Five New Systems Heuristics To Analyze Small Group Teamwork

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I consider my time at MIT transformational. I started out as a technologist thinking that later I would participate in another technology startup as I had done previously and help raise it from grounds up. The dream is still there. What has changed is means. Previously I would put technology at the center of the work. Today I put both technology and people at the center of the work. The journey has been fascinating and many people at both MIT and Harvard provided their incredible support for this. I would like to take this space to acknowledge their support.

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Dedicated to my father Sri. Madan Lal Goel
and mother Late Smt. Devki Devi.
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Five New Systems Heuristics to Analyze Small Group Teamwork

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Submitted to the System Design and Management Program on December 15, 2015 in Partial Fulfillment of the Requirements for the Degree of Master of Science in Engineering and Management.

ABSTRACT

Small groups are the most common of all organizations. In this thesis we apply a systems architecture approach to small group teamwork in order to study small groups. We propose five new systems heuristics and use these heuristics as lenses to view small groups. We make use of concepts from systems and complexity theories in order to come up with these heuristics.

With each heuristic, we provide literature review both from systems and small group perspectives. We find that in many cases there is sufficient literature available to support application of each heuristic on small groups, but in some cases the literature is scant.

We further apply these heuristics to small group work in a movie called “Twelve Angry Men” to provide an application example of these heuristics to analyze the work of a jury group presented in the movie. We find that each heuristic within its scope is able to provide significant insights into the working of the group.

We finally provide guidelines for how these heuristics can be used for the practice of leadership in small groups. We report that each heuristic covers different aspects of group life and together can be used to analyze group work in details. Understanding group work in real time opens up opportunities for a member or members to influence the work and thus help practice leadership.

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CHAPTER 1: INTRODUCTION AND MOTIVATION

BACKGROUND

What is common in a MeetUp (meetup.com) jogging group of ten members, an engineering department in a small for-profit organization, a fund-raising group in a non-profit organization, and a project group of five members in an organization behavior class of an MBA program? They all consist of small groups to get some tasks done and such groups are common in many aspects of our lives.

As per Fisher & Ellis (1990), small groups are the oldest and most common of all social organizations with examples such as family groups, groups of friends, groups of associates at work, recreational group and so on. Many of these groups serve individual social needs (for example MeetUp group above), but some of them create economic benefits as well (engineering department above).

Vigil (2008) suggests that “small group share certain common characteristics: they share a common goal, are self-regulating, maintain balance through sensing and feedback and interact with the environment to get the tasks done.” Fisher & Ellis (1990) mention that as a member of a group you will be expected to participate; work well with others; assume leadership responsibilities; present ideas clearly; disseminate information both internally and externally; be sensitive to the decision making process; and possess good oral and written communication skills. We clarify what we mean by small groups in the definition section.

Many times, small groups are brought together to meet certain goals at certain level of productivity and quality. Too many times, these groups run into issues. Robbins & Finley (2000) provide fifteen chapters covering reasons where teams go wrong: (1) misplaced goals, confused objectives, (2) bad decision making, (3) empowerment uncertainties, (4) unresolved roles, (5) the wrong policies and procedures, (6) the people problem, (7) dealing with difficult people - personality conflicts (8) leadership failure (9) faulty vision (10) toxic teaming atmosphere (11) competitive hazards - anti-team culture (12) communication shortfalls - insufficient feedback and information, (13) rewards and recognition - ill-conceived reward system, (14) trust hell - lack of team trust, and (15) change issues - unwillingness to change. Hence, it becomes important to understand the dynamics and processes of small groups in order for small groups to do well.

There has been over a century worth of literature dealing with small group processes. As described in Gillette & McCollom (1990), Small (1905) discussed a sociological definition of groups. Similarly, there is a psychological dimension of groups discussed by Freud in 1922 in his fundamental work: Group Psychology and the Analysis of the Ego. As per Gillette & McCollom (1990), both sociological and psychological dimensions are
incomplete by themselves. Sociological dimension seeks to examine “the external aspects of group life”, while the psychological one “the internal terrains of groups”. In this sense, the sociologists may see “societies as (composed of) groups” while psychologists see “groups as societies” (Gillette & McCollom, 1990, p5).

Then there are studies to understand different stages of group life. A work by Tuckman (1965) as reviewed by Bonebright (2010) identified now classical the four stages of forming, storming, norming, and performing. Wheelan (2009) considers these stages as level of development and adds that groups that work at higher level of development are more productive. There is little doubt that understanding small group dynamics becomes a worthwhile academic endeavor from both social and economic perspectives.

In this research, we use an approach based on systems architecture to understand small group teamwork – we propose five new heuristics and apply them to small groups to provide an analysis of group processes. To support these heuristics, we utilize concepts from the fields of systems, systems theory, complexity theory, and system architecture. We provide a detailed literature review of these fields in a later section.

**METHODOLOGY**

We use support from the existing literature as the primary media of research in this thesis. We propose five new system architecture heuristics and provide support for them from systems theory, complexity theory and system architecture literature. We then reformulate these heuristics to apply them to human groups. We again provide support for these heuristics from both systems and group literature. We then apply these heuristics to a movie “Twelve Angry Men” to show an application of how these heuristics can be used in real life. Further, we discuss an implication of these heuristics for group leadership work. We postulate that understanding these heuristics can help group members lead the groups better. We finally discuss conclusion and areas for future research.

**STRUCTURE OF THESIS**

Chapter 1 provides an introduction of small groups, relevance of the studies related to small groups and how we plan to study small groups – using system architecture heuristics.

Chapter 2 provides literature review related to systems, systems theory, complexity theory and system architecture. We further discuss systems literature related to small groups and literature related to the critique of systems literature for human groups. We also discuss important definitions pertaining to this work.

Chapter 3 proposes five new system architecture heuristics. These heuristics are built
over existing literature in system architecture, systems theory and complexity theory. We also make use of concepts from other domains such as marketing in furnishing the discussion.

Chapter 4 describes the human group version of five heuristics discussed in chapter 3 and provides support for them from the group literature.

Chapter 5 applies five heuristics discussed in chapter 4 to a movie “Twelve Angry Men” to show an example application of these heuristics. Our intent of this application is to show how these heuristics can be used in real life.

Chapter 6 provides guidelines for how these heuristics can be used for the practice of leadership in small groups. Understanding group work in real time opens up opportunities for a member or members to influence the work and thus help practice leadership.

Chapters 7 and 8 conclude this research and discuss areas for future research.
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CHAPTER 2: LITERATURE REVIEW AND DEFINITIONS

In this section, we cover an overview of literature in the following fields that are relevant to this thesis:

1. Systems
2. Systems Theory
3. Complexity Theory
4. Systems Architecture
5. Systems Theory and Human Systems

SYSTEMS

Bertalanffy in his 1968 book started his introduction with the heading “Systems Everywhere”. He meant everything around us including us can be considered a system or part of a system. A steam engine, a clock, an automobile, or a radio receiver are all good examples of systems. An automobile consists of many subsystems including but not limited to engine, chassis, tires, brakes, transmission, steering, exhaust, controller etc. An automobile is a complex system with components originating from many disciplines including mechanical, chemical and electrical.

Before proceeding further, let us define systems. Cordon (2013) lists many definitions:

- “A regularly interacting or interdependent group of items forming a unified whole”
- “A group of devices or artificial objects or an organization forming a network especially for distributing something or serving a common purpose”
- “A set of things—people, cells, molecules, or whatever—interconnected in such a way that they produce their own pattern of behavior over time”

We find a definition provided by Rechtin (1991) in the following two parts an excellent one:

1. A system is a complex set of dissimilar elements or parts so connected or related as to form an organic whole.
2. The whole is greater in some sense than the sum of the parts, that is, the system has properties beyond those of parts. Indeed the purpose of building systems is to gain those properties.

Based on the above definition, systems have a structure consisting of elements, parts or subsystems, all connected directly or indirectly. Viewing from the perspective of this definition, an automobile is made up of various dissimilar parts to provide a function of
moving from point A to point B, a function that does not exist in the parts themselves. In this sense, the whole has properties beyond those of parts.

Patrashkova-Vozdolska (2005) states, “Every system can be modeled as a collection of subsystems. Each subsystem can be defined as a system on its own. Outputs of one subsystem can be considered as inputs, or the environment, of another subsystem.” Figure 1 pictorially depicts this idea.

![Figure 1. Nested systems](image)

To distinguish one system from another, systems have boundaries. As per Bailey (2009), “the boundary has special significance in systems theory as it, by definition, separates the system from its environment.” In this sense, a system boundary can further be thought of as a media through which the transfer of energy or mass takes place both inside or outside of the system. A membrane of a living cell provides a good example of boundary. The membrane keeps the outer environment separate from the inside of cell system, but at the same time allows the flow of energy and mass through it (an open system). In the absence of this flow, the cell will parish. In different words, all systems have boundaries that distinguish one system from what's outside it (reference Cornell-U) and thus define the scope of the system.

A system map of Canon PowerShot A430 shown in Figure 2 provides a concrete idea of boundary in engineering systems. Solid thick line around the camera shows the system boundary of the camera.

Rechtin (1991) also states that only thing that is added to parts to make the whole greater than its parts is the interrelationship among them. These interrelationships are called interfaces. As an example of interface, a connection between the printer and the camera, as shown in Figure 2, is an interface.
Interfaces exist at two levels: interfaces among parts themselves and interfaces of the system with its environment (or other systems in the environment). But since a system itself is a subsystem in its larger environment, characterization of interfaces at these two levels is the same.

Interfaces are a crucial point in the design of systems. The information that flows through interfaces can make a system very elegant, flexible or in contrast very rigid. In other words, permeability of interfaces can make a system open, closed or isolated. In an open system, mass and energy can transfer across the boundary, while in a closed system they do not, but there is still a possibility of transfer. In an isolated system, there is no possibility of transfer.

Regarding permeability of interfaces Alderfer (1980) defines two more terms: underbounded and overbounded systems. If the permeability of interfaces in an open system is less than what is optimal for the system's relationship to its environment, he terms such systems overbounded. If permeability is more than optimal, he terms such systems underbounded.

Emergence is next important aspect of systems. Referring to properties in the second part
of the systems definition “system has properties beyond those of parts”, such properties are called emergent properties. As we discussed earlier, the motion of an automobile is an emergent property that does not exist in any of its parts. In fact, engineered systems are created to produce these emergent behaviors. In this sense, the idea of emergent property is at the heart of the systems theory. Georgiou (2003) provides an excellent coverage of emergent properties of the systems. This work explains an emergent property can be seen as an unforeseen consequence, as a reference point or as a foundational epistemological concept. We will discuss emergence in more details under a related heuristic later.

Until now, we have only given examples of man-made or engineered systems. But system can also be living systems. Cordon (2013) elaborates on human beings as systems themselves. Human beings are further made of subsystems including various organs. In fact, as we know, every living being on Earth are inter-connected through the food chain and are part of a system. These systems are called natural (or biological) systems.

To distinguish between an engineered and natural system, engineered systems are made with some purpose in mind. This purpose as we will discuss below is an emergent property. Natural systems on the other hand as per Laszlo & Krippner (1998) are a product of slow but vast processes of evolution in nature. They may not have an apparent purpose in the short run.

