies, including Texas Instruments, Owens Corning, and Duke Power have successfully implemented BPR to improve focus on processes associated with their firms' core competencies (Hammer and Stanton 1999). These firms realized significant reductions in process time, improvements in quality and customer satisfaction, and increases in productivity.

In another study on process change, Al-Mashari and Zairi (1999) defined five dimensions related to organizational change; change management system and culture, management competency and support, organizational structure, project planning and management, and information technology infrastructure. They also identified numerous success and failure factors associated with each of these dimensions**.**

Of course, BPR is a significant and time consuming endeavor that must transcend all parts of the organization (Cao et al. 2001). A holistic approach utilizing process, design, cultural, and political classifications is a common method of implementing BPR (Flood 1996a and 1996b). Flood argues that all types of organizational change fall into these four categories. Thus, all four categories must be analyzed in order for BPR to be successfully implemented.

However, organizational change must not conflict with organizational behavior. Moorhead and Griffin (1995) define organizational behavior as, "the study of human behavior in organizational settings, the interface between human behavior and the organization, and the organization itself" (4). Wagner and Hollenbeck suggest that organizational behavior can be divided into three areas; micro - the study of individuals in organizations, meso - the study of work groups, and macro - the study of how organizations behave (2010). Thus, organizational change must strategically fit with the organizational structure at all three levels (micro, meso, and macro).

The objective of this study, therefore, is to explore the impact of process change through the lens of scientific law. This study seeks to establish conceptual links between truths found in the natural sciences and truths found in managerial sciences in order to understand the complexities involved in process change. Specifically, we seek to establish some conceptual links between the First Law of Thermodynamics and the complexities of organizational behaviors and change.

LITERATURE REVIEW

In order to assess a relationship between scientific laws and business process change, a link must be made between the firm’s economic viability and scientific law. This research proposes to do this by examining two economic theories which will form the basis for the relationship between scientific law and organizational change: resource dependency and group behavior.

Resource Dependence Theory

Resource dependence theory (RDT) argues that the fundamental units for understanding how interfirm relationships aid society are in the relational dependencies between firms. These relationships are not autonomous, but rather are constrained by a network of interdependencies with other organizations. These relationships then leads to a situation in which survival and continued success are uncertain and, as such, organizations take actions to manage external relationships to produce new patterns of dependence. This, in turn, produces power. It is this power, then, that has a significant effect on organizational behavior (Hillman et al. 2009).

There are several implications associated with this theory on many aspects of an organization’s structure and behaviors. These implications can entail decisions associated with the optimal structure of the organizations, the recruitment of board members and employees, the production strategies chosen, the structure of contracts, and the links created to external organizations. Casciaro and Piskorski (2005) noted that the survival of an organization hinges on its ability to source critical resources. Thus, in order to mitigate risks associated with disruptions of flow, firms will try to restructure their relationships with a variety of tactics, including reducing the interest in valued resources, cultivating alternative sources of supply, or forming coalitions. RDT is one of many theories of organizational studies that characterize organizational behavior; but it is not a theory that necessarily explains an organization's performance. In many ways, however, it seems that RDT predictions are similar in nature to those of transaction cost economics.

Group Behavior Theories

Vallacher, Read, and Nowak (2002) stated that "because of its inherent dynamism and complexity, the subject matter of personal and social psychology represents a serious challenge for the methods and tools developed within the traditional natural science paradigm". Thus, given the overarching nature of scientific law and the behavior of nonlinear dynamic systems, should not the laws of natural science apply to the social sciences?

Research into social interaction has shown that overtime groups will form common opinions, altruistic values, and other group level properties. At the individual level, spontaneous self-organization of cognitive and affective elements into higher order structures will develop social judgment, action identification, and self-reflection process (Vallecher et al., 2002). The implications of this work are that organized patterns of social thinking can develop without higher level cognitive mechanisms.

The self-organization of a system reflects its attempt to satisfy the constraints placed on it by its environment. The degree of evolution represents the degree of success that the system has achieved in satisfying these constraints. Dynamic systems are rarely self-contained; instead they are often open to the influences of external forces. These external forces will cause changes in the system through their ability to influence the internal dynamics of the system. As such, changes to the macro level properties of a dynamic system under the influence of an external force frequently are not proportional to the magnitude of the influencing forces (Vallecher et al. 2002).

