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QUALITY MODELLING USING GENERAL SYSTEM THEORY

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ABSTRACT

The concept of quality in accordance with ISO 9000 emphasizes a holistic view of organizations. This holistic view requires a description language to modulate organizations to specify the implied quality needs. Systems theory represents a holistic generic method of modeling organizations. This paper suggests the general systems theory as a generic method of modeling quality systems. The method is based on a simple rule: begin with the definition of quality, introduce the doctrine of duality to enhance a new quality aspect, and continue the quality doctrine to enhance new aspects in a tree structure.

Based on this simple rule, the total aspect of a quality system model is specified, in which a quality system is represented by dual views. System architecture represents how a quality system is organized, system dynamics represents how the quality systems are developing with time, system ethics represents the quality system purpose and system learning represents the ability to adapt to a quality purpose. This method introduces a generic modeling method of technical, social and biological organizations before the model is limited by specified needs.

1 INTRODUCTION

The term quality originates from the word qualis, meaning a distinctive feature of an object. The focus of the term is therefore on one object. Right quality refers to something else. This term indicates that the object's properties are consistent with user expectations, which implies an expected relationship between two or more objects. The concept of quality in accordance with ISO 9000 emphasizes the totality that affects its ability to satisfy stated or implied needs. Here, the concept of totality is introduced as being related to specified needs, which means that a specification of a total system must be related to external needs.

The concept of totality requires a framework of organization descriptions. System modeling is a special method of modeling such an organization framework. Systems theory may than be a used as a generic method to discover the holistic feature of ISO 9000 and to establish the quality specifications. Systems theory represents a method to modulate systems. A system model is a representation of a set of partners working together for a common purpose.

Systems theory as a framework

Systems theory is a philosophical doctrine of describing abstract organizations independent of substance, type, time and space. When Bertalanffy wrote his first paper on systems theory, the theory was a revolt against the specialization in science and the tendency of viewing nature as a machine. At that time, systems theory represented a paradigm shift in a direction of a more holistic view of science [Bertalanffy, 1978].

However, no unified systems theory exists. One direction has been related to mathematics and stems from system dynamics (Newton), cybernetic systems (Wiener), information systems (Shannon), filter systems (Kalman), self-organization systems (Ashby) and fuzzy systems (Zadeh) [Mesarovic and Takahara, 1975]. The other direction of systems theory has been described as systems thinking, or a manner of thinking [Checkland1981, Senge 1990].

Modulation of organizations using systems theory requires something different: a generic notation language that is useful for modeling organizations. In the 1990s, a general systems theory was developed as a generic modeling framework for modeling organizations. This framework was influenced by the mathematics and systems thinking tradition. The core idea was to create a modulation language to bridge the modeling of technical, social and biological organizations.

The framework was first presented at an international conference on general systems theory [Yndestad, 2001]. Later, this approach was applied as a useful method to modulate complex ecosystems [Yndestad, 2004]. The notation language has also been introduced as a framework for teaching cybernetic and programming agent-based systems. This paper is a discussion of how this general systems theory approach may be used to modulate quality systems.

2 METHODS

The general systems theory is based on the following simple rules:

- Start with the definition of quality.
- Introduce the principle of duality to enhance a new quality aspect.
- Continue the duality principle to enhance new aspects in a tree structure.

These rules imply that every quality aspect has a new dual aspect. From these simple rules, the total aspect of the quality system model is developed. The quality system model then represents a generic framework of modeling quality specifications.

3 RESULTS

3.1 A quality

In any organization, a closed core exists. This core substance may be expressed by

$$\text{Substance} = S \in W,$$

where W is a closed finite purpose. This substance S may have a quality X.

The dualism principle

The dualism principle is based on the idea that substances, objects, organizations, systems and models of thoughts use two and only two contrary principles, which implies that a contrary substance B exists where

$B = \leftarrow S$,

where B has a non-closed purpose and is connected to two or more other substances.

Comment:
The dualism principle indicates that a quality has a relation to its context.

3.2 Right quality

Right quality indicates an expected relation between two objects, organizations or system elements. This relation may be expressed by the set

$S=\{B\{S1,S2\}\} \in W$,

where S1 represents the organization that has the expected quality X, S2 is the organization that expects that S1 has this quality, B represents mutual relations between S1 and S2, and W represents the common purpose.

