Synthesizing Systemic Intervention Approaches: Combining Viable System Model, Knowledge Management, and Toyota Production System for a Sustainable Holistic Management Model

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ABSTRACT

Non-profit service organizations existing in dynamic environments are often presented with management challenges, such as necessity for non-centralized management structures, knowledge retention, and meeting diverse stakeholder demands. Many intervention approaches exist to address these challenges, such as the viable system model (VSM), knowledge management (KM), and the Toyota production system (TPS). These approaches each stem from specific weltanschauungen (world views), capable of leading interventions in particular problem contexts. Previous work such as total systems intervention, creative design of methods, and boundary critique provide roadmaps on how to combine different approaches to act in complex problem contexts. However, they require the analyst to possess significant systems thinking knowledge. This research explores a complementarist framework to assist those that are not educated in systems thinking in intervening in complex problem contexts. The proposed framework is presented through a case study based on a non-profit service organization that performs knowledge-based project work in a dynamic environment. The development of the proposed complementarist approach is presented through 1) the problem context definition, 2) selection of applicable intervention approaches, 3) the analysis and matching of relevant literature to the problem context, and 4) illustration of the resulting framework for the case study organization. Discussion on potential future applications and development of the proposed framework are also presented.

Keywords: Engineering management, systems thinking, viable system model, knowledge management, Toyota production system, organization, non-profit, service, dynamic

Introduction

Some organizational management challenges are internally-driven, such as adhering to non-profit budgets, applying knowledge to complete work tasks, and creating management structures to sustain viable operations. Conversely, some challenges are environmentally-driven, such as maintaining knowledge despite rapid turnover of the workforce and meeting diverse stakeholder demands. If organizational performance is to be improved, internal and external challenges must be addressed. Without guided intervention approaches, “ad hoc” management initiatives can have detrimental effects (Jackson, 2003). “Ad hoc” structures prohibit organizations from reaching their full potential by not fully utilizing collaborative potential (Bryan, Matson, & Weiss, 2007). When collaboration is poor, organizational performance suffers due to poor utilization of knowledge (Mohamed, Stankosky, & Murray, 2004). Sy and D’Annunzio (2005) found that matrix organizations often suffer from misaligned goals, unclear roles and

responsibilities, ambiguous authority, lack of matrix guardian, and silo-focused employees. A holistic framework for management intervention would help inform managers of more effective practices to improve performance through (Jackson, 2003).

As a starting point, let us consider a non-profit service organization that performs knowledge-based project work in a dynamic environment. In this case, a matrix organizational structure is likely to be used as it combines the benefits of functional and project structures (Sy & D'Annunzio, 2005). Such an organization faces several management challenges such as the necessity for a non-centralized management structure, knowledge retention, and meeting diverse stakeholder demands. Three intervention approaches that are designed for such problem contexts are viable system model (VSM), knowledge management (KM), and Toyota production system (TPS; also known as lean manufacturing).

There are several intervention approaches to address management challenges, such as VSM, KM, TPS, soft systems methodology (SSM), operations research, and organizational behaviour. These were developed in different problem contexts, with different weltanschauungen (world views), to achieve various outcomes. The weltanschauung of an intervention approach drives its methods and outcomes (Jackson, 2003). Managers who wish to act on experienced management challenges should consider their own problem context and desired weltanschauung to design an applicable intervention.

One intervention approach may not be sufficient to address a vast set of management challenges (Jackson, 2001). Methodologies exist to synthesize approaches, such as SSM, total systems intervention (TSI), boundary critique, and creative design of methods. These methodologies require working knowledge in the field of systems thinking. To those not educated in systems thinking, these methodologies would likely appear to be prohibitively rigorous (Jackson, 2003).

There is a need for a model to guide managers to appropriate intervention approaches without necessarily requiring systems thinking knowledge. With such a model, managers would consider how their problem context and weltanschauung match those of existing intervention approaches. From this model, an intervention approach, or combination of approaches, will be prescribed to suit the manager.

VSM, KM, and TPS have been selected as promising intervention approaches for a non-profit service organization that performs knowledge-based project work in a dynamic environment, which presents a diverse set of management challenges. These three intervention approaches each address a partial set of the mentioned challenges, but a single intervention approach does not exist to address all of the challenges. Combining the three provides enough diversity to address the three primary management challenges in the case considered: the necessity for a non-centralized management structure, knowledge retention, and meeting diverse stakeholder demands. An ideal intervention would synthesize these to extract beneficial elements from each. This is referred to as a complementarist approach (Jackson, 2003). The three approaches have differing weltanschauungen and were developed to act in differing problem contexts. A manager

acting at an organization such as the one considered here would benefit from a model to define several problem contexts and the approach to apply in each. Such a model could also advise, in a complementarist approach, how to prioritize the simultaneous application of multiple intervention approaches, thus guiding a holistic management intervention.

Viable System Model

Efforts must be made to ensure cohesion of managers and workforce. If such considerations are not made, the "silo effect" may occur, where components of the organization are not effectively collaborating. This can have detrimental effects in organizations such as competing or conflicting objectives, organizational policy or structural breakdown, slow decision making, poor coordination in completing products, employee confusion, poor communication, poor sharing of resources, and poor training (Sy & D'Annunzio, 2005). The viable system model (VSM) frames organizations in terms of roles and interactions, opposing the blame-based culture that may result from hierarchical organizational structures (Beer, 1984).

According to Stafford Beer, creator of VSM, organizations must consist of particular roles and interactions to ensure viability. A viable organization is one that is capable of existence independently of other entities in its environment. Organizations can exist in non-viable states, but they are at risk of failure, or at least not meeting their potential (Beer, 1984). Thus, organizations are benefitted by striving for viability.

Viability is achieved by components of an organization filling roles defined by VSM. There are five necessary components, referred to as subsystems, within VSM. Subsystem 1 consists of operational elements in an organization. This subsystem consists of the workers generating products or services for the environment. It is broken into components based on their contribution to the environment. Each subsystem 1 component has its own management unit. Subsystem 2 coordinates the operations of subsystem 1. It maintains stability and smooth operations. Subsystem 3 provides resources to subsystem 1, intervening with management of subsystem 1 components when necessary. Subsystem 3* sporadically audits the outputs of subsystem 1 to inform subsystem 3. Subsystem 4 observes the environment to help the organization react and plan for the future. Subsystem 5 is in charge of organizational policy. It represents the organization in the outside world. It also supports subsystems 3 and 4 (Beer, 1984; Vidgen, 1998). Each subsystem has a limited role to play in an organization. A breakdown in any of the subsystems will lead to non-viability of the organization. VSM is focused on control to facilitate effective collaboration, which depends heavily on communication throughout the organization (Beer, 1984).

