ASSESSING THE BEHAVIOR OF HUMAN ACTIVITY SYSTEMS THROUGH THE OBSERVATION AND INTERPRETATION OF SOCIOTECHNICAL SIGNS

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ABSTRACT

The study of communication as a system is largely unexplored in both literature and empirical research, however its role in human activity systems is critical for understanding and adapting organizational behavior. Currently most literature on organizational indicators or signs do not make a connection back to a system of communication or delve into the theoretical virtues of signs as they pertain to the human activity system; building a message that can be understood by and between analysts of the system under observation. Signs are the most basic elements of communication, indicating properties about the system from which the signs emerge. Signs can be conceptual or concrete in form and provide the means for assessing system behavior. When combined with context, signs become information about the system and the information is used to develop a message and transmit from a sender to one or more receivers regarding the necessity for change. This research shall focus on signs are and how they can contribute to change initiatives through their relationship to system behavior. Furthermore, a case study on organizational change will be employed to illustrate the use of signs to indicate whether management is balancing organizational intelligence (thinking) and organizational practices (doing), as indicated by Sir Geoffrey Vickers concept of appreciative systems, in change management initiatives. This research will lay the foundations for system analysts to assess how a perspective system is doing, from the observation and interpretation of its signs, and what needs to change in order for a system to reach its intended goal.

Keywords: Signs, human activity systems, organizational change, communication system, thinking and doing

INTRODUCTION

The study of communication from a systems perspective is largely unexplored but plays a substantial role in understanding and adapting organizational behavior. Currently, communication and systems theory are united by such authors as Wiener (1948, 1961) in his theory of cybernetics of control in the machine and animal and Ashby (1961) in cybernetics as it pertains to behaviors and requisite variety, and furthermore with Beer (1959) in his development of the Viable System Model. However, what is missing in nearly all of the systems research on communication is an exploration of communication as a system in itself; having complex, autopoietic, evolving characteristics and dynamic interactions with the human activity system it emerges from and systemically impacts. In answer to this research opportunity, a paper was published by Kittelman, Calvo-Amodio, and Martinez-León (2018) which set the foundations for characterizing communication as a system within human activity systems undergoing change initiatives. A conceptual model was presented using the three system principles developed by Rousseau (2017) for systems in general. This work contributed to the knowledge base for 1) how communication impacts organizational change through its nature of emergence, 2) the interdependencies between systems and subsystems, and 3) the complexity difference between interacting systems that lead to misalignment of information (Kittelman, Calvo-Amodio, & Martinez-León, 2018). The intention of the authors was to propose a systems perspective of communication that might lead to a more enlightened understanding of message development, transmission, and resulting impact on human activity systems.

To provide further rigor and integrity to the proposed communication system by Kittelman et al. (2018), the authors of this present research seek to address the development of messages for the adaption of human activity systems using the most basic elements of communication system, "signs". In other words, how the human activity system signs relate to the state of the system and how they impact the resulting change initiatives based on the emergence and interpretation of the signs in developing the message to enact change. This research shall unfold in the following phases, 1) a definition of human activity system "signs" and their types and nature regarding the human activity system from which they emerge, 2) to discuss the relationship between the signs and organizational thinking and doing, and 3), to explore a case study on organizational change to illustrate signs of thinking and doing and the resulting human activity system behavior when the signs indicate a balance between thinking and doing versus heavy focus on one or the other.

The authors believe that the information presented in this research will benefit researchers and practitioners alike in understanding the nature and importance of signs as they relate to the state of the human activity system.

DEFINING HUMAN ACTIVITY SYSTEM SIGNS

Research by Calvo-Amodio and Rousseau (2019) defined human activity systems with rigorous principles to guide the design and development by which complex engineered systems can be modeled and realized. In this paper, human activity systems are described through their emergence and holistic design, their purpose, boundaries, and the relationships between components comprising the system. Accompanying a brief overview of the research presented by Calvo-Amodio and Rousseau (2019) is a deeper exploration into the emergence of sociotechnical signs from the interaction of components within human activity systems, the role of these signs in human activity systems' fulfillment of its purpose, dependence on relationships, and the interchange of signs within and across boundaries.

Emergence of System Signs

According to Hillary Sillitto (2018), systems are perceived wholes exhibiting a stable state of low entropy (i.e. high organization). Calvo-Amodio and Rousseau (2019) use Sillitto's definition to define human activity systems which are complex, holistic, and purposeful systems that maintain a stable trajectory in pursuit of a goal while minimizing variation through control mechanisms. There are three key characteristics of every human activity system: 1) human activity systems exist to fulfill one or more purposes, 2) human activity systems are aware of and actively pursue their purpose(s), and 3) human activity systems have the causal powers to pursue their purpose(s) intentionally. Purpose governs the formation of human activity systems and provides motivation for the causal powers of the system to accomplish the goals in pursuit of their purpose. Furthermore, a successful human activity system is that who achieves its purpose(s). The specific purpose and context of the system is subjected to the perception (or weltanschauung) of the analyst studying the system (see Figure 1). Calvo-Amodio et al. (2014) states that, though the analyst will assign the general purpose and boundaries for the system as he/she perceives the system, the interaction of the purpose and boundaries are dynamic for which the knowledge of the analysist changes with a clearer, better understanding of the system. In this way, the weltanschauung of the analyst is considered fluid and changes as the knowledge of the system changes. This description of the analyst's fluid knowledge of the system is a paramount concept regarding message creation by the sender (Kittelman, Calvo-Amodio, & Martínez León, 2018).

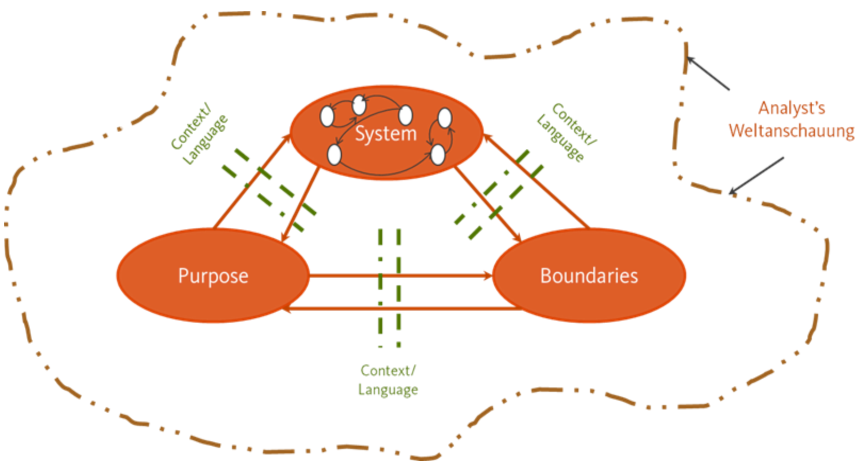

Figure 1. Systems by Calvo-Amodio, et al. (2014)

From the interaction of elements, emerge the holistic system whose characteristics and behavior are more than the sum of those relating to the independent elements comprising the system (Bertalanffy, 1972). However, the interaction and structure of the elements contribute to the complexity and capability of the emerging system. According to Russell Ackoff (1981), this interaction is based on three conditions that must be satisfied regarding the behavior of the elements and the system:

- The behavior of each element has an effect on the behavior of the whole.
- The behavior of the elements and their effects on the whole are interdependent.
- However, subgroups of the elements are formed, all have an effect on the behavior of the whole, but none has an independent effect on it.

Each element of the emerging system has its own composition and nature which contributes to the interactions between other elements. Given the complexity of each element analyzed, ranging from atoms to planets comprising the solar system, each element may itself be considered a system comprised of smaller or less complex elements according to the systems hierarchy (Skyttner, 2005). Examples are departments comprising a plant or people comprising a society. In addition, according to the first system principle by Rousseau (2017), each element submerges specific characteristics or independent behaviors in the emergence of the larger, more complex system; the freedom of a single soccer player to make independent decisions versus all players succumbing to the plan of the coach for a much stronger, unified defense/offense play.