Thus, economic theory is predicated on the assumption that human behaviors have a degree of predictability. In fact, in a study of human mobility it was found that humans were 93% predictable across all user bases (Song et al. 2010). But, in an effort to make sense of and to understand unpredictability, humans typically attempt to simplify large tasks by breaking them into smaller ones (Heiner 1983).

Other studies have further examined how humans attempt to predict the unpredictable. Kosinski, Stillwell, and Graepel (2013) discuss how personal traits and attributes of individuals can be predicted based upon digital records such as shopping records, Facebook and other social media data. Pentland and Liu (1999) proposed that human behaviors could be accurately described using a set of dynamic models sequenced together in a Markov chain. In using this approach, they were able to prediction automobile driver's actions with 95 percent accuracy.

SCIENTIFIC LAWS

The laws of science, according to Nagel (1979), are laws derived by "observing things and events that are encountered in common experiences. The scientific thought process aims to understand these observable things by discovering some systematic order in them . . . the final test for the laws that serve as instruments of explanation and prediction is their concordance with such observations." Simply stated, the laws of science attempt to articulate relationships between objects, events, and phenomena that we observe in nature. In order to be considered a law, the relationship should be consistent over time, function, and space.

The Firm as a Heat Engine

The process by which a firm takes investment dollars and creates production of goods and services, with some inevitable waste, may be likened to a thermodynamic heat engine which extracts heat from a high temperature reservoir and converts it into useful work with inevitable waste heat. In this metaphor we might liken *energy* to *money* or some other measure of value. The goal here is to see if a production process can be likened to a cyclic heat engine producing work. Since we are aiming to optimize the efficiency of the production process, we will focus on the properties of an ideal heat engine.

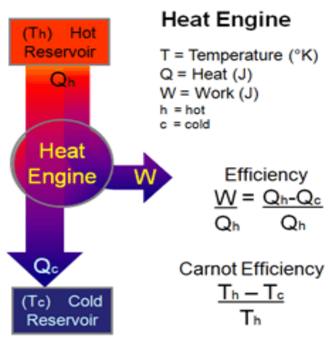

Figure 1: The Carnot Heat Engine

The thermal properties of engines are based on the First and Second Laws of Thermodynamics. These laws dictate the thermal properties of matter in all processes, that is, changes in the macroscopic thermal variables like temperature, pressure, volume, etc. Understanding heat engines from a fundamental perspective requires an understanding of these laws and how they relate to thermodynamic processes. For this study, we will examine the First Law of thermodynamics.

The First Law of Thermodynamics

The 1st Law of Thermodynamics is essentially a statement of Conservation of Energy. It is a relationship that must hold throughout any process, which means literally when anything happens in the natural world. Energy is the "stuff" that stays the same throughout any process, such as a swinging pendulum. When a pendulum swings, energy is constantly being converted from gravitational potential energy into kinetic energy and back again. However, the total energy, the sum of the potential and kinetic, remains a constant.

A thermodynamic system can be characterized by an internal energy, which is a sum over the energies of all of the molecules or atoms in the system. The First Law states that the change in the internal energy of a system like a cylinder of gas must equal the heat energy (Q) added minus the work done by the gas (W), e.g. in expanding against a piston:

$$\Delta E_{\text{int}} = Q - W \tag{1}$$

Where, E is the internal energy of the system, Q is the heat energy (i.e., internal energy), and W is the work accomplished by the system (i.e., energy transferred by the system to another).

This statement on the conservation of energy also applies to the production capabilities of the firm. The available capacity (ΔE_{int}) of a process is equal to its design capacity (Q), or maximum sustainable capacity, less the capacity currently committed to production (W). W can also be expressed as:

$$W = Q * OEE \tag{2}$$

Where, OEE is defined as the percent machine availability times the percent quality yield times the % optimal production rate that equipment operates at. OEE ranges from 0% to 100%.

Ideal Gas

As seen in figure 2, a heat engine can best be understood in terms of processes based on a pressure versus volume diagram. In particular, the ideal heat engine, or Carnot Engine, may be expressed as a series of isothermal and adiabatic processes in an Ideal Gas. An adiabatic process is defined as one in which no heat is transferred either in or out of a system. From the first law of thermodynamics, this type of process is expressed as:

$$E_{\text{int}2} - E_{\text{int}1} = \Delta E_{\text{int}} = -W \tag{3}$$

In an isochoric process (i.e., constant volume), no work is done on its surroundings, thus:

$$\Delta E_{\text{int}} = Q = (p_2 - p_1)V \tag{4}$$

With isobaric process (i.e., constant pressure), neither ΔE_{int}, nor Q, nor W is zero; thus:

$$W = p(V_2 - V_1) \tag{5}$$

Isothermal processes (i.e., constant temperature) the relationship between ΔE_{int}, Q, and W is defined by a function which is shown in a pressure versus volume diagram.

