SUPPORTING ORGANIZATIONAL DESIGN TOWARDS LEAN WITH THE VIABLE SYSTEM MODEL

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ABSTRACT

This paper provides an approach to support design of organizational control structures in lean construction projects. Abstracting and analyzing lean practices from the perspective of Management Cybernetics and the Viable System Model (ViSM) in particular was found to elevate understanding of the former in previous research. It seems promising to further investigate how applying the ViSM can aid the implementation of lean thinking in environments that face cultural- and other hurdles to sustainably establishing lean practices.

To take further steps in this direction of research we present an approach for identification and design of organizational control structures in the context of lean practices utilizing the ViSM. Then, we present an exemplary application of said approach, showcasing supportive design of control structures within a pull-based material supply system at a hospital construction project in San Francisco, California.

The example shows that the ViSM and its underlying principles of Management Cybernetics can largely support establishing control structures in lean context. Responsibility assignments and information channels could be transparently included in the organization structure and their assumed contribution to sustainable lean implementation could initially be verified.

KEYWORDS

Management Cybernetics, Viable System Model, Lean Construction, lean control mechanisms, lean implementation

INTRODUCTION

Lean Thinking, originating in Toyota's production system initiated by entering the automobile industry and facing economic challenges in the early 1950s, has evolved to being a management approach of major success, not only in car manufacturing

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context. Its principles, firstly formulated comprehensively by Liker (2004) have been adapted successfully to the construction industry over the last two decades in numerous forms. Cases include the Last Planner System® of production control, allowing for lean and pull-based scheduling of work assignments (Ballard 2000), or kanban-supported material supply (Tommelein and Li 1999, Arbulu et al. 2003), to name just a few of many examples. However, applying said lean principles to companies other than Toyota, be it in manufacturing or any other industry, often times still holds challenges due to the sometimes fundamental differences in thinking about production and management (Bhasin 2012). Simply mimicking Toyota's methods and tools to implement Lean Thinking usually produces unsatisfactory results since the principles and philosophy behind them are not integrated in the whole organization (Womack 2007). Especially in the construction industry, where project participants from numerous different companies are involved, aligning mindsets without any misunderstanding or misconceptions holds additional difficulties. Therefore, anchoring methods and according principles in the organization, e.g. by control structures seems promising to foster sustainable lean implementation.

Also beginning in the 1950s, an alternative approach to management, Management Cybernetics, was developed by English professor Stafford Beer. His approach of transferring theoretical principles from cybernetics brought about the Viable System Model (ViSM), which is a functional reference model for organizational design (Beer 1972). Cybernetics is the science of communication and control in living organisms and technical systems (Wiener 1948). It is largely concerned with designing feedback structures and the information transmitted within to provide stable and adaptable control systems. Accordingly, feedback and control structures play an essential role in the ViSM which aims at facilitating adaptability and the ability to maintain a separate existence in a dynamic environment, i.e. viability (Beer 1985). In previous research, connections between Management Cybernetics and Lean Thinking have been found (Steinhaeusser et al. 2013, Herrmann et al. 2008). Cybernetic principles and structural characteristics of the ViSM were identified to align with principles of Lean Thinking. Also, first control structures could be found within lean, e.g. pull as adjusted feedback or the principle of going and seeing for yourself as audit and feedback (Steinhaeusser et al. 2013). These findings show general eligibility of Management Cybernetics and in particular the ViSM for further investigation in Lean Thinking context. It seems that the functional ViSM can support organizational design towards lean serving as a reference model for control structures which presumably aid lean implementation (as stated above).

Therefore, an approach to practical application of the ViSM towards facilitation of lean principles and control structures in an organization is presented in the following. First, however some theoretical background of Management Cybernetics and the ViSM is provided. In an initial case study the approach was applied at a construction project in San Francisco, California. The results are presented in the third section of this paper. Finally, conclusions are drawn from critical reflection of the practical application case and possibilities for future research are highlighted.