VSM uses the law of requisite variety to guide an organization's interaction with its environment. This law states that variety in the environment should be addressed with variety in the organization. The goal is for an organization to possess enough variety to match the variety of its environment, meaning that it has the tools to address any threat the environment poses (Beer, 1981; Beer, 1984). This can be seen as having a plan for any scenario the environment presents. One method to boost variety within the organization is by using conferences to encourage participation (Beer, 1981). Thus, organizations benefit

from using groups rather than individuals to complete tasks and fill roles, encouraging a collaborative workforce.

Creating a non-centralized management structure (management delegation) is one technique to reduce the variety in an organization's environment (Beer, 1981). This reduces the burden of an organization boosting its own variety to match that of its environment. For example, subsystem 5 should focus its efforts on policies of the organization, allowing others fill complementary organizational roles. It should not act on the roles of any other subsystem unless a subsystem lacks sufficient variety to address a threat to the organization (Beer, 1981). A top-heavy organizational structure can threaten its own viability (Jackson, 2003).

VSM supports viability of an organization as a whole, but advises against subsystems seeking viability in their own right (Vidgen, 1998). However, VSM exhibits recursion, meaning full versions of the VSM structure are contained within every VSM structure, creating infinite levels of recursion. According to the recursive nature of the VSM, operational elements within subsystem 1 must be full viable systems within themselves. This means that each level of recursion contains a complete VSM structure within each of its subsystem 1 components, and its whole structure is within a subsystem 1 component of another VSM structure (Beer, 1984). This does not mean that subsystem 1, or any other subsystem in VSM, should attempt to be viable (Vidgen, 1998). Non-centralized management structures prevent the concentration of too many roles on too few employees in the organization, thus simultaneously boosting variety and discouraging attempts at viability over performing dedicated roles.

Knowledge Management

Drucker defines a knowledge worker as "a knowledge executive who knows how to allocate knowledge to productive use" (as cited in Nonaka and Takeuchi, 1995, p. 7). In this research, knowledge-based work is defined by work tasks completed by knowledge workers.

Direct experience is the most valuable method of learning (Nonaka & Takeuchi, 1995). Because of this, experienced workers have knowledge that is not expected of new workers (Levy, 1965). This creates a management challenge because distribution of knowledge must take place to ensure that workers can complete their tasks. Employees that can independently complete their tasks are valuable to an organization. But knowledge, and thus value to the organization, is developed over time (Davenport & Prusak, 1998; Levy, 1965). Time can be saved if knowledge is transferred, rather than having to be regenerated for each worker that requires it (Fong & Kwok, 2009). Not only must knowledge be shared amongst the workforce, but it also must be retained to be applied beyond the tenure of any member of an organization.

In this research, rapid turnover of workforce refers to when employee tenures at an organization are short. This presents challenges in sustaining a sizable workforce and utilizing the knowledge gained by employees. When a worker possesses valuable knowledge, if action is not taken to retain it, the knowledge will be lost when this person

leaves the organization (Fong & Kwok, 2009). Knowledge loss has detrimental effects on the organization. One potential effect is the loss of output quality when knowledge is no longer present in an organization. Another effect is an increased burden of management to train a replacement worker, which occurs more frequently in rapid turnover environments due to a higher frequency of employee departures. Allowing new employees access to an organization's knowledge base can aid training efforts (Nonaka & Toyama, 2003).

Knowledge management (KM) strives to make the best use of knowledge within and created by an organization to improve operations (Davenport & Prusak, 1998). It fundamentally defines knowledge in two ways: tacit and explicit. Tacit knowledge is contained within an individual and difficult for others to access. Explicit knowledge is documented and available for others to access. A primary goal of KM is to make the conversion from tacit to explicit knowledge so that it may be shared and applied. The four steps of KM can be described as 1) collection (individual tacit to group tacit), 2) retention (tacit to explicit), 3) distribution (separate explicit to systemic explicit), and 4) application (explicit to tacit) (Nonaka, 1991; Nonaka, Umemoto, & Senoo, 1996). Organizations experiencing rapid turnover of the workforce benefit from retaining and sharing knowledge by converting it from tacit to explicit knowledge before workers leave the organization.

Toyota Production System

Complexity is defined by emerging characteristics due to the structure of a system. Emergence in complex production systems can present higher risk of production problems compared to simpler systems, thus creating management challenges (Calvo & Flumerfelt, 2015; Senge, 1990). Two characteristics of operations that increase complexity are many steps in production and dependent events. Having many steps in a process is an example of detail complexity (Senge, 1990). Having more steps in a production process means there are more potential sources of error or defects. It may also mean that there are many different tasks involved in production. According to the law of requisite variety, an organization with a large variety of tasks demands a large variety of resources (Beer, 1984).

Another feature that increases complexity in operations is dependent events. When sequential tasks must be performed in series, rather than in parallel, they are dependent on each other. Dependent events represent dynamic complexity because the consequences may become apparent as time passes (Senge, 1990). A given task cannot begin until the preceding task is complete. In this case, variability in task completion time can be detrimental (Hopp & Spearman, 2001).

Constraints are limits placed on operations. Project work often has constraints placed on it. Commonly, project constraints exist to meet quality expectations, limit costs, and limit duration to completion (Larson & Gray, 2011). These requirements are generally set by the owner of the project. The owner is in control of the project and can terminate it at any time (Checklnd, 2000). The owner is often the individual or agency funding the project.

Toyota production system (TPS), later known as lean manufacturing, was developed in the manufacturing sector and has been adapted for service organizations (Lander & Liker, 2007). The primary goal of TPS is cost reduction. There are three sub-goals necessary to

achieve the primary goal; including quantity control, quality assurance, and respect for humanity. Its method to achieve these goals is eliminating waste in operations, which leads to better quality and less costly production (Monden, 1983). TPS uses several tools to identify waste and seek opportunities for improvement; however it should be viewed as a systemic approach, not simply a set of tools (Lander & Liker, 2007). It identifies four concepts for process improvement; including just-in-time production, automation, flexible workforce, and creative thinking or innovative ideas. These concepts are addressed by eight systems and methods (Monden, 1983). Some of these are more difficult to connect to low volume, high variety environments, such as service organizations, because of the roots of TPS being in high volume automobile manufacturing (Lander & Liker, 2007). The TPS methods that will be most applicable in the case considered here are reduced setup time, employee involvement and empowerment, quality at the source, equipment maintenance (not literally equipment in this case), and standard operations. These principles can help service organizations in meeting diverse stakeholder demands.

