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Management Cybernetics as a Theoretical Basis for Lean Construction Thinking

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Abstract

Question: Management cybernetics claims that any successful organization responds to its laws. As there are numerous successful enterprises that use lean thinking as a management philosophy, including increasing numbers of construction companies, does this claim hold and if so, do these laws offer the opportunity to sharpen understanding of Lean Construction practices?

Purpose: The purpose of this paper is to explore the use of management cybernetics—specifically Stafford Beer's Viable Systems Model—as a theoretical basis for Lean Construction thinking.

Research Method: Review, analyze, and compare literature on management cybernetics and Lean Construction. Develop an example to illustrate such use.

Findings: Through a theoretical approach of describing lean thinking rules from the perspective of management cybernetics, we were able to show that following this argumentation, the Lean Construction idea of Built-in Quality (BiQ) fulfills all requirements of a viable system in management cybernetics.

Limitations: Only a small selection of rules is analyzed in this paper.

Implications: Management cybernetics can help sharpen understanding when implementing lean thinking in an industrial context. It may also help identify new concepts that can be incorporated into lean thinking. Conversely, understanding lean thinking principles from the perspective of management cybernetics may also help to identify problems where the implementation of lean thinking does not live up to the desired results. However, further exploration of these potential implications is required.

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Value for authors: Introduce management cybernetics to the Lean Construction community in order to support lean systems thinking and spur interest in using the Viable Systems Model when diagnosing lean practices.
Keywords: Lean Construction, Lean Thinking, Theory, Built-in Quality (BiQ), Management Cybernetics, Viable System Model (ViSM).
Paper type: full paper.

Introduction

Ever since Toyota rose to be a major car manufacturer, their way of managing an organization, known as the Toyota Production System (TPS) and called 'lean' thinking, has received great attention in industry and in the scientific world alike. Meanwhile, a less well known approach to management was developed by an English professor named Stafford Beer, who drew his ideas on managing organizations from the findings of systems theory and cybernetics. His "management cybernetics" proposes a model for an organizational structure, called the "Viable System Model" (ViSM[5]), that integrates the rules he found to apply to organizations and their management. Unlike lean thinking, Beer's work had little impact in the construction industry, although it was received with interest by the scientific community (Espejo and Harnden, 1989, p. ix). Several explanations in literature express why this is the case, mostly his work is said to be impractical or at least difficult to apply to real situations (Espejo and Harnden, 1989; p. 146; Beer, 1979, p. 120/204).

The idea that lean thinking might embrace the notions of management cybernetics originated from our and other scholars' (Herrmann *et al.*, 2008; Dominici and Palumbo, 2010; Gregory, 2007; Koskela and Howell, 2002) study of Beer's ideas. Beer argues that in order to persist in a complex environment, an organization must be viable, meaning "capable of independent existence" (Beer, 1984, p. 7). From a cybernetics perspective, viable systems have "necessary and sufficient conditions of their independent existence" (Beer, 1979, p. 118), and there is a "set of rules" that applies to *all* viable systems, be it a human or an organization consisting of humans (Beer, 1984, p. 9). Beer (Espejo and Harnden, 1989, p. 211) continues his argumentation: "If the argument that there are laws governing the structure and dynamics of any viable system is valid, then all successful enterprises will respond to those laws". As a great many firms have become successful through the application of lean thinking (e.g. Liker, 2004, p. 4; Hines *et al.*, 2004), researching the question if lean thinking embraces the notions from management cybernetics seems promising. Not only may it offer the opportunity to sharpen understanding of lean practices and possibly identify new concepts that can be incorporated into lean thinking, it is also a contribution towards the notion that Lean Construction periodically requires new theoretical constructs (Abdelhamid, 2004).

Conversely, understanding lean thinking principles from the perspective of management cybernetics may also help identify problems where the implementation of lean thinking does not live up to the desired results. We may reverse the above line of

5 In the literature on management cybernetics, the 'Viable System Model' is referred to by the acronym VSM. However, in the literature on lean production, VSM is the acronym for Value Stream Mapping. In order to avoid confusion, ViSM here refers to the Viable System Model.

reasoning and pose as a hypothesis: "If a corporation is not successful and there is a set of rules governing *all* viable systems, then the corporation does not respond to the laws of management cybernetics."

In this paper we look at a Lean Construction practice, namely Built-in Quality (BiQ), and cast it in the language of the theoretical framework presented by the ViSM. Expressions not explained in the paper can be found in the glossary at the end.