THE VIABLE SYSTEM MODEL

The Viable System Model (ViSM) was designed beginning in the 1960s and is based on cybernetic principles applied to an organizational context. It was derived from analogies to natural viable systems, i.e. systems capable of maintaining a separate existence in their environment (Beer 1972). More precisely, the human nervous system reaching from the brain as the center of decision making to the organs and muscles doing the "operational" work was the main object of study.

The resulting ViSM is a functional model for organizations composed of five interconnected subsystems. Feedback loops between the organization and its environment and within the organization enable control and adaption and thus viability. In the following, the ViSM's five subsystems are presented briefly with regards to its recursive[1] and partly autonomous[2] character (cf. Beer 1972, Beer 1979, Beer 1985, Péres Ríos 2012). Figure 1 gives an overview of the ViSM, its subsystems and their interconnections.

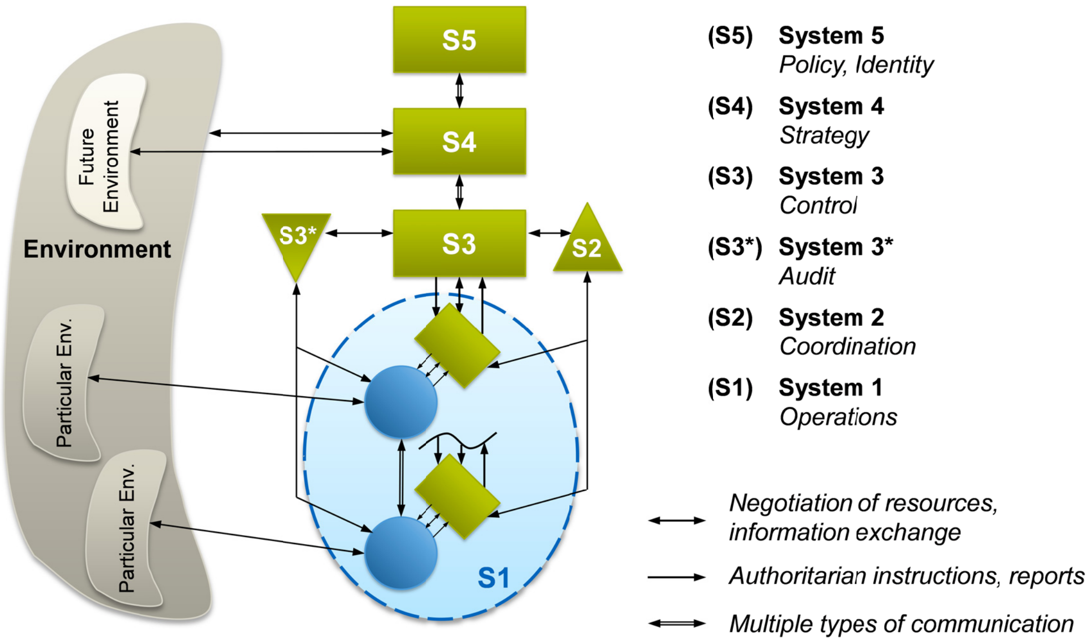

Figure 1: The ViSM with its subsystems and their interconnecting communication channels (arrowed lines) (adapted from Pérez Rios 2012)

System One (S1) is concerned with producing the organization's products or services and delivering them to the environment. (S1) correspondingly interacts directly with the environment. Its several elements, which are viable systems themselves,

1 Recursion means that the ViSM's basic structure of five subsystems repeats at any given level of the organization (Beer 1972). Each element of operational System One is a viable system itself with its own subsystems.

2 Autonomous parts of the ViSM are the elements within the operational part (System One) of the recursion level in focus. They are coordinated and controlled, however, and the organization's cohesion as a whole sets the limits to System One's autonomy (Pérez Rios 2012).

furthermore interact with each other and with the coordinating and controlling Systems Two and Three, respectively.

