Managing Disruptions in Complex Adaptive Systems A Case for Resilience in Airline Operations Control

Kenneth E. IGBO[a]
[a]*Swinburne University of Technology, Melbourne Australia*

ABSTRACT

Introduction: Studies in naturalistic decision-making and resilience engineering have made significant advances towards characterising emergent cognitive behaviours in highly dynamic and distributed work settings. This doctoral project draws on such advances to examine disruption-management processes that involve multiple players spanning multiple functions, expertises and differing levels of authority in the way each player influence the overall outcome. **Method**: This research integrates ethnographic and grounded theory methods in examining distributed decision-making, negotiations and coordination processes in airline operations control. **Results and discussion:** Preliminary findings suggest that complex networks of interdependencies—relating to resources and performance variables—across units involved in airline operations control promote reciprocity and the adoption of cooperative strategies. The findings further suggest that such emergent cognitive behaviours must be examined in context of the specific work setting studied. Such insights provide a framework for delineating how decision-makers collectively adapt formalised procedures *in-flight* while managing many-to-many mappings across conflicting goals.

KEYWORDS

Distributed decision-making; resilience; reciprocity; common ground; sense-making; airline operations control.

INTRODUCTION

Airline operations control, given its highly dynamic and distributed nature, presents a fitting 'natural laboratory' to re-examine propositions developed while studying cognitive behaviours in other complex and highly adaptive systems. Control activities in airline tactical operations are often characterised by goals that are dynamically changing or locally adapted across multiple centres of control. Regulating interactions across these centres of control presents interesting challenges because each centre possesses 'partial authority, partial autonomy and partial responsibility' (Ostrom, 1990) in relation to the extent they can adapt overall operational goals and activities. Complex interdependencies between key resources controlled by the different centres further exacerbate the challenge to adapt planned operations, particularly in the event of unforeseen perturbations (see Abdelghany, Abdelghany, & Ekollu, 2008; Clausen, Larsen, Larsen & Rezanova, 2010; Jarrah, Yu, Krishnamurthy & Rakshit, 1993; Teodorović & Guberinić, 1984; Yan & Yang, 1996).

Clearly, managing such interdependencies, often under severe economic pressures and time restrictions, necessitates that decision-making protocols reflect the intrinsic complexities of interactions across multiple centres of control. This premise is typically exemplified in most accounts of airline operational recovery in the wake of a disruptive event (Yu & Qi, 2004). The following section briefly reviews theoretical perspectives that underpin this research. Thereafter, a brief description of the methodological approach, including the unit of analysis, the research carried out so far and future fieldwork plans, is presented. Preliminary findings and expected theoretical contributions are documented afterwards. In the concluding section, this paper argues for the originality of its contributions.

THEORETICAL PERSPECTIVES THAT UNDERPIN THIS RESEARCH

This doctoral research integrates notions, metaphors and theories in resilience engineering and naturalistic decision-making research to develop a theoretical framework with which to investigate disruption management in complex adaptive systems. From a naturalistic decision-making perspective, this study examines the research on distributed decision-making to ascertain how shared understanding and common grounds are constructed *in-flight* in rapidly changing environments. Notions that emerged from this stream of research provide one part of the theoretical foundation on which this doctoral research is grounded. These include joint predictability, sense-making, team situation awareness, and other aspects of macrocognition (see Klein, Orasanu, Calderwood & Zsambok, 1993; Montgomery, Lipshitz & Brehmer, 2005, Mosier & Fischer, 2011; Rasmussen, Brehmer & Leplat, 1999; Schraagen, Militello, Ormerod & Lipshitz, 2008). On the other hand, this research also draws from

H. Chaudet, L. Pellegrin & N. Bonnardel (Eds.). *Proceedings of the 11th International Conference on Naturalistic Decision Making (NDM 2013), Marseille, France, 21-24 May 2013*. Paris, France: Arpege Science Publishing. ISBN 979-10-92329-00-1

insights developed within resilience engineering perspective that revolve around basic tradeoffs in human adaptive systems. Of particular interest is the advancement of a proposition to consolidate multiple tradeoffs observed in human adaptive systems into a few fundamental ones (e.g., Hoffman and Woods, 2011; Woods and Branlat, 2011). Along this frontier, scholars have begun to explore a set of critical properties of human adaptive systems, as well as fundamental architectural principles, in regards to managing tradeoffs across multiple centres of control (see Woods and Branlat, 2011).