Relevant Literature

Steinhaeusser (2013, section 1.2) reviewed literature in three categories, namely literature about:

- Management cybernetics,
- Lean thinking and Lean Construction thinking, and
- Literature on similar approaches to management.

As the scope of this paper is limited, we cannot even come close to presenting the reviewed literature here. The result of this literature review was that research combining lean thinking and management cybernetics has received little attention so far. For further information, please refer to Steinhaeusser, 2013.

Rules of Management Approaches

Our claim that management cybernetics forms a theoretical basis for lean thinking is based on the assumption that any management approach (such as management cybernetics or lean thinking) is based on a set of describing terms. Next, the fundamental terms we found to describe management cybernetics and lean thinking are defined and put together in a framework (see Figure 1). Using this framework, we were able to develop several examples and thereby support the claim that management cybernetics forms a theoretical basis for lean thinking. In this paper we focus on one example (BiQ) due to space constraints. To be clear on the language, some definitions follow:

Aphorism: According to Babcock (1986), an aphorism can either be "a concise statement of a principle" or a "terse and often ingenious formulation of a truth or a sentiment".

Law: "A statement of fact, deduced from observation, to the effect that a particular natural or scientific phenomenon always occurs if certain conditions are present" (Oxford University Press, 2013).

Mechanism: "A natural or established process by which something takes place or is brought about" (Oxford University Press, 2013).

Method: "A particular form of procedure for accomplishing or approaching something" (Oxford University Press, 2013).

Model: "A thing used as an example to follow or imitate." Models are used to understand or handle systems in reality (Oxford University Press, 2013).

Principle: A "general or fundamental truth" or a "governing law of conduct: an opinion, an attitude, or belief that exercises a direct influence on the life and behavior" (Oxford University Press, 2013). This definition helps to distinguish two kinds of principles:

- A principle formulated as a "truth" (first-order principle or systemic principle): a statement is formulated in a way that it can be amended by the following opening sentence without changing its meaning: "it is a fact or a fundament for the system of belief that…". Using this definition, the term axiom, defined as "a statement or proposition that is regarded as being established, accepted, or self-evidently true" (Oxford University Press, 2013), serves as a synonym for first-order principle.
- A principle formulated as a guideline for action (second-order principle): a statement is formulated in a way that it can be amended by the following sentence without changing its meaning: "You must/should do … in order to achieve …".

A principle formulated as a truth is more theoretical in nature than a principle formulated as a guideline for action. Guidelines for action correspond to principles that form the basis for methods in lean thinking (such as pull and kanban, total productive maintenance, etc.).

Process: "A series of actions or steps taken in order to achieve a particular end" (Oxford University Press, 2013). In the literature, "process" is often used synonymously with procedure: "An established or official way of doing something: a series of actions conducted in a certain order or manner" (Oxford University Press, 2013).

System: "A set of things working together as parts of a mechanism or an interconnecting network; a complex whole" (Oxford University Press, 2013).

Technique: "A particular way of doing something, especially one in which you have to learn special skills" (Babcock, 1986).

Theorem: "A general proposition not self-evident but proven by a chain of reasoning; a truth established by means of accepted truths" (Oxford University Press, 2013). If a statement is formulated in a way that it can be amended by the opening sentence *"from several facts, the following fact can be derived…"*, it is regarded as a theorem.

Tool "Something that serves as a means to an end: an instrument by which something is affected or accomplished" (Babcock, 1986).

Based on these definitions, we were able to understand the relations between the different terms used to describe lean thinking and management cybernetics, and whether they describe qualitatively- rather theoretical- or practical aspects. Applying these definitions during our literature review, we found that lean thinking tools[6] (such as BiQ) appear to be founded on second-order principles ("You must/should do … in order to achieve …"). The second order lean principles in turn seem to be derived from observing business practice. (see section "Example: ViSM as a theoretical background for BiQ"). Conversely, management cybernetics seems to stand on a sound theoretical fundament, however with few rules for practical application. This perception led to the idea that the first-order principles, theorems, and models of management cybernetics may provide a theoretical basis for lean thinking (Figure 1).

[6] In the literature, the terms "method," "mechanism", "technique", and "tool" are often used interchangeably, typically describing a procedure to achieve a certain outcome.