Framework Development

Intervention Application Literature

Selected literature articles, containing real world applications of VSM, KM, and TPS in environments similar to the example case presented here, were gathered. Ten articles with appropriate applications were gathered for each of the three intervention approaches, for a total of 30 articles. The six elements of the CATWOE methodology were recorded. CATWOE is a mnemonic for customer (C), actor (A), transformation (T), weltanschauung (W), owner (O), and environment (E). It is a tool of SSM to define systems of purposeful activity (Checkland, 2000). It was used here to describe applications of the three intervention approaches to real world cases. The goal was to identify similarities and differences in the approaches and their applications.

Once CATWOE elements for all articles were noted, generalizations were made about each of the three intervention approaches. A key component of this was categorizing the stakeholder elements: customer (C), actor (A), and owner (O). Categories of stakeholders included company, consultant, government agency, citizens, academic institution, and researcher. Figure 1 gives a basic summary of the categorization of C, A, and O. Number of Customers, Actors, and Owners is the number of these stakeholders identified in the application articles. “Most Common” is which stakeholder appeared the most in the articles considered. “Frequency of Most Common” is how many times (out of the ten total articles for each approach) the most common stakeholder appeared.

	Customer			Actor			Owner		
	Number of Customers	Most Common	Frequency of Most Common	Number of Actors	Most Common	Frequency of Most Common	Number of Owners	Most Common	Frequency of Most Common
VSM	5	Company	5/10	2	Researcher	9/10	3	Company Management	5/10
KM	2	Company	7/10	4	Company Management, Researcher	4/10	3	Company Management	7/10
TPS	2	Company	9/10	5	Consultant	3/10	2	Company Management	9/10

Figure 1. Application Literature Summary for C, A, and O

After analysing stakeholders, focus was shifted to the transformation (T), weltanschauung (W), and environment (E) for each intervention approach. It was determined that Venn diagrams were the most effective way to organize and display the findings for these CATWOE elements. Figure 2 shows a Venn diagram for T. In practice, VSM, KM, and TPS are all used to diagnose problems or for auditing functions.

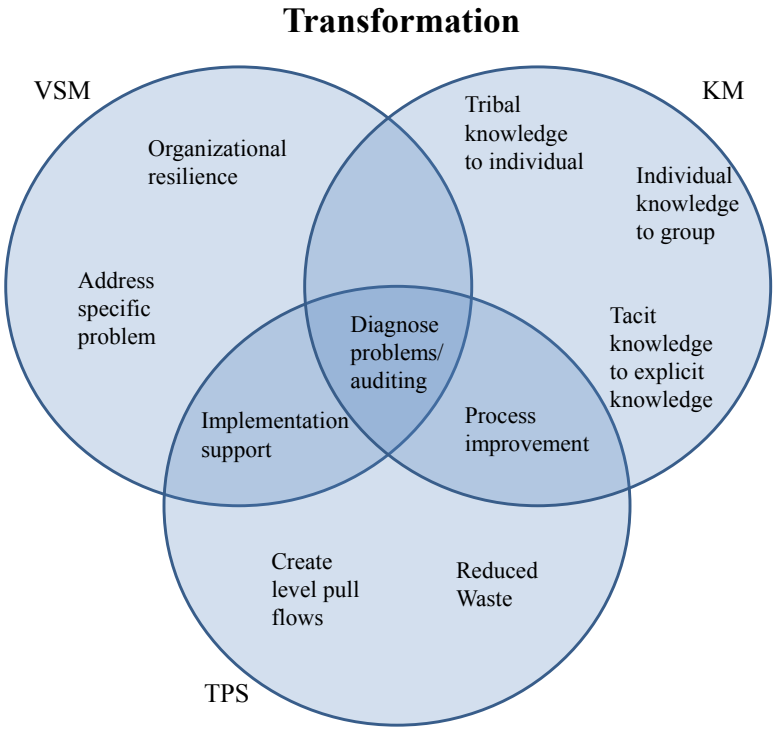

Figure 2. Application Literature Transformation Venn Diagram

Figure 3 shows a Venn diagram for W. The only weltanschauung shared by VSM, KM, and TPS is responding accurately and rapidly to the environment. Three have differing methods of responding to the environment, but all value interactions with the environment. Many other weltanschauungen are shared between pairs of two of the three intervention approaches.

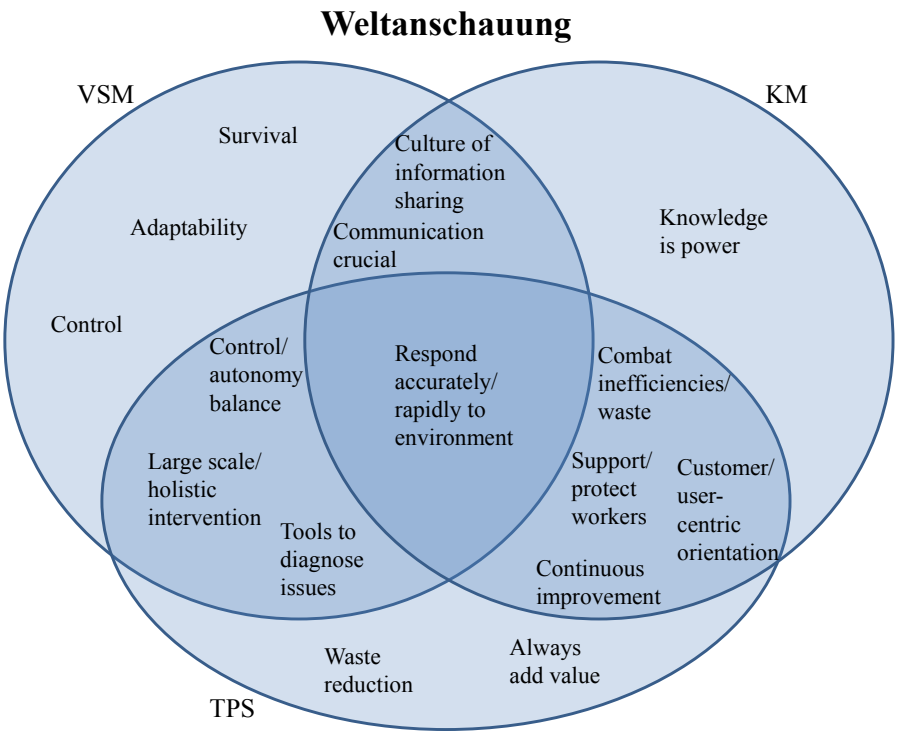

Figure 3. Application Literature Weltanschauung Venn Diagram

Figure 4 shows a Venn diagram for E. Unlike for T and W, the three intervention approaches share many environmental factors, implying that they are applied in similar cases.