This discussion summarizes what we mean by systems and some important properties of systems. Next, we discuss fields that study systems and are relevant to this thesis. The list of these fields is as follows:

- Systems Theory
- Complexity Theory
- System Architecture
- Systems Theory and Human Systems

We also discuss the following:

- Limitation of Systems Theory for Human Systems

**OVER VIEW OF SYSTEMS THEORY**

One of the seminal works on systems is called General System Theory (GST). As per Laszlo & Krippner (1998), “As a response to the increasing fragmentation and duplication of scientific and technological research and decision making in the first half of the 20th century, Ludwig von Bertalanffy advanced what he called Allgemeine Systemlehre (general theory of systems or, more popularly, general system theory -- GST).” Bertalanffy is considered the father of GST.
As described further by Laszlo & Krippner (1998), the current “specialized approach” of decision-making in many parts of the world is based on “individualism, competition, training for a specific profession, and indoctrination into a specific culture. On the other hand, the general systems approach encourages the development of a global, more unitary consciousness, team work, collaboration, learning for life, and exposure to the universal storehouse of accumulated knowledge and wisdom.”

Throughout the twentieth century, many original thinkers contributed to the systems theory. As per Laszlo & Krippner (1998) these thinkers include likes of “Alfred North Whitehead, Ludwig von Bertalanffy, Anatol Rapoport, Kenneth Boulding, Paul A. Weiss, Ralph Gerard, Kurt Lewin, Roy R. Grinker, William Gray, Nicolas Rizzo, Karl Menninger, Silvano Arieti, and, in more recent years, the dynamical systems theorists, the family systems theorists, and those who deal with dissipative structures and holistic paradigms.” However, the work of Bertalanffy still stands out.

Bertalanffy defined the major aims of GST as the following (p. 38):

1. There is a general tendency toward integration in the various sciences, natural and social.
2. Such integration seems to be centered in a general theory of systems.
3. Such theory may be an important means for aiming at exact theory in the nonphysical fields of science.
4. Developing unifying principles running "vertically" through the universe of the individual sciences, this theory brings us nearer the goal of the unity of science.
5. This can lead to a much-needed integration in scientific education.

Through GST, Bertalanffy wanted to provide an overarching theory that could be applied to systems in general at any level of nesting in any discipline or to systems encompassing multiple disciplines.

Another term that is commonly used for systems theories is called Open Systems Theory (OST). OST has its root in GST itself. OST is more applicable to biological or social systems. Bertalanffy maintained that since biological or social systems interact with their environment, closed systems theory was not really applicable to them. Hence, OST is more appropriate term for such systems.

Laszlo & Krippner (1998) provide a detailed literature review on how the systems theory came into development. We advise our readers to refer to this work for any more information on the systems theory. Next we discuss complexity theory.

**Over view of Complexity Theory (CT)**
As mentioned in Cabrera (2006), word “complex” comes from the Latin root *complexus*, which means, “to entwine”. Complex systems therefore mean the systems whose elements and environment have an entwined relationship.

“Complexity Theory is a broad-based movement that contains new tenets about a type of system, referred to as Complex Adaptive Systems (CAS)” (Schneider & Somers, 2006). CAS is the only relevant part from the point of this work, and hence we only include a review of CAS under this section.

As per Cordon (2013), “Some systems, with various levels of hierarchies, networks, and layers of complexities, have the ability to learn to adapt to its changing components and environment.” These systems are termed as complex adaptive systems (CAS). As per the same author CAS are also referred to as complexity science.

As per Surana et al. (2005), “The study of CAS augments the systems theory and provides a rich set of tools and techniques to model and analyze the complexity arising in systems encompassing science and technology.”

As per Sturmberg et al. (2014), “The behaviors of a complex adaptive system cannot be explained by the behavior of specific agents (reductionism); instead, complex adaptive systems show emergent behaviors.” This is inline with our earlier definition of systems.

As per Ellis & Herbert (2011), “Complex adaptive system ideas are associated with developments in second-order thinking. The second-order view of systems describes recursive interactions between layers of systems (control loops and feedback); principles that guide a variety of systems to achieve their purpose by ‘the return of information to form a closed loop’.”

Santa Fe Institute of New Mexico was an earlier pioneer of CAS concepts. Kauffman (1993) and Holland (1995) Santa Fe studied and developed a list of CAS attributes. However, the list of CAS attributes seems to be changing depending on the application of CAS and the author. We discuss some of the relevant CAS attributes in the following paragraphs.

A CAS consists of a large number of interacting components, usually called agents (Holland 2002). Examples include species of plants in a rain forest or a network of retailers and wholesalers in a city like New York City. Lichenstein et al. (2006) adds groups of agents to this lists as well. As per this paper the agents and their groups resonate “common interests, knowledge and/or goals due to their history of interaction and sharing of worldviews.”

“Agents in a CAS undergo constant interactions, both autonomously and with their
environment” (as quoted by Heylighen in Alaa & Fitzgerald, 2013). What autonomy means, as per Wycisk et al. (2008) is that “their actions may be self-initiated without any external influence steering or controlling them, though there are usually a few imposing influences.”

The agents can exhibit a large degree of diversity or heterogeneity. Holland (1995) gives various examples of CAS and heterogeneity. For one, in a tropical rain forest as CAS, it is possible to walk half a kilometer without encountering the same species of tree. Similarly, a city like New York consists of a variety of retailers and wholesalers. Holland (1995) further states:

This diversity is neither accidental nor random. Persistence of any individual agent whether organism, neuron, or firm depends on the context provided by the other agents. Roughly, each kind of agent fills a niche that is defined by the interactions centering on that agent. If we remove one kind of agent from the system, creating a “hole,” the system typically responds with a cascade of adaptations resulting in a new agent that “fills the hole.” The new agent typically occupies the same niche as the deleted agent and provides most of the missing interactions. This process is akin to the phenomenon called convergence in biology.

The agents have an ability to learn and adapt as they accumulate experience. As per Wycisk et al. (2008), “Adaptation includes structural, physiological and/or behavioral processes of systemic change that increase the expected long-term success of a system” and “Through processes of adaptation CAS are able to cope with environmental changes they are interrelated to.”

The agents in CAS interact in non-additive (non-linear) ways (Holland, 2002). Haken as quoted in Wycisk et al. (2008) hints at the reason, "Since, subsequent actions are not necessarily pre-determined, the entire system behavior of a CAS is unpredictable."

Further, CAS produce multi-level (hierarchical) structures in which “an emergent whole at one level is merely a component of an emergent system at the next higher level” (Heylighen, 1989, p. 2). However, the system works more efficiently if these components are as autonomous as possible or as described in Wycisk et al. (2008) – “nearly decomposable” – meaning “only the most essential connections and interactions with other units remaining.”

Concept of boundary becomes more intricate when it comes to CAS. As per Cilliers (2001), “The relationships amongst the components of the system are usually more important than the components themselves. Since there are also relationships with the environment, specifying clearly where a boundary could be is not obvious.” The same
work claims that boundary in such systems is an emerged property where boundary is simultaneously a function of the activity of the system itself, and a product of the strategy of description involved, but these systems still have boundaries.

For this research, there are two more important aspects of CAS worth going in details with: attractors and basin of attractors. As per Gros (2008), attractors are a bounded region in phase space to which orbits with certain initial conditions come arbitrarily close. Attractors can be isolated points (fixed-points), limiting cycles or more complex objects. As per Gros (2008), a basin of attraction is the set of initial conditions that leads to orbits approaching a certain attractor arbitrarily closely.

We refer our readers to the following works for any further details of CAS attributes:

- Holland (2002)
- Lichtenstein et al. (2006)
- Wycisk et al. (2008)
- Sheard & Mostashari (2008)
- Alaa & Fitzgerald (2013)

Next, we discuss system architecture.

**OVER VIEW OF SYSTEM ARCHITECTURE**

We have already discussed what we mean by systems in the section above. We next discuss what we mean by architecture. Architecture as per Merriam-Webster dictionary is defined as “the art or science of building; specifically: the art or practice of designing and building structures and especially habitable ones.” It is no wonder that the field is commonly associated with designing and building structures such as buildings, gardens, automobiles, ships etc. that humans commonly use or inhabit. Still, as per Lim (1998), every system human-habitable or not has architecture.

As per Lim (1998), system architecture is thoroughly researched and documented in the field of building and ship design. However, with the advent of more complex systems such as the ones in telecommunication, the need of system architecture becomes more pronounced in the modern time.

As per Rechtin (1991), “Architecting is working for a client and with a builder, helping determine the preferred architecture, that is, helping determine relative requirement priorities, acceptable performance, cost, and schedule – taking into account such factors, as technology risk, projected market size, likely competitive moves, economic trends, political regulatory requirements, project organization and the appropriate ‘illities’ (availability, operability, manufacturability, survivability etc.). Towards the end of the project, architecting is also certifying completion and satisfactory operation of the
system." This definition connects client needs, environment, ongoing operation, and maintenance and support with the act of architecture.

More generally, Crawley et al. (2016) defines system architecture as "the embodiment of concept, and the allocation of physical/informational function to elements of form, and definition of interfaces among the elements and with the surrounding context." This is depicted in the following diagram.

![Diagram of Form-Function-Concept Relationship](https://example.com/diagram.png)

**Figure 3. Form-Function-Concept Relationship (Crawley et al. 2016)**

Again as per Crawley et al. (2016), a concept is a mental image or vision of an architect to map function to form. A function answers the question what we need the system to do or accomplish. Form is an attribute of the system that constitutes physical or informational embodiment. It is related to the structure and arrangement of elements. An architect has control over how far to decompose the form into smaller elements.

Rechtin (1991) defines four ways of system architecting:

- The normative (pronouncement) methodology: This is judgmental and experiential approach where the architect imposes his sense of right and wrong, good and bad on architecting.
- The rational (procedural) method: This approach uses science and mathematics in order to solve architecture problems procedurally. This approach fails where it is difficult to reach even the clarity of goals of architecting.
- The argumentative approach: This approach uses several versions of brainstorming to reach a solution. But the brainstorming can quickly evolve into a sociopolitical problem and get out of hand.
- The heuristic approach: This approach has some origins in both normative and rational approaches. Heuristics are based on “commonly accepted insights gained from experiences that bring order out of apparent chaos” (Rechtin, 1991). “Keep It Simple, Stupid” (KISS) is a good example of a heuristic.

In this research, we use heuristic approach to study group processes. And hence, it is worth describing in further details what we mean by heuristics.
To start with, we point out the distinction among heuristics, generality and principle. As per Lim (1998), a principle is defined as “underlying and long enduring fundamental with no credible exceptions.” A generality on the other hand is like a principle but may have some rare credible exceptions. A heuristic in comparison with generality may have many more credible exceptions, but is still a good guiding statement while architecting complex systems.

Word “heuristic” has a Greek root called “heuriskein”, meaning, “to find”. Merriam-Webster dictionary defines it as “using experience to learn and improve”. This fits the description provided by Lim (1998), “Heuristic is a way of applying the lessons learned from experience in designing a system architecture. Heuristics serve as a guide for the architect so that past mistakes will not be repeated.”

Heuristics in experiential sense are not very different from the normative method, which uses a judgmental and experiential approach as well, but heuristics are more impersonal in nature: heuristics draw lessons from many external sources and these lessons are more general in nature. This also creates a drawback for heuristics because in this manner their number can be very large and finding an appropriate heuristic to suit the situation at hand may become daunting.

Another drawback of heuristics comes from their distinction from principles and generalities as defined above. Since heuristics can have many more credible exceptions, their use may at times be misguiding. Lim (1998) quotes an excellent example for this. A well known heuristic “if you can’t analyze it, don’t build it” could eliminate more useful and innovative systems just because tools to analyze those systems do not exist or have not been developed yet.

