Regulating Interactions across Multiple Centres of Control
An Airline Operations Control Perspective

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Abstract. This paper elucidates the driving forces that shape a unit's choice of adaptive strategies. It is based on a two-stage field research conducted at four airline IOCCs. A total of 18 experts were both interviewed and observed across the IOCCs studied. In many aspects, the findings reiterate that human adaptive systems need a cooperative culture and structure in order to adapt formalised procedures across functions; particularly, in the face of myriad internal constraints and external pressures. On a rather interesting twist, evidence suggests that cooperative adaptation is not always preferred when managing trade-offs at the IOCCs. Building on the three locally adapted strategies proposed by Stephens and colleagues (2011) – cooperative, defensive and autonomous, we have found a fourth, *protective strategy*. The findings should be useful in advancing our understanding of trade-off dynamics that are context-specific and the ones that are shared across the broader human adaptive systems. Our position is that it is not whether adaptation is defensive, cooperative, protective or autonomous that determines its effectiveness. Rather, it is the extent that an adaptive strategy allows decision makers to effectively manage trade-offs to achieve a better overall outcome given prevailing circumstances.

1 INTRODUCTION

Strategies employ by individual actors and autonomous functions have been applied extensively in discourses relating to resilient modes of reorganisation (Cook, 2006; Cook & Rasmussen, 2005), management of risks and abnormal situations (Malakis, Kontogiannis & Kirwan, 2010; Woods & Wreathall, 2003; Reasons, 2008), and basic trade-offs in human adaptive systems (Hoffman & Woods, 2011; Hollnagel, 2009; Woods & Branlat, 2011). A recent study (Stephen et al., 2011) discusses a set of strategies—cooperative, defensive and autonomous—use by units in regulating horizontal interactions across multiple centres of control. This paper advances our knowledge of locally adapted strategies in human adaptive system by mapping these findings to the specifics of airline operations control. It delineates how specific events and the unique characteristics of the airline Integrated Operations Control Centre (IOCCs) shape a unit's choice of adaptive strategies. In particular, this paper examines external forces at play in the broader air transport system. The main intention is to elucidate how external pressures shape both horizontal and cross-scale (vertical) interactions at the IOCCs; at the same time, shed light on how resultant cross-scale interactions influence horizontal adaptive behaviours, particularly during *escalating situations* (Bergstrom, Petersen & Dahlstrom, 2011).

2 REGULATING INTERACTIONS ACROSS AIRLINE FUNCTIONS

Airline operations control, given its highly dynamic and distributed nature, is often characterised by goals that are dynamically changing or locally adapted across multiple centres of control. Governance is typically distributed across autonomous functions that possess specialised expertise in dealing with specific aspects of the operation (Clarke, 1998). Regulating interactions across functions 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 interdependence between key resources controlled by the different centres further exacerbates the challenge to adapt planned operations, particularly in the event of unforeseen disruptions (see Abdelghany et al., 2008; Clausen et al., 2010). Clearly, managing such reciprocal dependency, 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 paper is based on a two-stage field research conducted at four airline IOCCs. The first-stage involved brief discussion and observation sessions and lasted approximately three hours for each study site visited. Second-stage visits involved in-depth exploration of themes put together from field memos and literature review in several 45-mins-interview and 2-hour observation sessions. A total of 18 experts were both interviewed and observed across the IOCCs studied. Their current roles and previous experiences span key functions including aircraft control (ops-control), crew control, dispatch, maintenance watch, passenger recovery, port operations, and senior management. As the centre of operations control, most part of this study focuses on interactions between the ops-controllers and other actors at the IOCC. The field notes and interview transcripts were coded inductively to identify the driving forces that shape the adoption of specific strategies at the IOCCs studied. The findings are linked deductively to the discourse on "locally adapted strategies" and "teamwork strategies" in human adaptive systems (Cook, 2006; Malakis, Kontogiannis & Kirwan, 2010; Stephens et al., 2011) to provide a broader explanation beyond the specific case studied. The following sections present key factors that exert influence on the adaptive style employ at the IOCCs.

2.1 Mutual Beliefs, Shared Intentions and Interdependent Resources

Autonomous units tend to show willingness to cooperate when there is interdependence between resources controlled by different centres. Based on our findings, decision-makers at the IOCCs broadly agree that it is rather a rule than an exception for units that control interdependent resources to sacrifice their local margin for an anticipated better global outcome. This consensus was linked to the belief that it is hard to extricate the performance of one centre from the system's global outcome.