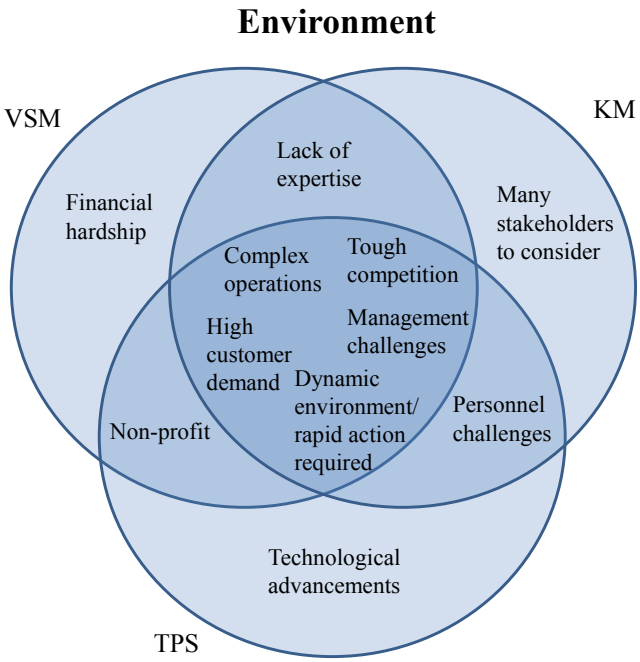

Figure 4. Application Literature Environment Venn Diagram

Based on observations regarding stakeholders (C, A, and O), and the other CATWOE elements, four categories of intervention approach definition were created.

Developing the Framework

Four Definition Categories

Four categories were developed to define intervention approaches. The categories are scope, inspiration, solution, and ideal. These categories each range between two extremes. Scope describes on what level of an organization intervention occurs, ranging from organizational operations to organizational design. Inspiration considers what gives meaning to the intervention, ranging from resource (internally) driven to context (environmentally) driven. Solution describes what the goal of intervention is, ranging from optimal amount of resources to right, or adequate, amount of resources. Ideal implies what the intervention approach values, ranging from organizational culture to organizational control. Intervention approaches may not be defined by either extreme. In this case, it assumed that they have either dual consideration for the extremes or indifference between the extremes.

Defining Intervention Approaches

VSM, KM, and TPS were each defined using the four categories of definition.

VSM functions using the law of requisite variety, which states that an organization should contain enough variety to address the variety of its environment (Beer, 1981; Beer, 1984). It does not state that an organization should be prepared to address every possible scenario in all existing environments. It teaches that an organization should prepare itself for the threats of the environment, and when an unanticipated threat arises, the organization should adapt using the autonomy granted throughout (Jackson, 2003). Therefore, it aims for the proper amount of resources to act in its environment, not necessarily the optimal amount of resources. VSM is primarily concerned with viability of an organization, not the specific stock of resources to achieve this. The method of achieving viability is based in the theory of organizational cybernetics, the science of effective organizations. This theory depends on organizational control (Beer, 1981). VSM proposes specific roles and interactions within an organization, and interactions between the organization and its environment, making it context driven (Beer, 1984). Thus the scope of VSM's intervention is organizational design.

According to Monden (1983), TPS is based on reducing waste in operations. It does not heavily consider organizational design, thus its scope is generally limited to organizational operations. It is internally driven, seeking optimality in utilization of resources, with a goal of eliminating waste. TPS strives for waste elimination with the understanding that this is an unreachable goal. In this way, TPS emphasizes continuous improvement, which requires an organizational cultural shift.

KM falls close to the centre of the spectrums of all four categories. KM is motivated by both internal operations and the environment, seeking to exploit knowledge from both (Grant, 1996). It is ultimately driven to improve organizational operations, but encourages modifying organizational design to support this if necessary (Grant, 1996; Nonaka &

Takeuchi, 1995). KM shares the concept of continuous improvement with TPS (Hicks, 2007; Nonaka, 1991). This implies a tendency for KM to strive for optimality in operations, rather than settling for adequate use of resources. KM depends on cultural shifts to make the most effective use of knowledge and to seek continuous improvement, including continuous innovation (Davenport & Prusak, 1998; Nonaka & Takeuchi, 1995). As a result, it is expected that the effective utilization of knowledge will spread throughout the organization. This implies an interest in organizational control in addition to organizational culture.

Beneficiary Identification

Upon definition of VSM, KM, and TPS in terms of the four categories developed, it was noted that, when applied in organizations, these benefit different stakeholders. The two categories of beneficiaries are workers and management. TPS primarily benefits workers by empowering them and providing support in operational settings (Monden, 1983). VSM primarily benefits management as it considers the functioning of the organization as a whole, not considered with how subsystem 1 workers do their work (Jackson, 2003). Primarily worker benefiting interventions focus on supporting workers and improving the work they do. Primarily management benefiting interventions act in the organization on a larger scale, which does not consider the workers directly, but control over the work they do.

The Proposed Framework

A framework for intervention definition and application has been created. This framework is provided in Figure 5. The four axes explain the emphasis of the intervention approaches within the graph, using the four definition categories developed. The beneficiary line appears diagonally across the graph, from the corner where the Scope and Inspiration axes meet to the corner where the Ideal and Solution axes meet. This line is not intended to be definitive divide, but a progressive trend, where the distinctions are stronger in the far corners than through the diagonal where the line is drawn.