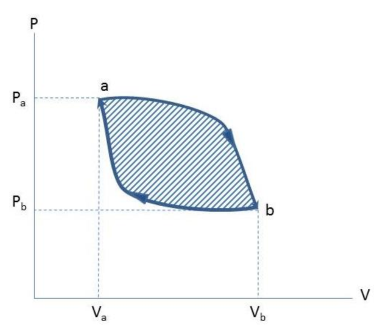

Figure 2: The P-V Diagram

The Ideal Gas Law relates the thermodynamic variables of pressure, volume, and temperature for a theoretical gas of non-interacting particles, and may be written:

$$pV = nRT \tag{6}$$

Where, p is pressure (metric units: Newton/meter^2; standard units: pounds per square inch), V is volume (metric units: cubic meters; standard units: cubic inches), n is the number of moles of the gas. R is proportionality constant also known as the Universal Gas Constant and T is the temperature of the system as measured in Kelvins.

From a business perspective, these variables can be described as follows; p is the price the firm has set for each units sold in the marketplace; V is the number of units sold; due to moles being scientifically defined as the number of atoms determined experimentally to be found in 12 grams of carbon-12. For the firm, one mole of a product is equal to the number of units that can be placed in an industry standard shipping container; R is still a proportionality constant; and, T is the market value of a single unit of production for a given product.

Due to equation 6 using moles as the measure of mass instead of a measure of atoms, another way of expressing the ideal gas law is to use Boltzmann's constant, which is symbolized as "k". Avogadro's constant is the number of constituent particles; the atoms or molecules that are contained in the amount of substance given by one mole. Thus it is the proportionality factor that relates the molar mass of a material to its mass. Bolzmann's constant relates energy at the individual particle level with temperature by dividing the gas constant (*R)* by Avogadro's constant (N_A):

$$k = R/N_A \tag{7}$$

This constant is defines the energy in a gas molecule as being directly proportional to the absolute temperature. So, as the temperature of a system increases, the kinetic energy per molecule increases; thus, increasing the pressure if the gas is confined in a space of constant volume, or increases the volume if the pressure remains constant. Thus, we rewrite equation 6 as follows:

$$pV = nRT = NkT \tag{8}$$

Where, N is the number of molecules and k is Boltzmann's constant. From a business process perspective, the value of a process' output is equal to the price charged (p) times the number of units produced (V). Another way of stating this is, the number of units for a given product that is firm's marketshare adjusted demanded (N) times the value (T) that the market places on a unit times an industry/product specific constant (k).

For a closed system, that is a container of gas that cannot lose or gain any additional molecules, then the Ideal Gas Law may be written in the following useful form:

$$\frac{pV}{T} = nR = Nk \tag{9}$$

Expanding on the nR = Nk relationship, if we define n as the number of products in a given market, N is the total demand for that market, and k is a given firm's marketshare within that market, then R is a constant that relates the number of product variants to market demands as follows:

$$R = \frac{Nk}{n} \tag{10}$$

We can further expand on this relationship to make it more specific to a given firm, or a single product line by relaxing the scientific definition of R as a universal gas constant as follows:

$$\overline{R} = \frac{1}{n}\sum_{i=1}^{n} R_i \tag{11}$$

Given that the number of molecules in an ideal gas is constant, then the quantity $\frac{pV}{T}$ will always remain constant. So if we have an initial state and final state we may write:

$$\frac{p_i V_i}{T_i} = \frac{p_f V_f}{T_f} \tag{12}$$

If it is also the case that the temperature remains constant, then the law takes the form:

$$p_i V_i = p_f V_f \tag{13}$$

This concept is consistent with the economic principle of demand elasticity.

Internal Energy

The internal energy of the gas is the sum total of the energies of all the molecules and may be written as:

$$E_{\text{int}} = nC_V T \tag{14}$$

Where, C_v is the specific heat at a constant volume $C_v = (^f/_2)R$ for molecular degrees of freedom *f*. The degrees of freedom have to do with the number of different ways a molecule may move. In a business/manufacturing environment the degrees of freedom for a given product best equates to the number of variants that exist for the product. For a monatomic gas (like Helium He or Neon Ne) the atom may move in 3 physical dimensions (*x*, *y*, *z*) and so the number of degrees of freedom is *f*=3 For a diatomic gas (like Oxygen O_2 or Nitrogen N_2) the molecule may move in the three physical dimensions as well, but additionally they may also rotate and vibrate, and so there are two more degrees of freedom. Hence, *f* = 5 for diatomic gases.

