Quality Festival 2019
ISSN 2620-2832

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A CYBERNETIC VIEW OF QUALITY SYSTEM

Abstract: *The work exposes a quality system model of an industrial entity based on cybernetic theory that deals with complex systems, nonlinearity, uncertainty and information in broad sense. Quality system encompass continuous cycle of information extraction, information creation and information transformation. Information extraction generates environment model that undergoes the Law of requisite variety. Information creation determines design quality and information transformation determines product quality. All the process can be understood as activity of a cybernetic system. It is obvious that methods like Quality Function Deployment, ISO 9000, and so on, are embodiments of a cybernetic system with the aim of adaptability to chaotic environment.*

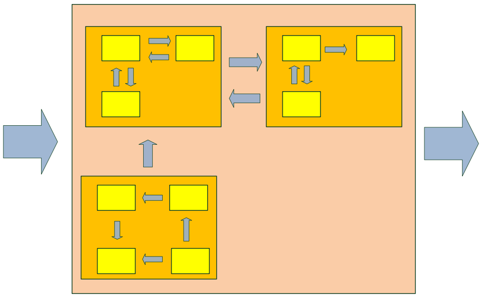
Keywords: *System, Complexity, Uncertainty, Information, Adaptability, Nonlinearity Quality*

1. Introduction

1.1. System theory

Norbert Wiener in his 1985 book argued that everything can be described as a system, broken down into “black box” components with inputs and outputs, and then understood using the ideas of information flow, noise, feedback, stability, and so forth.

In a structural sense under the term system is supposed a certain object regarded as consisting of interrelated material and conceptual objects which are called subsystems of the given system. The subsystem of a certain system may also be considered as a system composed of other subsystems. There is always some ultimate level of a system decomposition containing elementary subsystems that cannot be broken down into constituent subsystems (Figure 1.).



Legend: ⇨ - input or output;
□ - system or subsystem

Figure 1. Example of an open system

Real physical nature of the elementary subsystems is of no significance for the Systems Approach, where only behavior of the subsystems matter. So, the nature of subsystems may be fundamentally different, but if at certain level of systemic description they are arranged and interrelated in the same way (considering the behavioral aspect), then from the point of view of

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General System Theory they can be considered as identical at this level (Turchin, 1977).

Open system is defined as a system with the input or output (Figure 1.).

Here are also applicable the following definitions of systems:

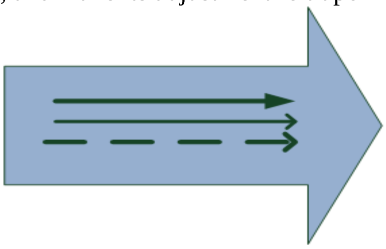
- "A system is a set of interacting elements that form an integrated whole" (de Rosnay, 1979) .
- "A system is a network of interdependent components that work together to try to accomplish the aim of the system" (Deming, 1994).
- A system is that part of the universe that we are interested in. The surroundings is the entire universe excluding the system. The system and surroundings are separated from each other by a boundary. A system is at any time in a certain thermodynamic state or condition of existence. A system is said to be closed if it can exchange heat with the surroundings but not matter. But if matter can be exchanged between system and surroundings the system is said to be open. An isolated system is one in which the boundary permits neither matter nor energy to pass through (Haynie, 2008).

Organisations should understand their quality management systems (QMS) as a system and make the best use of it for business management. So, when they talk about 'system', they firstly think of the system as consisting of many elements and secondly that the whole system has objectives. By determining system objectives, identifying their elements, and understanding relations between these objectives and elements the system can be optimised. The model for QMS in ISO 9001:2015 exactly follows this thought (Gillet et al, 2015).

1.2. Concepts of information and uncertainty

The input or output of a system can be considered as a information consisted of material, energy or messages (Figure 2.).

Information is defined as a measure of the reduction of uncertainty (entropy) that results from receiving a message (Shannon and Weaver, 1949). Information is a name for the content of what is exchanged with the outer world as a homeostatic system adjust to it, and make its adjustment felt upon it.