As the behavior of elements within Human Activity Systems contribute to the behavior of the whole (Ackoff, 1981), it is important to understand both the characteristics of the individual element in addition to its interaction with other similar or dissimilar elements. For instance, the soccer team mentioned afore may be struggling to rise above a streak of losses through intensive training, when in fact, a single toxic player is impacting the psychological stress of several of the players and impacting the success of the whole team. However, if the coach is not looking at the behavior of the individual player and the player's interaction with other players; it will not improve the team to try and regulate the whole team through additional training. The coach must look for the *signs* of problematic behavior among the players and the player's interactions.

Similarly, system analysts must look at the behavior of element's interactions with other elements to understand the emerging system characteristics. A non-unitary way of looking at the behavior is to collect and analyze the signs these elemental interactions produce. Signs are considered the echoes of element behavior. According to Skyttner (2005) a sign is the smallest component of meaning and can be "something that stands for anything for somebody'. Signs have no units and are also subjected to the weltanschauung of the analysist in how he/she collects and interprets the signs. When context, units, characteristics, and/or content are associated with the signs, they become information and the result is the significance of the signs, called signals. Signs are powerful in that they indicate the state of the element, interaction between elements, and/or the state of the emerging system as a whole, to the analyst in the form of data. Human activity systems produce an infinite number of signs every day relating to the interactions of elements in the system.

The role of signs is important in determining the degree of success of a system regarding the pursuit of its purpose. As stated earlier, human activity systems are purposeful in nature and intentionally pursue their goals. They are considered successful when they have fulfilled their purpose or set of purposes (Calvo-Amodio & Rousseau, 2019). The system is satisfied in the alignment of what the purpose is and the intentional pursuit for fulfilling that purpose on a stable trajectory while minimizing variation through control mechanisms. Signs embody the indicators for the state of the system and provide a way to identify where a system is in its trajectory toward its intended goal, both in progression and in direction. This concept may be demonstrated with a model from Sprunger et al. (2016) and adapted from Calvo-Amodio et al. (2014), for an organizational culture moving from a current state of behavior (Initial Culture) to a future, more desired state of behavior (Idealized Culture); shown in Figure 2. As the system adapts and progresses towards its goal, the gap between the current culture and the idealized culture narrows. It is believed that signs will provide the data needed to observe and measure the success of the human activity system in reaching its goal and identifying whether deviations from the expected trajectory are occurring.

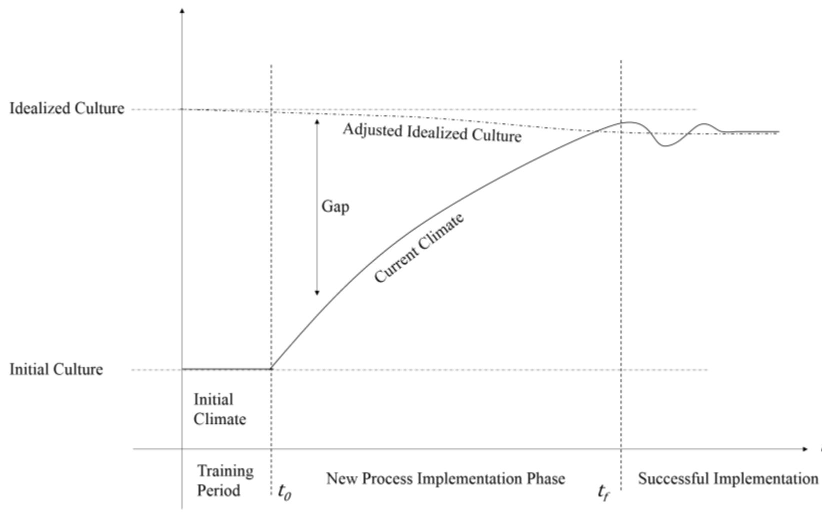

Figure 2. Transition-Phase Management Model adapted for Culture (Sprunger et al., 2016)

SIGNS OF THINKING AND DOING IN HUMAN ACTIVITY SYSTEMS

Human activity systems are composed of two types of systems, concrete and conceptual (Calvo-Amodio & Rousseau, 2019). Concrete systems are described by their persistent structures, behaviors, and/or processes, from which causal powers are generated (Calvo-Amodio & Rousseau, 2019). They can be both living and nonliving systems that exist in a physical reality of space and time and either man-made or natural in form (Skyttner, 2005). Conceptual systems are those that demonstrate persistent meaning and result in models about real world systems (Calvo-Amodio & Rousseau, 2019). In addition, they include an output of both scientific and non-scientific disciplines due to their nature of interrelated entities rather than just interacting elements (Ackoff, 1964). According to Wallis (2015) these systems are generally considered any form of theory; including models, concept maps, mental models, policies, etc.

Additionally, Skyttner (2005) states that conceptual systems only exist *within* concrete systems and produce other conceptual and concrete systems. An example of this is a human (concrete system) formulating a conceptual architectural design (conceptual system) which gives rise to the physical design and manufacturing of structural members (concrete systems) and teams working, communicating, and interacting (both concrete and conceptual systems) to construct the physical building and its elements (concrete systems).

Human activity systems are comprised of both conceptual and concrete system components which contribute to its autopoietic behavior in the parts and interaction of those parts (Swanson & Miller, 2009). Additionally, as stated by Checkland (1981), they are less tangible systems than natural or designed systems but consist of *humans* and their *activities*, including the social interactions and use of tools for some purpose or mission. In this way, it can be concluded that human activity systems are sociotechnical systems of social and technical components which exists for a purpose or mission, such as to attain service or production goals. Though human activity systems are less tangible, they exhibit a natural and designed nature. This is true with both on the social side, as with the development and interaction of social elements, and on the technical side with the conceptualization and design of physical elements. In this, human activity systems are perceived with both conceptual and concrete systems as subsystems within both their social and technical system components. This concept of sociotechnical systems and their subsystems are explained further in the following section and illustrated hierarchically in Figure 3.

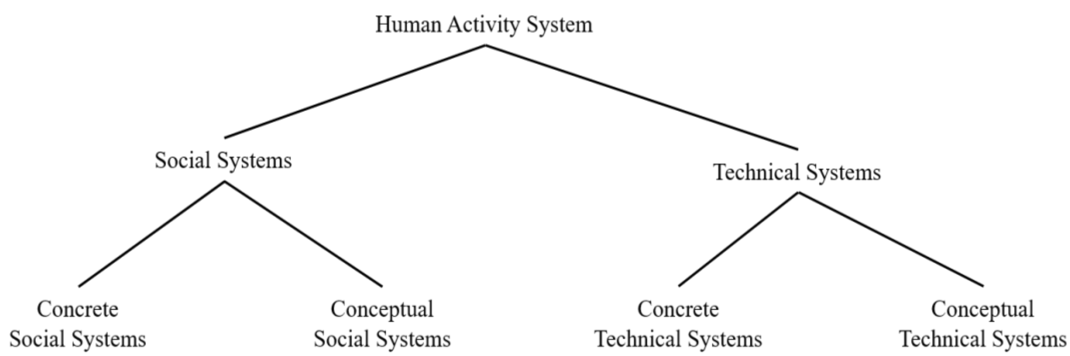

Figure 3. Hierarchical Configuration of the Human Activity System

Sociotechnical Systems as Social Systems

Sociotechnical theory aroused great interest between the late 1950s to early 1970s and remains a relevant topic in organizational management literature. Offering a more balance alternative to the era of Taylor's (1919) scientific management school and the human relations movement (Van der Zwaan, 1975), sociotechnical theory gained momentum from organizational theorists and consults wanting more than in the polar viewpoints of a purely technical system perspective or a purely humanitarian one. The origin of this theory was introduced by the Tavistock Institute in conjunction with field projects that were being undertaken in the post war era of the early 1950s (Trist, 1980). The most novel characteristic of the sociotechnical theory was the perspective of openness of the system to interact with its environment (Van der Zwaan, 1975). These systems are also successful in maintaining a steady state behavior, given the system and environment mutual dependence, ensuring maximization of the potential energy to reach the systems goal, regardless of the environmental changes occurring around the system (Emery, 1969; Van der Zwaan, 1975). The concept of a sociotechnical theory is believed to be originally founded upon Bertalanffy's (1968) General Systems Theory, where the organization is a holistic system comprised of interdependent and interacting parts (Whitworth, 2009) with a purposeful nature (Ackoff & Emery, 1972), and interacting with their environment as principle of open systems (Van der Zwaan, 1975) to self-organize and self-maintain (Maturana & Varela, 1987).