Using the Proposed Framework

The proposed framework's most useful feature is likely the ability to prescribe intervention approaches based on a given problem context. An organization can evaluate the circumstances of a particular problem context, based on a situation or desired state, based on the four axes and primary beneficiary. By selecting values for at least two of the axes, a point on the graph can be identified. Existing intervention approaches will be placed appropriately on the graph. Whichever intervention approach is closest to the given point will be assumed to be the best for the given problem context.

If a complementarist approach is desired, and multiple intervention approaches have been deemed applicable, the proposed framework will suggest precedence for the selected approaches. The selected approaches should first be placed on the graph. When a problem context arises, a manager can find the corresponding point on the graph using at least two axes. The intervention approach on the graph closest to the desired point should be primary; the next closest should be secondary, and so on. The ranking of intervention approaches will guide the manager to how much emphasis to place on each of the intervention approaches.

Synthesizing Systemic Intervention Approaches

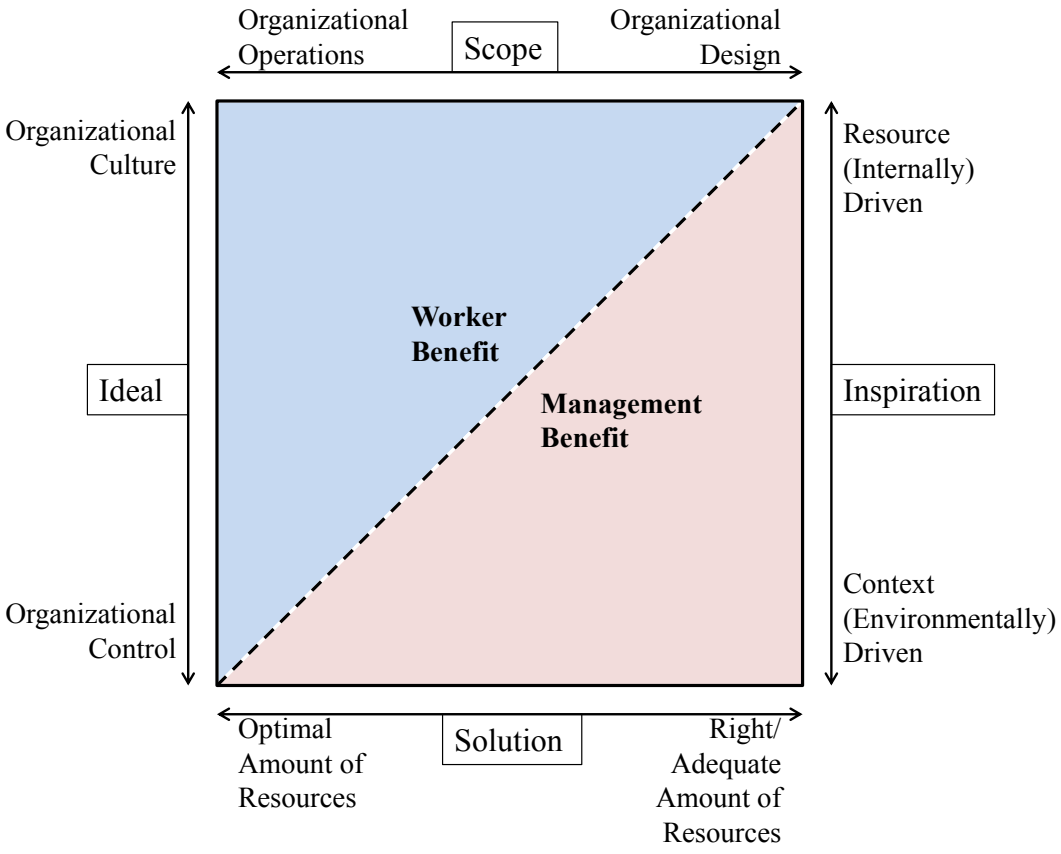

Figure 5. Intervention Definition and Application Framework

Case Study

Background

The Oregon State University (OSU) Energy Efficiency Center (EEC) is a student-operated organization with faculty oversight that engages in outreach to promote energy and resource efficiency. The primary project of the EEC is the Industrial Assessment Center (IAC), which exists primarily to perform industrial energy efficiency assessments. Other grants have been earned by the EEC to pursue other projects, including assessments of facilities in other sectors. Additionally, the EEC works to increase awareness of energy efficiency and provide resources for the public to self-assess energy efficiency measures (OSU Energy Efficiency Center, n.d.).

The EEC has a multi-faceted mission, which includes performing facility assessments, providing energy efficiency resources for the public, developing skills of university students, facilitating a connection between academia and industry, providing research opportunities, and generating funding flow through the university (OSU Energy Efficiency Center, n.d.). As a result, the EEC has many stakeholders, including the EEC director, faculty, and employees; assessment clients; OSU administration and some faculty; and the general public.

Synthesizing Systemic Intervention Approaches

As a non-profit service organization that performs knowledge-based project work in a dynamic environment, the EEC presents several management challenges. These challenges include developing a non-central management structure, retaining knowledge in a rapid turnover environment, and meeting diverse stakeholder demands. This case matches the one discussed earlier, where VSM, KM, and TPS were selected to guide intervention.

Management Structure

One recent EEC management modification has proven to be beneficial, but would likely benefit from additional guidance. The director established a management structure based on management segments of focus (SOFs). The goal was to distribute management tasks amongst many analysts, rather than all being handled by the director and graduate student operations managers as in the past. This intervention came at the time that the director began scaling back his involvement and desired to delegate tasks to others. The segment of focus (SOF) structure also provides opportunities for analysts to be more involved in EEC operations and gain management experience.

EEC management tasks were divided into several SOFs and assigned to various workers, based in existing experience, skill, or interest. Each SOF has a lead and an understudy, who supports the lead and is intended to become the next lead. Leads are not intended to do all the work associated with their SOF, but to manage the necessary tasks and ensure fulfilment of the role. This has led to management silos, where SOF leads are fixated on their role, but lack coordination with other management roles. Ambiguity in roles of authority has also occurred due to the large management variety. A persistent challenge has been designing an effective avenue for SOF leads to provide operations managers with status updates in their respective SOFs.