System Two (S2) is the first of the four systems concerned with management functions. Its task is to coordinate the (S1)-elements by providing a communication medium, guidelines and rules or according coordination services. This type of coordination ensures cohesion of the autonomous (S1)-elements and prevents conflicts over resources. Besides its obvious connections to (S1), (S2) is closely connected so System Three.

System Three (S3) has the task to control (S1)'s operational actions and to ensure its harmonious and synergetic functioning. Therefore, it sets expectations, translates strategic goals and principles as defined by higher management levels and negotiates resources with (S1). Feedback is provided by gathering information about day-to-day business and status of (S1)'s elements with the help of (S2) and (S3*), which is a complementary system to (S3) concentrating on auditing (S1)'s operational business. (S3) has decision power and can thereby take corrective action via authoritarian instructions towards (S1) if necessary. Besides operational management, (S3) contributes to strategic decision making at higher management levels.

System Four (S4) is concerned with strategic planning and adaption of the whole organization. It monitors the environment, anticipates future changes and derives strategic plans for the organization. Collaboratively with (S3), those plans are matched with the organization's capabilities and resources to change and adapt.

System Five (S5) is the highest level management system within the ViSM. Its role is to provide the organization's identity, core values, the ethos and goals which set the boundaries within the rest of the organization acts autonomously. Furthermore, it has ultimate decision power over strategic and operational management and it ensures that strategic and operational adaptions are aligned with the organization's identity and values by approving (S4) and (S3)'s collaborative planning.

The reoccurring control structures within the ViSM and between the ViSM and its environment are the structural prerequisites for a stable and adaptive organization. However, from a cybernetic point of view, these control structures should be designed as to provide the controlling units with so-called "requisite variety" (Ashby 1956). Variety is a measure for complexity, defined as the number of distinguishable states of a system. A control unit has requisite variety if it has the regulatory capacities to respond to every possible state of the controlled unit. In organizational context, the varieties of controlled units (e.g. all operating elements) greatly exceed the capacities of the controlling units (e.g. management) (Beer 1985). Communication channels and systems as well as transferred information should therefore be designed to reduce (attenuate) and enhance (amplify) variety to the appropriate levels. This can be done by defining Key Performance Indicators or by training and multi-skilling of personnel, to name just a few simple examples (Espejo and Reyes 2011, Herrmann et al. 2008).

AN APPROACH TO APPLY THE VISM TO LEAN CONSTRUCTION PROJECTS

As mentioned earlier, previous research has shown that Management Cybernetics and the ViSM can serve as an approach to explain the theoretical background of Lean Thinking and its principles linked to organizational structure and communication design (Steinhaeusser et al. 2013). Based on these findings, applicability of the ViSM to aspects of Lean Thinking[1], its methods and tools was further investigated in research work this paper draws from. Control aspects are identifiable in methods such as the Last Planner System® which incorporates several feedback stages for adjustments and capacity-matching of work assignments from the master- and phase schedules to the weekly or daily work plans (Ballard 2000). Also pull-based material supply utilizes feedback mechanisms such as kanban or CONWIP (Tommelein and Li 1999), andons and poka yoke provide workflow- and quality control mechanisms. Further elaboration on how these control aspects were identified and on how distinctions were made from lean methods and tools not representing control mechanisms is left out at this point since it would exceed the scope of this paper which is mainly concerned with presenting the practical approach of applying the ViSM to support organizational design in the sense of lean. Said approach is presented in the following.

One note ahead: The ViSM suggests organizational functions that are very generic and may be hard to understand in their original form without extensive studies of the theory behind them. This is also recognized as the reason for the ViSM not being as acknowledged in practice as its history and its often times successful applications in industrial practice might suggest (Pfiffner 2010, Schwaninger 2006). To allow specific application of the ViSM and to ease the user's handling of the complex underlying theory, the presented approach suggests to translate the generic functions to the application context. This is a novel approach and it is embedded in the basic logic of initially outlining the system in focus followed by further detailing and analysing which draws from existing methods for ViSM-applications (Péres Ríos 2012, Espejo and Reyes 2011). In the following, the single steps are listed as an overview and subsequently described in greater detail.