In sociotechnical theory, work systems produce outcomes of both a physical and the social/psychological nature through the pairing of the social and technical system, with the goal of a joint optimization for the holistic human activity system (Appelbaum, 1997). Both the social and the technical systems demonstrate their own regularities and behaviors but they are jointly coherent and impact one another (Van der Zwaan, 1975). Earlier research on sociotechnical systems saw a clear distinction between the technical or social side of the system (Cooper & Foster, 1971; Van der Zwaan, 1975; Walker, Stanton, Salmon, & Jenkins, 2008), however authors such as Van Der Zwaan (1975) argued that, the system was comprised largely of a social system with people and technical aspects for and regarding people. He states that:

> "From a system-theoretical point of view this means that *only people* may be regarded as the *elements* of an (organizational) system. For organizations are designed and maintained by men, and people are the bearers of value preferences and the bearers of assumptions regarding the instrumentality of structures and actions with respect to goals, but also the users of machines and skills."

Van Der Zwaan (1975) argues that the technical system is actually a derivation of the social system for such reasons as the stewardship and goal oriented utilization of technology for social standards of productivity and efficiency. In addition, the layout and design of the technical components depend on and are related to the "number of (implicit) assumptions about human behavior and on a number of (implicit) social standards for the (desired) behavior of the organization" (Van der Zwaan, 1975, p. 154). He continues on to argue that there is no reason why human activities and elements, such as motivation and leadership, should be purely social rather than technically oriented behaviors. Boulding (1956) similarly expressed this concept in his scales of systems complexity, suggesting that organizations are open social systems that seek and process information from the environment to base organizational action (Daft & Weick, 1984). In doing so, sociotechnical systems are able to grow and survive in changing markets. Furthermore, Luhmann conceptualizes sociotechnical systems as social systems that only operate through modes of communication and are autopoietic in their nature (Nassehi, 2005).

In referring back to the hierarchical model in Figure *3*, it is important to clarify the validity of the model still stands, even further reinforced, by making the case that human activity systems are social systems (focused on humans) comprised of social and technical system *activities* (Checkland, 1981). Furthermore, these social and technical system activities are comprised of concrete and conceptual parts or characteristics (Calvo-Amodio & Rousseau, 2019). This research differentiates social system activities as dominated by human interaction and dynamics, whereas technical system activities consider human performance (such as output or attainment of goals) and development (such as personal and training). Human activity systems responding and adapting to changes in their environment, employ both social and technical activities to maintain viability and progression toward fulfillment of purpose(s) as demonstrated in Figure 2 for culture change in organizations.

Assessing the Behavior of Human Activity Systems

Sir Geoffrey Vickers (1983) discusses human activity systems as ecological (comprised of social and environmental elements) and technical systems, which he calls 'appreciative systems'. Appreciative systems, according to Vickers, are a "work of art" that is constantly revised and adapted and can exist as mental constructs. They should correlate to reality to guide actions and are chiefly related to concern; for he believed concerned minds drive responses and pursues solutions. He concludes that if human systems lacked concern, then there would be no issues and subsequently no solutions. Checkland, in a planetary speech at The Operational Research Society (2018) clarified further Vickers' appreciative system as a flux of *ideas* and *happenings* unfolding through time and continuously impacting one another. Vickers' considered this concept as a two stranded rope which can be "appreciated" in specific segments at a time. The appreciation of each segment of time, leads to an assessment of the system behavior (the flux between ideas and happenings) and allows for action to be taken to alter one or the other of the two strands of rope. The terms "ideas" and "happenings" can be considered conceptually as the relationship between thinking about things and doing something about things.

However, a balance must be reached between the thinking and doing within human activity systems. Too large an emphasis on thinking may cause stagnation and delays or the system, whereas an emphasis on doing may propel the system off course without assessing the system regard to its goals/objectives. For human activity systems to be successful, there must be a balance between the thinking and doing within human activity systems. In Figure 4, the distance from the top of the thinking/doing curves to the x-axis of time represents the gap between the ideal culture and the current culture of the human activity system undergoing change. The further apart thinking and doing fluctuations are from the x-axis, the larger the gap will be, and subsequently, the larger the effort required to bring the current culture to the ideal cultural state as defined by the analyst.

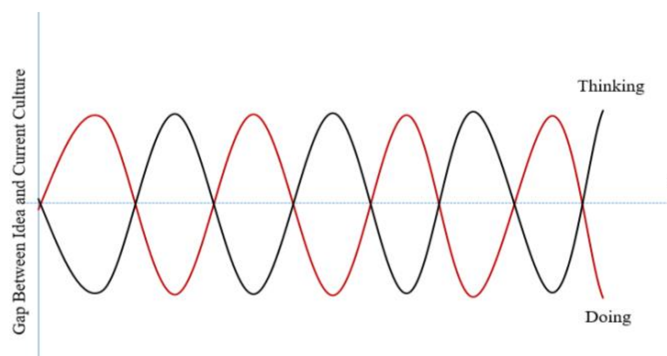

Figure 4. Vickers Appreciative System Demonstrated by a Two Stranded Ropes of Thinking and Doing

Looking at each of these strands of rope separately, two renown models are used to showcase the application of thinking and doing in organizational systems, demonstrated with Tuckman's (1965) theory on small group development as a largely social example and using Deming's (1950) Plan-Do-Study-Act (PDSA) method as a largely technical example. From these two examples, the conceptual and concrete system components are identified for the investigation of signs in the thinking and doing activities. If a balance exists in thinking and doing, the human activity system will demonstrate the optimal, stable trajectory with minimal variation from the desired state of the system.

Conceptual and Concrete Components of a Sociotechnical System

Tuckman's (1965) theory on group development provides an example of a sociotechnical system that is focused rather more on the social activities of teams comprised of psychological and task related components, as will be demonstrated through in the stages *forming, storming, norming,* and *performing.* The fifth stage *adjourning* is ignored in this example for simply acknowledges the dispersal of the team after the goal for which they are formed, is reached and their purpose fulfilled. Similarly, Tuckman's model showcases the concrete (task activities) and conceptual (group structuring) for the social system (as shown in Figure 3). To recap, concrete social systems demonstrate persistent structures, behaviors, and processes and conceptual social system demonstrate persistent meaning (Calvo-Amodio & Rousseau, 2019). These are explained in the following stages:

Forming

Concrete Social System - the team members come together to form a structured group with roles, boundaries, personality characteristics, and submerge themselves to rules and interpersonal and task behaviors (Bonebright, 2010). This includes an element of engagement on behalf of each team member in meeting, socializing, and exploring the team members and requirements of the team as a whole toward the project goal.

Conceptual Social System – team members establish relationships and invest in social capital (Resnick, 2001) to capitalize on communication alignment (Kittelman, Calvo-Amodio, & Martinez-León, 2018) through such attributes as establishing shared values, trust, common knowledge, etc.

Storming

Concrete Social System – the team reaches a turning point from the novelty of a new team and team member bonding/investigation of each other, to intergroup conflicts and influences of external pressures; adding physical burdens internally on the team members, such as deadlines and coping with the project unknowns. They resist the submergence into group structure (Bonebright, 2010) and hold to independent control.

Conceptual Social System – this stage includes conflict of special interest and polarization of opinions between team members, misalignments of personal behaviors wear on each other's nerves, and straining to be an independent voice above the others. Through discussion, conflict, and frustration, teams are able fortify and test boundaries as well as establish their team culture through daily adjustments of their climate (Kittelman, Calvo-Amodio, & Barca, 2016; Sprunger et al., 2016).