Legend: - message flow; - energy flow ; - material flow

Figure 2. Input or the output of a system

The process of receiving and of using information is the process of its adjusting to the contingencies of the outer environment, and of its existing effectively within that environment (Wiener, 1985, 1989). The information is content of a message. "Messages are themselves a form of pattern and organization. Indeed it is possible to treat sets of messages as having an entropy like sets of states of the external world. Just as entropy is a measure of disorganization, the information carried by a set of messages is a measure of organization. In fact, it is possible to interpret the information carried by a message as essentially the negative of its entropy. That is, the more probable the message, the less information it gives" (Wiener, 1989).

1.3. On Cybernetics

Cybernetics was defined by Norbert Wiener as "the science of control and communication, in the animal and the machine" (Wienner, 1985).

Since its inception, cybernetics was more or less identified as a science of self-regulating and equilibrating systems. Thermostats, physiological regulation of body temperature, automatic steering devices, economic and political processes were studied under a general mathematical model of deviation-counteracting feedback networks (Maruyama, 1963).

Also, there are systems in which the mutual causal effects are deviation-amplifying. Such systems are ubiquitous: accumulation of capital in industry, evolution of living organisms, the rise of cultures of various types, interpersonal processes which produce mental illness, international conflicts, and the processes that are loosely termed as "vicious circles" and "compound interests"; in short, all processes of mutual causal relationships that amplify an insignificant or accidental initial kick, build up deviation and diverge from the initial condition. (Maruyama, 1963).

So, there are circular mechanisms that induce mutual causation between a system components, which means that those components influence each other either simultaneously or alternatingly and that the size of influence in one direction is dependent on the size of influence in the other direction. There are deviation-counteracting and deviation-amplifying mutual causal system components. The difference between the two is that the deviation-counteracting system components has mutual negative feedbacks while the deviation amplifying system components has mutual positive feedbacks.

Mutual causation is represented by closed loops in subsystem networks diagrams (Figure 3.). For example, subsystems E and C are mutually causal by way of loops EDCBAFE and EDCE. Sign "+" means that system input is directly proportional to its output. Sign "-" means that system input is inversely proportional to its output.

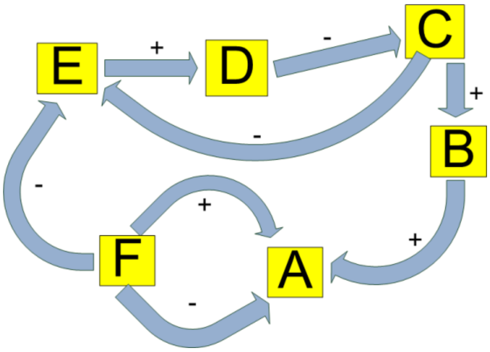


Figure 3. An example of a mutually causal network

Since the deviation-counteracting type has predominantly been studied under the title of cybernetics, it can be termed the first cybernetics, and the studies of the deviation-amplifying mutual causal relationships can be termed "the second cybernetics." (Maruyama, 1963).

Cybernetics is the science that studies the abstract principles of organization in complex systems. It is concerned not so much with what systems consist of, but how they function. Cybernetics focuses on how systems use information, models, and control actions to steer towards and maintain their goals, while counteracting various disturbances. Being inherently transdisciplinary, cybernetic reasoning can be applied to understand, model and design systems of any kind: physical, technological, biological, ecological, psychological, social, or any combination of those (Heylighen, 2001).

In first order cybernetics observer and observed systems are separated, and the result of observations will not depend on their interaction (Heylighen, 2001), (Figure 4).

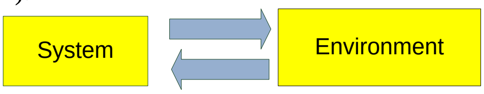


Figure 4. First order cybernetics view of a system

Second-order cybernetics in particular studies the role of the (human) observer in the construction of models of systems and other observers (Heylighen, 2001). Figures 5. and 6. take into consideration the role of the observer in analysing systems.