- Step one: Define scope and outline system in focus
- Step two: Specify ViSM to application case
- Step three: Detail functional assignments and organizational design

Step One – The first step aims at outlining the system or part of the organization that shall be considered. Basic information about the organization such as organization charts, job descriptions or even process information can be used to roughly outline the focused system, for example the pull-based material supply system of a construction project or even its whole production phase in which lean principles shall be implemented. Identifying the recursion levels of the whole organization and its environment as suggested by Péres Ríos (2012) and Espejo and Reyes (2011) can help creating an overview and appropriately designating the system in focus.

Step Two – After having obtained first information, step two is concerned with a more detailed mapping of the ViSM's functions to the system in focus. This involves translation of the generic functions as provided in Table 1 to the specific application case which ought to be one of intended implementation of lean methods, e.g. pull-based material supply or the Last Planner System®. Actors involved in the system in focus are then mapped to the translated ViSM functions. Outcome of this step is a should-be representation of control structures in the organization supposedly aiding

[1] Including ist industry specific branches such as lean construction, manufacturing etc.

later implementation of lean methods. A schematic dawing of the ViSM similar to Figure 1 amended by the assignments can serve as a visualization tool to ease overview.

Step Three – The ViSM-based control structures shall now be compared to the as-is or as-planned organization structure of the system in focus. Responsibility assignment matrices, a.k.a. RA(S)CI-charts, are suggested as a helpful tool for further detailing of functional assignments at this point (Jacka and Keller 2009). First, any shortcomings in the existing plans are identified, e.g. missing functions. Second,

Table 1: Generic ViSM-functions from literature to be specified in step two

ViSM Subsystem	Functions fulfilled by subsystems (after Beer 1972, Schwaninger 2009, Péres Ríos 2012)
System 5 (S5)	• Define and maintain identity, role and strategic goals of organization • Define ethos, supreme values, norms and rules for organization • Receive strategic management information from S4 and operational management information from S3 • Decide what S3 and S4 cannot agree on • Balance internal and external perspectives
System 4 (S4)	• Collect information about environment, monitor environment • Use and maintain a model of the corporation • Diagnose environment and organization, anticipate possible changes • Plan the future of the organization • Provide S5 with strategic management information • Communicate and negotiate necessary changes/adaptions with S3
System 3 (S3)	• Receive status reports from S1 • Receive information from / have insights into S2 • Receive audit information from S3* • Receive strategic change information from S4 • Receive goals, values, instructions from S5 and higher recursion levels • Decide over necessity of corrective action • Communicate and negotiate limitations to changes/adaptions with S4 • Provide S5 with operational management information • Instruct/command S1s according to management decisions • Translate vision, goals, identity from S5 to S1 • Assign goals to each S1 unit • Negotiate and allocate resources for S1 • Define accountability mechanisms for S1 • Provide synergies between S1-elements, establish overall optimum
System 3* (S3)	• Audit operational work of S1 • Validate S3's instructions for S1 • Complement information for controlling purposes of S3 and higher
System 2 (S2)	• Provide communication medium connecting System 1s • Transmit information about changes beween S1s

	• Amplify self-regulatory capacity of S1, coordinate S1's activities • Prevent S1 from competing over resources • Inform S3 about changes exceeding S1's self-regulatory capacity • Filter information input from S1 into S3
System 1 (S1)	• Produce and deliver company's goods/services • Autonomously adapt to changes in particular environment • Optimize ongoing business • Communicate with other S1s • Utilize coordination/communication system provided by S2 • Report status to operational controlling (S3) • Report "extreme risk" to management up to S5 • Receive corporate instructions from management • Negotiate resources with S3 • Receive goals from S3

according amendments are made and responsibilities are detailed. The RA(S)CI-logic allows for assignments to different degrees, either as responsible, accountable, supporting, consulted or informed. Thus, consistent information flow can be realized within the control mechanisms by transparently designating "producers" and "customers" of information necessary for control and management. Further analysis can be conducted based on the so-called organizational pathologies in ViSM-context provided by Pérez Ríos (2010, 2012).