Comment:
This model demonstrates that *right quality* integrates the quality elements to a new system element S at a higher abstraction level and is oriented by the purpose W, which implies that right quality is related to an external subject.

3.3 Quality control

A quality state X in a substance S1 may have a disturbance from an unknown system element S4. In such cases, *quality control* represents the introduction of a new system element S3 that compensates or adjusts the quality state X of S2. This relation may be expressed by the set

$S=\{B\{S1,S2,S3,S4\}\} \in W$,

where S1 represents the organization that has the expected quality X, S2 is the organization that expects that S1 has this quality, S3 represents the control system, S4 represents the unknown disturbance source, B represents all mutual relations, and W represents the common purpose.

Comment:
This simple model indicates that quality control by a control element S3 must be based on substance S3 having information on the state X of all the others, which implies that all the elements are observable and controllable.

3.4 Quality systems

The concept of quality in accordance with ISO 9000 emphasizes the totality that affects its ability to satisfy states of implied needs. Here, the concept of totality is used, which permits the concept of quality to be linked to a set of external relations.

A total system may be expressed by a set of system elements:

S={B{S1,S2,,,,Si,,,,,,,Sn}} $\in$ W,

where Si represents a sub-system element, B represents the mutual relations between the elements, and W represents the common purpose.

Comments:
When Si represents a sub-system in S, all systems are elements in systems of systems, which implies that each sub-system Si may have a different purpose. In addition, a system element is a sub-system if and only if it supports the purpose of the meta-system.

Example:
An electronic card may be a system element of a computer, a computer a system may be an element in a production line, and the production line may be a system element in a company. In this manner, the quality of a system is based on its ability to fulfill its specified purpose in a meta-system.

System
A system can be defined as a set of partners working together for a common purpose. A system has an ontology view and an epistemology view. These views may be formulated as

S ={S(Ontology),S(Epistemology)},

where S(Ontology) represents physics quality aspects in a system and S(Epistemology) represents the dual view and the internal knowledge quality aspects of system organization.

Comments:
This definition implies that the quality aspect of an organization is more than we can observe using an external measurement and is also related to internal system knowledge.

Using this system doctrine, a system quality model is more than a sum of interacting parts. Systems are dynamic processes in which the dynamics is a synthesis of the system architecture, systems ethic and the ability of system learning.

System ontology
System ontology is the theory of existence. This physical view of organizations may be separated into the two dual views:

S(Ontology) = {S(Architecture), S(Dynamics)},

where *S(Architecture)* has a structure view and *S(Dynamics)* has a process view. When analyzing these views, the system architecture contains information on the system dynamics and the system dynamics contains information on the system architecture.

Comments:
The quality of organization architecture and how the organization is developed in time are dual aspects of the same concept, which implies that system architecture influences system dynamics and that system dynamics influences system architecture.

Example:

A machine architecture model influences the machine dynamics. In addition, a machine dynamic model will influence the machine architecture.

System Architecture
System architecture is the structure of a set partners that have a common purpose. System architecture has the two dual views:

S(Architecture) ={S(Binding), S(Partners)},

where *S(Partners)* represents a set of partner objects in a system organization and S(Binding) represents a set of relations between mutual related partners.

Comments:
This concept means that architecture may be understood as a network of partners and as a set of partners that have a mutual relation.

System Partners
Each partner object p in the partner set,

S(Partners) ={p1,p2,,,pi,,,pn},

may have a state vector

X ={x1,x2,,,xi,,,xn}

that represents a quality substance that may be measured.

System Binding
System binding represents a substance interaction between two or more partner objects. System binding has the dual views

S(Binding) ={S(Coupling), S(Cohesion)},

where *system coupling* indicates the strength of a direct connection between two partners. The total coupling between all partners in a system architecture may be expressed by a coupling matrix A:

$A = \{a_1, a_2, \ldots, a_n\}$,

where each element ai represents a coupling connection.

System cohesion represents the dual aspect of system coupling. This dual relation represents not the direct relation but the structure of relations. System cohesion may be understood as a gravity effect between a set of partner objects and cannot be measured between single partners.

Comments:
The concept of system binding implies that coupling and cohesion are mutually related. Strong cohesion leads to weak coupling, while strong coupling leads to weak cohesion.