Next we provide an overview of systems application for human groups.

**Overview of Systems Application to Human Groups**

Viewing human groups as systems has been around since the inception of systems theory. Bertalanffy (1968) devotes three pages in describing how systems can be applied to “human groups, societies and humanity as a whole.” Bertalanffy further mentions about the history of humanity that if a theoretical history were possible, it must be an “investigation of systems as a suitable units of research – of human groups, societies, cultures, civilizations, or whatever the appropriate object of research may be.”

Following Bertalanffy, within few years of the development of his systems theory as per Alderfer (1971), many authors including Argyris, 1960; Katz & Kahn, 1966; Rice, 1969; and Schein, 1965 used this theory to understand human groups. Alderfer (1971) itself presents a study that looks at a training program as a sub-system within the larger organization as a system and studies the intergroup relations.
Gillette & McCollom (1990) compiled work from various authors some of which analyze groups using systems perspective. Arrow et al. (2000) compiled over century worth of academic work and presented a general theory of small groups as complex systems.

Similarly, use of heuristics for humans can be found very commonly. Loss aversion and reflection effect are very commonly used heuristics in many disciplines related to humans. Loss aversion as per Gonclaves (2009) suggests, “Individuals hurt more when experiencing losses than they enjoy when experiencing gains.” Reflection effect as per the same author suggests, “Individuals make risk-averse decisions when facing gains, but make risk-loving decisions when facing losses.”

Tversky & Kahneman (1978) describe the following human judgment related heuristics:

- Representativeness Heuristic: As per this heuristic, the degree to which a given event is representative of, or similar to, some essential features of previously known event assess the probability that this event will occur.
- Availability Heuristic: As per this heuristic, there are situations in which people assess the frequency of a class or the probability of an event by the ease with which instances or occurrences can be brought to mind.
- Adjustment and Anchoring Heuristic: As per this heuristic, people make estimates by starting from an initial value that is adjusted to yield the final answer. The initial value, or starting point, may be suggested by the formulation of the problem, or it may be the result of a partial computation.

Particularly in human group domain, Lubell & Scholz (2001) suggest, “The set of heuristics in a given society represent specialized cognitive mechanisms for solving social dilemma problems, which are an ancient and central part of human society.” Since dilemmas are also part of small human groups, we can extrapolate from the above statement that a heuristic approach is equally applicable to small groups.

Donohue & Fox (1993) investigate people-sequential heuristic method of group formation. They study twelve heuristics of group formation based on the use of balanced groups and report that only one of the hypothesized relationships was supported.

Hurley (2005) describes a social heuristic called “mirror heuristic”, which prescribes that a player cooperate with others acting on the same heuristic and not on the behavior of player itself. In this sense, mirror heuristic is a meta-heuristic.

Cohen & Bailey (1997) use a heuristic framework to study group effectiveness. They build a framework of effectiveness based on environmental factors, design factors, group processes, and group psychosocial traits. He et al. (2013) build on the work of Cohen and Bailey to study team effectiveness through a heuristic model of positive and negative
leadership attributes.

Reimer et al. (2008) use two non-compensatory heuristics called minimalist and take-the-best heuristics to study how groups can help detect hidden profiles. Hidden profile is a piece of information held by a single group member. Minimalist heuristic as per the authors “draws cues randomly. Alternatives that do not have the highest observed cue values are eliminated. Information search stops as soon as one alternative remains in the choice set.” Take-the-best, on the other hand, only draws cues according to an order established by their validity.

Clearly, use of heuristics to study small group processes is not new. We provide more literature as we apply systems approach and heuristics on small groups in the later sections. But before that we throw some light on the limitations of using systems approach for the purposes of human groups.

LIMITATIONS OF SYSTEMS AND HEURISTICS APPROACHES

There are limitations of using systems theory, complexity theory or heuristics approach for studying human systems. To start with, not everybody agree that systems theory is a panacea for all. For example, Lansing (2003) quotes Horgan saying the following: “The history of 20th-century science should also give complexologists pause. Complexity is simply the latest in a long line of highly mathematical 'theories of almost everything' that have gripped the imaginations of scientists in this century.”

In the words of Helmreich, Lansing (2003) further casts shadows on the simulation approach systems researchers take, "Simulation models are like Rorschach tests, revealing the researcher's cultural background and psychological idiosyncrasies. All statements, especially theoretical pronouncements, are taken not as statements about the world but as evidence about the author's beliefs and mode of thought."

Schneider & Somers (2006) raise a concern that the complexity theory should not be idealized since the emergence may also lead to destruction since outcomes of emergence may not be desirable in terms of an organization’s criteria of interest.

Then heuristic approach also has limitations. We noted some obvious ones under the architecture section stating that heuristics are good guiding statements while architecting complex systems, but they may have some credible exceptions.

While some may deem the critique of systems and heuristics approach valid, we hope that our readers find value in our analysis of small groups using heuristics in the subsequent pages. Next we present some operational definitions.

OPERATIONAL DEFINITIONS
**SMALL GROUPS**

Before we continue, let us agree on what we mean by small groups. Although a dictionary might define a group as “any collection or assemblage of persons or things” (dictionary.com), we think there is much more to small groups; we believe a small group is more than a mere collection of individuals. We like the definition provided by Luft (1984) (as quoted in Wheelan, 2005, p1):

> A group is a living system, self-regulating through shared perceptions and interaction, sensing and feedback and through interchange with the environment. Each group has unique wholes qualities that become patterned by way of members’ thinking, feeling and communicating, into structured subsystems. The group finds some way to maintain balance while moving through progressive changes, creating its own guidelines and rules, and seeking its own goals through recurring cycles of interdependent behavior.

and by Alderfer (1984) (as quoted in Gillette & McCollom, 1990, p5) using an open systems perspective:

> A human group is a collection of individuals 1) Who have significantly interdependent relations with each other; 2) who perceive themselves as a group by reliably distinguishing members from non-members; 3) whose group identity is recognized by non-members; 4) who have differentiated roles in the group as a function of expectations from themselves, other members and non-group members; 5) who as group members acting alone or in concert have significantly interdependent relations with other groups.

Although both of these definitions are equivalent in many aspects such as interdependence, there are certain elements that are better highlighted in one than other. For example, Alderfer clearly highlights boundaries recognized by both members and non-members. On the other hand, Luft only implies the existence of boundary by emphasizing interaction with environment. We agree with both and stand somewhere in the union of these definitions.

There might also be some confusion between groups and teams. Vigil (2008) provides a good working definition of teams as a group of individuals, usually between three and twenty, who are committed to a common goal or purpose, who possess complementary skills, and who assume mutual accountability for the accomplishment of a goal. As per Vigil (2008), the primary difference between a group and a team is the level of accountability and commitment assumed by the team and the level of interaction required to achieve success. In this work, we do not distinguish teams from small-groups and use the words interchangeably.
Finally, one may query about the difference between a small group and a regular or large group. Wheelan (2009) covers the concept of group size in details. We consider any group between 3 and 20 members as small group. Although, we would like to think that the concepts we discuss here apply to a group of any size, the evidence we provide here primarily comes from small groups and hence we would like to stick with small groups in this work and leave the discussion of larger groups for future research.

Next we discuss five new heuristics based on the foundation of the literature review carried out in this section.

**GROUP OR TEAM LEADERSHIP**

In the context of using this research for group leadership, one may wonder what we mean by leadership. Although leadership is a vast subject by itself, in this section we provide some pointers to define leadership in the scope of this research.

For leadership, we primarily follow the definition provided by Heldal & Antonsen (2014). As per them, group leadership may be defined as “the process of facilitating individual and collective efforts to accomplish shared objectives.” They also link this definition to the following set of core team leadership functions: (a) setting the direction for team action, (b) managing team operations, and (c) developing the team’s capacity to manage their own problem-solving processes. For any further description of group leadership, we advise our readers to consult this work.

For a more general discussion of leadership, we point our readers to the following two works:

- Heifetz (1994)
- Williams (2005)
CHAPTER 3: FIVE NEW SYSTEM ARCHITECTURE HEURISTICS

In this chapter, we propose five new system architecture heuristics and provide their links with the existing literature. Overview of the background literature related to these heuristics has been addressed in the previous chapters. We include references to more relevant literature as we describe each heuristic further.

The following is the list of five heuristics:

1. H1: Change in a significant boundary condition will change the state of a system
2. H2: Significant initial conditions will change the state of a system
3. H3: Significant pivotal conditions will change the state of a system
4. H4: Nature of subsystems is determined by the system and its environment
5. H5: Any novel quality emanating from systemic interaction is of emergent nature

Next, we go into details of each heuristic.

H1: Change in a significant boundary condition will change the state of a system

We discussed the system boundary in the literature review section above. In general, a complex system will have many boundary conditions. For example, an automobile may have a range of operating temperature, fuel type, road conditions etc. Some of these boundary conditions may be more significant than others, meaning a change in some of the boundary conditions may have a larger impact on the state of a system. “Significant” is defined in this relative sense.

By the state of a system, we mean the current value or state of function, concept and/or form of the system under design. For example, possible function value of transportation may be walking, wheeling or flying. Depending on the speed boundary (for example), one or more of these may be desired values. This heuristic is suggesting that change in a significant boundary condition will influences the choices of these values.

Intent of this heuristic is already well understood in the system architecture literature as there are many principles and heuristics available in the literature to express a similar sentiment. Consider the following principle and three heuristics from Lim (1998) as examples:

1. Principle: Boundaries confine the system. Expanding the boundaries expands the range of the solutions. Once a concept is chosen, the boundaries help architect develop that concept. However, premature boundaries definition may also restrict the architect from creating a purposeful system. Expansion here is a type of significant change to increase the range of solution. In this sense, this principle is a more restricted form of the heuristic we have proposed.
2. **Heuristic: Choose system boundaries to simplify the problem.** Once a system boundary is chosen, it separates the system from its environment and defines what is inside and what is outside this system. In this sense, the problem becomes simplified. Choosing a system boundary is equivalent to changing the value of that boundary from nothing to something. Therefore, choosing is also a special case of change and hence this heuristic is a special form of the heuristic we have proposed.

3. **Heuristic: Set product/process boundaries to translate an open system to a closed one.** As we discussed under open and closed systems, a system boundary may be thought of as a point at which data flows from one system to another (as input or output). The degree to which the data is free to flow from one system to another is known as the permeability of the boundary. A permeable boundary allows data to flow freely, resulting in an open system. An impermeable boundary is the one that strictly controls (or even restricts) the acceptance or dispensing of data, resulting in a closed system. In this sense, this heuristic is a special form of the heuristic we have proposed where opening or closing of certain boundary is the significant change.

4. **Heuristic: Don't accept predefined boundaries as absolute.** This heuristic is suggesting that predefined boundaries may either constrain an architect or lead him or her to a solution concept that may not be the best for stakeholders. In this sense, this heuristic is similar in sentiment to the principle described above and is a special form of the heuristic we have proposed.

One important aspect of these principle and heuristics discussed above is that they are mostly focused towards the beginning phases of architecting. The proposed heuristic here is suggesting that the change in the boundary condition will impact the state of a system throughout the process of architecting. Hence, an architect needs to be aware of any changes occurring in the boundary conditions all the time.

As a corollary, this heuristic is also suggesting that an architect can use the boundary condition as a tool to impact the state of a system. As an example, in the case of an automobile, an architect may suggest using electricity as a fuel type instead of gasoline, changing the concept from gasoline based car to an electric car. From modern experience of electric cars, we know that these two are very different system, even though the purpose of both is same.