The presented approach leads to transparent identification of control structures specific to lean methods and the principles they are based on. These control structures allow for transportation of values and principles from management to the operational part of an organization and for monitoring of implementation success and necessary adaptions. In an extended analysis, the information flow between the organizational elements regarding requisite variety can also be addressed. However, necessary explications and verifications by the conducted case study would exceed the scope of this paper hence structural analysis is emphasized. In the following, a case study applying the approach is presented to verify its applicability and relevance in lean construction context.

CASE STUDY: APPLICATION TO A PULL-BASED MATERIAL SUPPLY SYSTEM

This paper's case study presents a practical application of the approach introduced above. It was conducted at the Cathedral Hill Hospital (CHH) project in San Francisco, California. The 13-story, 300 bed, 83,600 m² (920,000 ft²) facility located in central San Francisco is owned by Sutter Health, a northern Californian not-for-profit healthcare provider. Construction manager and general contractor is HerreroBoldt, a partnership of Herrero Builders, Inc. and The Boldt Company (Boldt 2014).

The case study was concerned with supporting organizational design of the pull-based material supply system as part of the project's production system. As an outcome of the first step, operational (S1) was identified to be represented by working crews, foremen and material handling crews active on site. Management functions (S2-S5) comprised project management personnel and trade partners' production management experts. The environment relevant to the material supply system was identified as consisting of suppliers (trade partners and others) and stakeholders such as the owner.

Outlining the system in focus was followed by translating the generic ViSM-functions to the pull-based material supply system context. Necessary information was obtained from the previous step and from expert interviews. Subsequently, the positions planned for in the organization structure at the time the case study was conducted were assigned to the translated functions. Both the translations and assignments are not listed at this point due to spatial constraints.

Detailing the functional assignments based on existing organizational design documents lead to suggestions for new activities (i.e. functions) in the existing RASCI-chart utilized at the project. Concerning the pull-based material supply system as part of the production system, 10 new functions could be added to the existing document. These included already conducted, yet not explicitly documented activities representing the translation of lean principles as part of the vision and identity defined by (S5) into guidelines, values and rules used for coordination of (S1)'s actors concerning material ordering, buffering and handling. Auditing the working crews' compliance to the defined rules could also be established in the revised RASCI-chart, closing the respective feedback loops between executing (S1) and planning and controlling (S3). Already planned information systems transporting necessary data such as visual dashboards could be highlighted as crucial part of the control structures and the according information channels could be included in organizational design by respective assignments within the responsibility matrix. The input to controlling and adapting on-site activities coming from strategic planning of the whole supply chain was also added to allow long-term maintenance of the pull principle in material supply. Examples would be adaptions of lean-related guidelines and rules such as buffer sizes, temporary storage durations or even adaptions of push-pull-relations in prefabrication and delivery, induced by e.g. foreseeable fluctuations in supply chains or customer demand changes. Assignments of positions to both the added and the already existing activities being part of the lean-related control structures to the appropriate RASCI-degrees were subsequently added, amending the existing document by 208 entries (Figure 2).