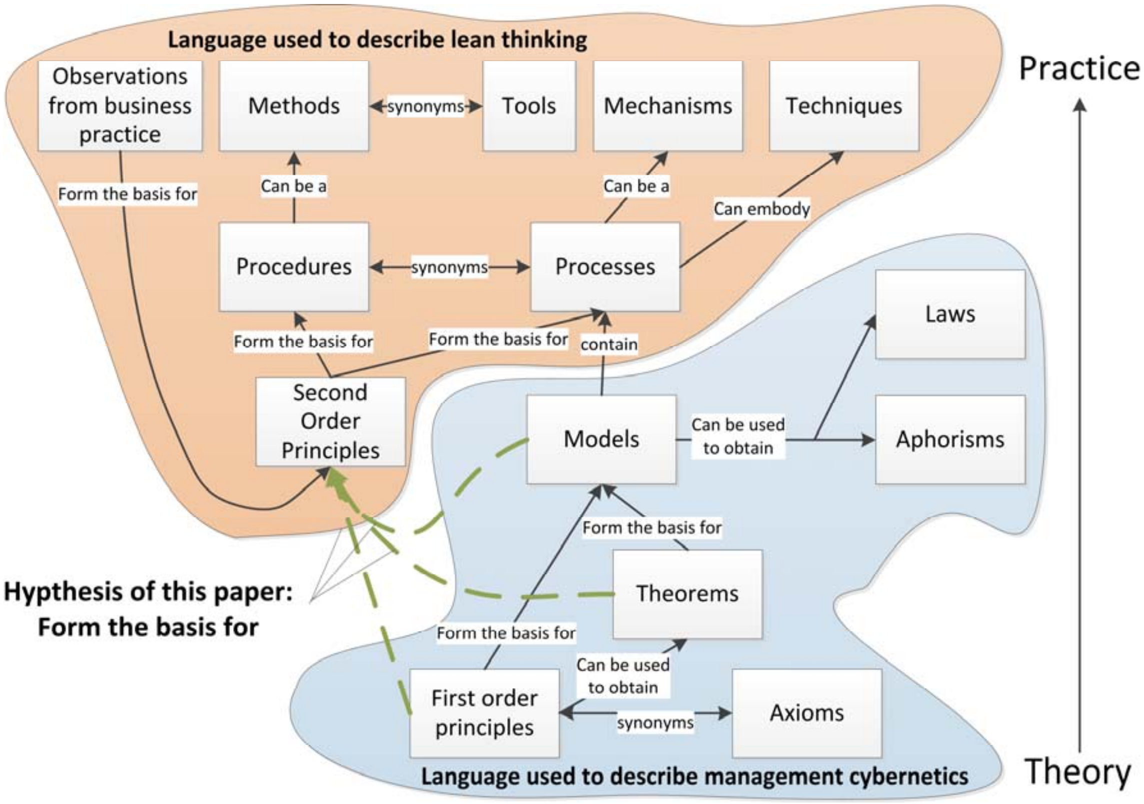

Figure 1: Language framework including the hypothesis for this paper

Viable System Model in Management Cybernetics

As the length and thus the scope of this paper is limited, we cannot present all rules of management cybernetics and lean thinking or describe how they connect. Thus, in this section, we describe the ViSM as one example for a management cybernetics' model and, in the next section, we use it as a theoretical basis for the idea of BiQ in Lean Construction.

In his writings, Beer uses the human body and the way it is controlled by its nervous system as a model to derive a structural model of any viable system, the ViSM. The model "represents the isomorphisms which underlie any viable system, natural or artificial, biological or social" (Espejo and Harnden, 1989, p. 3), therefore the human body is but one out of many examples that could have been used as a basis to formulate the ViSM (Beer, 1972, p. 99).

Five Systems of the Viable System Model

Essentially, the ViSM consists of five systems (Figure 2).