This discussion provides a theoretical basis of the heuristic we have proposed. Next, we discuss H2 on initial conditions.

**H2: Significant initial conditions will change the state of a system**

We find wide level of support of dependency of the state of a system on initial conditions in CAS literature. As we discussed in CAS above, CAS are sensitive to initial conditions.
and very small changes in initial conditions may result in a big change in the outcome. In the CAS literature, attractor is a region in the state space of all possible patterns to which the system flows and remains. The set of initial conditions that leads a system arbitrarily close to a certain attractor are called basin of attractors.

As per Kellert (1992), “A dynamical system that exhibits sensitive dependence on initial conditions will produce markedly different solutions for two specifications of initial states that are initially very close together. In fact, given any specification of initial conditions, there is another set of initial conditions close to it that will diverge from it by some required distance, given enough time.”

Impact of initial conditions on a state of system is also supported by what in systems literature is called path dependency. As per Yin & Herfel (2011), a wide range of complex systems exhibits path dependency. A given set of initial events sets the current system at hand on certain path. Note that for the purpose of this discussion, we use initial conditions as synonymous with “initial events”. Different authors have used these terms to mean the same thing.

These concepts can explain how significant initial conditions can influence the state of a system during architecture. For example, from a system architecture point of view, we can model various available concepts to meet stakeholder needs as different basin of attractors. Certain set of initial conditions can bring the process of architecting closer to one basin of concept than another and thus influence the architect’s preference of one concept over another.

As a corollary, an understanding of initial conditions can help an architect evaluate the impact of an initial condition or a set of initial conditions on the process of architecting and thus in turn help him or her to influence these initial conditions in order to help influence the process of architecting. However, not all of these initial conditions may be in control of the architect. This brings us to the question of what consists of these initial conditions. We will answer this question towards the end of this discussion. For now, we continue to look for evidence of this proposed heuristic from existing system architecture literature. Lim (1998) for example describes the following principle and heuristic for architecting complex systems that speak in support of this heuristic:

1. **Principle**: Mental models and expectations begin forming at the earliest stages of a system development process (including at the first meeting) and quickly gain inertia, so carefully select who participates in the architecting process. Lim further describes that individual tend to be attracted towards what is familiar to gain a sense of control. But this attraction may obscure other alternative concepts, which may be more advantageous.

2. **Heuristic**: All the really important mistakes are made on the first day. Although
mistakes happen every day, what this heuristic is suggesting is that the mistakes made on the first day will have a more long-term impact on the state of system being architected.

Both who participates and mistakes made on the first day can be considered part of initial conditions. The heuristic we propose provides a more general perspective on the impact of initial conditions. This discussion indicates that the existing systems architecture literature also has support of the heuristic we have proposed. Next we attempt to answer the question for what may consist of initial conditions.

For this, we build upon definition of Kotler & Armstrong (2012) of internal-, micro- or macro- global marketing environments to provide a detailed idea of initial conditions. As per Kotler & Armstrong, “The microenvironment consists of the actors close to the company that affect its ability to serve its customers—the company, suppliers, marketing intermediaries, customer markets, competitors, and publics. The macroenvironment consists of the larger societal forces that affect the microenvironment—demographic, economic, natural, technological, political, and cultural forces.” The internal-environment is defined as forces and actions inside the company. Diagram in figure 4 provides a list of categories of factors in each environment.

We posit that initial conditions can come from any of these environments. Of the three, however, the internal environment is the most potent because it is closer to where the action is happening. Nothing in this environment should be discounted to observe initial conditions. How the building looks, how offices are arranged, what pictures are hanging on the walls, how people dress, what they bring to the meetings, how chairs are arranged, who sits next to who, who speaks first etc. are all important.

To answer the question raised above on what conditions an architect may be able to influence, it should now be understood that the architect may have more control on internal- and micro- environment based conditions, and limited control on macro-environment based conditions.

This completes our discussion of initial conditions and their sources. The concept of initial conditions will become further clearer as we discuss subsequent sections. For now, we proceed to discuss next heuristic on pivotal conditions.

H3: SIGNIFICANT PIVOTAL CONDITIONS WILL CHANGE THE STATE OF A SYSTEM
This is in continuation of the previous heuristic of initial conditions. We further use the concept of attractors and basic on attractors as defined previously to define pivotal conditions. As per CAS literature, attractor is a region in the state space of all possible patterns to which the system flows and remains. A condition or set of conditions that provide transition from one attractor to another is what we call pivotal conditions.
To understand pivotal conditions from Kellert’s perspective, we quote Kellert (1992) again, “Given any specification of initial conditions, there is another set of initial conditions close to it that will diverge from it by some required distance, given enough time.” And hence, pivotal conditions are the conditions that provide transition between one set of conditions to another set so that the system can diverge by some required distance.

While initial conditions bias a system towards one attractor, pivotal conditions provide a transition function from one attractor to another. That is the main difference between initial and pivotal conditions.

We believe the concept of pivotal conditions becomes significant as an architect can use it as a framework to help transition from one state of a system to another or from one situation to another.

As discussed above about the sources of initial conditions, significant pivotal conditions can come from any environment: change in customer requirements, change in political or
legal environment, change in social environment etc. As an example, let us consider the
evolution of automobiles. In a larger scheme of things, a pivotal condition of the
development of the steam engine moved the vehicle trajectory from horse driven carts to
automobiles.

Pivotal conditions can also be inserted deliberately to move the system from one state to
another. For example, an architect may bring a new technological development in a
different domain to influence the state of the system currently under design. In fact, this
is more of a norm for complex systems, which are primarily based out of multi-
disciplines. Thus, the concept of pivotal conditions provides an architect with a tool to
help move a system in a desired direction. In this sense, this heuristic is a leadership tool
an architect carries in his back pocket.

The concept of pivotal conditions will become clearer when we apply this heuristic on an
example application. For now, we proceed to describe our next heuristic H4.

H4: NATURE OF SUBSYSTEMS ARE DETERMINED BY THE SYSTEM AND ITS ENVIRONMENT

Subsystems, systems and environment are discussed under the literature review section.
Through this heuristic, we are suggesting that the roles subsystems or parts play in a
system are determined more by the system and its environment than by the subsystems or
parts themselves.

The emergence literature provides support for this heuristic. Georgiou (2003) definition
of emergent property “if such an emergent property did not exist, there would be no
foundation upon which to posit that certain parts and certain interrelationships constitute
certain system” indicates that roles in a system exist to serve the purpose of the system.

The intent behind this heuristic also appears in the definition of interface in Rechtin
(1991). As per Rechtin, the only thing that is added to parts to make the whole greater
than its parts is the interrelationship among them. These inter-relationships are called
interfaces. Subsystems or parts sit among various interfaces with other subsystems or
parts to serve the purpose or emergent behavior of the system. Since the interfaces are
systemic properties of a system (developed through synthesis process for example; also
addressed under the discussion of next heuristic), the roles subsystems play in the system
are also a systemic property.

For the synthetic process of system architecture, refer to the figure 5 from Crawley et al.
(2016). Here beneficiary and need determine the goal, concept and subsequently
architecture, which in turn determine the roles and interfaces of subsystems. Thus roles
and interfaces are system level properties of a system and tools such as Design Structure
Matrix (DSM) are common ways to determine them.
- In synthetic direction, proceed from needs to goals, concept and architecture, plus sense of operator, operating and cost issues.

Figure 5. Synthesis Process from Needs to Architecture (Crawley et al. 2016)

Figure 6. V-Model of Conceive, Design, Implement and Operate (Crawley et al. 2016)
This heuristic is also restating what is already understood in the synthesis process of system architecture and popular V-model of system engineering. A four phased V-model of Conceive, Design, Implement, Operate as used by Crawley et al. (2016) shown in figure 6 suggests that the value identification leads to design and eventually to the role of objects in achieving that value. Thus, both synthesis process and V-model are in line with this heuristic.

This provides the theoretical basis of heuristic 4. Next we proceed to discuss the last heuristic in our set, H5.

**H5: ANY NOVEL QUALITY EMANATING FROM SYSTEMIC INTERACTION IS OF EMERGENT NATURE**

We defined emergence under the literature review section. Although literature provides varying views of emergence, popular belief is that only the properties for which the system was originally designed are of emergent nature. In the above example of the automobile, one may only consider movement from point A to point B as emergent and ignore the following as emergent:

- Nature of interfaces and subsystems
- Form and amount of modularization
- Life time cost of operations
- Maintenance
- Safety
- Quality
- Support systems
- Sustainability
- Knowledge about and future development of subsystems
- Knowledge about and future developments of automobile as a system
- Knowledge about and future development in the environment (roads for example)

This heuristic attempts to dispel this popular belief and suggest that any novel property emanating out of systemic interaction is of emergent nature. One can find enough support for this heuristic in the system literature of emergent properties.

As per Christopher (2006), emergent properties represent a significant challenge for the engineering of complex systems and “can be thought of as unexpected behaviors that stem from interaction between the components of an application and their environment.” Addition of the word “unexpected” helps mark a number of items mentioned in the list above as emergent. Examples include maintenance, safety and quality.

Georgiou (2003) provides another excellent coverage of emergent properties. This work
explains the emergent property in the following ways:

- Emergent properties as unforeseen consequence: it may be difficult to predict all consequences of complex interrelated parts and their dynamics. These unforeseen consequences can be termed as emergent properties. As an example cited in this paper, consider use of compulsory seatbelts while driving an automobile. The intended logic of this law is to reduce accident injuries (and fatalities), but an unforeseen consequence is drivers taking more risk, causing more accidents and hence higher number of injuries. This higher number of injuries is an emergent property.

- Emergent property as reference point: As an example, the paper cites clock: “The emergent properties of the clock (indicating the time) can be used as a point of reference to simply consider the relational changes of its parts. Without this a clock may be seen as computationally complex.” Thus the emergent property provides an identity for a system, a reference point for a group of interrelated parts.

- Emergent property as foundational epistemological concept: This idea positions emergent property a notch higher than emergent property as a reference point and suggests such properties being the epistemological foundation of systems, meaning what emerges is not the emergent properties, but the knowledge of parts from the given system; emergent properties themselves are conceived instantly.

However, Georgiou also produces a dilemma: which of the above three categories are to be considered true emergent properties? As discussed in Fromm (2005), works of Chalmers and Bedau distinguish weak, nominal and strong emergence to resolve this dilemma. As per them, weak emergence is unexpected given the properties and principles of parts; nominal emergence is a macro level property closer to the conventional definition of emergence; and strong emergence is not deducible from the laws of lower level parts.

We believe the work of Fromm (2005) provides relatively comprehensive categories of emergence in four parts:

- Type I: Simple or nominal emergence without top-down feedback. This category includes two sub-categories: simple intentional emergence and simple unintentional emergence.
- Type II: Weak emergence including top-down feedback. This can also be of two types: stable and instable.
- Type III: Multiple emergence with many feedbacks. There are two sub-types: stripes, spots and bubbling; and tunneling and adaptive emergence.
- Type IV: Strong emergence.
The following table taken from Fromm's work provides different perspectives on the above four types of emergence. Please refer to Fromm's work for further details on these categories.

We believe Fromm's work is comprehensive enough to help decide whether the property observed is an emergent property or not. The proposed heuristics thus provides a simplified version of this work that can help an architect to view various levels of emergence in the process of architecting and not to get tied to a pre-conceived notion of just one type of emergence.