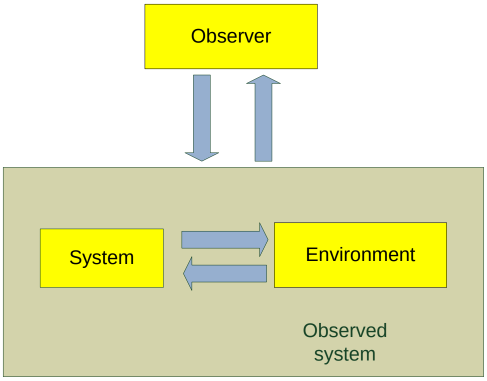


Figure 5. Explicit second order cybernetics view of a system

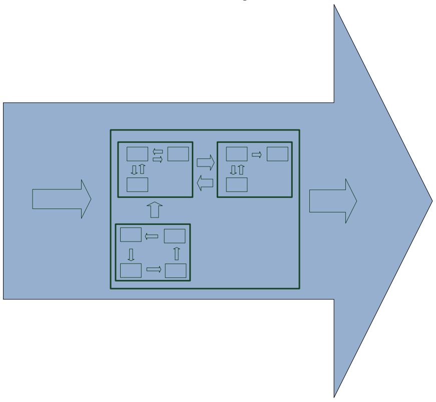


Figure 6. Implicit second order cybernetics view of a system

1.4. Complexity and nonlinearity

There are many aspects of complexity. Commonly, the term "complex" refers to something involving a lot of different but related parts, or something difficult to understand or find an answer to because of having many different parts (Cambridge Advanced Learner's Dictionary 2nd ed,, 1995). Consequently, a system is more complex if more parts could be distinguished in it, and if there are more connections between them (Klir,1991).

Taking into consideration that increased number of distinctive components leads in the limit to disorder, chaos or entropy and increased number of relations between them lead to order or negentropy, complex systems can be understood as systems situated somewhere between order and disorder (Grassberger,1989).

Also, under the term complex system is referred a system of many parts which are connected in a nonlinear way with respect to the behaviour of the system. That means that behaviour of the whole differs from the sum of behaviours of its parts or, in other words, system level effects cannot be assigned to particular causal components because all components interact with each other (Scott, 2007). In this case complexity can be seen as a paradigm of some sort of holism meaning that reductionist scientific method of analysis is improper for complex systems. So, there is a difference between system modeling which is understood as a creative activity at system level description, and system simulation, which is based on a componental level of system description and is algorithmic, which means that it can be performed by a computer. System that cannot be simulated is termed a complex system (Rosen,1985*)*.

Causality in the classical thinking means that similar causes produce similar effects. Therefore, unsimilar causes lead to unsimilar effects. According to nonlinear science some deviation-amplifying interaction between components of a system may also produce the unsimilarity, so the law of causality in nonlinear theory is corrected to state that similar causes may result in unsimilar effects by means of deviation-amplifying mutual causal processes that are not necessarily indeterministic and probabilistic (Maruyama,1963).

1.5. On quality terminology

In this work terms “quality system” and “quality management system” have the same meaning.

2. Informational structure of a quality system

Figure 7 depicts cyclic nature of a quality system. The information extracting is essentially making the model of the environment (the theory of the environment) with respect to the model of organization`s primary goal.

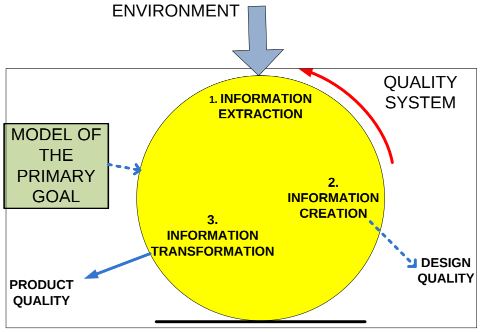


Figure 7. A cyclical model of quality system

In order to be efficient the environment model must satisfy the law of requisite variety: It states that for the system to survive in its environment the variety of responses that the system is able to make must equal or exceed the variety of influences that the environment can impose on the system, whereas under the term variety is generally supposed the number of distinguishable elements in an area under consideration (Ashby, 1956). External influences with high variety affect the system's internal state, which should be kept as close as possible to the primary goal state of the system, and therefore exhibit a low variety. That means that environmental model must encode complete variety of a possible environmental influences, based on which future environment model could be predicted and wished environmental model attained through appropriate response consisting of mission, vision, conceptual design, embodiment design, and process design, which all is identified as information creation (Figure 8). The environment model and the primary goal model act as constraints on the freedom of information creation. So, information creation resolves the indeterminacy implicit in the information creation freedom by choosing one of the possible responses.

