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Nasim Nahavandi
Faculty of Engineering, Tarbiat Modarres University, Tehran, Iran
E-mail: n_nahavandi@modares.ac.ir

Farzad Haghighi Rad
Faculty of Engineering, Tarbiat Modarres University
E-mail: haghighirad@yahoo.com

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MEASURING SUPPLY CHAIN ENTROPY USING TSALLIS METHOD

ABSTRACT. Quantitative techniques for the measurement of uncertainty have been developed in information theory studies. One of these techniques, based on an entropy measurement, has been applied to the assessment of supply chain uncertainty. Using this technique, it is possible to consider two fluctuations. Therefore in this paper for calculating entropy, customer and supplier effects in uncertainty have been employed simultaneously.

JEL Classification**:* C5 ***Keywords: entropy, supply chain, uncertainty, Tsallis.

Introduction

The concept of entropy has been very widely used in scientific literature. Confusion regarding the exact nature of the concept is equally widespread (Haynes, Phillips, & Mohreeld, 1980). In thermodynamic context entropy is the friction inherent in any real system that defined as follow:

$$dS = \frac{dQ}{dT} \quad (1)$$

Where *dS* is the change in entropy in a closed system due to a physical process in which a quantity of heat, *dQ*, flows from a higher to a lower temperature (*dT*) (Clausius, 1979).

From the perspective of communication and information theory, there is a close correspondence between entropy and uncertainty. Shannon looked at information as a function of a priori probability of a given state or outcome among the universe of physically possible states (Shannon, 1948).

Shannon defined information as “that which decreases uncertainty” (Shannon & Weaver, 1963). He showed that the basic information measure over a set of informational symbols, $x_1, x_2, x_3, \ldots, x_N$ is:

$$H(x) = \sum_{i=1}^{N} - P(x_i) \ln P(x_i) \quad (2)$$

Where *H(x)* is the information, X is a random variable with a domain of N informational symbols, $x_1, x_2, x_3, \ldots, x_N$, sometimes called alphabet, and the range of the random variable is the probabilities, $P(x_i)$ (Sneddon, 2007).

Many researchers have been used from Shannon method for measuring entropy in various cases. Since the aim of this paper is measuring entropy in supply chain, therefore in the following of the paper, the related literature of entropy in the supply chain is mentioned.

Ronen and Karp have employed entropy based formulations to depict the flow of raw material and information flow in the supply chain (Ronen & Karp, 1994). Some researchers have used from entropy-based formulation to quantify a supply chain's structural and operational complexity derived from the material and information flow uncertainty (Frizelle & Woodcock, 1995) and (Sivadasan, Efstathiou, Frizelle, shirazi, & Calinescu, 2002). Olvera has proposed an entropy-based formulation as the basis of a methodology for comparing different information sharing approaches in a supply chain environment (Olvera, 2008). Shuiabi and et al have employed Shannon method for measuring flexibility of manufacturing operations (Shuiabi, Thomson, & Bhuiyan, 2005). Inventory is one of the important driver in supply chain. Brindle and Gibson have used Shannon entropy method for the assessment of medical device diversity in large inventories of medical equipment (Brindle & Gibson, 2008)

Some researchers have used entropy versus quality. Radosavljevic and Williams are presented a way in which to establish the level and change of entropy, employing the six sigma rate/probability of defectives/defects evaluation (Radosavljevic & Williams, 2005). Sharma and et al have been defined system entropy, wastivity and quality and they have presented conceptual relationships between them (Sharma, Sushil, & Gupta, 1994). Dissanayake and et al have described the application of entropy concept in quality control and they have proposed a method for evaluation of sources of risks and quality reduction in the complex system (Dissanayake, Pankov, & Shestakov, 2004).

Most researchers in the field of supply chain have employed Shannon entropy-based formulation to measure diversity, flexibility, quality, information sharing level and other subjects. In this paper we have used Tsallis method to calculate entropy in supply chain. This method is more suitable for entropy measurment in supply chain than Shannon, because it employ two type fluctuations.

In section 2, we will explaine the Tsallis entropy brifly. Section 3 describes the use of Tsallis method for measuring entropy in supply chain and finally the paper is concluded in section 4 discussing the results and further related research opportunities.