Drawing on these insights, this research advances the legitimization of a unified conceptual framework of tradeoffs. It examines disruption-management processes in airline operations control through the lens of the unifying framework proposed by Hoffman and Woods (2011), and further discussed in Woods and Branlat (2011). The notion of disruption is used here to represent varying degrees of perturbations to a complex system processes and operations (see Westrum, 2006), as opposed to interruption of an individual's cognitive task processes that has become a major research focus in the fields of human-computer interaction and cognitive psychology (e.g., Latorella, 1998 ; Suchman, 1987, Wickens, 2002). The intention of study is to delineate a set of contextual variables that allow controllers to regulate interactions across multiple centres of control. In particular, this research uses its investigation of decision-making processes in airline operations control to shed light on the roles that pertinent informational and organizational dynamics play—including architectural principles, communication systems, work culture and the associated social organizational factors—in managing tradeoffs and conflicting goals across multiple centres of control. Further, it draws on interesting phenomena observed in various airline operations control centres (OCCs) to speculate on the underlying mechanisms that influence the construction of common ground, sense-making, reciprocity, and the choice of recovery strategies in most highly adaptive and distributed work settings.

METHODOLOGICAL APPROACH

This research integrates a variety of theoretical orientations and qualitative research traditions. Whilst the methodological approach adopted here draws heavily from both ethnography and the grounded theory perspectives, it also integrates insights from deductive qualitative approaches (Atkinson, Coffey, Delamont, Lofland & Lofland, 2001; Charmaz, 2006; Denzin & Lincoln, 2011; Glaser & Strauss, 1967; Strauss & Corbin, 1990). The mix in methodological and theoretical perspectives underscores the philosophy that investigations into contextual factors in complex adaptive systems stand to gain from the strengths of a range of methodological choices available, while minimising their latent limitations. The fieldwork was designed to be undertaken in four stages, each successive stage builds on the findings of the earlier stages (Charmaz, 2006; Denzin & Lincoln, 2011). Initially, the study aim was broadly defined in line with the grounded theory approach (Glaser & Strauss, 1967). This approach allowed the researcher to progressively narrow the study focus around key issues and lines of inquiry as these were identified in the field (Straus & Corbin, 1990). Participant observation, audio-recorded interviews and documentary analysis were used for data collection purposes.

Unit of analysis

The unit under analysis is the *Airline Operations Control* system spanning both international and domestic operations. This system encompasses all processes and interactions geared towards the execution of planned schedule of services, as well as all schedule recovery processes in the wake of a disruptive event. The chief actors include the operations controllers (*ops controllers*), crewing operations, flight dispatch, maintenance operations, customer services and shift managers. However, *ops controllers* and shift managers occupy the central position in this research. Hence, this research focuses mainly on their interactions with other actors within and across the system boundary during negotiations, decision-making and coordination processes. Whilst air traffic controllers (ATCs), airport authorities and station operations (ramp, gates, passenger and baggage handling, etc.) are only considered as agents within the broader air transportation environment, the negotiation processes between these agents and the OCCs are considered part of the operational system under analysis.

Participant Characteristics

Ethnographic study was undertaken in four airline OCCs (see Atkinson, Coffey, Delamont, Lofland & Lofland, 2001). Two of the airlines operate large, multi-hub networks with extensive international connections and large regional feeder services. The third airline operates medium-sized international networks with extensive domestic and regional feeder services for its affiliated airlines in other geographic locations. The fourth airline operates extensive domestic and regional networks and code-shares some regional feeder services with its parent company. All four airlines are based within Asia-Pacific and the Middle East regions.

Field research

The first-stage visits to three OCCs served as a preliminary study to allow the researcher get acquainted with disruption-management practices as they are currently adopted at the sites visited. The visits lasted approximately three hours for each site. During these visits, the researcher adopted the role of a mentee and sat with *ops controllers* to learn how they interact with other functional units involved in the operations control processes. During periods of minor perturbations, *ops controllers* and/or shift managers explained certain

domain specific terms and intimate the researcher on the state-of-affairs, their recovery options and rationale behind their choices. Evidence gathered was initially documented as field memos. The memos were discussed with randomly selected participants to ensure that the documented observations accurately reflect meanings that are held by participants within this work setting. The revised memos were later used in conjunction with deductively derived themes from the literature to design a structure for the next stage of study. Further, the researcher identified critical operational points of interest and formal interview sessions were arranged with selected participants in charge of some roles of interest to this research.