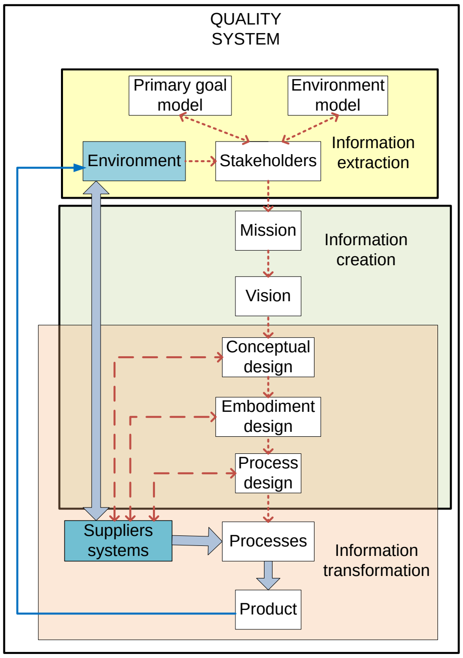


Figure 8. Informational view of a Quality system

Then, the conceptual product model is transformed to the real product through embodiment design, process design, and production processes (Figure 8.), which is called information transformation. In that way information extraction, information creation and information transformation exercise control over a system with the aim of achieving the primary goal of the system which, in the case of an organization, is its stakeholders satisfaction.

3. Some modern forms of a Quality System

Quality planning is the activity of developing the products and processes required to meet customers' needs. It involves a number of universal steps (Juran and DeFeo, 2010):

- Define the customers.
- Determine the customer needs.
- Develop product and service features to meet customer needs.
- Develop processes to deliver the product and service features.
- Transfer the resulting plans to operational personnel.

All designs must fulfill the following general criteria (Juran and Godfrey, 1999):

- Meet the customers' needs
- Meet the suppliers' and producers' needs
- Meet (or beat) the competition
- Optimize the combined costs of the customers and suppliers

According to Juran and Godfrey (1999) the most convenient and basic quality planning tool is the quality planning spreadsheet. The quality planning process makes use of several kinds of these spreadsheets, such (Juran and Godfrey, 1999):

- Customer needs spreadsheet
- Needs analysis spreadsheet
- Product design spreadsheet
- Process design spreadsheet
- Process control spreadsheet

Quality Function Deployment (QFD) form of a Quality System in its core uses a special kind of quality planning spreadshit for design of a product or service based on customer demands, a system that moves methodically from customer requirements to specifications for the product or service (technical means). In its simplest form QFD involves a matrix that presents customer requirements as rows and product or service features as columns, in which respect is essentialy the same as the spreadshits recommended by Juran and Godfrey, 1999. The cell, where the row and column intersect, shows the symbol representing degree of correlation between the individual customer requirement and the product or service requirements (technical means) (Pyzdek, 2013). This matrix is sometimes called the "requirement matrix." When the requirement matrix is enhanced by showing the correlation of the columns with one another, the result is called the "house of quality." Figure 9 shows one commonly used house of quality layout.

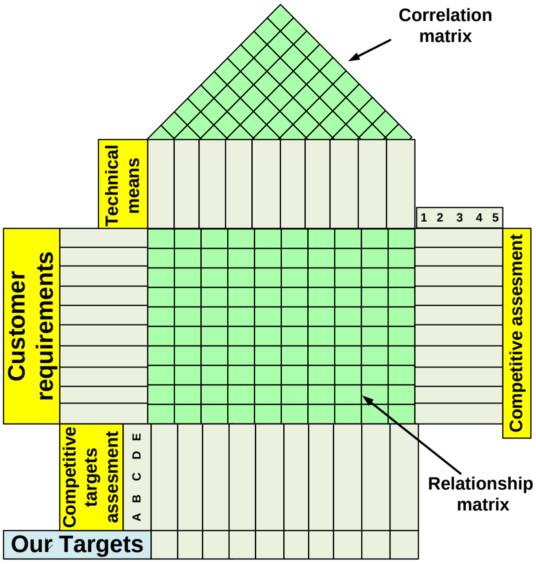


Figure 9. The "house of quality"

The very bottom of the house of quality diagram shows the target values of the technical characteristics, which are expressed in physical terms. The target technical characteristics may be used to generate the next level house of quality diagram, where they become the WHATs, and the QFD process determines the further details of HOW they are to be achieved. In this way the process 'deploys' the customer requirements all the way to the final operational stages (Oakland, 2014).