**Table 1. Types of Emergence (Fromm)**

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Roles</th>
<th>Frequency</th>
<th>Predictability</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Nominal or Intentional</td>
<td>Fixed</td>
<td>Abundant</td>
<td>Predictable</td>
<td>Closed, with passive entities</td>
</tr>
<tr>
<td>II</td>
<td>Weak</td>
<td>Flexible</td>
<td>Frequent</td>
<td>Predictable in principle</td>
<td>Open, with active entities</td>
</tr>
<tr>
<td>III</td>
<td>Multiple</td>
<td>Fluctuating</td>
<td>Common-unusual</td>
<td>Not predictable (or chaotic)</td>
<td>Open, with multiple levels</td>
</tr>
<tr>
<td>IV</td>
<td>Strong</td>
<td>New world of roles</td>
<td>Rare</td>
<td>Not predictable in principle</td>
<td>New or many systems</td>
</tr>
</tbody>
</table>

To close this discussion, we provide an example of a known heuristic in the literature and use the knowledge in this section to analyze what may be termed as emergent.

*Heuristic: Be prepared for reality to add a few interfaces of its own.*

Firstly, to complete the picture, we would extend this heuristic to include parts as well.

*Modified Heuristic: Be prepared for reality to add a few interfaces and parts of its own.*

Next, using knowledge in this section, this is clear that the reality has an influence on the final set of interfaces and parts that emerge out of the process of architecting. In principle, this set could have been predicted in the beginning and hence, the set of interfaces and parts can be considered Type II emergence. That said, as per this heuristic, reality brings its own unpredictability and hence the final set of interfaces and parts will be of Type III emergence.

In the next section, we discuss these heuristics from the point of view of small groups.
CHAPTER 4: FIVE HEURISTICS AND SMALL GROUPS

We discussed under the literature review, various authors have used systems theory to study small groups. In this section, we reformulate five heuristics proposed in the previous section for their application on small groups and provide further literature support that these heuristics can be applied to analyze small groups. We reformulated these heuristics for small group using the following guidelines:

1. We consider small groups as complex systems
2. We consider various roles in a group equivalent to subsystem in a system
3. Wherever applicable, we add events or activities in the discussion of initial or pivotal conditions to include actions performed by various roles.

The following is the reformulated version of these heuristics:

1. H1: Change in a significant boundary condition will change the state of a group
2. H2: Significant initial conditions will change the state of a group
3. H3: Significant pivotal conditions will change the state of a group
4. H4: Nature of roles is determined by the group and its environment
5. H5: Any novel quality emanating from group interaction is of emergent nature

Next we go in details of each of these heuristics and provider literature support from existing works.

H1: CHANGE IN A SIGNIFICANT BOUNDARY CONDITION WILL CHANGE THE STATE OF A GROUP

In the previous section, we discussed that all systems have boundaries. Considering human groups as complex systems, not all of these boundaries are easy to notice in human groups. Some of the team boundaries such as membership, physical space, time and budget may be apparent; many boundaries are qualitative in nature. For example boundaries that Hirschhorn & Gilmore (1992) call “authority” boundary, the “task” boundary, the “political” boundary, and the “identity” boundary are all qualitative.

Smith & Berg (1987) suggest, “Without boundary, there can be no relationship. For example, only as the infant builds a sense of a self that is distinct from mother can it develop a relationship with mother. Without boundaries, there is fusion.” Smith & Berg (1987) further mention, “Boundaries are at the base of everything in group life. For the group to have a sense of itself as an entity capable of acting as a whole, it must have clear external boundaries.”

McCollom (1990) describes that “human systems like other living systems (think of the cell), maintain vitality by importing material across a boundary, transforming that material into life-sustaining products, and exporting some of the products of this
transaction back across the boundary to the environment." The ways through which these transactions take place across boundaries are called interfaces. We discuss interfaces in more details in previous sections. However, from the point of view of boundary, interfaces are the ones that provide permeability between human groups and their environment.

If the permeability is kept lower than what is needed, the system becomes what Alderfer (1980) calls overbounded system. If the permeability is more than what it should be, the system becomes underbounded. Both underbounded and overbounded systems are less than ideal for group work to occur. But Alderfer (1980) proposes eleven criteria to detect whether the system is overbounded or underbounded. The following describes these criteria in brief. We recommend our readers to refer to Alderfer's work for a detailed discussion.

Brief description of each of Alderfer's eleven criteria is as follows:

1. Goals: Goals are evaluated on the clarity and consensus among the stakeholders. Underbounded systems lack clarity as well as consensus on the goal systems and a sense of "meaninglessness" is prevalent. Overbounded systems have clearly defined goals.

2. Authority relations: Authority is evaluated on central vs. diffused, monolithic vs. multiple. Overbounded systems are typically centralized and monolithic while the underbounded systems are fragmented and unclear. In underbounded systems, responsibility of work may rest with several entities or no one.

3. Economic conditions: Economic conditions have an effect on psychological boundaries. An overbounded system might organize itself closely in order to use resources efficiently and take advantage of opportunities; an underbounded system may waste resources and create financial problems.

4. Role definitions: Overbounded systems have clearer and more consistent role definitions. Underbounded are unclear and conflicting.

5. Communication patterns: In underbounded system, it is not clear who should talk to whom and who should gather what people to communicate the issues of concern. In overbounded systems, it is possible to get the right set of people together, but the rigid role definition and clear hierarchy introduces information distortions that benefits certain roles. Lower ranks withhold information from senior officials as much as possible.

6. Human energy: One purpose of boundary is to confine or channel energy in order to get something productive done. In underbounded systems, the energy is more diffused and difficult to channel.

7. Affect distribution: Underbounded systems are chaotic and disorganized. People lack confidence in them or in the system. Typically, a positive feeling is amiss.
Overbounded systems have a positive affective balance partially due to the existence of repressive forces.

8. Intergroup dynamics: There are primarily two classes of groups: task groups and identity groups. Task groups are defined by the kind of work people perform (R&D, manufacturing, marketing etc.). Identity groups are defined by group affiliations that individuals have to shape their personal identities, groups based on gender, demographics, race, color, ethnicity etc. Overbounded systems tend to have conflicts among their task groups, while underbounded have conflicts in their identity groups.

9. Unconscious basic assumptions: Underbounded systems tend to carry an assumption of flight-fight. Overbounded systems tend to believe in an all powerful leader in order to gratify their needs.

10. Time-span: Overbounded systems tend to have a longer-term time perspective. Underbounded on the other hand have a shorter term.

11. Cognitive work: Underbounded systems have no theory or have multiple theories. Overbounded systems on the other hand have a coherent body of theory.

Alderfer also claims that it is difficult to detect boundaries precisely in human systems. Therefore detecting an optimal point of boundedness may not be feasible. Still, one can work with these eleven criteria to change a boundary condition and help move the group from over-bounded towards under-bounded or vice versa, and thus this heuristic comes into play. We will see an application of some of these criteria in the next section.

Next, we discuss H2 from the perspective of small groups.

H2: SIGNIFICANT INITIAL CONDITIONS WILL CHANGE THE STATE OF A GROUP

There are moments in the group life when the level of instability is very high. Some of these moments are as follows:

- In the beginning when the group has no state and the initial conditions can predispose the group to develop in qualitatively different ways (Arrow et al., 2000, pp 79).
- The group is under distress (due to high level of conflict for example) and is seeking ways to let the steam off.
- The group is bored due to lack of activity or good ideas.

In such cases, small differences in conditions can sway the group in a very different direction: not only on a different path, but also with very different outcomes. Following our discussion in the previous section, we would call the conditions for the first case as initial conditions and the conditions for the latter two cases as pivotal conditions. However, please note that when it comes to human groups, both initial and pivotal
conditions will need to be expanded to include any human activity or actions and any event from within the system or the environment. We again use conditions and events interchangeably for the purpose of this section. We will discuss pivotal conditions in the next section.

Consider the following example from the author's own experience in a class of 120 students on experiential leadership:

A Jewish Student: Something a German classmate said in the last class has been sitting with me for a while. She said, "I don't think in our country there is a racial issue. It is more of an American issue." To me there have been many racial issues, very harsh ones that lead to holocaust and to violence against gypsies and homosexuals.

The German student takes up the stage next and tries to justify her statement. For the rest of the session, the class only discusses the racial issues primarily focused on Jewish and Germans. The opening statement by the Jewish student is an example of initial event.

Arrow et al. (2000) further elaborate on initial conditions. "The sensitive dependence on initial events should be especially marked when new members have no previous experience with one another, when the purpose of the group is vague or the project is ill defined, and when members feel anxious and uncertain." These are the conditions, when as per Heifetz et al. (2009) the group is in need of direction, protection and order and any event that can help to provide direction, protection and order can significantly affect the group direction.

Gersick (1988) also notes the impact of initial conditions (although she does not call them by this name) when she analyzes the following excerpts. In her study, a team of three graduate management students starts their first meeting with the following discussion.

Excerpt 1:

Jack: We should try to read the [assigned] material.
Rajeev: But this isn't an organizational design problem, it's a strategic planning problem.

[Jack and Bert agree]
Rajeev: I think what we have to do is prepare a way of growth (for the client).

[Nods, "yes" from Jack and Bert]

It took less than one minute for the team to decide that they were not going to read the
material and work as per the professor's definition of task. This is how they continued until the 5th meeting out of a total 11.

Ginnett (1993) also notes how the initial few minutes form the perception of the impact of the leader in the following discussion between RCG (initials of Ginnett) and pilot:

RCG: How can you tell which kind of guy you’re working with?
Pilot: Oh, you can tell.
RCG: How?
Pilot: I don’t know how you tell but it doesn’t take long. Just a couple of minutes and you’ll know.

These works suggest how initial conditions or events play an important role in impacting the state of a group. Note that initial conditions in a group life do not have to be related to only conversations; they can also be related to the environment, how chairs are arranged, the order in which members sit, the items members bring with themselves (food, music player etc.), the way members dress etc. For what may consist of these conditions, please refer to the same heuristic under the previous section.

Next we discuss heuristic related to pivotal conditions.

**H3: Significant Pivotal Conditions Will Change the State of a Group**
The previous section provides an introduction of pivotal conditions in the context of small groups. The main difference between initial conditions and pivotal conditions is that pivotal conditions impact the state of a group anytime during the lifetime of the group work, while initial conditions only apply in the beginning of group meetings. While initial conditions put a group on a certain path to start with, pivotal conditions provide transition from one path to another. In this sense, initial conditions are a type of pivotal conditions where the pivotal conditions occur in the beginning of group life.

To describe pivotal conditions, let us consider another example from the same class of 120 students, where the following situation occurs in the middle of the discussion:

One Student: We have been talking about X, but I think Y is equally important.

The class then switches to discussing Y and continues to do so for the next 15 minutes. This intervention by the student is an example of pivotal condition or event.

Gersick (1988) work further provides an example of a pivotal event or condition. Consider the second excerpt from the 6th meeting for example:
Excerpt 2:

Rajeev: I think, what he said today in class - I have, already, lots of criticism on our outline. What we've done now is OK, but we need a lot more emphasis on organization design than what we - I've been doing up to now.

Jack: I think you're right. We've already been talking about [X]. We should be talking more about [Y].*

Rajeev: We've done it, and it's super but we need to do other things, too.

[Bert agrees.]

Jack: After hearing today's discussion, we need to say [X] more directly and we want to say more explicitly that ...

Rajeev: ... should we be ... organized and look at the outline? ... We should know where we're going.

[The group goes quickly through the outline members had prepared for the meeting, noting changes and additions they want to make.]