1. Tsallis entropy

Tsallis entropy was first introduced by Havrda and Charvat and examined in depth by Aczel and Daroczy (Sneddon, 2007). This entropy measure differs from Shannon entropy, which is an extensive measure. In extensive entropy, the entropy of a system is equal to the probability-weighted sum of the entropies of each part of the system. In addition to probabilities, there is another parameter in Tsallis entropy for measuring intrinsic fluctuations (Wilk & Wlodarczyk, 2008).

$$S_q = -\sum_i P_i Ln_q P_i = -\sum_i P_i \frac{(1 - P_i^{q-1})}{1-q} \quad (3)$$

Here, q is a parameter that is grater than 0. Note that, in the limit that q goes to 1, this reduces to the Shannon measure. For understanding equation 3 see following example (Wilk & Wlodarczyk, 2008).

Consider a system of size V_0 and divide it into cells of size V each; we then have $M=V_0/V$ such cells (divisions). Suppose now that in one of these cells an object is hidden and that the probability to find it in a cell is the same for all cells and is $\frac{1}{M}$. The corresponding Shannon entropy, describing the situation of finding this particle in one of the cells. Suppose that the in a cell there can be more (or less) than one particle (see *Figure 1*).

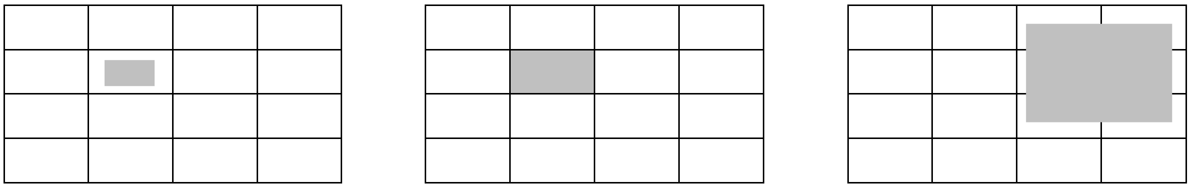

Fig 1. Schematic illustration of three possible situation encountered when gathering information (Wilk & Wlodarczyk, 2008).

In this case, equation 3 rewritten in the following form.

$$H = -\sum_{i=1}^{M} \frac{V}{V_0} \frac{(\frac{V}{V_0})^{\frac{V}{v}} - 1}{\frac{V}{v} - 1} \qquad (4)$$

$k = \frac{V}{v}$ is the number of particles that can put in a given cell. As illustrated in *Fig. 1* one can encounter three typical situations:

- Even when one finds the right cell one still has to search for a while before deciding that the chosen particle is the right one. In our example this is visualized by the fact that the particle is smaller than the cell and there can be more than one particle per cell (left panel of *Fig. 1*).
- It can happen that one is sure that the chosen particle is the right one even before the right cell has been identified. In our example this corresponds to a situation when the particle is bigger than the cell (right panel of *Fig. 1*).
- The information needed to locate the particle is the same as to find the right cell. It means that volumes of cell and particle are equal and there can be only one particle per cell (middle panel of *Fig. 1*).

2. Application of Tsallis entropy in supply chain

Tsallis entropy is a more comprehensive method comparing to Shannon entropy method because in shannon method we have only P_i parameter (probability of possible events in the sample area) but in Tsallis method we have also *q* parameter. *q* parameter presents somehow the intrinsic fluctuation of the physical system. In this article two types of fluctuations in supply chain have been selected. One of them is from the role players perspective and the other is from the customers perspective in supply chain.

Based on Chopra and Meindl definition: A supply chain consist of all stages involved, directly or indirectly, in fulfilling a customer request (Chopra & Meindl, 2001). According to the above mentioned definition, the main purpose of supply chain is to fulfill the customers' needs. These needs can be divided into two groups:

1. Predefined requirements that have been covered through product design.
2. Implicit needs of the customer that come across after using the product.

In many products such as automobiles, home appliances and cell phones, the product is guaranteed by a specific manufacturer. The number of requests for using guarantee services depends on the type and complexity of product.

In Iran, the experiences show that a considerable amount of requests for using guarantee services are based on customers implicit needs which have not been considered in product design.