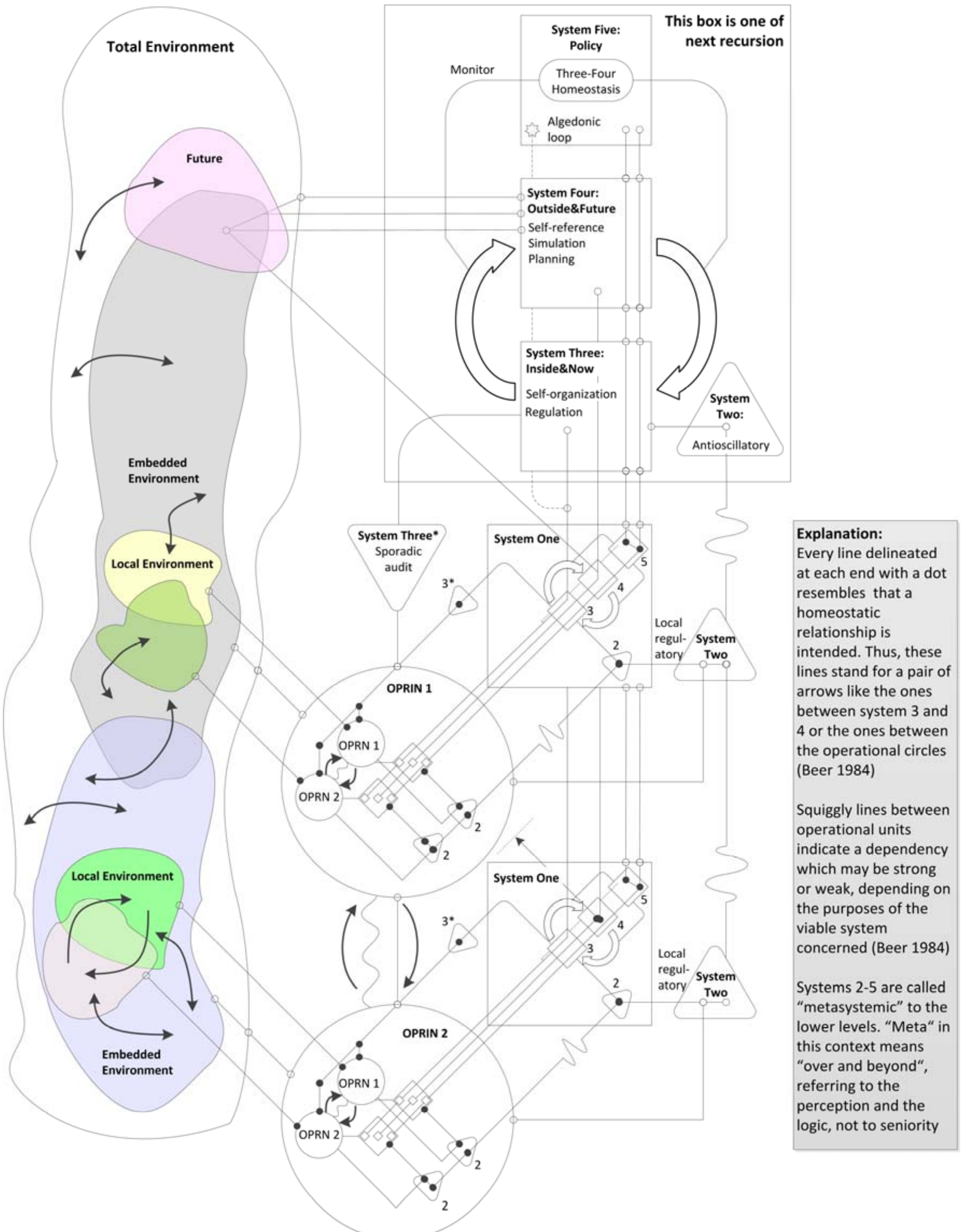

Figure 2: Viable System Model (Steinhaeusser, 2013 after Beer, 1984)

Each of these systems has several control functions. Subsequently, the systems of the ViSM and their control functions are described.

System One: Operational Control

System One controls an operational unit (OPRIN). As Figure 2 shows, the ViSM is recursive and every recursion of the ViSM can contain any number of Systems One. This means that every System One is viable itself (Beer, 1984). System One is the model of the sympathetic nervous system of the human body (Beer, 1972, p. 167/170). For example, when modeling a corporation as a ViSM, System One's task is to control a business division, "in response to policy directives and over-riding instructions from above, in reaction to the direct demands of the external world upon it, and in awareness of the needs of other divisions" (Beer, 1972, p. 213).

System Two: Coordinating Function

System One inheres a metasystemic coordination tool, System Two (Beer, 1979, p. 174). In biological terms, it belongs to the sympathetic system of the human body's nervous system. It subsumes all Systems One and links them to System Three (Beer, 1972, p. 170/220/221). The coordination activity (allocation of resources, etc.) should be carried out in a way that ensures maximum autonomy of the parts, "just short from threatening the integrity of the whole". This notion is also known as the 'law of cohesiveness' (Beer, 2004).