System Dynamics
System dynamics is the theory of how systems develop with time. This view of system

organizations may be separated into the dual views

S(Dynamics) = {S(State dynamics), S(Structure dynamics)},

where state dynamics represents a state view and *structure dynamics* represents the structure view of dynamics.

System state dynamics is related to how the quality state in partner objects develops with time. Each partner pi may be represented by a time variant state vector:

X(t) ={x1(t), x2(t),,,xi(t),,,xn(t)},

which represents a quality substance state at time (t). Each state dynamics element xi(t) may be measured or estimated.

Structure dynamics represents the dual view of state dynamics. This dual view represents the dynamic change of binding between partner elements. This change nay be expressed by a time variant matrix:

$A(t) = \{a_1(t), a_2(t)\ldots, a_n(t)\}$,

where each element ai(t) represents the time variant coupling between partner objects. Structure dynamics also implies that the number of relations n and the number of partners in a system may change over time.

Comments:
State dynamics represents a deterministic view of reality in which a quality may be measured or estimated together with an uncertainty. Structural dynamics represents a non-deterministic view of reality that has been associated with chaos or three-body problems.

System Epistemology
System epistemology is the theory of knowledge in systems. This theory has the dual views

S(Epistemology) = {S(Ethic), S(Learning)},

where S(Ethic) is the goal toward which the system is striving and *S*(learning*)* is the strategy which the system uses to reach the goal.

Comments:
The quality aspects of system epistemology imply that quality does not need to be a fixed substance and may be related to learning, fitness and adoptions.

System Ethics
System ethics is the main idea toward which a system is striving. This idea may be a process-oriented approach. System ethics may be separated into the dual views

S(Ethics) ={S(Purpose), S(Potential)},

where S(Purpose) represents a system motive or goal, and S(Potential) represents some limitations related to the system S.

The *system purpose* has an external and an internal view. The external view is related to a fitness of external needs. The internal view of system purpose is related to internal fitness or cost management. The *system potential* is related to external and internal limitations or recourses to meet the system purpose.

Comments:
The quality aspect of system ethics implies that quality is not absolute but is related to the system potential.

System Learning
System learning is an adoption of system ethics. This adoption may be separated into the dual views

S(Learning) = {S(Identification),S(Control)},

where *system identification* represents the ability to observe and identify the state of external partners. System control represents the ability to attain the system purpose by controlling the dynamics of internal states.

System learning is dependent on a set of variables. In practical cases, various priority conflicts may arise. A simple method to resolve such conflicts is to introduce an object cost function in which each control element has a weight priority.

Comments:
The quality control aspect of system learning implies that the system elements are accessible, which means that a partner element has access to the state of all the other elements. The second implication is that the system elements are controllable, which means that a control object can change the state of all the other elements.

4 DISCUSSION

This approach of system modeling represents a generic method of modeling biological, social, technological and abstract organizations. Such a model is useful in a modulation process before the quality content is specified for an implied need.

The traditional view of quality has been related to industrial production. The motive of quality production has been the standardization of mass production. The introduction of ISO 9000 and Total Quality Management has enhanced this view to a more holistic view of the quality of an organization. In addition, the need for standardization and procedure-related activities represents a mechanistic view of organizations.

Quality modeling using general systems theory, as presented, represents an organic view of organizations. This view does not have to be a conflict with the ISO 9000 approach. The focus on control, learning and other aspects are similar.

What are the limitations?
Quality modeling using general systems theory represents a modulation process of a quality

system, which implies that this modeling does not represent the quality system but is a framework of what should be specified in a quality system. This framework is helpful in developing a holistic model in which a modeler is forced to decide what should be specified.

Example:
Quality modeling of a machine requires a model of the system architecture and system dynamics. A quality model of a computer control system requires a model of the system architecture, system dynamics, system ethics and system learning.

What are the applications?
In mechanical and electrical engineering, creating standard quality specifications related to product architecture and dynamics is simple. In practical situations, a mechanical product is placed into an organization context. Quality is than related to the total organization, which means that quality is related to more than a system. Quality is related to systems of systems, which means that quality is more than a specification of a sum of parts. The system approach of an ISO 9000 quality system may see organizations as systems of systems, in which each system element has the ability to learn in connection with a common purpose.

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