Taking into account the above explanations, the selected parameters for calculation of supply chain entropy are as follows:

N: Total number of requests for using guarantee services in a specified period.
m_i: Number of problems mentioned by customer i which are realistic and can be fixed.
n_i: Number of problems mentioned by customer i which are based on his/her implicit needs.
P_j: Contribution of player j in causing realistic problems

Therefore the value of *q* in equation 3 is:

$$q = \frac{\sum_{i=1}^{N} m_i}{\sum_{i=1}^{N} (m_i + n_i)} \qquad (5)$$

Figure 2 shows the role of *q* in calculation of entropy. In this image the assumption is that the supply chain has three members and for each members P_{jk} equals 1/3.

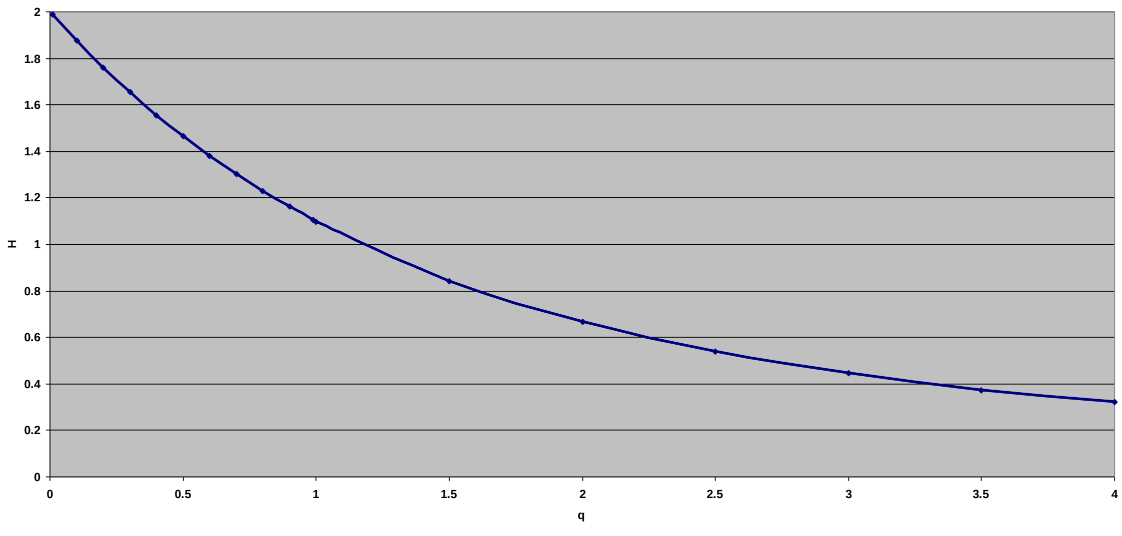

Fig 2. Effect of *q* parameter in Tsallis entropy value

As illustrated in *Figure 2* the reduction of *q* results in the increase of entropy. In this case, the increase of entropy is not due to producing the defective product but it is due to lack of attention to the implicit needs of the customer. So it is possible to reduce entropy by improving the specifications of product.

3. Numerical example

Figure 3 present an automotive supply chain in top level in Iran. As illustrated, autopart manufacturers deliver produced parts to supplier company of automotive parts (named SAPCO) and it delivers the parts to the automanufacturing company and the automanufacturing company assembles the parts and delivers the autos to the customers.

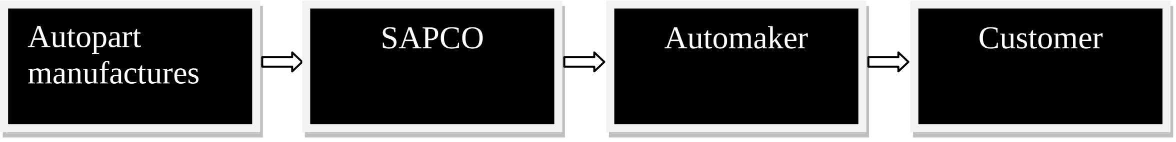

Fig 3. Automobile supply chain in the top level

All cars are guaranteed for a specific period. *Table 1* shows the information about 10 customers who have asked for using guarantee services.