System Three: Managing the "Inside and Now" (Beer, 1979, p. 199)

System Three is the model of the autonomic nervous system of the human body. Its job is to monitor the autonomic functions, implement plans within physiological limits and report upwards (Beer, 1972, p. 169/171). System Three's job can also be formulated as assuring that the coordinated Systems One achieve a greater effect than the sum of the Systems' individual activities (Malik, 2006).When modeling a corporation as a ViSM, System Three resembles the middle management that is responsible for all divisions.

System Three*: Auditing/Monitoring

System Three* is the model of the parasympathetic loop of the human body's nervous system. Its job is to watch for signs of strain in the operational units (OPRIN); it does not exert any command function at all (Beer, 1979, p. 169/210). System Three* bypasses the operational control (System One) and thus provides an opportunity for System Three to obtain a genuine impression of the state of affairs in the operational units. According to Beer (1979, p. 211) an example for System Three* in a corporation is an audit channel. Schwaninger (2008, p. 84) describes the system as a means to investigate and validate the information flowing between Systems One, Two, and Three.

System Four: Managing the 'Outside and Future'

System Four and System Five resemble the model of the somatic nervous system of the human body (Beer, 1972, p.170). Systems One, Two, and Three assure a stabilization of the internal milieu, but they do not take account of 'progress'. Therefore, System Four is "dedicated to the larger environment, and to regulation in its regard" (Beer, 1979, p. 226/227).

System Five: Policy/'The Three-Four Balancer'

System Five's task is to "monitor the operation of the balancing operation between Three and Four" (Beer, 1979, p. 259). The need for a balancing system between the "Inside & Now" and the "Outside & Future" emerges from Beer's observation that in practice, Systems Three and Four will not achieve an equilibrium state without regulation. Viability of the organization can be achieved only if neither one dominates over the other: they must be properly balanced (Beer, 1979, p. 258). On a corporate recursion level of the ViSM, System Five is responsible for the policy of the corporation (Schwaninger, 2008, p. 106).

To supplement these systems, an algedonic loop in management cybernetics regulates in a non-analytic mode (Beer, 1972, p. 305). Although algedonic loops are not Systems of the ViSM, they are still essential in its structure. The difference to a conventional, analytical mode of regulation is that if something is regulated algedonically, the "why and how" is not explained. The regulation is simply based on a system of rewards and punishments that offers no such explanation. In the ViSM, an algedonic control loop exists between System Three and System One, which ends in System Five (Figure 2). An algedonic loop can be used to override an analytic control circuit: For instance, a whole plant is shut down because some critical operational variable is exceeded. On the plant-management level, nobody knows why the shutdown occurred. The signal does not contain the information why operation must be shut down, only that it is mandatory to maintain viability (Beer, 1972, p. 305).

Beer (1972, 1979) describes the five subsystems and the ViSM in more detail. The core idea of management cybernetics is that if Systems One to Five are present and work as intended in a system, its viability in a complex environment is ensured. The following example from Beer (1972 pp. 169 and 170) is to help the reader understand the application of this model.

Example: Catching the bus and the five systems

Suppose a child wants to catch a bus. In order to do so, it must decide to try to catch the bus and then get its body to run for the bus. So first, the policy to run for the bus is formulated in the cortex (System Five). To assess whether this policy seems achievable, information from the somatic nervous system (System Four) about the environment (distance, velocity of the bus, etc.) is evaluated. If the policy to catch the bus still seems feasible after the assessment, the body goes into action (the information is passed along from System Five to Four to Three and down to System One). The activity of lungs, heart, muscles, etc. (OPRIN) is increased by System One, the system that controls the operational units. The Medulla/Pons (System Three), which is located in the middle between System Five and One, monitors the effects. The sympathetic nervous system (System Two) supervises the proper interaction of the organs during the run. At the same time, the parasympathetic nervous system (System Three*) watches for signs of strain. If the policy to catch the bus is practically impossible because of the body's physical limitations, it will notify the Medulla/Pons in order to prevent organ failure. The Medulla/Pons will then inform the cortex, from where the policy originated, that the achievement of the plan is endangered. Through evaluation of the information provided by the somatic nervous system and the Medulla/Pons, the cortex can then decide whether to further pursue the original plan or to change it. If the viability of the whole is imminently endangered, the parasympathetic nervous system (System Three*) algedonically shuts down the whole body in a state of unconsciousness. Even if the cortex (System Five) wanted to, it couldn't prevent it from happening (Beer, 1972 pp. 169 and 170).