Norming

Concrete Social System - the team openly exchanges relevant interpretations and information and has a much greater level of intimacy in this phase. They confide in each other (Clapham & Solare, 1958; Coffey, Freedman, Leary, & Ossorio, 1950), reinforce trust that influences communication and collaboration (Morita & Burns, 2014)

Conceptual Social System - cohesion is reached among the team and roles and norms are established (Bonebright, 2010). They understand where strengths and weaknesses are in the team and develop with constructive feedback and commitment to the team and the goal they are working toward. Consensus within the team is derived from various forms of bargaining and negotiating and aids in strategic decision making (Amason, 1996; Priem, 1990).

Performing
Concrete Social System – Adaptability of team members as a whole to respond to changes in the environment and perform problem solving capabilities (Bonebright, 2010) to deal with system uncertainties. The team becomes a unit with flexible roles and structure for supportive task activities and team performance overall.

Conceptual Social System – This stage of team interaction is characterized by collaboration, commitment, and cooperation between and among the team members. They support each other rather than hinder the process (Tuckman, 1965) and have a freedom and friendliness of nature that is supportive of the goal and insightful behavior (Corsini, 1957; Stoute, 1950; Wolf, 1950).

Deming's (1950) model for Plan-Do-Study-Act (PDSA) was developed on the foundation of Walter Shewart's concept back in the 1920s and later modified into one of the most renown quality improvement methodologies today. The process outlined in Deming's (1993) wheel or PDSA cycle is easily identified as a technical system of activities for process improvement. Similar to Tuckman's (1965) model, each step of Deming's wheel can be broken down into conceptual and concrete system components for the technical system illustrated in Figure 3. However, contrary to Tuckman's (1965) model, Deming's cycle is much more data focuses rather than a strict focus on teams or development. Therefore, this model offers a convenient example for a more technical side of the sociotechnical system, though there are components human to the model. The following four stages of Deming's (1950) PDSA model is listed below with a segregation the concrete and conceptual systems for each component of the Deming cycle. Though the PDSA might act overall seem like a technical process, incorporating aspects of Deming's (1993) theory of profound knowledge aids in understanding the conceptual and concrete elements within each of the PDSA steps.

Plan
Concrete Technical System – The development of impactful solutions, systematic steps to achieve desired state objectives and system behaviors, analysis tools and resources including flowcharts, task breakdowns, and simulations, and review of historical information regarding the system under investigation.

Conceptual Technical System – Forming a theory for the system's behavior (Berry, 2011). Conceptual models formed for vision, mission, shared goals and objectives through investigation. Communication within the team and across the system to better understand the nature and current state for forming gap analysis. Evaluation of leadership and team's efficacy to meet the challenge of the system change initiatives.

Do
Concrete Technical System – Begin implementation of solutions created in the *Planning* phase. Initiation and completion of steps with physical and observable outcomes toward the change in goals. These include and Kaizen events and TQM principles for continuous improvement (Kanji, 1996). Collect data on interventions and training events; 5S, six sigma, or other training events.

Conceptual Technical System – Testing of the hypothesis and theories formed in the *Planning* phase. Commitment to change by leadership and teams. Develop understanding of the systems reactions to interventions. Test team's ability to do the work needed for system adaption, having the training, skillset, and/or abilities as a team to meet the variety of the project, per Ashby's (1958) theory of requisite variety.

Study
Concrete Technical System – Reports success or failure of interventions and reevaluate the current state of the system to perform a gap analysis. Includes an evaluation of information collected from the system and resolution of issues through management involvement (Kanji & Asher, 1993).

Conceptual Technical System – Mental and conceptual models assessed and updated based on behavior of system after intervention. Incorporates an evaluation of team's adaptability to new circumstances while facing unknown circumstances and requirements and evaluation of team's efficacy to achieve the project objectives (Calvo-amodio, Patterson, & Smith, 2014).

Act
Concrete Technical System – Implementation of problem solving strategies for remaining gap analysis. Evaluate strategies for fixing root causes found in the *Study* phase. Standardize new tasks and problem solving strategies. Readjustment of resources, tasks, modify training, reschedule necessary intervention steps and improvement strategies for further system development, adjustment, etc.

Conceptual Technical System - Understanding the current state system variation causes and ranges. Formulate predictions of the future behavior of the system based on the post-intervention observations. Reevaluate the system's identity and revised mission, vision, and goals.

These two models, Tuckman's (1965) small group formation model and Deming's (1950) PDSA model help to portray a social and technical activities within the human activity system. Combining the concepts behind these models which Vickers' (1983) two stranded rope, it is possible to understand what Flumerfelt's et al. (2014) meant in the double helix model they presented for organizational intelligence (thinking) and organizational practice (doing). The model suggests that with a congruence between thinking and doing teams maturity can be accessed for needed adjustments to the congruency of knowledge and practice for holistic, balanced outcomes (Flumerfelt et al., 2014).

This model paints a picture of a harmonious balance within sociotechnical systems that optimizes their trajectory and minimizes their variation from the expected path of goal attainment. It is believed that signs collected from the thinking and doing components of the human activity system will provide a means for also measuring and managing deviations from the expected progression of teams (i.e. problem solving for improved quality checks on a production line). Referring back to Figure 3, the human activity system model can be conceptually thought as a fulcrum by which thinking and doing are balanced by the social systems and technical systems (see Figure 5).

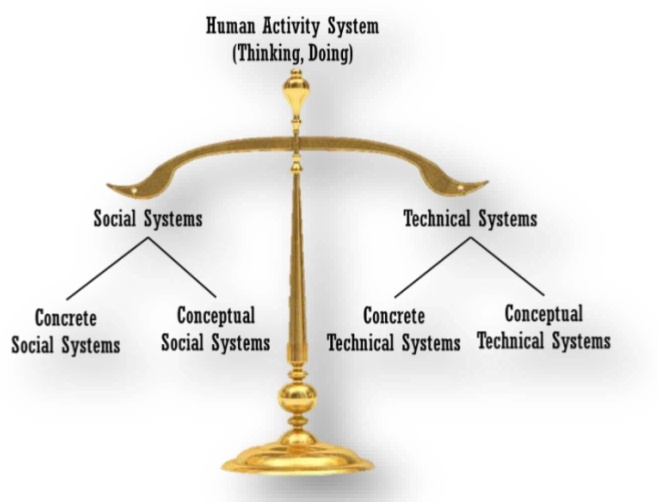

Figure 5. Fulcrum of Human Activity System Optimization

Set theory for Human Activity System Signs

To mathematically represent the fulcrum of human activity system optimization, an application of set theory is used for the expression of signs. Set theory originated from the author Georg Cantor (1941), considered "one of the most original minds of mathematical history" (Bezhanishvili & Landreth, 2013). Sets are defined by Cantor as aggregates that allow for people to understand the collection of parts of a whole of definite and independent objects which are known as elements. Human activity systems is the whole comprised of both thinking and doing elements which must be in balance to optimize their trajectory and attainment of the system's goal. Both thinking and doing are comprised of social and technical components and each component is comprised of concrete and conceptual systems which have signs.