Knowledge Utilization

Ideally, knowledge would be accessible to employees at point of use. Many employees begin their work at the EEC with little-to-no experience in industrial energy efficiency. This creates dependence on experienced staff to train new employees on technical analyses in addition to operational policies and practices. Once employees possess the foundational knowledge and skills for energy efficiency analyses, learning is driven by experience (Levi, 1965). As analysts gain experience at the EEC, their general and specialized knowledge grows.

The work at the EEC is knowledge-based. It consists of performing technical analyses, for which skills are expected to be developed while working at the EEC. When employees depart from the organization, much knowledge may be lost with them. This knowledge was likely developed over time during their tenure as an employee (Fong & Kwok, 2009). Being a rapid turnover organization, with average employee tenure of approximately two years, the EEC would benefit from improved knowledge retention.

The EEC uses shared digital storage spaces to make electronic resources accessible to employees. There are several shared spaces, including a network drive, an online database, online applications, and websites. Looking for a particular piece of information can lead to a searching process across storage spaces. Better definition and organization of shared storage spaces would be beneficial, allowing access to appropriate resources more quickly.

Complex Operations and Stakeholder Requirements

The deliverables of facility assessments are reports prepared for client companies. A report contains information about the client company and recommendations for process improvements and cost savings, which can include reducing energy use, reducing waste, and increasing productivity. The report generation process contains many mutually dependent events, combining the efforts of several employees, whom are all college students, meaning they have limited time and attention for EEC tasks. Furthermore, employees often require assistance in completing tasks if they are not experienced. For these reasons, there is much potential for bottlenecks to occur in the report generation process. Thus operational efficiency increases are desired.

Operations at the EEC are driven by requirements of stakeholders. Funding agencies place constraints on the assessment process in terms of total number of employee hours used, time to complete reports, and quality of reports. Continuation of funding depends on delivering reports subject to the constraints of funding agencies. Additionally, clients have expectations for assessment reports; some have special requests or needs that require accommodation. Since the reputation of the EEC and OSU depend on positive interactions with clients, delivering reports of maximum usefulness to clients is desired.

Intervention

Because of the need for a non-centralized management structure, retention of knowledge in a rapid turnover environment, and adhering to diverse stakeholder demands, the EEC is in need of a management intervention. A holistic management model is sought by the EEC, especially as the faculty director delegates more responsibility onto student managers. VSM has been selected to provide an organizational structure with strong and effective collaboration within it. KM will facilitate improved utilization of employee knowledge, including improved organization and retention of knowledge. TPS techniques are will aid in ensuring maximum value is delivered to stakeholders with minimal waste. VSM, KM, and TPS have been placed on the proposed intervention definition framework discussed earlier. The framework diagram with these approaches placed on it is provided in Figure 6.

VSM, KM, and TPS all have contributions to improving management of the EEC, but none of them alone address the entire problem. Therefore, these intervention approaches must be synthesized, combining crucial elements of each, to create a holistic management model for the EEC and similar organizations. The questions that remain are the following.

- Are VSM, KM, and TPS compatible with each other?
- Are VSM, KM, and TPS suitable for the EEC?
- How shall VSM, KM, and TPS be applied to the EEC?

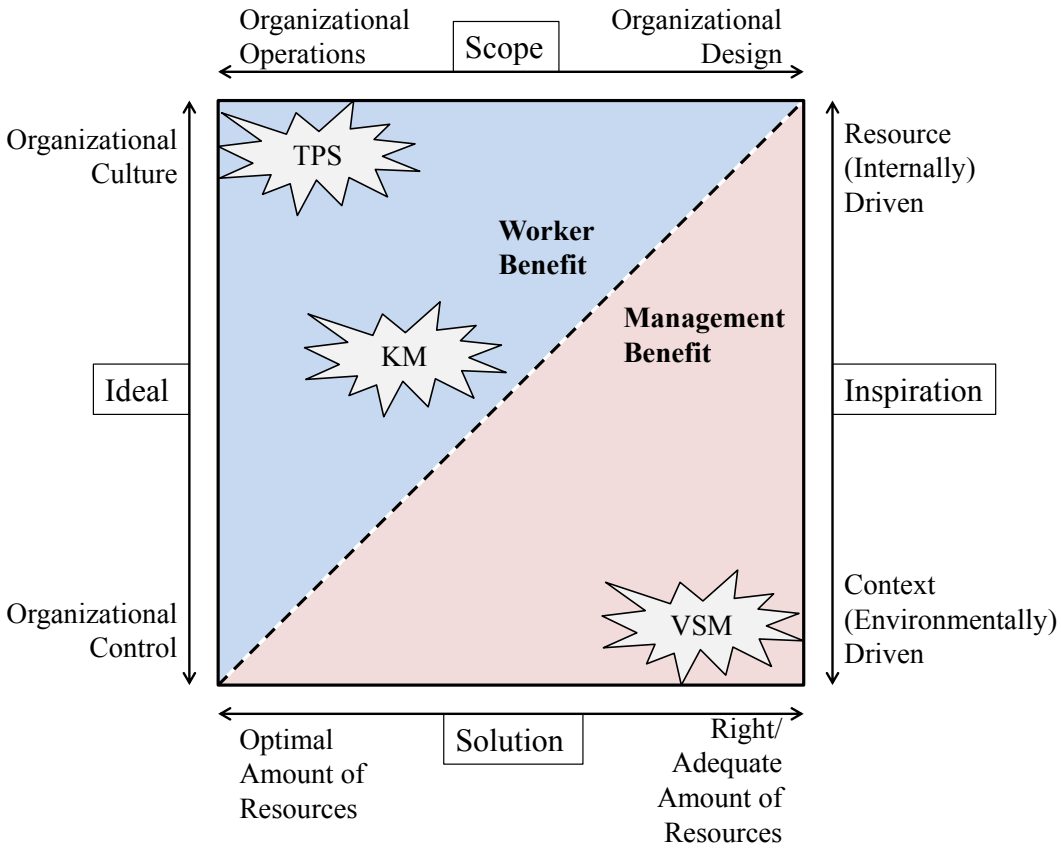

Figure 6. Intervention Definition and Application Framework with VSM, KM, and TPS

Compatibility of VSM, KM, and TPS

Characteristics of E (environment) were discovered to be similar across the three intervention approaches, meaning that these interventions are applied to similar organizations. This is demonstrated in Figure 4. It has been identified that they all serve to address some part of the set management challenges at an organization such as the EEC. Furthermore, as Figure 1 shows, these approaches tend to be applied to similar types of customers with similar types of owners.