Table 1. Customers Information

Customer Number	*Identified Problem*			Source of the Problem		
	Quantity	*Realistic*	*Implicit*	Autopart manufactures	SAPCO	Automaker
1	4	3	1	1	0	2
2	6	2	4	0	1	1
3	8	3	5	2	1	0
4	3	1	2	0	0	1
5	7	5	2	3	1	1
6	5	4	1	0	2	2
7	6	2	4	0	0	2
8	2	2	0	1	1	0
9	6	4	2	2	1	1
10	9	6	3	1	2	3
sum	**56**	**32**	**24**	**10**	**9**	**13**

According to the equation 3 the entropy of the above table is:

$$q = \frac{32}{32+24} = 0.57 \qquad P_1 = \frac{10}{32}, P_2 = \frac{9}{32}, P_3 = \frac{13}{32}$$

$$H = 1.39$$

Conclusion

Measurement of entropy can be helpful in identifying improvement ereas in supply chains. In this paper, Tsallis entropy method is used for measuring supply chain entropy. Tsallis entropy method is more comprehensive compared to the Shannon entropy method and in specific point (q=1) both methods are applicable. In this method, the irregularity occurred in the supply chain is measured from both customer and supplier perspectives. Sometimes customer realise his/her implicit needs after using a product. He/she assumes these needs as real shortcomings of product and go to dealership offices to get the problem fixed. These expectations can be identified and considered in product design. It will result in considerable decrease in entropy.

Future research

Differentiating between customer's implicit needs and real product defects is not an easy thing to do. In these cases the entropy can be measured by combining the above method and fuzzy set theory.

References

Brindle, G. W., & Gibson, C. J. (2008), Entropy as a measure of diversity in an inventory of medical devices, *Medical Engineering & physics*, 30, pp. 399-401.

Chopra, S., & Meindl, P. (2001), *Supply chain management: strategy, planning, and operations*: Upper Saddle River, NJ: Prentice-Hall.

Clausius, R. (1979), *The mechanical theory of heat*: Macmillan, London.

Dissanayake, Y. B., Pankov, A., & Shestakov, V. (2004), Quality control on the basis of entropy determination, *Transport*,19(2), pp. 51-55.

Frizelle, G., & Woodcock, E. (1995), Measuring complexity as an aid to developing strategy, *International Journal of Operations & Production Management*, 15(5), pp. 268-270.

Haynes, K. E., Phillips, F. Y., & Mohreeld, J. W. (1980), The Entropies; some roots of ambiguity, *Socio-Economic Planning Science*, 14, pp. 137-145.

Olvera, C. M. (2008), Entropy as an assessment tool of supply chain information sharing, *European journal of operational research*, 185, pp. 405-417.

Radosavljevic, D. A., & Williams, W. F. (2005), *QUALITY VS ENTROPY.* Paper presented at the 32nd International Annual YUSQ Conference-Toward integrated management systems, Belgrade, Sebia & Montenegro.

Ronen, B., & Karp, R. (1994), An information entropy approach to the small-lot concept, *IEEE Transactions on Engineering Management*, 41(1), pp. 89-92.

Shannon, C. E. (1948), A mathematical theory of communication, *Bell System Technical Journal*, 27, pp. 379-423, 623-656.

Shannon, C. E., & Weaver, W. (1963), *The Mathematical Theory and Communication*: University of Illinois Press, Urbana.

Sharma, H. D., Sushil, & Gupta, A. D. (1994), Entropy, Quality and wastivity, A unified view of system performance, *Kybernetes*, 23(8), pp. 47-54.

Shuiabi, E., Thomson, V., & Bhuiyan, N. (2005), Entropy as a measure of operational flexibility, *European journal of operational research*, 165, pp. 696-707.

Sivadasan, S., Efstathiou, J., Frizelle, G., Shirazi, R., & Calinescu, A. (2002), An information-theoretic methodology for measuring the operational complexity of supplier-customer systems, *International Journal of Operations & Production Management*, 22(1), pp. 80-102.

Sneddon, R. (2007), The Tsallis entropy of natural information, *Physica A*, 386, pp. 101-118.

Wilk, G., & Wlodarczyk, Z. (2008), Example of a possible interpretation of Tsallis entropy, *Physica A*, 387, pp. 4809-4813.