What is Business Entropy?

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What is Entropy?

Entropy was first glimpsed in 1824 when Sadi Carnot, son of a Prime Minister of France, observed that steam engines wasted 97% of their heat energy, and wondered how efficient they could be. An engine works by drawing *input* heat Energy E_i from e.g. gasoline and exploding it at high temperature T_i, the energy in the gas then pushes on a piston to turn a crankshaft and do useful external work, but some of the input heat Energy, an amount E_w, is delivered to the environment as *waste* at a lower temperature T_w .

In 1850 Rudolph Clausius found a mathematical expression for Carnot's ideas. Clausius found that the ratio of heat energy to temperature, at both the *input* and *waste* could at best be constant, and he called this constant Entropy:

$$\text{Entropy} = \frac{E_i}{T_i} = \frac{E_w}{T_w}$$

We can solve this equation for the minimum energy that an engine must waste:

$$\text{Minimum Energy Waste} = E_w = T_w \left(\frac{E_i}{T_i} \right) = T_w \ \text{Entropy}$$

Thus, no matter how clever the design, an engine must waste some of its input energy. The equation tells us that if we increase the input combustion temperature T_i we can reduce the entropy and waste. The knowledge of this functional form of waste has focused engineers to seek ever higher temperatures starting at about 100°C for the engines at the time of Carnot to 3000°C for modern gas turbines which are 40% efficient. Clausius also found that the entropy of a gas was proportional to the logarithm of the volume V of the gas, log V.

What is Business Entropy?

Businesses purchase material and labor as input to a manufacturing or service process to create products and services of value to customers. Inevitably business processes must *waste* some money on effort not really of value to customers such as warehouses, quality defects, obsolescence, etc. Is there some minimum amount of waste in a business process? Can we find an equation for this waste similar to that of Clausius that may tell us how to reduce the waste and focus the development of more efficient companies?

An early clue to the equation of business waste was provided by Henry Ford. He found that by reducing the time to build a car (called the cycle time) from 14 days to 33 hours, that he was able to eliminate most of the waste cost and make more profit selling the same car for $345 instead of $850. Thus somehow waste is related to the cycle time from the beginning of work to its completion as a finished product or service but we would like to know the functional relationship. The cycle time of any business process is governed by Little's Law[1]:

$$\text{Average CycleTime} = \tau = \frac{\text{Number of Units of Work In Process}}{\text{Average Completon Rate}}$$

For example, if you are receiving and completing about 10 requests per hour and have 20 requests on your desk "in process", then the average cycle time of a request through your desk is 20 requests/ 10 requests/hour = 2 hours.

Little's Law has been referred to as the "Newton's 2^{nd} Law" of processes[1]. In the paper on the home page and RePEc[2] we took this comment seriously: we calculate the velocity of a process as the inverse of the cycle time. We then calculate the acceleration of the process by taking the derivative of the velocity. Finally, we calculate the amount of energy needed to reduce the cycle time say from 14 days to 33 hours. We obtain an equation for the logarithm of the cycle time, $\log\tau$ which looks just like Clausius' equation for the entropy of a gas. At constant Average Completion Rate, Little's Law allows us to alternatively use log(Number of Units of Work In Process =W). If W consists of Q different part numbers with w_i units of the i^{th} part number, $\log_2 W$ can be shown[2] to equal:

$$\log_2 W = -\sum_{i=1}^{Q} p_i \log_2 p_i + \sum_{i=1}^{Q} p_i \log_2 w_i = H_Q + H_{PD} \text{ where } p_i = \frac{w_i}{W} \text{ and } W = \sum_{i=1}^{Q} w_i$$

H_Q is the Shannon Entropy due to Randomness of Variety which is diminished by complexity reduction[3], and H_{PD} is Entropy due to Process Deficiencies such as defects, setup time, etc which can be reduced by process improvement (e.g. the Toyota Production system[4]). Thus the addition of information through process improvement reduces the entropy of the process. Information is negative entropy.

Hypothesis of $\log\tau$ as a predictor of cost reduction

We know that the minimum waste in an engine is proportional to the entropy, and that the entropy of the working gas is proportional to logV. We know that the entropy of a business process is proportional to the log of the cycle time, $\log\tau$, and case studies support *the Hypothesis that the waste is also proportional to* $\log\tau$. If we observe $\log\tau$ in a large number of cases, we can then equip business executives with a strong financial justification for cycle time reduction as a means of reducing cost and increasing profit.

Testing the Hypothesis

To prove or disprove the hypothesis, we need to determine if the cost falls as a function of $\log\tau$. To calculate τ we must accurately know the factors in Little's Law. This data is not available with adequate accuracy from the public financial statements of corporations. Thus the Institute of Business Entropy is involved in effecting the appropriate data collection to test the Hypothesis using the tools of Statistical Inference. Academics and Companies who have an interest in cost reduction are encouraged to inquire at mike@entropy2718.com.

Origins of the word Entropy

Many different versions of the origin exist, but at least one sheds some light on the concept. The Greek entropy (εντροπη) has been said to mean[5] "one sided transformation". We have learned above that *not all* the input heat energy in the gasoline can be transformed to useful work…some energy must be wasted due to entropy. However, *all* the energy of useful work can be transformed to heat by means of friction, such as hitting the brakes of your car. The one sided *not all* versus *all* distinguishes entropy from energy, the latter being entirely symmetrical.

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[1] Factory Physics, W. Hopp and M Spearman, Irwin Press 1996,
[2] ftp://65.115.58.47/econ/RePEc/PDF/LogCycleTimeasaPredictorofCostReduction.pdf
[3] Conquering Complexity, M.George and S. Wilson, McGraw-Hill 2004
[4] Lean Six Sigma, M. George, McGraw-Hill 2002
[5] Textbook of Thermodynamics, P. Epstein, Wiley 1961