The second-stage visits were undertaken in only one OCC and lasted approximately 18-hours over three weeks. Here, the researcher explored, in greater depth, the themes put together from field memos and literature reviews in several 45-mins interview sessions. In addition, a decision was made to extend the discussions beyond phenomena recorded in the memos to accommodate 'memorable' disruptive events that are particularly significant to the participants within six months prior to the interview dates. This decision is imperative given that it is not guaranteed that the researcher could have observed all requisite phenomena due to access and time limitations. Reflecting on past events provided opportunity for participants to discuss events that pushed their operations outside the planned envelope, but which were not observed directly. Hence, participants were allowed to talk freely about scenarios they had witnessed and their experiences, but were brought at some point to address selected themes of interest. Data collected was used to develop a more structured framework with which to compare practices and processes in that particular OCC against the other sites participating in this study.

The third-stage visits will be undertaken in the other three airlines, and will involve mainly participant observation and retrospective protocols. The purpose here is to determine how the phenomena observed so far is reflected across the four participating sites. Fourth-stage visits, if necessary, will entail clarifications and further validations, and will involve selected participants across all four airlines. Overall, ideas generated from these fieldworks and the ones deduced from literature reviews will be integrated to form a 'mid-range' theory (Glaser & Strauss, 1967; Charmaz, 2011) of disruption management in airline operations control. This could be extended to the broader human adaptive systems to validate the framework developed in this project against findings in other complex adaptive systems.

PRELIMINARY FINDINGS

So far, evidence from one airline OCC suggests a reciprocal relationship across centres involved in airline operations control. This phenomenon is linked to the tight-coupling of operational activities across these centres. The participants appear to share a common belief that it is hard to extricate the performance of one centre from the global system's performance. This belief in itself, coupled with a complex network of resource interdependencies, promotes reciprocity and the adoption of cooperative strategies.

On the definition of resilience, participants unanimously contend that resilience depends on what a company wishes to achieve as their operational goals. Using complex mappings between location, size of operation, company policies, political and cultural values, etc., participants argue that various airlines have very divergent perspectives in relation to what resilience means to their operations. In particular, a senior network-control manager suggests that to understand resilience in context of a specific airline's operations, one must 'dig deep' to unveil not only the economic drivers, but also cultural, political and social driving forces behind key decision considerations or criteria deployed in that company. Of course, it is broadly acknowledged in the literature that such factors do influence the adoption of either cooperative, autonomous or defensive strategy. However, it is not yet clear how precisely they influence these strategies in airline operations control. Perhaps subsequent stages in this study will elucidate on this phenomenon.

Other interesting lines of findings include the effect of co-location, the driving forces behind the adoption of'command-and-control' in airline OCCs, the necessity to validate information emanating from multiple centres, and how loosely *ops controllers* and shift managers hold onto their 'illusion of control'. Regrettably, due to space limitations, these findings would not be documented here but will be presented in the consortium.

EXPECTED THEORETICAL CONTRIBUTIONS

It is expected that the final thesis findings will produce a framework for comparing contextual mechanisms in complex adaptive systems, including bush-fire fighting, large-scale commercial laundry services and social-services systems. Comparing driving forces and contextual variables across these complex work domains has the potential to delineate variables that are shared across the broader human adaptive systems and those that are context specific. Furthermore, it is expected that this research will contribute towards the formalization of a unified framework of tradeoffs by characterising more definitively how the phenomena observed in airline operations control relate to previous studies of other complex adaptive systems. Such characterisations could lead to the development of more comprehensive understanding of the notions studied as they relate to complex adaptive systems. Lastly, this paper contributes to the validation of theories developed in other domains by testing them empirically against the specifics of airline operations control.

ORIGINALITY OF CONTRIBUTIONS

With regards to originality, this research integrates advances in two theoretical perspectives: resilience engineering and naturalistic decision making, in explaining the driving forces behind distributed decision making, reciprocity and the construction of common ground. Specifically, our study highlights that autonomous and protective modes of adaptation are particularly significant in airline operations control. This phenomenon is indicative of the necessity to implement a course of action under severe time constraints, while managing complex network of interdependencies relating to resources and performance variables controlled by different units. As strange as it sounds, there is a compelling evidence to suggest that autonomous and protective strategies are especially useful in speeding up decision making processes in highly dependent but distributed systems. Furthermore, the findings underscore the need to maintain an autonomous regulation strategy between safety-critical units and other units in the broader system. Given that safety is important in aviation, this move will ensure an internal regulation mechanism that monitors the position of a system in relation to its boundary of acceptable performance. Overall, we surmise that different modes of adaptation are best suited for managing different forms of trade-offs under different circumstances. The challenge for both researchers and practitioners, therefore, is to ascertain what contextual mechanisms that support the effectiveness of specific modes of adaptation when managing specific trade-offs in varied contexts.

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