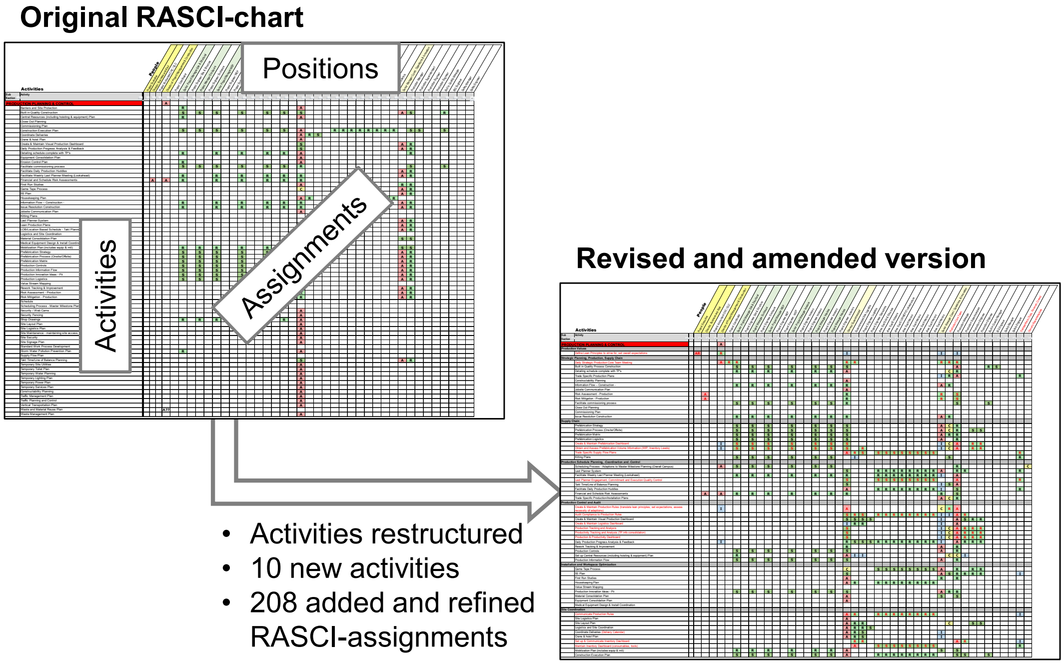

Figure 2: Original RASCI-chart of the CHH production system and revised version after applying the ViSM for control structure design

Evaluation of this initial case study's results together with project management experts came to the conclusion that the presented approach provides useful results especially in terms of supporting organizational design in early project phases. Providing control structures specifically aiming at supporting lean methods and principles and transparently including them in org structure documents was said to very likely aid sustainable lean implementation in general. Key functions were identified in translating lean principles to operation-specific rules and guidelines and subsequent auditing of compliance to those allowing for appropriate corrective action. The ViSM's complex underlying theory however was found to be demanding further simplification or support by appropriate methods to increase practicability in business practice.

CONCLUSIONS AND OUTLOOK

This paper provides an approach to support organizational design based on the ViSM aiming at providing control structures in the organization which aid sustainable implementation of lean methods and principles. The approach comprises of the three steps (1) define scope and outline system in focus, (2) specify ViSM to application case, and (3) detail functional assignments and organizational design. An application to the pull-based material supply system at the CHH project served as an initial case study. In this context, control structures could be established in the project's planning documents which foster sustainable, or viable, implementation of said lean material supply system. The case study only being initial and focusing on one type of lean construction practices, it remains for further applications to validate long-term effectiveness of the presented approach.

Challenges to applying the ViSM in business practice remain its complex structure and abstract background theory. Translating the generic ViSM-functions to specific cases requires precognition of the ViSM, thus maximizing the methodology's practicability could be achieved by preparing a set of specific translations in the lean context for future applications.

Further research in the field of applying the ViSM in the context of Lean Thinking could focus on intensified studies of information flow between management's several subsystems and the operational part compliant to requisite variety demands, e.g. regarding necessary data for stable control of pull-based material supply chains including strategic adaptions. Widening the scope to other contexts within lean construction, e.g. the Last Planner System® or Takt time planning would contribute to further validating the presented approach.

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