The human activity system may be represented as the overarching set, denoted S_j, which is a family of sets.

$$S = X_1, X_2, \ldots . X_n$$

Understanding that the human activity system is comprise of thinking and doing elements, the set expression becomes the following, where the human activity system is a proper subset of thinking and doing sets:

$$S_{HAS} = \{X_T, X_D\}$$

Where both X_T and X_D are comprised of social and technical components:

$$\{y_{social} \cap z_{technical}\} \in X_T$$
$$\{y_{social} \cap z_{technical}\} \in X_D$$

As shown in Figure 3, the human activity system can be delineated into three hierarchical levels, 1) the holistic system level, 2) the thinking-doing/social-technical level, and 3) the concrete/conceptual level where signs exist at their most basic form. The nested levels of system elements can be expressed with Cantor's (1941) power sets, in which the human activity system is the set of all subsets of system elements. For the first level, the power set of:

$$S_{HAS} = \{X_T, X_D\}$$

Is converted to:

$$P(S_{HAS}) = \{\{X_T, X_D\}, \{X_T\}, \{X_D\}, \{\ \}\}$$

Which includes the possibility that the human activity system could contain both thinking and doing elements, only thinking or only doing elements, or none of the elements. This last statement, though theoretically possible, is practically impossible or the system would cease to function. Ultimately, the optimal solution would be for the power set to equally include all beneficial elements of thinking and doing in balance. Systems that focus heavily on the thinking side (planning, organizing, modeling, etc.) will become stagnant in productive gains whereas systems that are focused heavily on the doing side will struggle with the control, quality, and problem solving that requires intellectual capital. The second level looks at the power set for thinking and doing as two sets of subsets for social and technical components along with their power set:

$$X_T = \{Y_{soc}, Y_{tech}\} \qquad P(X_T) = \{\{Y_{soc}, Y_{tech}\}, \{Y_{soc}\}, \{Y_{tech}\}, \{\ \}\}$$
$$X_D = \{Z_{soc}, Z_{tech}\} \qquad P(X_D) = \{\{Z_{soc}, Z_{tech}\}, \{Z_{soc}\}, \{Z_{tech}\}, \{\ \}\}$$

As with the human activity system power set, the power set of the thinking and the doing can include both social and technical elements, only social or only technical, or neither. Practically, neither elements would once again meet the human activity system wouldn't exist, however, as illustrated with the case studies in the following section, having a focus on purely social elements or purely technical elements will result in an unbalanced and unhealthy system. Finally, the last level looks at the sets of elements within the social and technical sets. These are the conceptual and concrete elements or "signs" of the human activity system at their most basic form, representing meaning and structure of the system. The set and power set of signs for each social and technical set are:

$$Y_{Soc} = \{\theta_{concept}, \theta_{concrete}\} \quad P(Y_{soc}) = \{\{\theta_{concept}, \theta_{concrete}\}, \{\theta_{concept}\}, \{\theta_{concrete}\}, \{\ \}\}$$
$$Y_{Tech} = \{\theta_{concept}, \theta_{concrete}\} \quad P(Y_{Tech}) = \{\{\theta_{concept}, \theta_{concrete}\}, \{\theta_{concept}\}, \{\theta_{concrete}\}, \{\ \}\}$$
$$Z_{Soc} = \{\theta_{concept}, \theta_{concrete}\} \quad P(Z_{soc}) = \{\{\theta_{concept}, \theta_{concrete}\}, \{\theta_{concept}\}, \{\theta_{concrete}\}, \{\ \}\}$$
$$Z_{Tech} = \{\theta_{concept}, \theta_{concrete}\} \quad P(Z_{Tech}) = \{\{\theta_{concept}, \theta_{concrete}\}, \{\theta_{concept}\}, \{\theta_{concrete}\}, \{\ \}\}$$

As with the human activity system and the thinking/doing power sets, these power sets include the possibility of having both concrete and conceptual signs, just concrete signs, or just conceptual signs, or neither. As in the higher levels, if only the structural behavior without the meaning is observed, or meaning without observing the emerging behavior and structural composition, the system will not be optimized in the doing of executing adaptive changes matched with thinking (including reflections on, understanding, and experience of and in the system). Understanding and experience gained through interaction with the human activity system plays a significant role in the ability of change agents, such as managers and teams, to make successful and substantial impacts on systems during change initiatives.

Signs of Team Thinking and Doing

Consider, as an example, a manufacturing organization as the human activity system and the change agents as the managers and teams working towards the goal of implementing a new philosophy or new process. As the agents impact the system, they are also impacted by new situations, rules, climates, etc. and must also adapt to manage the change; maintaining a requisite variety as explained by Ashby (1958). To determine whether teams are maturing in an isomorphic trajectory with the system they are changing, the observation and interpretation of signs of the teams may result in an assessment of whether thinking and doing is balanced. Flumerfelt's et al. (2014) model for the DNA double helix content and competency aligns very closely with Vickers' (1983) idea of the appreciative system (clarified by Checkland (2018) as the double stranded rope), both expressing the need for balance in thinking and doing for systems design and adjustment by the change agents. Competency is described as the 1) conceptualization of a system, 2) the appreciation of that system, and the 3) ability change the system through the manipulation of its elements. In addition, training and acclimation to the system is necessary, along with cognitive, disposition, and application development.

Flumerfelt's et al. (2014) competency attributes of training, acclimation and application development can be expressed as the development of the team in parallel with the changing system, and the performance of the team to meet the requirements for managing the system's change. Thus, it can be stated that the doing elements of the change agents are the team's development (TDe) and team's performance (TP). In addition to Flumerfelt's et al. (2014) cognitive and disposition development attributes for change agents, how the team interacts with each other and the climate they form are also contributing attributes to team maturity. Elaborating on disposition development, is the temperament of team members individually and as a whole in working toward management's predefined goal for the system. This is defined as the team's temperament (TT).

The terminology of temperament is typically applied to explain the nature of personal characteristics and behavior patterns (Joyce, 2010). This description includes individual dispositions, humors, moods, and tempers mixed with the moral character and personality (Joyce, 2010). The phenomena outlined in temperament typically incorporates physiological components and reactions, such as the mental, physical, emotional, and social characteristics (Rice, 1992) that are largely dependent upon the individual's constitutional make-up, are hereditarily acquired (Allport, 1961). Holistically, the temperament can be applied to a group of individuals forming a cooperative team and their reactions to changes, local within their group and system wide. This system is reliant more on the disposition of the team members and less on the mediating influences of the environment surrounding the system (Joyce, 2010).

For the team to be successful, all members of the team must have equal participation in upholding the mental and physical "burdens" that are placed on the team during day to day operations and large to small scaled organizational changes. These burdens induce pressure on the team in the form of cognitive strain (i.e a growing quantity of emails and project juggling) and/or the physical demands, embodied in time on the floor/in meetings, overtime, and physical labor. Active participation requires that each team member is engaged both in the social resources and team performance aspects (Torrente, Salanova, Llorens, & Schaufeli, 2012), such as developing and sustaining an inclusive and supportive team climate. Participation, or engagement, as described by Schaufeli et al. (2002), is the affective-motivational and work-related psychological state. Team member engagement is characterized by the vigor, dedication, and absorption of each member within a work related setting. Kahn (1990) defines employee engagement as "harnessing of organization members' selves to their work roles by which they employ and express themselves physically, cognitively, and emotionally during role performances (p.692)." Research into employee engagement embodies the understanding the depth of selves that individual employees attribute to their daily work in response to momentary ebbs and flows of those days through which they express or defend themselves (Kahn, 1990). Employee engagement can be expanded to include all members within a given work team and the engagement of that team, as a unit, toward the fulfilment of the organizations interest.

Engagement in both work related and extracurricular activities with other members of the team, create a "sharedess" perception of responsibilities for the team, policies, and practices of the organization (Anderson & West, 1998; Reichers & Schneider, 1990). The exposure to, whether mandatory or self-constructed, common experiences will result in levels of shared perceptions of climate (Reichers & Schneider, 1990). The moral character (Joyce, 2010) and social characteristics (Rice, 1992) of each team member as showcased by their engagement activities, will largely predispose the overall temperament. Furthermore, team temperament is defined by the behavioral reactions of the team members in adjusting together to their changing environment. The collaborative efforts, such as systematic problem solving, of a team fully engaged, increases the likelihood of maintaining positive attitudes within the team. Ultimately, through positive collaboration, the team as a whole will have a temperament predisposed to be more successful in responding and adapting to expected and unexpected system changes.

Adaptability of a team to environmental changes, will also impact their overall temperament and affect the outcome of their performance and development. Literature generally defines adaptability as successfully responding to unknown situations (Klarner, Sarstedt, Hoeck, & Ringle, 2013; Priest, Burke, Munim, & Salas, 2002; Resick et al., 2010). For team adaptability this expands to include information gained by a team to adjust strategies (Cannon-Bowers, Salas, & Converse, 1990), maintain constructive behavior while altering the team's course during changing conditions (Brannick, Prince, Prince, & Salas, 1995), and continuous improvement of teams processes (Kozlowski, Gully, Nason, & Smith, 1999). Adaptability to change is influenced by the personality and mindset of the individual, trust in management (Devos, Buelens, & Bouckenooghe, 2007; Seppälä, Lipponen, Bardi, & Pirttilä-Backman, 2012), and information received about the change (Miller, Johnson, & Grau, 2016; Wanberg & Banas, 2000). Wanberg and Banas (2000) believed that employees with a positive view of a change were much more open to the change. Researchers also found that trust in executive management and organizational support were more important to acceptance of change than individual factors (Cullen, Edwards, Casper, & Gue, 2014; Miller et al., 2016). This trust develops from receiving timely information about the change and the quantity of that information (Wanberg & Banas, 2000).