Rajeev: The problem is, we're very short on time.**

There are two pivotal events in this conversation. One is to include content [Y] marked as * above and another on shortage of time marked with **. Both of these events propelled the team to work harder and finish the project on time.

Note that similar to initial conditions, pivotal conditions in a group life do not have to be related to only conversations; they can also be related to the environment, how chairs are arranged, the order in which members sit, the items members bring with themselves (food, music player etc.), the way members dress etc.

In summary, application of this heuristic provides a participant with capacity to observe the group processes and intervene accordingly to help transition group from one state to another.

**H4: Nature of Roles is Determined by the Group and Its Environment**

It was relatively easy to see how this heuristic applied on engineered systems. When it comes to human groups however, it may not be easy to accept how the group members may be playing puppets to the whole group as a system. Hackman (1992) in his group influence chapter details five mechanisms through which groups achieve exactly this (in Hackman's words):

1. Groups provide the immediate context for individual thought and action: The
attributes of the people in a group, the characteristics of its task and the properties of the place where the group works collectively provide a stimulus rich context for individual behavior.

2. Group enhance or depress member arousal: The mere presence of other members in the group setting, as ambient stimuli, can affect an individual’s arousal and thereby alter his or her behavior and work effectiveness.

3. Groups directly and contingently reinforce specific individual behaviors: the selective application of discretionary stimuli by a group shapes member behavior in real time.

4. Groups affect behavior indirectly by shaping member’s belief and attitude: Because people generally try to behave in ways that are consistent with their beliefs and attitudes, group-induced changes in member’s private thoughts and feelings have direct effect on behavior.

5. Groups create and maintain normative structures that efficiently and powerfully shape and constrain behavior.

Hackman’s work is strong evidence in support of the heuristic proposed here.

Fisher & Ellis (1990) have studied human groups and provide a role definition that is inline with this heuristic as well:

A role is a set of communicative behaviors performed by an individual and involves the behaviors performed by one member in light of the expectations that other members hold toward those behaviors... Thus each member (together with the other group members) works out his or her role through performing communicative behaviors.

Here the key phrase is “in light of the expectations that other members hold toward those behaviors”, which indicates that each communicative behavior is performed under the influence of the rest of the system.

Next, Wells (1990) goes into the psychological dimension of groups through his analysis using “group-as-mother” in answering the following three questions:

1. Of what substance is the group’s élan vital made?
2. Using the group as the unit of analysis, why are co-actors considered interdependent? And, why are all of their behaviors conceptualized as mere manifestations and representations of the group’s existential core?
3. Do individuals have ultimate control over determining what they say, think, and do in groups?

Wells (1990) suggests, “The roles are interdependent and distribute the group’s élan vital.
The distribution produces a variety of actors with different scripts. These actors play their 'parts' in service of the group's plot.

These evidences provide the theoretical basis of our heuristic for human groups. Next we discuss H5 on emergence.

**H5: ANY NOVEL QUALITY EMANATING FROM GROUP INTERACTION IS OF EMERGENT NATURE**

Similar to engineered systems, small groups as systems have many properties that emerge out of interaction among members and that do not exist in any one or a group of members. Since generally the groups are brought together for some purpose, it is easy to see that the purpose being the emergent property as a reference point or foundational epistemological concept (Georgiou (2003)), but how about the following:

- Understanding of self from the group interaction
- Individual learning from this group interaction
- Understanding of group behavior from the group interaction
- Individual behavior in the group
- Group roles played by individuals
- Group leadership
- Group cognition, trust, cohesion and conflict
- Group identity
- Etc.

We suggest all the attributes mentioned above are emergent properties of groups. As described previously, they may be of different type (II, III or IV), but they emerge out of group interaction nevertheless. There is a considerable coverage of emergent properties of group work in literature.

"Mead's rigorous speculation on how the self emerges out of social interactions has also been of great importance ..." (Mead, 2007) suggest how even self emerges out of group interactions. Hackman's work of five mechanism of group influence as mentioned previously depicts how groups shape individual thoughts and actions, arousal, and behavior in general. Also as per Fisher & Ellis (1990) again, "A role is a set of communicative behaviors performed by an individual and involves the behaviors performed by one member in light of the expectations that other members hold toward those behaviors." Ginnett (1993) also suggests that in a group life over time, various roles emerge. Ginnett identifies these roles as task roles (contributor, seeker, giver, evaluator, summarizer), maintenance roles (harmonizer, gatekeeper, encourager, compromiser) and blocking roles (dominator, blocker, aggressor, disruptor). These works suggest that roles and individual behaviors in a group's life are all group constructs and hence emergent properties.

Swart & Powell (2012) model knowledge as a network and show how knowledge propagates and gets created in an organization structure of a society or a firm. They claim that knowledge itself is an emergent property of those groups.
Lichtenstein et al. (2006) claim that the leadership itself is an emergent behavior from the interaction of “spaces between people and ideas” meaning “leadership is a dynamic that transcends the capabilities of individuals alone; it is the product of interaction, tension, and exchange rules governing changes in perceptions and understanding.”

Curseu (2006) argues that team cognition, trust, cohesion and conflict are interdependent states that emerge from interactions among virtual team (VT) members, and are essential drivers for VT effectiveness.

Without belaboring the point further, based on the evidence cited above, we state that just like engineering systems, human groups also have many emergent properties including various roles, the group outcome and the leadership itself and the heuristic proposed here aptly captures this idea.

This concludes our discussion of five heuristics in the context of human groups. Next we discuss an application of these heuristics to a jury group in a movie called “Twelve Angry Men”.
CHAPTER 5: EXAMPLE APPLICATION OF FIVE HEURISTICS

In this section we apply five heuristics proposed in the previous section to a group work in a 1953 Henry Fonda movie called “Twelve Angry Man”. The purpose of this application is to show how these heuristics can be practically applied to group work. A twelve people group in the movie is an ideal setting for this application. Although we do acknowledge that a movie is an artificial setting and may be different from an actual life group. This section nevertheless reveals some important insights for the application.

Furthermore, use of movies in academic work is not new. There is substantial amount of work analyzing Twelve Angry Men itself. Garfinkle (2011) explores psychological barriers to truth in the movie Twelve Angry Men itself. Weisselberg (2007) describes how the same movie should not be taken as our ideal for an American jury. Evirgen (2009) describes how the movie can be used in teaching organizational behavior classes. The author of this thesis himself had an opportunity to study the movie in a leadership class in Harvard Kennedy School and has a first hand knowledge of the movie being used as a teaching tool in Anderson School of Management at UCLA.

Using movies as example has its merits since these movies are available to any reader and it becomes easier for the reader to follow our work. We leave application of these heuristics on actual teams for future research.

Next we apply five heuristics proposed in the previous section to the jury group in the movie.

H1: CHANGE IN A SIGNIFICANT BOUNDARY CONDITION WILL CHANGE THE STATE OF A GROUP

For this application, we will first use Alderfer’s eleven criteria to see whether the jury group in the movie is overbounded or underbounded. Once we determine the boundedness, we will follow the developments in the movie to see how the boundedness changes over the length of the movie.

The following is an application of Alderfer’s eleven criteria on the jury group:

1. Goals: While the goals or purpose of the jury is clear from the justice system point of view, the members of jury themselves do not seem to have a clear understanding of critical terms such as “reasonable doubt”.

2. Authority relations: Justice system has clear authoritative relationships (the judge rules, for example). The jury itself is a self-managed team with no hierarchical lines.

3. Economic conditions: This criterion is not really applicable to a government organization and the jury.

4. Role definitions: While the justice system has clearly defined roles, there is no
role segregation in the jury. All jurors have the same weight on their votes.

5. Communication patterns: Jurors have no guidelines or rules for communication patterns; they are a self-managed group of individuals. The justice system on the other hand has clearly defined patterns: judges, lawyers, police, jurors etc.

6. Human energy: Judges, lawyers and police have more focused human energy in the justice system. Most of the members of jury on the other hand want to get out of the room quickly without focusing energy on the judgment.

7. Affect distribution: Jury group in the movie is in a chaotic and disorganized state in the beginning. There is hardly any attachment among the members. In fact, jurors are ready to fight with one another.

8. Intergroup dynamics: Different stakeholders in the justice system have clearly marked identities – judges vs. lawyers vs. police etc. There are no predefined group demarcations among jurors.

9. Unconscious basic assumptions: Jurors just want to get done with the decision and go home. In this sense, flight or fight is prevalent in the jury group. The justice system on the other hand is well organized with powerful heads (police, judges etc.) to govern the system.

10. Time-span: This jury has been assembled for this particular case only – jury is really short-term focused; the justice system has a long-term horizon.

11. Cognitive work: Justice system has constitution to govern any action. The jury in the movie on the other hand does not seem to have any guidelines for the action. Even clarity on terms such as “reasonable doubt” is missing.

It is apparent that most of the above criteria do not have clearly defined values for the jury; hence we believe jury in the movie is an underbounded system in an overbounded justice/social system. Please note that we mention justice/social system only tangentially for the sake of completeness, but any further analysis of justice system is not the intent of this work.

Next we follow the movie and evaluate how the boundedness develops over the length of the movie. To keep this discussion contained, we discuss only the following three parameters out of eleven criteria: goal boundary, authority and task boundaries.

**Goal Boundary**

At a higher level, it can be said that the primary goal of the jury is to make a decision whether the boy is guilty or not. However, when we start looking at details for what is needed to make such a decision, we find initial understanding of this goal by group members is superficial at best. For example, not all jurors are clear on what “guilty beyond doubt” may indicate. However, the goals do become clearer as the conversation among jurors proceeds. Consider the following excerpts from the movie in a
chronological order.

Excerpt 1:

Juror 7: Yeah, let us vote. Who knows, maybe we can all go home.

Foreman: Just let us remember. We have got a first-degree murder charge here. If we vote ‘guilty’ we send the accused to the electric chair. That is mandatory.

Excerpt 2:

Foreman: One. Right. Okay, eleven to one — “guilty”. Now we know where we are.

Juror 10: Boy-oh-boy! There is always one.

Juror 7: So what do we do now?

Juror 8: Well, I guess we talk.

Excerpt 3:

Juror 7: Look, supposing you answer me this. If the kid didn’t kill him, who did?

Juror 8: As far as I know, we’re supposed to decide whether or not the boy on trial is guilty. We’re not concerned with anyone else’s motives here.

Juror 9: Guilty beyond a reasonable doubt. This is an important thing to remember.

In the first conversation, juror #7 appears to think the voting is the way to decide; and he simply wants to get done and go home. He is seemingly less concerned that voting guilty can put someone to death. Foreman clarifies what voting ‘guilty’ may mean.

In the second conversation, juror #10 is blaming juror #8 for voting against. Juror #8 proposes that the group talk further about the decision. Juror #8 takes heat for this action since most of the jurors want to get done and go home. However, action of juror #8 also creates space for the group to discuss the case further.

In the third conversation, juror #7 seems confused about the purpose of the jury between finding the actual killer and making a decision on the current one. Juror #8 clarifies the purpose. Juror #9 emphasizes the term ‘guilty beyond reasonable doubt’.

Based on these excerpts we conclude that as the movie proceeds, the goals of the work of the jury become clearer and the process of dialogue starts to form. This indicates that
from a goals perspective, the group becomes more bounded than before. We next analyze how authority and task boundaries evolve.