The willingness to cooperate has also been linked to one's interpretation of and trust in other's reputation (Ostrom, 2003), intentions and beliefs (Meggle, 2001; Tuomela, 1995). While internal beliefs are hard to capture in most cases, evidence suggests that the participants gained understanding of each other's beliefs through *shared intentions* (Bratman, 1993). A specific event was observed that captures the interplay between interdependent resources, shared intentions and *mutual beliefs* (Colombetti, 1993; Tuomela, 1995). In this event, a crewing officer requested a 35-minutes delay so a reserve crew could be flown to another port to replace a sick crew. The ops-controller obliged without hesitation in spite of the obvious negative effect the request would have on current flight's punctuality performance. The reasoning, as described by the ops-controller, was based on the belief that the borrowed margin was for the greater good of the system rather than for own benefits. By cooperating with the crewing officer, the ops-controller was able to avert cancellation of two flight legs and potential cascade of cancellations.

In airline operations, tight coupling of system resources leads to a high level of interdependent operational activities. A direct consequence of this tight interaction is that the interconnected web of activities makes it difficult to extricate one centre's performance from the others. Therefore, we surmise that the tight coupling of system resources and the emergent socio-cognitive mechanisms of positive mutual beliefs and shared intentions promote *reciprocity* (Ostrom, 2003), which in turn encourage autonomous functions to adopt *cooperative* strategies.

2.2 Shared Referents and Clearly Defined Basis for Cross-Functional Adaptation

In order to maintain *situational awareness* (Endsley, 1995) of the state of the system, ops-controllers source and effectively make use of most current operational information across functions that are involved in tactical operations control. Nevertheless, as captured in the framework of generic competencies for handling complex and escalating events (Bergstrom, Petersen & Dahlstrom, 2011), autonomous units need more than just a means of sharing information to be able to cope amidst escalating demands. To guarantee readiness to respond as new information surfaces, autonomous functions need a common referent and clearly defined basis for negotiating and adapting plans (Hollnagel, 2011, pp. 284-287).

Decision-makers across functions were observed using explicitly defined criteria to create mutual understanding. Updates were periodically displayed on a whiteboard requesting all units to work towards a common goal. Themes that were displayed include "protect OTP" (on-time performance), "maximise slot allocations", and "passengers first". The need to have a common set of evidence as a basis for revising plans is also evident in the findings of the study that examine Swedish railway tunnel projects (Cedergren, 2011). Therefore, we posit that sharing common and explicitly defined referents fosters the creation of *common ground* (Klein et al., 2005) and a shift towards more *cooperative* strategies.

2.3 Lack of Time and the Dynamic Nature of Airline Operations

Airlines operate in a highly *fluid* and competitive business environment, which necessitates that fast and fiscally sound decisions must be deployed within a reasonable timeframe. A delayed decision may no longer be feasible at the time of implementation because the relationships between resources are constantly changing over time and space. Therefore, decision-making must be quick, pragmatic, responsive to change, and above all amenable to myriad conflicting constraints. Consequently, satisficing decisions, which could be easily iterated over time and space, are often preferred over "one-off" optimised decisions at the IOCC (see a related discussion in Hollnagel & Woods, 2006, p. 355).

While reflecting on the dilemma pose by the interplay between time criticality and the dynamic relationship between airline system resources, a participant used the term *command-and-control* to describe a strategy "…that gets the job done…" when there are too many variables to negotiate, particularly when time is critical. Although all participants did not explicitly share this position, there seems to be an implicit agreement, based on their reflections, that command-and-control does allow for quick, approximate solutions to be deployed, which are later iterated. Specifically, the more experienced participants tend to support the idea that command-and-control expedites decision-making processes. Some openly argue that command-and-control is probably a more attractive strategy to adopt during high-risk events or when a decision of 'high importance' is to be made within critical timeframe. Thus, we postulate that the interplay between complex decision variables, time criticality, and the dynamic relationships between system resources often influence higher-echelon governance to initiate a *command-and-control* procedure for horizontal adaptations.

2.4 Awareness of Risks and Commitment to Safety

Internal safety regulation was also found to be one of the driving forces that shape the choice of adaptive strategy across functions at the IOCCs. The role of engineering maintenance as guardian of maintenance schedules of aircraft necessitates a fully autonomous unit that has full authority to initiate and implement aircraft maintenance decisions and activities. Engineering maintenance is typically consulted when safety issues arise regardless of how trivial the case might seem (see Dekker, 2007; Hale & Swuste, 1998). Based on the needs to maintain a constant sense of unease (Hollnagel & Woods, 2006, pp. 355-356) and to remain sensitive to the possibility of failure in safety-critical systems (Hollnagel, Nemeth & Dekker, 2008), a maintenance engineer argues that it is indeed criminal for maintenance watch to base safety decisions on uncontested assumptions or be unduly influenced by other considerations. With this understanding, the engineering maintenance departments see themselves as internal regulators or "watchdogs" when balancing trade-off between safety and many other pressures at the IOCCs.