Therefore, the component of team temperament (TT) may be expressed as team engagement and team adaptability; consisting of 1) the willingness to participate in extracurricular team activities (bolstering team a "sharedness" perceptions), 2) the team's attitude toward change and reaction toward change, and 3) trust in the success of the change and the vision as presented by management.

In addition to team temperament (TT), the team's interaction and cohesion impacts the organizational thinking in their ability to collaborate as a whole. Myers (2013) defines the team's unconscious and psychological forces impacting the behavior of the team and their performance as team dynamics (TDy). The theory of team dynamics has many associated components that act as internal and external forces on the team. These components, explored through engineering management, healthcare, and psychology literature, include cooperation or collaboration (Nijhuis et al., 2007; Zhuge, 2003), consensus (Priem, 1990), cohesion (Dion, 2000), commitment (J. W. Bishop & Scott, 2000), and trust (Author & McAllister, 1995; Jones & George, 2016). Though this list is not exclusive, it yields a general sense the forces acting on and within a team can influence the team's behavior and productivity.

Collaboration/cooperation between team members directly affects the success of the team. This success is dependent on the level of participation each team member contributes in communicating, decision making, goal setting, and problem solving (Nijhuis et al., 2007; Zhuge, 2003). Consensus within a team, derived through various forms of bargaining and negotiating, aids in strategic decision making and influences organizational performance (Amason, 1996; Priem, 1990). Cohesion is a multidimensional term that refers to the forces or processes acting upon an entity to keep it together, including molecules, members of small groups, or entire organisms (Dion, 2000). Group cohesion correlates with group performance (Dion & Evans, 1992), key indicators of organizational functioning, and influences greater communication (Schachter, 1951). Furthermore, cohesion is a force both vertically (subordinates to leaders) and horizontally (across peers) (Dion, 2000). Commitment to the team in the acquisition of goals and willingness to exert effort on behalf of the team also correlated to team performance (J. Bishop & Scott, 1997) and cohesion (Zaccaro, 1991; Zaccaro & Lowe, 1988). Team and organizational commitment are related to communication both horizontally among members, with informal and socio-emotional content, and vertically through management, with strategic and formal content (Postmes, Tanis, & de Wit, 2001). This communication improves team commitment through the act of team bonding, clarification of organizational objectives, and role identity in the group. In addition, trust is a vital component to team dynamics in that it influences all of the previously stated components, as well as performance (Mach, Dolan, & Tzafrir, 2010; Politis, 2003), openness to communicate (Leenders, Van Engelen, & Kratzer, 2003), and strength of the cohesive forces (Joo, Song, Lim, & Yoon, 2012; Mael & Alderks, 1993). Trust within a team, and with management, sets the foundation on which interpersonal growth and team productivity can develop. Finally, throughout the investigation of team dynamics in literature, the most common emerging theme for all components was communication. Communication promotes positive and proactive team dynamics with stronger trust relationships (Zaugg & Davies, 2013). Elving (2005) states that organizational communication has two goals, to share information about the organization and to create a community.

Therefore, team dynamics (TDy) may be defined as 1) the commitment of all team members to the success of the team as a whole, 2) trust in individual team members and team as a whole, and 3) the shared vision and values of the team through active communication. At this point, the authors have made a case for the balance of thinking and doing within sociotechnical human activity systems and further, built off the research by Sprunger et al. (2016) and defined the elements of thinking as team temperament (TT) and team dynamics (TDy) and the elements of doing as team performance (TP) and team development (TDe). Each element, the methods for measuring signs, and the tools for collecting and interpreting signs are listed below in Table 1.

Table 1. Collecting Signs of Team Thinking and Doing

Element	Team Performance	Team Development	Team Temperament	Team Dynamics
Measurement	Measured through production measurements	Measured through completion of training programs or extracurricular experiences	Measured through frequent climate checks with the team	Measured through frequent climate checks with the team

Element	Team Performance	Team Development	Team Temperament	Team Dynamics
Methods	Control charts for quality, quantity of units produced, rate of production, safety metrics, on-time delivery, etc.	Cross training, Kaizan events, Six-sigma training, TQC teachings, and other continuous improvement opportunities, etc.	Qualitative assessments for willingness to participate in extracurricular team activities, team's attitude toward change, trust in success of change, etc.	Qualitative assessments for commitment to team's success, trust in team members, shared vision and values through communication, etc.
Signs	Cost, quality, takt time, days without incident and safety oriented behaviors, delivery, etc.	Training, education, extracurricular activities, team building exercises, etc.	Engagement in team related activities or experiences, adaptability to expected and unexpected change, trust in management's vision of change, etc.	Commitment to team, collaboration with team, cohesion of the whole team, trust in the whole team, communication of values and vision of the team, etc.

While there are currently many tools and methods for collecting signs of team performance and team development, there is virtually no research on measuring team temperament and team dynamics. Research that skirts the edge of defining these two components are those on climate, such as with Anderson and West (1998) with the Team Climate Inventory (TCI) theory or Eisenbeiss, Boerner, and Knippenberg (2008) on transformational leadership and team innovation. Many authors, including Anderson and West (1998) rely on qualitative measurements such as surveys with Likert Scales. However, much like the team performance and team development elements have for assessing the doing component of human activity systems through real time and rapid, non-invasive collection of data, so also is the need to be able to measure the thinking components of team temperament and team dynamics.

Referring back to the set equations for socio-technical signs and tying them into the thinking and doing components for teams, it is possible to model the signs of team performance, team development, team temperament, and team dynamics as:

$$Tp = \{Cost, quality, takt\ time, safety, etc.\}$$

$$TDe = \{Training, cross\ training, education, extracurricular\ activities, etc.\}$$

$$TT = \{Engagement, adaptability, trust\ in\ management's\ vision\ of\ change\}$$

$$TDy = \{Committment, cohesion, trust, communication\ of\ team\ values\ and\ vision\}$$

The following section will evaluate a case study by Michael Tushman (1974) on the transformation of an industrial plant, called Becket which specializes in glass production in Boise, over the span of a three and a half year period (1968-1971). This study focuses on the systematic process of organizational change in general, however for the purpose of this research, the authors aim to identify and categorize different aspects of thinking and doing within the sociotechnical system of Becket to identify imbalance leading up to the derailment of Becket and to find specific signs of team performance, team development, team temperament, and team dynamics. The case study will include a pre-change initiative culture, post-change culture, and a discussion on the thinking and doing contributing to the success of the organization identified in the sociotechnical signs.

CASE STUDY: ASSESSING THINKING AND DOING AT BECKET

The case study used in this section includes a glass manufacturing plant called Becket, a Boise company from January 1968 to August 1971. The plant included three areas, 1) manufacturing which was the largest and most influential area, 2) the staff group that encompassed purchasing, scheduling and accounting functions for Becket, and 3) engineering which handled the responsibilities of the industrial processes and development of engineering subgroups. Most production was scheduled by a divisional sales force, not having a dedicated sales group, and included mostly standard catalogue product items and some specialty items, about 20 percent of the total production.

In the late 1960s Becket faced dramatic changes from the economic market which in the earlier part of the decade had presented Becket with an extended period of growth and prosperity. Then, in the beginning of 1968, the company faced a rapid reversal of the economy. Orders decreased or were sent to other Boise plants for cheaper costs. Additionally, due to a slow and lazy culture at the plant, Becket suffered from a sluggish response to the changing market, reaching a 1.5 rate of increase and loss of over a hundred employees.