Authority and Task Boundaries

In the beginning of the movie, jurors enter the room in a chaotic state; authority hierarchy is absent. There are no predefined roles. Most of the members want to get done and go home. The initial vote of 11 to 1 shows that except juror #8, nobody is interested in even discussing the case. As the movie progresses however, various authority boundaries start to take shape. For the purpose of this thesis, we provide an analysis of the development of the following authority and task boundaries:

- Foreman taking the role of facilitator
- Henry Fonda (juror #8) developing into informal authority
- Juror #6 helping to create safer environment for weaker members to participate

Foreman’s role as facilitator starts developing from the beginning when he starts tearing slips for ballot. By the middle of the movie, Foreman is confirmed facilitator for the group. The following conversations shed light on how this role develops.

Excerpt 1:

[Foreman starts tearing slips. Juror 10 pauses beside Foreman and points to the slips of paper]
Juror 10: Hey, what's that for?
Foreman: Well, I figured we might want to vote by ballots.
Juror 10: Great idea! Maybe we can get him elected senator.

Excerpt 2:

Juror 7 [to Foreman]: Hey, how about getting started here?
Foreman: Well, I was figuring we'd take a five-minute break. I mean, one man's in the bathroom...

Excerpt 3:

Juror 5 [hesitantly to Foreman]: Are we going to sit in order?

Excerpt 4:

Foreman: Don't tell me to calm down. Here! Here's the chair. You keep it going smooth and everything. What d'ya think,
it's a snap'? Come on, Mr. Foreman. Let's see how great you'd run the show.

Juror 10: [Sarcastically] did you ever see such a thing?
Foreman: You think it's funny or something?
Juror 12: Take it easy. The whole thing is unimportant.
Foreman: Unimportant? You want to try it?
Juror 12: No. Listen, you're doing a beautiful job. Nobody wants to change.
Juror 7: Yeah, you're doing great. Hang in there and pitch.

Excerpt 5:

Foreman: Listen, let's take seats. There's no point in milling around here.

[They begin to move back to their seats]

The first conversation shows how Foreman gets started into the role of facilitator when he starts tearing ballot slips. Even then there is resistance by juror #10, who simply laughs at him. In the second conversation, another juror looks up to him to get started. In the third conversation, juror #5 asks him a question for seating order. Foreman hesitates to answer the question. In the fourth conversation, there is further resistance by juror #10. This conversation at the same time also provides support for his role. By the fifth conversation, we see that the role of the facilitator clearly evolves and Foreman start to practice his authority as a facilitator.

Similarly, juror #8 (Henry Fonda) gains informal authority over the timespan of the movie. The following four conversations show how this development unfolds.

Excerpt 1:

Juror 10: Then what do you want?
Juror 8: Nothing. I just want to talk.
Juror 7: Well, what's there to talk about? Eleven men here agree. Nobody had to think twice about it, except you.
Juror 10: I want to ask you something. Do you believe his story?

Excerpt 2:

Juror 9: He didn't change his vote. I did. Would you like me to tell you why?
Juror 7: No I wouldn't like you to tell me why.
Juror 9: Well I'd like to make it clear anyway, if you don't mind.
Juror 10: Do you have to listen to this?
Juror 9: Thank you. This gentleman [juror 8] has been standing alone against us. He doesn't say the boy is not guilty. He just isn't sure...

Excerpt 3:

[Juror 8 sees juror 3 and 12 playing tic-tac-toe, snatches up the pad, tears off the top sheet, crumples it and drops it in the waste basket]
Juror 3: Wait a minute!
Juror 8: This isn't a game.
Juror 3 [shouting]: Who do you think you are?
Juror 12: All right, take it easy.
Foreman: Come on now, sit down.

Excerpt 4:

Juror 8 [to juror 5]: What do you think?
Juror 5: I don't know. About ten or twelve seconds, maybe.
Juror 3: What's all this for?
Juror 8: I'd say that was a fair guess. Anyone else?
Juror 11: That sounds right to me.
Juror 10: Come on, what's the guessing game for?
Juror 8 [to juror 2]: What would you say?
Juror 2: Ten seconds. Approximately.
Juror 4: All right. Say ten seconds. What are you getting at?

The first conversation shows how juror #8 takes a stand against the whole group. This is a daring move, for which he receives verbal attack when juror #10 asks him whether he really believes the story of the boy. Juror #8 somehow stands his grounds for just talking about the decision. In conversation 2, juror #9 gives juror #8's role some validity by supporting his stand. At the same time, he also bears some heat for going against the group. In the next conversation, juror #8 exercises his informal authority by stopping the
game of tic-tac-toe. Again, he takes the heat for it. In the last conversation, he starts inviting others to communicate and the group allows for it. At this point, he has established himself as an informal authority of the group.

The following two conversations show how juror #6 creates a safer environment for weaker jurors to participate.

Excerpt 1:

Juror 10: Do you have to listen to this?
Juror 9: Thank you. This gentleman [juror 8] has been standing along against us. He doesn't say the boy is not guilty. He just isn't sure...

Excerpt 2:

Juror 3: You keep coming up with these bright sayings. Why don't you send one in to a newspaper? They pay three dollars.
Juror 6: Hey! What're ya talking to him like that for?
Juror 6: A guy who talks like that old man oughta really get slapped on, y'know.
Juror 3: Get your hands off me!
Juror 6: You oughta have respect, mister. If you say stuff like that to him again -- I am gonna lay you out. [He releases 3rd juror and speaks to the 9th]. Go ahead. You can say anything you want. Why do you think the old man might lie?

In the first conversation, juror #6 creates safer space for older juror #9 to talk. In the second conversation, he even gets physical in order to create a safer space for juror #9. After this incident, more people feel safer to voice their opinion. This way, juror #6 helps create a safer environment for the whole group to participate without the fear from bullies.

From this analysis, we can see that as the movie progresses, authorities and tasks evolve and this underbounded system moves towards a better-bounded system. Thus, it is not surprising that the movie was able to culminate into a unanimous decision.

Next we apply H2 to initial conditions in the movie.
H2: Significant initial conditions will change the state of a group

In this section, we see an application of initial conditions and their impact on group functioning.

We start with the physical environment. The jury is located in a large room with a washroom on the other end. The room looks very antiquated. Three windows in sidewall open towards the New York skyline. The large table in the middle of the room appears old and scarred. It is a hot summer day and the only fan in the room is not working. These conditions appear in the following conversation:

Juror 7: You know something? I phoned up for the weather. This is the hottest day of the year. You'd think they'd at least air condition the place. I almost dropped dead in court.

These physical conditions obviously are not conducive for the jury to stay in the room for long deliberation on the case. Thus, it is not surprising that most of the jurors want to make a decision as soon as possible. This wish to finish quickly appears in the following initial conversations.

Juror 3: Yeah, let's get this over with. We've probably all got things to do.

Juror 7: This better be fast. I got tickets to a ball game tonight.

The next types of initial conditions come from the individual experience of the jurors that set the group in a direction against the person on trial. Consider the following statement from juror #10 for example.

Juror 10: I'm telling you they let the kids run wild up there. Well, maybe it serves 'em right. Know what I mean?

We believe these unfavorable initial conditions set a stage in favor of jurors making quick decision and getting out of the room. It is not surprising that as a result, 11 out of 12 voted guilty in the first pass of ballot. If it were not for Henry Fonda to come up with the courage to counter these powerful initial conditions, the boy would have been declared guilty. Also, without an understanding of initial conditions, one may be tempted to call jurors 3, 7 and 10 as immoral people who simply want to get done and go home. However, an application of initial conditions allocates a considerable responsibility on the system itself. From this perspective, we believe that this heuristic has significant
implication in understanding group processes. Next we apply heuristic of pivotal conditions on the movie.

**H3: SIGNIFICANT PIVOTAL CONDITIONS WILL CHANGE THE STATE OF A GROUP**

In this section, we see an application of pivotal conditions and their impact to group functioning.

As we discussed in the previous section, initial conditions may have contributed to jurors voting guilty 11 to 1. If it were not for Henry Fonda to find a way to counter the powerful initial conditions, the boy would have been declared guilty. In this sense, Henry Fonda's call of “not guilty” is a pivotal condition or event and this condition sets the stage for further discussion to take place among jurors.

Next, Juror #8’s taking out an identical-looking knife when no one expected is another pivotal event in the movie. It gives juror #8 grounding to request the next secret ballet and helps turn one more “guilty” vote into “not guilty”. This appears in the following excerpt.

```
Juror 4: Take a look at that knife. I've never seen one like it. Neither had the storekeeper who sold it to the boy. Aren't you asking to us accept a pretty incredible coincidence?

Juror 8: I'm not asking anyone to accept it. I'm just saying that it's possible.

Juror 3: And I'm saying it's not possible.

[Juror 8 stands for a moment in silence and then he reaches into his pocket and swiftly withdraws an identically looking knife. There is a burst of sound in the room.]
```

Following similar lines of thought, we can follow the movie and identify many more pivotal conditions or events every time a “guilty” vote turns into “not guilty”.

In a subsequent section, we present guidelines for using pivotal conditions for practicing leadership in the group. Next, we discuss an application of heuristic #4.

**H4: NATURE OF ROLES IS DETERMINED BY THE GROUP AND ITS ENVIRONMENT**

For the application of this heuristic, we elaborate on the development of the role of facilitator taken up by Foreman. We proceed with an assumption that there is a need for the role of facilitator in the group.

In the absence of this heuristic, one may argue that Foreman chose his role as facilitator. In this section, we analyze how the role of facilitator came to be. For this, we consider the
following three excerpts from the beginning of the movie:

Excerpt 1:

[Foreman starts tearing slips. Juror 10 pauses beside Foreman and points to the slips of paper]

Juror 10: Hey, what's that for?
Foreman: Well, I figured we might want to vote by ballots.
Juror 10: Great idea! Maybe we can get him elected senator.

Excerpt 2:

Juror 7 [to Foreman]: Hey, how about getting started here?
Foreman: Well, I was figuring we'd take a five-minute break. I mean, one man's in the bathroom...

Excerpt 3:

Juror 5 [hesitantly to Foreman]: Are we going to sit in order?

In the first excerpt, Foreman starts tearing up slips for voting. We believe this planted seeds for Foreman being a facilitator. However, juror #10 mocks his act by saying, “May be we can get him elected senator.” One can argue that this comment can potentially create tension for Foreman and open up space for some other contender for this role. We believe this tension shows up in the third excerpt where Foreman is not sure whether he is supposed to answer the question. However, this comment also sets the stage for the group to look towards him when it comes to organizing the group. This is apparent in excerpt 2 in juror #7’s comment to Foreman, “Hey, how about getting started here?” and juror #5 asking Foreman, “Are we going to sit in order?”

Based on these excerpts, we argue that the role of facilitator arises out of interaction with the other group members. There are sufficient circumstances that Foreman could have backed off from this role after a disparaging comment from juror #10 in the first excerpt. After this comment, somebody else might have suggested raising hands instead of taking ballot and thus creating another contender for the role of facilitator. As a matter of fact, Foreman did show his sensitive side when he received resistance from juror #10 in the following excerpts:

Excerpt 1:

Juror 10: Ah, stop being a kid, will you?
Foreman: A kid! Listen, what d'you mean by that?


Foreman: What, just because I'm trying to keep this organized? Listen. [he rises.] You want to do it? Here, you sit here. You take the responsibility. I'll just shut up, that's all.

Juror 10: Listen, what are you getting so hot about? Calm down, will ya?

Excerpt 2:

Foreman: Unimportant? You want to try it?

Juror 12: No. Listen, you're doing a beautiful job. Nobody wants to change.

Juror 7: Yeah, you're doing a great. Hand in there and pitch.