Example: ViSM as a Theoretical Background for BiQ

BiQ builds on the plan-do-check-act (PDCA) process (the so-called Deming cycle) with the aim of ensuring that the outcomes of a production process meet the expectations ideally without requiring ad-hoc inspection or rework. Figure 3 shows the schematics of BiQ process.

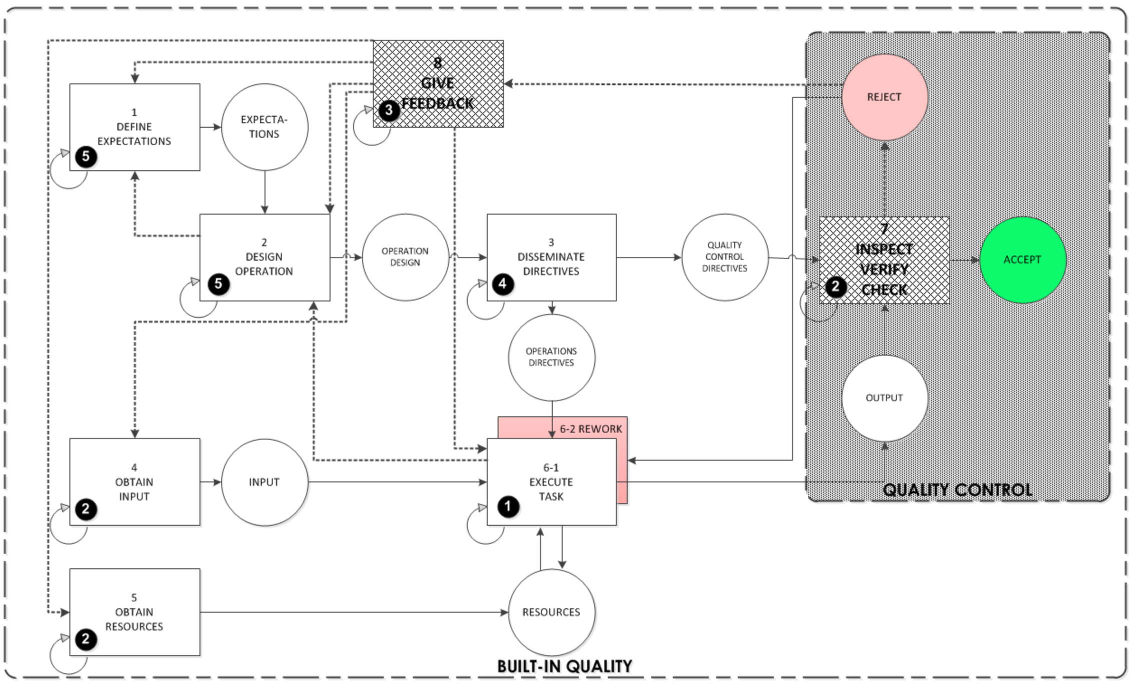

Figure 3: Schematics of the BIQ process (inspired by Lichtig, 2011)

The main process flow is to identify the customer expectations, upon which the operation is designed. This results in directives for the operating process, based on which the process is executed. The operating process produces the output that is checked in the quality control part of the BiQ. If the output conforms to the established quality criteria, it is accepted, otherwise it is rejected. In either case, the stakeholders are informed and, if needed, measures are undertaken. For example, in case of conformance, the stakeholders are informed that the output is going through and the operations are running well. Whereas in case of non-conformance, expectations can be changed, inputs replaced, or new resources obtained. In addition, changes to how the process is executed could be undertaken by changing / updating the operational directives. Which measures are suitable, depends on the circumstances.

The lean ideas of PDCA and thus BiQ in the context of our framework (see Figure 1) are examples for second-order principles: "You should plan, then do, then check and finally act before you start planning again" or respectively implement the BiQ scheme into your company. As we have shown in our framework, second-order principles are based on observations from business practice and thus lack a theoretically sound reason why they should be implemented in a company. We believe that a theoretical basis is needed for lean thinking principles and ideas, as it can make them universally valid; independent from the application case. Therefore, we subsequently map BiQ onto the ViSM. We argue that if all Systems and features of the ViSM can be identified in the BiQ framework, then BiQ is applicable in any company. This directly results from the claim of management cybernetics, that its first-order principles and theorems apply to "*all* viable systems, be it a human or an organization consisting of humans" (Beer, 1984, p. 9).