Initial Cultural State of Becket

Regarding each of the three departments, a brief overview of the initial cultural state of 1) Manufacturing, 2) Engineering, and 3) Staff are provided with an accompanying table of the socio-technical system behaviors representing each in Table 2. Each column is arranged by the department, social system, or technical system and the team thinking and doing signs in parenthesis included in each cell. Those without indication of TT, TDy, TP, or TDe signs were not seen with a direct or explicit connection to one, or more, of the four types of team signs.

Manufacturing: This area of Becket received the most attention given its sheer size and the importance of its role in the production of actual products. It seemingly had full support and attention of the current plant manager (Mitchell) and the pull for getting much of their own demands met. Relations between departments on the manufacturing floor were poor. They perceived an infringement of duties and responsibilities. Additionally, integration was very competitive. The manufacturing floor was large and inefficient contributing to the confusion of employees.

Engineering: The engineering department at Becket was essentially nonfunctional with no purpose, budget, or status. They were considered a third-rate team with the primary activities of constant firefighting. They maintained machines and looked after the piece-rate system. Engineering was looked at with distain and had to struggle for cooperation when necessary to complete tasks. They were near sighted for planning and had a total lack of consideration in technological advancements contributing to the inability of Becket to stay competitive with the outside competition.

Staff: Purchasing and scheduling were on call for manufacturing and as such, had a very short term planning window with week to week perspectives at best. They were perceived as flying by the seat of their pants planners in the absence of long-range goals and a management by crisis response to the Becket processing.

According to the study saw no perceived need for change in operating practices. The culture was “fat and lazy”. Becket was operating heavily on activity based behavior rather than organizational intelligence (doing versus thinking). Management at the plant were not working toward a competitive advantage with the market. They were not investing in technological innovation, interpersonal relationships or collaboration, or any long-term plans or goals for the plant.

Table 2. Initial Cultural State of Becket

Department	Social System Signs (TT, TDy)	Technical System Signs (TP, TDe)
Manufacturing	Use to getting their way (TT)	Most influential (TP)
	Lack of inclusion and authority with Superintendent (TDy)	Mfg. Area inefficient and confusing (TP)
	Poor relationship between and within departments (TDy)	Poor monitoring of material (TP)
	Infringement of duties and responsibilities (TDy)	Integration competitive (Tde)
	Cooperation win/loose nature (TDy)	
Engineering	No function or role (TT, TDy)	No budget
	No status (TT)	Constantly fighting fires (TP)
	No purpose (TT)	No new projects or process modifications (TDe)
	No recognition or inclusion (TDy)	Lack of technological considerations (TDe)
	Considered third-rate team (TT)	Business good, customer happy, all is well (TDe)
	Looked at with distain (TT)	
Staff	Succumbed planning to the will of manufacturing (TT)	No long range-goals
	On call for manufacturing	Management by crisis
	Nearsighted planning (TT)	

Management Change and Cultural Transition of Becket

Management shifted in January 1970 when Mitchell was promoted to a corporate position and Doug Freeman replaced him as plant manager. He started asking difficult questions, and required justification for techniques and methods used. He began to establish goals and focused on more planning (thinking). Becket started to see a change in culture within and across different departments. Similar to Table 2, table 3 is provided to highlight socio-technical system behaviors for each department and how they relate to the thinking and doing signs of the organization.

Engineering: Saw the promotion of a new plant engineer, John Brown, and a felt a newfound responsibility for developing new and innovative, processes, techniques, machines, and the energy to transform Becket with state-of-the-art glass technology. Brown forced his people to think and take risks for innovative progress. Firefighting on the floor still remained but was reduced dramatically, with engineering duties distributed between 80% projects and 20% maintenance. Within engineering, they were often considered "special" and expected to work hard and be dedicated. Additional changes socio-technical elements of change as specified in the case study (Tushman, 1974) are listed in Table 3.

Manufacturing: The large and uncontroverted status of the manufacturing floor realized, arguably, the most dramatic change to their department. Immediately, special connection and privileges between manufacturing and the plant manager was severed and Smith, the production superintendent, was finally given full authority and responsibility over the department as he saw fit. Reconstruction of the power distribution took place, reducing tenure employees. Competition between the input (hot) and output (cold) areas of the manufacturing floor saw competition, causing a less than optimal situation for cooperation and coordination. Furthermore, attention from Freeman toward engineering, stirred continual dislike from manufacturing. Additional socio-technical elements of change as specified in the case study (Tushman, 1974) are listed in Table 3.

Staff: One of the most substantial changes in staff was the emancipation of staff from the influence of manufacturing and manufacturing's short term planning. With reduced manufacturing influence, the staff department bloomed with decision-making power and longer-range perspective. Communication and coordination between staff and manufacturing suffered due to the manufacturing dominance but the emancipation led to the freedom from day-to-day planning. New goals between manufacturing and engineering were to establish relationships, trust, improve communication between and within the groups, and improve problem-solving.

Culture change throughout Becket increased with the success attributed to Freeman and his top team that carried a consistent and encouraging spirit of change, innovation, and taking risks. This phase of the cultural change for Becket balanced a lot more of the organizational thinking and strategizing with the organizational doing as shown with the socio-technical signs in Table 2 versus the signs in Table 3. Over the next year Becket would still struggle with interpersonal relationships, especially among leadership and between departments.

Between April 1970 and March 1971, the preverbal ropes of thinking and doing, as described by Vickers (1983), seemed to go from an oscillating narrowed and balanced fluctuation to an exponentially growing gap between where Becket needed to be according to Freeman and the nature of the actual culture at Becket, illustrated in Figure 6. Production increased by a mere 1.8 percent. Adjustments in manufacturing removed more influence, producing insecurities, withdrawal, and myopia. Staff experienced a social transformation with better relationships and communication and overall better team dynamics and temperament, though they also faced insecurities from the threat of layoffs. Communication and collaboration between staff and manufacturing, staff and engineering, and engineering and manufacturing still remained hampered and ineffective. The year was referred to as "bloody and strained" (Tushman, 1974, p. 46) by the plant wide tension and stress. By April 1971, the level of interdepartmental conflicts and the mutual dysfunctional effects driven by the inability to communicate within and across departments, finally led to the decision of enrolling in the Blake and Mouton project.

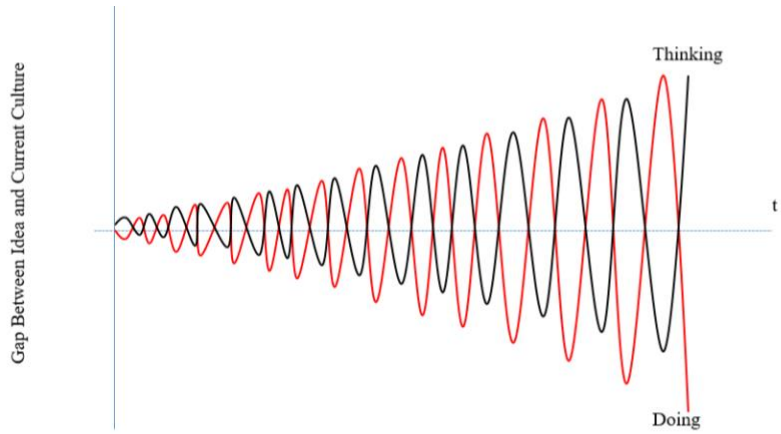

Figure 6.Thinking and Doing Exponential Growth and Oscillation at Becket

While a full description of the Blake and Mouton project and its integration and implications can be found in Tushman's (1974) book, a brief overview and Table 4 for the behavioral change of the sociotechnical elements is presented for observation purposes. After the change initiative of the Black and Mouton project, the following changes were experienced within and between the departments listed.

Manufacturing and Staff: Realized that the old meeting arrangements were dissatisfying and did not satisfy the need for dispersal of critical information accurately. They reformatted how they met and the exchange of information processes that would be regular and effective for handling planning and discuss immediate problems. Firefighting still increased but due to improved informal contacts, increased interpersonal competence, and new planning meetings resulted in effective problem solving and management of issues.