VSM, KM, and TPS for the EEC

According to the CATWOE analysis, previous applications of VSM, KM, and TPS match the EEC well in C, A,O, and E. Furthermore, W and E in previous applications of VSM, KM, and TPS serve the management needs at the EEC. These phenomena demonstrate that the collection of the three intervention approaches fit the case of the EEC.

Synthesizing VSM, KM, and TPS

There are conceptual elements of the three approaches that are shared between two, yielding strong pairwise bonds, which, fuse all three when all are considered. VSM and TPS share a goal of guiding operations within an organization. VSM does not particularly define how operational elements should act, but defines the method of controlling their actions (Jackson, 2003). To compliment this, TPS focuses on constantly seeking methods

to improve operational elements (i.e., subsystem 1 in VSM). This involves delivering high quality to the customer, doing so in a timely manner, and with the least amount of waste possible (Monden, 1983). TPS aims to improve the operational elements, while VSM describes the way those operational elements should interact with the rest of the organization.

KM and TPS have customer- and user-centric orientations. TPS strives to produce the right product at the right time in the right quantity for customers (Monden, 1983). Similarly, KM strives to make relevant information available for a user in need, at the time of need (Davenport & Prusak, 1998). KM can be used in two ways. First, it can be used to gather, store, distribute, and utilize information from the environment (e.g., customers and competitors) to the organization, specifically through subsystem 4 of the VSM, which observes and responds to the environment (Teece, 1998). KM can also be used to collect, retain, share, and apply knowledge within an organization (Nonaka, 1991; Nonaka, Umemoto, & Senoo, 1996). KM provides inspiration for internal organizational communication, which VSM values heavily. Furthermore, a principle that TPS holds paramount is employee empowerment (Monden, 1983). This demonstrates that TPS values employees, who can be empowered by the information provided to them via KM.

One of TPS's main foci is to serve customers' needs and desires (Spear & Bowen, 1999). In the case of non-profit organizations, where an agency is funding the organization to serve a purpose, the funding agency is a customer in addition to the end user of the organization's outputs. The non-profit organization must satisfy the needs and desires of its funding agency customers, because doing so will secure funding, thus allowing it to remain viable. TPS enhances value delivered to customers by process improvement (Bowen & Youngdahl, 1998). Process improvement ensures that viability is maintained (Leonard, 2009).

Application of VSM, KM, and TPS to the EEC

VSM, KM, and TPS all have something to offer the EEC in its management challenges. VSM is a robust template to strive for organizational viability. KM and TPS can be used to support the functioning of the subsystems included in VSM. In this way, the three methodologies will be synthesized to one holistic management model for the EEC.

VSM will be used to structure and define the roles within the EEC. KM will be used in several communication channels in the model. It will assist in gathering, storing, distributing, and utilizing information from the environment to the organization through subsystem 4. It will also assist subsystems 2 and 3* in resource planning and auditing, respectively, of the operational elements (subsystem 1). Lastly, KM will be used to share information and knowledge between operational elements (within subsystem 1).

TPS will provide support primarily for subsystems 1, 2, 3, and 3*. It will apply feedback from the environment to operational elements (subsystem 1). At the same time, it will assist subsystem 1 in providing high quality outputs to the environment while reducing waste. It will aid subsystem 2 in managing the resources of subsystem 1. It will also assist subsystem 3* in auditing subsystem 1. Furthermore, TPS can benefit other components of the organization. It provides tools for auditing and criticism, which VSM alone lacks

(Vidgen, 1998). It also provides the concept of continuous improvement, which will encourage the organization to constantly adapt to the environment. Figure 7 graphically summarizes the synthesis of VSM, KM, and TPS as it may be applied to an organization such as the EEC.

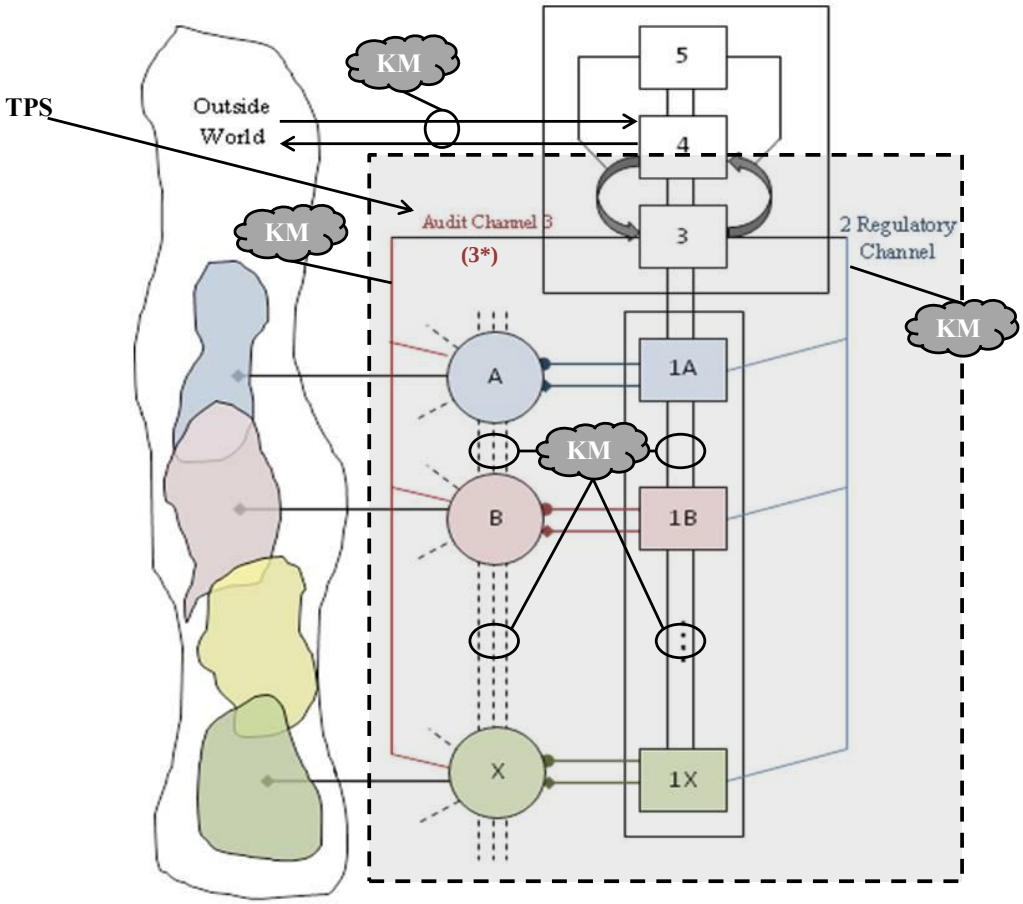

Figure 7. VSM with KM and TPS Framework

Limitations of the Proposed Framework

It is possible that some intervention approaches cover not just a point, but a region in the proposed framework graph as some interventions may be more applicable to multiple problem contexts, cover a larger portion of the space. It may be more appropriate to model the intervention approaches as regions rather than points. These regions would likely have differing sizes and shapes.