A specific case was recounted where a ground operator reported a supposedly scratch near the engine of an aircraft caused by collision with a fuelling truck. On chasing up this information, maintenance watch found that it was actually a dent that might have compromised the structural integrity of the aircraft. Consequently, maintenance watch grounded the aircraft for further assessment despite the lack of spare aircraft at the port to continue the operation. The participant further noted that issues of unplanned maintenance checks require an independent assessment of the risks involved with minimal influence from units that shoulder other responsibilities in addition to safety. In parallel, a maintenance engineer (at a different airline) highlights that maintenance units typically coordinate scheduled aircraft maintenance with strategic planning and operations control units. However, the participant emphasised that maintenance watch reserves the rights to ground an aircraft as long as is necessary until the aircraft is deemed fit for duty again.

The common denominator in the accounts narrated by both participants is that maintenance units largely exercise autonomy in their assessment of risks to safe aircraft operations. Therefore, we assert that the need to regulate risk-taking behaviours and to guarantee that an operational system is not drifting precariously towards its boundary of safe operation would often compel functions that exercise regulatory powers over others to lean toward *autonomous* strategies.

2.5 Pressure to Remain Competitive

In efforts to remain competitive following the deregulation of air transport industry, airlines devised a number of strategies for dealing with competitors and other organisations within the broader air transport system (Holloway, 2008; Williams, 1994). The expensive nature of resources and equipment needed for seamless operations often necessitates pooling of resources and reciprocal sharing of resources for mutual benefit (Pilarski, 2007). For example, airlines largely cooperate with other carriers for key services at out-of-station ports, including catering, check-in, maintenance and ground service operations (Wu, 2010). It is not uncommon for airlines to engage the services of other carriers during major disruptions to recover their crew and passenger schedules (Wu, 2010).

Nonetheless, the pressure to survive the extreme competitiveness of the industry often pushes airlines to adopt more *defensive* strategies (Williams, 1994). This is typically reflected in practices, such as hoarding landing/take-off slots and initiating policies and practices that favour local airlines over non-local carriers at home ports (Holloway, 2008). Anecdotal evidence suggests that during critical incidents, airlines often give priority to variables that has the potential to damage their reputation, whether they relate to safety, political or economic factors. In most cases, sacrificing decisions are made where necessary to protect a company's reputation.

Another event was recounted that depicts how a committee that reviews business strategies during critical incidents influenced an operational decision to continue flight operations into a region that has lost economic attractiveness at the peak of a political upheaval. Beyond imminent financial losses due to reduced passenger traffic, the committee identified potential risks to business relationship with the government. Also, the committee was compelled to void the decision to discontinue flights given the broader impact a damaged business relationship could have on the airline reputation in that region.

Protective strategy is frequently evident in the way airlines offer generous reimbursements and free flights in efforts to save their reputation and customer base after major incidents, such as computer glitches, booking system failures, union strikes, etc. (Park, Robertson & Wu, 2006). In resilience engineering parlance, a protective approach represents a situation where priority is given to chronic goals (e.g., long-term customer goodwill) over short-term gains (acute goal). Therefore, we posit that the pressure to sustain competitive advantage amidst high operating costs (Pilarski, 2007), as well as myriad political and regulatory factors often trigger a shift toward *defensive* and *protective* strategies.

3 DISCUSSION

This paper sheds light on the driving forces behind a unit's choice of adaptive strategies, with particular focus on how internal constraints (e.g., interdependent resources, time criticality and safety) and external drivers (e.g., regulatory, economic and political forces) shape the adoption of specific strategies. Collectively, both the specific events observed and the unique dynamics of airline operations control highlight the characteristics of these compelling factors when regulating both inter-organisational and intra-organisational interactions.

In many aspects, the findings reiterate that human adaptive systems need a cooperative culture and structure in order to adapt formalised procedures across functions; particularly, in the face of myriad internal constraints and external pressures. The tight coupling of system resources underscores a key motivation that compels functions to cooperate, in that it is hard to extricate one unit's performance from the performance of other units. Cooperative adaptation is more likely in units that share symbiotic relationships, where individual actors share mutual beliefs of one's positive affect towards the other (Meegle, 2001; Tuomela, 1995); and perhaps, shared intentions to cooperate as well (Bratman, 1993). On the contrary, units that share only unidirectional (one-way) interaction may likely lean toward autonomous or defensive strategies.