Manufacturing and Engineering: This relationship also improved with the establishment of task groups and the inclusion and representation of all areas of the plant in any given project. As projects increased, so did the interaction between the two areas on time and with great success. Mutual respect for and the working towards cooperation and collaboration resulted in success for both areas.

Table 3. Culture Change Midterm Progression of Becket

Department	Social System Signs (TT, TDy)	Technical System Signs (TP, TDe)
Manufacturing	Special connection between manufacturing and plant manager severed, no special considerations (TT, TDy)	Lacking problem-solving abilities (TP)
	Power and influence of manufacturing limited (TDy)	Structure so fat, each department had few responsibilities (TP)
	Reconstruction of power distribution (TDy)	Elimination and encouraged retirement of tenure employees
	Technical interdependence between groups high (TDy)	More responsibility given to foremen without problem-solving abilities (TDe)
	Department heads maintaining myopic viewpoints (TT, TDy)	No effect on authority or responsibility (TDe)
	Shift foremen felt cut off of information and authority (TDy)	Loss in control and acceptance of other department's gain in influence (TDe)
	Intergroup relationships improved with improved responsibility (TDy)	
	Competition between input and output end of department (TDy)	
	Shift foremen and department heads relationships remained poor (TDy)	
	Intergroup relationships still strained, chaotic, confused (TDy)	
	Insecurity from loss in employment and technological changes (TT)	
	Improved attention for engineering from plant manager created animosity from manufacturing (TDy)	
Engineering	Encouraged to take risks (TT)	Development and innovation (TDe, TP)
	Emphasis on risk taking (TT)	Firefighting reduced (TP)
	Long-term planning (TT)	Project development increased (TDe)
	Considered "special" and expected to work hard (TDy)	Measured by performance (TP)
	Added stress to perform and maintain employment (TDy)	Quality control focused on assisting manufacturing and engineering rather than rejecting parts (TDe)
	Evaluated in problem-solving abilities and $ amounts (TDy)	
	Quality control focused on assisting manufacturing and engineering rather than rejecting parts (TDy)	
	Improved relationship internally and with rest of plant (TDy)	
	Improvements required support and cooperation of maintenance and manufacturing areas (TDy)	
Staff	Long-term planning and decision-making power improved (TT)	Emancipation from manufacturing's influence (TDe)
	Freedom from day-to-day planning for production (TT)	Elimination of information expediters led to direct contact between areas (TDe)
	Elimination of information expediters led to direct contact between areas (TDy)	Success measured by problem-solving ability as well as glass out the door (TP, TDe)
	Communication and cooperation between manufacturing still difficult with manufacturing dominance (TDy)	Change in computer technology for scheduling (TDe)
	Reversal of influence over manufacturing through technological innovation (TDy)	Deemed fat and took a personnel loss, increased responsibility above and beyond expectation (TP)
	Trust, relationships, communication, and problem-solving were required with production (TDy)	

Engineering and Staff: Similar to manufacturing and engineering, engineering and staff experienced more frequency in their informal contact with each other and staff was included in many of the task groups and engineering to the planning meetings. The overall lack of interaction and confusion was decreased between them and the new interactions increased the spirit of collaboration between departments across the plant.

Becket saw a new era of common techniques, language, and attitudes in the plant culture towards each other and towards their work and responsibilities. The culture emphasized and practiced honestly, openness within and across departments, confrontation of problems and increased problem-solving, and delegation of decision making for optimal information sharing and responsibilities. Final compilation of changes are is presented in Table 4.

Table 4. Cultural Change of Becket after Blake and Mouton Project

Department	Social System Signs (TT, TDy)	Technical System Signs (TP, TDe)
Manufacturing	Developed intradepartmental conflicts (TDy)	Lacked internal integration
	Increased responsibilities with department head cuts (TT)	Numerous improvements to the manufacturing area
	Interactions between shift foremen and department heads increased with daily meetings (TDy)	Restructuring and elimination of department heads and shift foremen
	Interactions more lively, active, and open (TDy)	Stable workloads (TP)
	Communication increased, more mutual (TDy)	Shift foremen given authority and responsibility (TDe)
	Involvement in task groups and planning-oriented work (TT)	Shift foremen responsible for their own budgets and areas (TP, TDy)
	Increased interaction and communication in area and between shift foremen (TDy)	Take a longer work perspective (TDe)
	Interpersonal skills improved (TDy)	Spans of cognition increased (TDe)
	Misconceptions and hostilities decreased (TDy)	Individuals at all levels more mobile (TP)
Interaction between Engineering and Manufacturing	Interaction with manufacturing improved (TDy)	Number of task groups established
	All areas of plant represented in projects (TT, TDy)	Reinforced newly acquired systems perspective (TDe)
	Interaction frequency increased with projects (TDy)	Finished projects on schedule and with success (TP)
	Reinforced mutual dependence (TDy)	Areas benefited from success (TP)
	Increased mutual respect and work toward cooperation and collaboration (TDy)	
Interaction between Manufacturing and Staff	Staff invited to attend manufacturing meeting (TDy)	New restructuring of meetings (TDe)
	Informal meetings increased at all levels (TDy)	Established need for accurate and critical information (TP)
	Shift foremen and schedulers and purchasers interacting regularly (TDy)	Number of fires increased (TP)
	Increased interpersonal competence (TT)	Planning meetings, informal contacts and interpersonal competence contributed to effective management of fires (TDe, TP)
Interaction between Engineering and Staff	Increased formal and informal contact between groups (TDy)	Included many task groups (TDe)
	Engineering invited to planning meetings (TDy)	Increased interaction with few issues (TP)
	Overall confusion and lack of contact decreased (TDy)	
	Increased spirit of plant wide collaboration (TT, TDy)	
	Overall confusion and lack of contact decreased (TDy, TT)	

The authors described two approaches to how Becket underwent change during the time frame of the change initiative, these included a 1) Structural, then Behavioral, Change and a 2) Behavioral, then Structural Change. The first approach Becket experienced in the beginning, before the Blake and Mouton program. This resulted in restructuring and elimination of personnel, and was more action oriented in "doing" changes. Then behavioral intervention followed to aid in plant integration. This approach focused on role conflicts and sequencing with group educational methods. This technique aids communication and interpersonal relationships in the clarifying of roles. With Blake and Mouton program the behavioral changes came as a necessary prerequisite to the structural changes, improving interpersonal skills, problem-solving, communication, and the general plant culture (Tushman, 1974). This approach focused on putting education to strategically plan for effective change in structure. In this way, the "thinking" about changes precedes the structural altering of the plant in addition to preparing the culture for a smoother transition. Tushman (1974) states in his discussion that structural change on its own is not an effective approach, nor is only a behavioral approach, but rather the intertwining of a structural and behavioral approach, aligning with Geoffrey Vickers (1983) view on appreciative systems and the balancing of thinking and doing components. It was determined that a dual approach was necessary to most effectively bring about change at the Becket plant.

CONCLUSION

This research introduces the concept of human activity system signs. Signs are critical to understanding and characterizing the behavior of the systems in general and during change initiatives. The authors defined the nature of concrete and conceptual signs that exist within the sociotechnical human activity systems and can aid in assessing the system's trajectory and variation in pursuit of the system's goal. Signs can be employed to demonstrate whether thinking and doing within human activity system is balanced for an optimal progression toward the system's goal. In the Becket case study by Tushman (1974), an illustration of the sociotechnical signs was presented to demonstrate thinking and doing fluctuations of system change as depicted by the TT, TDy, TP, and TDe signs of the employees, shown in Tables 2-4. Thereby, providing observations of the system's behavior for analysts to assess and respond to.

FUTURE WORK

In this research, sociotechnical signs in human activity systems were defined and mathematically represented with set theory, and a practical application showcased in the Becket study. This work merely touched on the possibility of using human activity system signs to measure their trajectory and variation in pursuit of a goal, without undergoing empirical data analysis. Future work will further define the role and interaction of signs in the communication system pertaining to message development to enact change. Future studies for collecting and analyzing empirical human activity system signs, representing the thinking and doing in change management, are expected to add further rigor to the systems perspective of communication.

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