Conclusions and Future Work

The need has been identified for a model to guide management interventions. Support for managers is needed to select and apply appropriate intervention approaches for given problem contexts. A framework was proposed to define and select intervention approaches for application in different problem contexts. This framework can be used as a guide for

practitioners to either select an approach for intervention, or to establish precedence of multiple approaches if a complementarist approach is desired.

To illustrate the need for such a model, the case of a non-profit service organization that performs knowledge-based project work in a dynamic environment is considered; specifically the EEC. Such an organization would benefit from interventions by VSM, KM, and TPS. Each of these approaches addresses a part of the EEC management challenge set, but none of them are sufficient alone. VSM, KM, and TPS have been defined within the proposed framework, with their positions validated.

VSM, KM, and TPS have differing weltanschauungen and methods of intervention, but they are applied in similar cases based on CATWOE of previous applications. This, combined with theoretical connections, demonstrates that the three are compatible with each other and may be combined for a holistic intervention. Future work will develop a methodology for applying a synthesized model that consists of VSM, KM, and TPS for problem contexts similar to those of the EEC. The proposed framework will be validated for use at the EEC and similar organizations. Then opportunities for application in other types of organizations will be explored.

In the future, more intervention approaches should be included in the proposed framework to provide managers with the most complete set of solutions possible. Methodologies such as TSI and SSM may be used to design implementation of complementarist approaches identified in the proposed framework. The framework presented here is an early version of what is hoped to become an applied systems thinking methodology for organizational management intervention. The goal is to provide resources in the field of engineering management that utilize systems thinking without the practitioner having to study systems thinking.

REFERENCES

Beer, S. (1981). *Brain of the firm: the managerial cybernetics of organization*. New York: J. Wiley.

Beer, S. (1984). The viable system model: Its provenance, development, methodology and pathology. *Journal of the operational research society*, 7-25.

Bowen, D. E., & Youngdahl, W. E. (1998). “Lean” service: in defence of a production-line approach. *International Journal of Service Industry Management, 9(3)*, 207-225.

Bryan, L. L., Matson, E., & Weiss, L. M. (2007). Harnessing the power of informal employee networks. *McKinsey Quarterly, 4*, 44.

Calvo-Amodio, J., & Flumerfelt, S. (2015). Sense-making between and across stakeholder perspectives. Proceedings from *2015 International Society for the Systems Sciences conference*. Berlin, Germany.

Checkland, P. (2000). Soft systems methodology: a thirty year retrospective. *Systems Research and Behavioral Science, 17*, S11-S58.

Davenport, T. H., & Prusak, L. (1998). *Working knowledge: How organizations manage what they know*. Harvard Business Press.

Fong, P. S., & Kwok, C. W. (2009). Organizational culture and knowledge management success at project and organizational levels in contracting firms. *Journal of Construction Engineering and Management, 135(12)*, 1348-1356.

Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic management journal, 17(S2)*, 109-122.

Hicks, B. J. (2007). Lean information management: Understanding and eliminating waste. *International journal of information management, 27(4)*, 233-249.

Hopp, W. J., & Spearman, M. L. (2001). *Factory Physics* (2nd ed.). New York, NY: Irwin/McGraw-Hill.

Jackson, M. C. (2001). Critical systems thinking and practice. *European Journal of Operational Research, 128(2)*, 233-244.

Jackson, M. C. (2003). *Systems thinking: Creative holism for managers*. Chichester: Wiley.

Lander, E., & Liker, J. K. (2007). The Toyota Production System and art: making highly customized and creative products the Toyota way. *International Journal of Production Research, 45(16)*, 3681-3698.

Larson, E. W., & Gray, C. F. (2011). *Project Management: The Managerial Process* (5th ed.). New York, NY: McGraw-Hill/Irwin.

Leonard, A. (2009). The Viable System Model and its application to complex organizations. *Systemic practice and action research, 22(4)*, 223-233.

Levy, F. K. (1965). Adaptation in the production process. *Management Science, 11(6)*, B-136.

Mohamed, M., Stankosky, M., & Murray, A. (2004). Applying knowledge management principles to enhance cross-functional team performance. *Journal of Knowledge Management, 8(3)*, 127-142.

Monden, Y. (1983). *Toyota production system*. Industrial Engineering and Management Press, Norcross, Georgia.

Nonaka, I. (1991). The knowledge-creating company. *Harvard business review,69(6)*, 96-104.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. Oxford university press.

Nonaka, I., & Toyama, R. (2003). The knowledge-creating theory revisited: knowledge creation as a synthesizing process. *Knowledge management research & practice, 1(1)*, 2-10.

Nonaka, I., Umemoto, K., & Senoo, D. (1996). From information processing to knowledge creation: a paradigm shift in business management. *Technology in society, 18(2)*, 203-218.

OSU Energy Efficiency Center (n.d.). Retrieved from http://eec.engr.oregonstate.edu/.

Senge, P. M. (1990). *The fifth discipline: The art and practice of the learning organization*. New York: Currency Doubleday.

Spear, S., & Bowen, H. K. (1999). Decoding the DNA of the Toyota production system. *Harvard Business Review, 77*, 96-108.

Sy, T., Beach, L., & D'Annunzio, L. S. (2005). Challenges and strategies of matrix organizations. *Human Resource Planning, 28(1)*, 39-48.

Teece, D. J. (1998). Capturing value from knowledge assets: The new economy, markets for know-how, and intangible assets. *California management review, 40*, 55-79.

Vidgen, R. (1998). Cybernetics and business processes: using the viable system model to develop an enterprise process architecture. *Knowledge and Process Management, 5(2)*, 118-131.