One rendition of QFD, called the Macabe

approach, proceeds by developing a series of four related matrices (King, 1987): product planning matrix, part deployment matrix, process planning matrix, and production planning matrix. Each matrix is related to the previous matrix, as shown in Fig. 10.

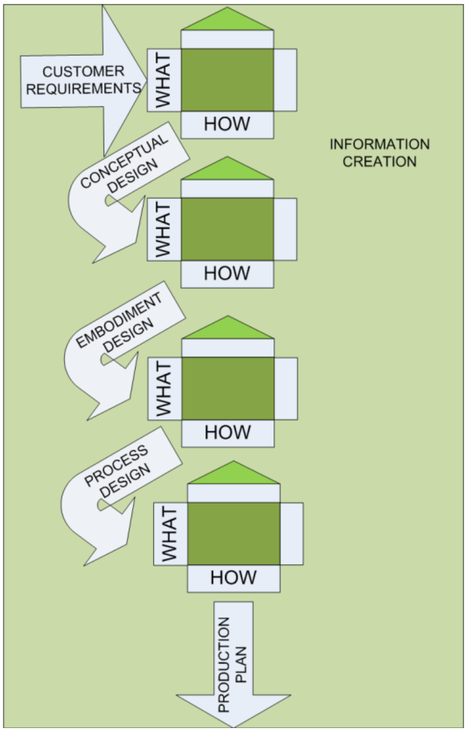


Figure 10. Quality System through QFD

Management Systems Standards and ISO uses the Deming Cycle as the framework around which all management systems standards, including ISO 9001 are now based (Gillet et al, 2015).

The system addressed by ISO 9004 is the whole organization and the way it functions; it is the system by which the organization accomplishes its mission and vision, i.e., its management system. The system addressed by ISO 9001 is the system that serves the achievement of customer requirements referred to as the quality management system. (Hoyle, 2009) .

ISO 9001 view of a quality system is expressed through Figure 11.

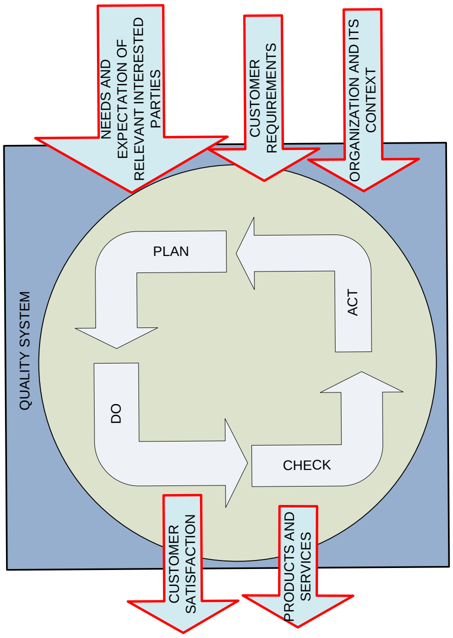


Figure 11. ISO 9001 view of a quality system

An organizations' management system should enable it to go further than satisfy its customers. It should enable it to satisfy all its stakeholders thus creating a enabler for sustained success as reflected in ISO 9004:2009. According to Hoyle, 2009, there is the cycle consisting of: (1) Stakeholders place demands upon the organization and these are fundamental indetermining its mission and vision. (2) The organization's mission, vision and values reflect what the organization is trying to do, where it is going and what principles will drive it towards satisfying stake-holder needs and expectations. (3) The organization accomplishes its mission and vision through a set of interacting processes that collectively form the business management system focused on the mission. In this respect each process will comprise the activities, resources and behaviours needed to produce the outputs necessary to accomplish the mission and vision. (4) The business management system delivers the organization's results that produce satisfied stakeholders. (5) The stakeholders consider whether their needs continue to be satisfied and through one means or another, redefine the demands they place upon the organization. (6) The cycle repeat.

4. Conclusion

Quality planning spreadsheets and Quality Function Deployment involves information extraction and information creation processes of a cybernetic system. Check Act and Plan processes of an ISO 9001 quality system involve information extraction and information creation of a cybernetic system. Do and Act processes of an ISO 9001 quality system involve information transformation of a cybernetic system. So, the methods are embodiments of a cybernetic system.

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