The operational unit is the part that executes the basic process (number 1 in Figures 3 and 4). System One (number 2 in Figures 3 and 4) of the ViSM fulfills the local control of the process by obtaining the inputs and resources for the process. It also autonomously rejects any output that does not conform to the quality criteria set by the directives. The directives in turn are a part of System Two (number 4 in Figures 3 and 4). They are continuously updated by System Three (number 5 in Figures 3 and 4), that has as its main duty to assess quality expectations and change the operational directives accordingly. How this mechanism works in reality can be illustrated by the following example.

The example (extracted from Milberg, 2006) relates to a project that entailed the seismic retrofit of a steel suspension bridge. The bridge retrofit required the replacement of rivets for bolts, replacement of cross-bracing with diaphragm plates, and installation of additional plates, steel tube section cross-bracing, seismic dampers, connection brackets, and more. In many parts of the bridge, new steel was installed for the retrofit, requiring more than four plies of steel to be bolted together. This tended to occur where filler plates were added to accommodate installation of larger plates that extended over areas where the existing steel plates did not form a single plane. During construction, the owner's inspector rejected a large number of bolts, either because their ends were not flush or because they stuck out more than ¼" (the quality control directives were 0 to ¼" (number 4 in Figures 3 and 4)). The contractor replaced the bolts, yet many were rejected again for the same reason. The issue subsequently reached the contractor's management level (System Three* reported to System Three, respectively numbers 3 and 5 in Figures 3 and 4), where the issue was revisited. The analysis of drawings by the contractor in combination with the owner's findings showed that the thread stick out could vary from –5/16" to +7/16" when using the required bolt length of 8.25", thus explaining the many rejections.

When using an 8.5" bolt length instead, the analysis showed the stick out could vary from –1/16" to +17/32". This means the 8.5" bolt was far less likely to fail the quality control directives than the 8.25" bolt. In the following, the owner (number 7 in Figures 3 and 4) asked for a verification of the quality criteria for the bolts to be carried out by the responsible departments (numbers 5 and 6 in Figures 3 and 4). Their tests showed that the acceptable range and thus the quality inspection directives (number 4 in Figures 3 and 4) for the bolt stick out could be extended to –1/16" to + ½". Thus, by using 8.5" bolts (numbers 1 and 2 in Figure 3 and 4) and revisiting the quality criteria, the problem could be resolved.