Excerpt 3:

Foreman: I don't care what you do.

In excerpt 1, juror #10 again creates tension for the role of facilitator by calling Foreman a kid. In the third excerpt, Foreman is willing to back off from this role. We believe if it were not for the support from jurors #12 and #7 as depicted in the second excerpt, Foreman would have reduced his participation as the facilitator for the group and thus creating space for someone else to take the role. But this support further reinforces his authority and establishes him as a facilitator.

Through these excerpts, we can conclude here that it wasn't up to Foreman himself to select the role of facilitator; the role was actually created through interaction with other roles in the group. The development of the role is actually a systemic property of the group.

H5: ANY NOVEL QUALITY EMANATING FROM GROUP INTERACTION IS OF EMERGENT NATURE

It is easy to suggest that the decision of “not guilty” is an emergent property of this jury group since it required a systemic interaction of the whole group. A pivotal event of different sort would have led to a ‘guilty’ decision, for example in the absence of support from juror #9 after the first ballot. However, one may not consider the following as emergent properties of the group:

- Foreman as a facilitator
- Juror #8 as an informal authority
- Participation of juror #9
Through the application of this heuristic, we would like to show that all of the above emerge out of the systemic interaction of the whole group and hence are emergent properties of the group.

Foreman as a facilitator emerges out of the group as a system. As we discussed under previous heuristic, Foreman goes through various interactions with other members before establishing his role as facilitator. There are moments when Foreman shows his sensitive side and is willing to walk out of this role, but then other members intervene and reinforce his role further. His role emerges out as the product of the group interaction and hence is an emergent property of the group.

Similarly, juror #8 as an informal authority emerges out of the group as a system. After voting ‘not guilty’ and facing strong opposition, he took a gamble to ask for another ballot. At that point, without juror #9’s support, he would have lost. Similarly, without support from other members after he provoked juror #12 by intervening in his tic-tac-toe game, it would have been difficult to contain the conflict and gain informal authority. He emerges out as an informal authority based on his interaction with other members and hence his role is an emergent property of the group as well.

Participation of juror #9 also emerged out of the group due to what other members did. His initial vote was guilty, but after juror #8 voted ‘not guilty’ and insisted on discussing the case, juror #9 changed his vote and provided the needed support to juror #8. Similarly, he could not have continued without support of juror #6 when juror #10 cut him off as we discussed previously. Clearly, the role played by juror #9 sits among relationships with other members in the group. In other words, his role emerges out of the group interaction and hence is an emergent property of the group.

This completes our discussion of five heuristics on small groups. In the next section we describe how these heuristics can help in the practice of leadership.
CHAPTER 6: FIVE HEURISTICS AND PRACTICE OF LEADERSHIP

In the five heuristics proposed above, we primarily discussed relevance of boundary conditions, initial conditions, pivotal conditions, role as a product of system, and emergence. In this section, we discuss how a practical understanding of these elements has many implications for practicing leadership in small groups. We begin this discussion with the understating of boundary conditions in heuristic 1.

It should be clear from the previous discussion that both overbounded and underbounded groups will obstruct the group work. A group member can use Alderfer’s eleven criteria to detect the group boundedness and play with different conditions to help move the group towards better boundedness. We do not claim that it will be an easy task. However, we do believe that, with practice and experience, group members can enhance their skills and become better at it. An application example as discussed previously in Twelve Angry Men is relevant here since it shows how group boundedness changes over time with interventions from various members (primarily from Henry Fonda). It is probably not a far-fetched conclusion that it was due to Henry Fonda’s skills in playing with group boundaries that the group turned towards facing its challenges and doing some work. In this sense, we conclude that an understanding of group boundaries as described in heuristic 1 is important for the practice of leadership.

Similarly, a better understanding of initial condition by group members should increase the effectiveness of work being done. We discussed in movie “Twelve Angry Men” how the weather and physical room conditions may have played a role in setting the group in a direction where all the jurors wanted to finish quickly and leave the room. Although Henry Fonda’s first intervention of voting ‘not guilty’ seemingly worked in the movie, it is not clear whether he himself understood the role of initial conditions. Because otherwise, a better approach for him would have been to make an opening statement to clarify the role of initial conditions explicitly and thus reduce their impact on the work of the jury. This approach would have further helped to contain the tension in the room. Without an understanding of initial conditions, the effectiveness of work undertaken may be left for chances where initial conditions may or may not favor the work. In this sense, a better understanding of initial conditions becomes a tool for practicing leadership in small groups.

Understanding of initial conditions also becomes important for any large organization in which small groups are embedded because the organization now can deliberately create an environment that is more conducive to the work being done. With the knowledge of initial conditions, in the example of Twelve Angry Men, the justice system could arrange for a better room next time where the jurors could work more comfortably and thus spend more time on deliberation and less on arguing.
Similar to an understanding of initial conditions, an understanding of pivotal conditions can help group members practice leadership as well during the ongoing work of the group. It is not uncommon that groups get stuck in the basin of attractors as described in CAS literature. To get the group out of this local point of stability (basin of attractors), practicing leadership may require a group member to experiment with pivotal conditions and thus help the group out of potential impasses. This is understood that the pivotal conditions may not be known in advance, but an understanding of dynamics of pivotal conditions can help a group member to make some interventions just like Henry Fonda does in the movie: he votes not guilty and makes the group get started on a path to discuss the case.

Next, heuristic #4 that roles are determined by the system sheds light on systemic aspects of membership and can thus help reduce interpersonal conflicts. It is not uncommon to hear the following types of complains:

- The member was a bad apple on the team
- One member did not do enough work
- The member was selfish
- A member had a personal agenda

From a systemic aspect, such problems have roots in the system rather than in individuals. For example, if a group has not put enough efforts in crystallizing the roles during the group life, the group may run into seemingly interpersonal issues later on. A member who takes an active role in helping group determine roles through this systemic understanding that the roots of seemingly inter-personal issues reside in the work of whole group including its environment may actually reduce such conflicts later on and thus help practice leadership.

There is another related problem when members are stuck in their roles too deeply, while changing circumstances in the environment require changing roles. Thus, practice of leadership further requires realizing that members are stuck in their roles and helping them to try out new roles in order to meet new challenges.

Finally, heuristic #5 that systems have emergent properties is an important understanding for group leadership. As we discussed above, many of the outcomes that groups are brought together for are emergent properties of group as a whole. These outcomes include but are not limited to team cognition, cohesion, trust, conflict, any concrete artifact such as a product or a report, a decision (as in case of Twelve Angry Men), role of individuals, or just leadership. This understanding can help a member or members to reduce stress trying to come up with intelligent answers and instead help lead with questions and active participation. Henry Fonda (juror #8) in Twelve Angry Men does not have any answers in the beginning; instead, he promotes a dialogue by asking group
to simply talk. The group decision in the end simply emerges out of this dialogue.

It is also worth noting that every member contributes to this outcome – even seemingly belligerent jurors #3 and #10 because without them there would be no opposition to "not guilty" and a guilty man might actually walk free. Therefore, one important corollary of this heuristic for the practice of leadership is to value each and every perspective howsoever belligerent or caustic.

To summarize, these five heuristics cover different aspects of group life and can be used together to practice leadership in the group and thus mobilize the group to deal with previously intractable issues.

Next, we conclude our research and discuss areas for future research.
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CHAPTER 7: CONCLUSION

Small groups are the most common of all organizations. In this thesis we use five heuristics from the field of systems architecture in order to study small groups. These heuristics are as follows:

1. H1: Change in a significant boundary condition will change the state of a group
2. H2: Significant initial conditions will change the state of a group
3. H3: Significant pivotal conditions will change the state of a group
4. H4: Nature of roles are determined by the group and its environment
5. H5: Any novel quality emanating from group interaction is of emergent nature

Many of these heuristics are only implied in the existing literature and not stated as we have done. This is one value this work provides.

We further studied each heuristic and provided literature from the small group perspective. In many cases we find that there is sufficient literature available to support application of each heuristic to small groups, but in some cases the literature is only scant. For example, heuristics #2 and #3 only have a limited coverage.

We further applied these heuristics to group work in a movie: Twelve Angry Men. We find that each heuristic within its scope is able to provide significant insights into the group work. For example, heuristic #3 explains how pivotal conditions play a role in determining the direction of group work; heuristic #4 describes how role formation takes place in a systemic fashion in Twelve Angry Men.

Lastly, we provided guidelines for how these heuristics can be used for the practice of leadership in small groups. We report that the set of heuristics covers different aspects of group life and can be used to analyze group work. Understanding groups in real time opens up opportunities for a member to influence it and thus practice leadership.
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CHAPTER 8: FUTURE RESEARCH

In this research, we have established five heuristics from the field of systems architecture to analyze small groups. We further applied them to a movie “Twelve Angry Men” to provide an example application of analyzing small group work portrayed in the movie. We propose the future research in the following three categories:

- Apply these heuristics to many more movies to analyze and learn,
- Establish many more heuristics to provide a more comprehensive analysis of the small group work in the same movies,
- Apply these heuristics to actual teamwork in an academic or organizational setting.

In the first category, we recommend looking into the following movies from a systems point of view (based out of experiential leadership classes at Harvard Kennedy School):

- King Rat (1965) – A movie about survival of prisoners of war (POWs) in Changi Jail. A small group led by King can be a good target of analysis using heuristics.
- Lean on Me (1989) – A movie about the leadership work of a principal in a decaying inner-city school. One can apply our proposed heuristics to the school as a system in the context of the inner city.
- The Man Who Would Be King (1975) – A movie about two white soldiers from India who set foot in Kafiristan (part of Afghanistan) and start ruling the subjects as deities coming from the lineage of Alexander the Great. The five heuristics can help analyze how their roles as deities came to be realized.
- One Woman One Vote (1995) – A documentary about women’s suffrage in the United States. It took over 70 years of struggle started by Susan B. Anthony for women to achieve right to vote. A heuristic based analysis can help shed light on how this struggle unfolded and what could have been done better in order to achieve the outcome faster.
- The Chosen (1981) – This is a story about a conservative Jewish kid who becomes a friend with a more liberal Kid from Brooklyn in 1944. There are many groups that can be analyzed as systems here including the Jewish family, the liberal family, the group of two kids etc.
- The Gate of Heavenly Peace (1995) – It is a documentary film about 1989 protests in the Tiananmen Square in China. The heuristics can be applied to analyze student leadership group and the government leadership group to understand what went wrong and what could be done better.
- Freedom Writers (2007) – A Hillary Swank movie about a “young teacher who inspires her class of at-risk students to learn tolerance, apply themselves, and pursue education beyond high school” (www.imdb.com). The five heuristics can
be applied to class as a system to draw conclusions and learn lessons that may have wider applicability.

Under the second category, we propose looking into other systems stages and determine heuristics to apply to the small group work. Some of these stages can be as follows:

- How systems come into existence to serve certain purpose
- How systems are dismantled and disposed of towards the end of life
- How systems are maintained and upgraded over the life of the systems

Under the third category, we propose applying heuristics on actual group work and contrasting the analysis with the analysis in movies. The following situations may be worth analyzing:

- Group work in academic setting, works such as class projects (refer to Rafferty (2011))
- Group work in conferences such as Tavistock Conferences (refer to work on group mirroring by Marcia (1991))
- Group work in an organizational setting such as hospitals and engineering teams (refer to Vigil (2008))

In addition to applying these heuristics to small group work, it may also be worth studying where the systems approach may not apply to small groups. With this remark, we conclude the work of this thesis.
CHAPTER 9: REFERENCES

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