To say that C_V is at constant volume means that the volume of the gas does not change, like it was in a rigid container that cannot expand or contract. In this type of process the pressure and/or the temperature may change as heat energy is added (or removed). We may also consider processes in which the pressure is held constant, in which case the temperature and/or volume will change. In this case we consider the Specific Heat at constant pressure (C_P) which may be written as:

$$C_P = C_V + R \tag{15}$$

Since $C_v = (f/2)R$ the Internal Energy may be written $E_{int} = (f/2)nRT$ and so for any process the change in the internal energy is $\Delta E_{int} = nC_V \Delta T$. The important aspect of this relation is that the internal energy depends only on the temperature of the gas.

The degrees for freedom for the firm are related to the number of ways that it can transform Product A from raw materials into throughput. The most common alternatives are related to the number of production lines capable of producing Product A, including outside sources, and the number of alternative processing methods. As the degrees of freedom for production increases and as the operational efficiency of those paths increase, the organizations flexibility also increases. Thus, for the firm, constant volume of the system would be calculated as:

$$C_v = \left(\frac{f}{2}\right)R \tag{16}$$

Therefore, C_v defines the average throughput of a process when $\overline{R}$ is for a single product (i.e., n=1), or for a firm when n=m, or for a whole market when n=n.

There are two types of specific heats defined for gases, one is for constant volume (**C_V**) and the other is for constant pressure (**C_P**). For a constant volume process with a monoatomic ideal gas the first law of thermodynamics gives:

$$Q = nC_V \Delta T = \Delta U + \Delta W \tag{17}$$

When there is no work being performed by the system, then:

$$Q = nC_V \Delta T = \Delta U \tag{18}$$

As heat is applied to the system and work is performed, at a constant pressure, the work performed is expressed as:

$$Q = nC_p \Delta T \tag{19}$$

The change in work done by this constant pressure system is:

$$\Delta W = p\Delta V = nR\Delta T \tag{20}$$

By substitution of equations 11, 12 and 13 into the first law of thermodynamics, $Q = \Delta U + \Delta W$, we obtain:

$$nC_p \Delta T = nC_v \Delta T + nR\Delta T \tag{21}$$

Further, application of the ideal gas law and first law gives the relationship for the specific heat at constant pressure:

$$C_P = C_V + R \tag{22}$$

The implications to the firm are that as C_v increases the forces exerted on the business by C_p become less significant.

CONCLUSIONS AND FUTURE RESEARCH

As marketplaces and society evolve, competitive pressures will build, forcing the organization to change. How the organization changes must be determined by management. Once strategic responses to the market pressures are developed, management must motivate the organization to evolve towards the new design/culture.

In relating the organization to thermodynamic systems, we must picture the individual people the organization as being atoms within a larger mass. Thus, in examining the First Law of Thermodynamics, we see:

1. That a firm can be looked at as a heat engine. The inputs to a system become the heat which is applied. This heat is then extracted from a high temperature reservoir, that is, the potential work and transformations that must take place. This heat that is extracted rom the reservoir is then converted into useful output along with the inevitable waste.
2. That the conservation of energy holds true in an organization. That is, the available capacity of a system must equal its design capacity.
3. That based on the Ideal Gas Law demand elasticity holds.

For the current direction of this research we would like to examine these conclusions and develop new ones so that we can more readily apply them to an organization. We would like to address the questions of: what do these principles mean with respect to the processes of a firm, how may the help manage the processes of a firm, and how might a firm best manage this change? Thus, we would like to examine how scientific law converges with process changes, and determine factors that make it difficult for an organization to manage change, with a theoretical foundation and framework in the natural laws. But, at the same time, we would like to relate our conclusions to the current economic theories that were discussed in the literature review.

As we continue to improve this manuscript, we anticipate examining the second law of thermodynamics and how we might be able to relate this law to organizational change. We feel this may make the research more robust and allow us to examine other constructs that may help bridge some of the gaps we currently feel are missing. We have also toiled with the idea of examining Flood's four categories of organizational change. We would like to address the question: is it possible to examine Flood's four categories of organizational change with respect to the first (and perhaps second) law of thermodynamics.

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