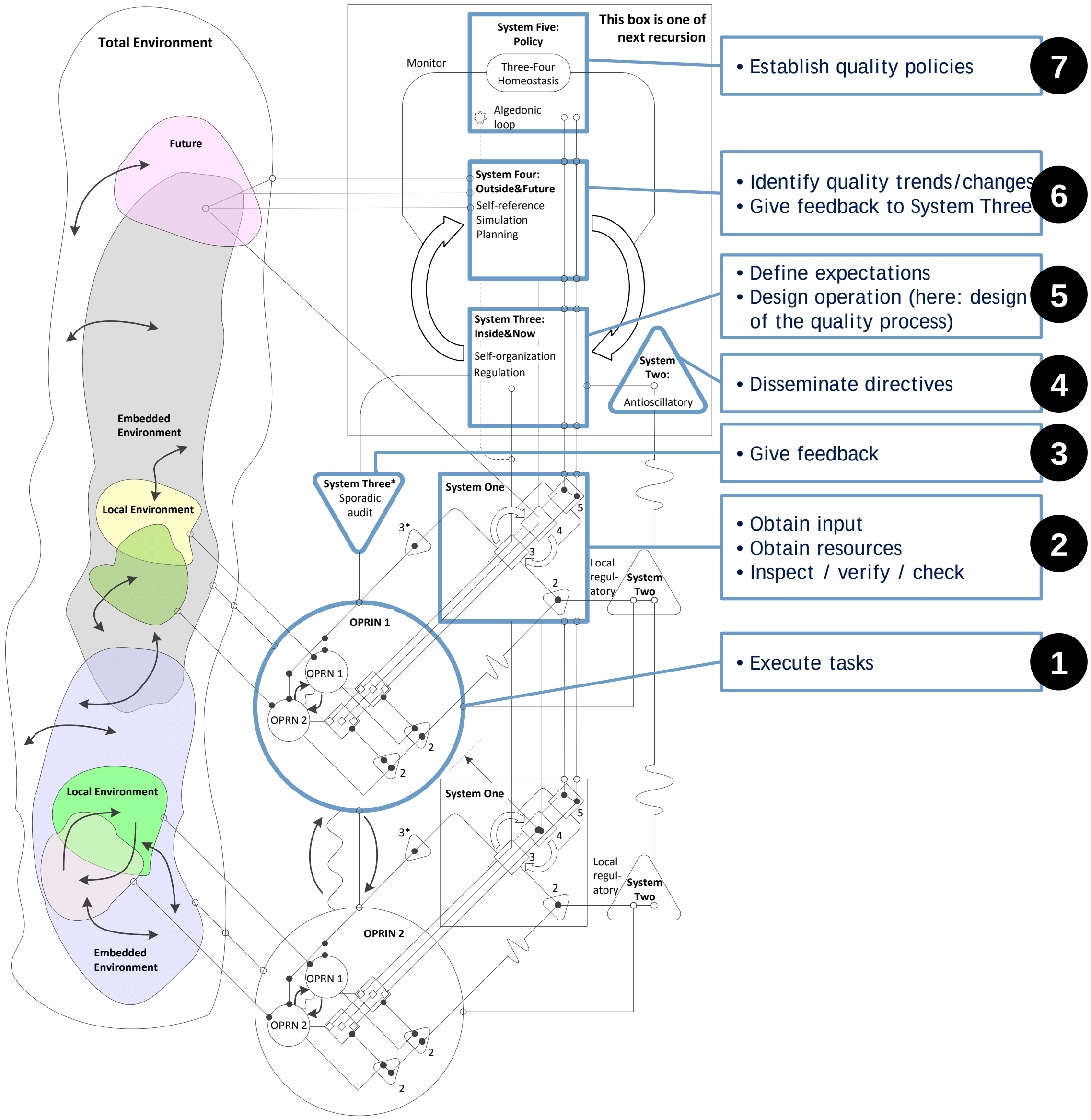

Figure 4: Mapping of BiQ onto the ViSM. The black-circled numbers indicate the corresponding system in the BiQ process (see Figure 3)

The ViSM analysis of this example of a successful elimination of a quality issue that had more than one root cause (e.g., accumulation of relatively-large dimensional variation, unsuitable bolt length, ill-fitted quality criteria) shows that all necessary functions from the perspective of management cybernetics (Systems One to Five) were in place and worked as intended. By being able to link the Systems of the ViSM directly with the systems in the BiQ process (numbers 1-7), we showed by example that the lean idea of BiQ implements the requirements for viability from the perspective of management cybernetics.

Conclusion

Our paper provides an approach for understanding lean thinking from the theoretical basis of management cybernetics. It contributes to the understanding of other scholars (e.g., Elfving *et al.*, 2002; Howell and Ballard, 1998) that lean thinking is a systemic approach to management, not merely a collection of tools. However, we argue that a theoretical basis is necessary in order to verify whether lean tools, such as BiQ, are applicable for any company. As most lean tools are derived from second-order principles and thus from observation of a limited number of examples from business practice, this conclusion cannot be drawn from within lean thinking. By using management cybernetics as a theoretical basis to analyze BiQ, we have shown how this gap can be closed: if a lean tool fulfills all requirements from management cybernetics, it is by definition valid for *all* viable systems, be it a human or an organization consisting of humans (Beer, 1984, p. 9). Although recent research has shown how the ViSM connects to the Last Planner System (Elezi *et al.*, 2015), the relation of several other Lean Construction practices to management cybernetics remains subject to future research.

Glossary of Terms in Management Cybernetics

Algedonic: pertaining to regulation in a non-analytic mode. For example, we may train others to perform a task by explaining analytically the "why" and the "how," as opposed to algedonically by a system of rewards and punishments which offer no such explanation (Beer, 1972, p. 305/306).

Algedonic Loop: a circuit for algedonic regulation, which may be used to override an analytic control circuit. For example, a whole plant may be switched off by a fail-safe device if a critical variable is exceeded, without the workers knowing what happened (Beer, 1972, p. 305/306).

Homeostasis: The capability of a system to hold its critical variables within physiological limits in the face of unexpected disturbance or perturbation (Beer, 1972, p. 305/306).

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