Nevertheless, having highly interdependent resources alone may not be enough to yield satisfactory results when teams cooperate toward a common goal. The need for quick reorganisation not only necessitates easily accessible means of acquiring, communicating and validating information (Bergstrom, Petersen & Dahlstrom, 2011), but also a clearly defined referent in order to guarantee readiness to adapt plans across functions in the face of surprises. Thus, our results give support to the postulation that cooperating functions need a common referent and clearly defined basis for activating responses (Hollnagel, 2011).

On a rather interesting twist, evidence was found to suggest that cooperative adaptation is not always preferred when managing trade-offs at the IOCCs. This twist reflects the necessity to implement a course of action under severe time constraints (Hollnagel & Woods, 2006, p. 355); particularly, when managing complex network of interdependencies relating to resources and performance variables controlled by different units.

More specifically, command-and-control has been found to expedite decision-making processes, when there are too many variables to negotiate; when time is critical; or when safety, regulatory or political issues are involved. It is also interesting to note that command-and-control strategy is mainly deployed during extreme or high risks negotiations between specialized units and traditional functions than during routine, horizontal resource regulations across traditional functions. The attractiveness of command-and-control strategy appears to go beyond the military and airline operations control. We found that command-and-control strategy is one of many coordination mechanisms use by the Australian Health Protection Committee for dealing with health related emergencies involving multi-party cooperation (pp. 6-7).

Likewise, autonomous adaptation appears particularly significant in airline operations control. Evidence suggests that autonomous modes of adaptation are well suited for internal safety-regulation purposes (Hale & Swuste, 1998). Units deploy autonomous regulation to checkmate a system-wide risk taking behaviours, particularly when there is a need to ensure a system is not drifting precariously towards its boundary of safe operation. Given the need to remain sensitive to the possibility of failure in aviation (Hollnagel, Nemeth & Dekker, 2008), having an internal regulation mechanism or unit will likely improve a system's ability to monitor its position in relation to its boundary of acceptable performance. The structural relationship between safety-regulatory units and other units parallels what is obtainable in the financial world, where some agencies are set up to regulate transactions within the financial market.

By mapping the three strategies suggested by Stephens and colleagues (2011) into an airline operations control context, we have found a fourth, *protective strategy* (possibly, a variant of autonomous/defensive strategy), which decision-makers employ to reorganise their margin when faced with very tough choices that have broader implications than immediate operational losses. While defensive and protective strategies share a lot in common, protective strategy encompasses both restrictive and sacrificing approaches mainly tuned towards survival of the system in the long term. Perhaps it is more appropriate to describe protective strategies as damage control procedures, which are mainly activated when there is need to address critical issues that would otherwise impact negatively on an organisation's reputation. Defensive strategy, on the other hand, is deployed purely to create monopoly power (Holloway, 2008, pp. 157-161) or competitive advantage by restricting opportunities of others (e.g., competitors) to gain market share (Williams, 1994). Although there was not enough evidence found in this study to suggest that defensive strategy applies within airline functions, we suppose our inability to capture a defensive mechanism *in situ* may be linked to the limited access that was allowed for this study. Nonetheless, issues of mistrust have been a long-standing problem in the broader airline industry since deregulation (Congress of the US Senate, July 27, 2000). The presence of mistrust is clearly evident in subtle defensive approaches adopted by airlines, especially when responding to competitor's pricing and revenue management (see Holloway, 2008, pp. 125-190 for a detail discussion on these strategies).

4 A CONCEPTUAL CHALLENGE AND FUTURE RESEARCH

In general, 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 contextual mechanisms that support the effectiveness of specific modes of adaptation when managing specific trade-offs in varied contexts. Whilst the discussions might have suggested that the different adaptive strategies operate as discrete strategies, it is important to note that these strategies actually operate within a continuum. For instance, an adaptive strategy deployed by a unit would more likely encompass a mix of cooperative, autonomous, defensive or protective behaviours; at the same time, project one or more as prominent trait(s). Future research should aim to formalise the defining attributes and dimensions within each strategy. A conceptual challenge at the moment is whether command-and-control can be categorised as a separate strategy or whether it can be classified as an autonomous, defensive, cooperative or protective strategy.

The findings presented in this study should be useful in advancing our understanding of why units prefer specific kinds of locally adapted behaviours over others. They also elucidate common denominators that managing trade-offs at the IOCC may share with the broader human adaptive systems. Research is continuing to ascertain possible links between a unit's choice of adaptive strategy and the nature of trade-off. Such insights should provide a framework for delineating underlying structures, culture and practices that support decision makers to adapt formalised procedures *in-flight*, while managing many-to-many mappings across conflicting goals, roles, and responsibilities.

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