Making the choice to split sectors or not in a complex Air Traffic Control environment

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ABSTRACT

Air Traffic Controllers (ATCOs) are essential sharp-end workers in the increasingly complex Air Traffic Management (ATM) system that the European ATM network has become. This research is based on an event that occurs many times daily in the Copenhagen Area Control Center (ACC). ATCOs choose whether or not to split sectors. To cope with workload, which is constituted by variation in traffic volume and complexity, the controller must make the choice to split sectors or not. It is not an easy choice, often judged retrospectively. Most splits turn out well, however a positive outcome does not necessarily indicate a good decision and vice versa.

This study uses a qualitative research strategy to investigate what competencies ATCOs possess to manage this task, and why controllers sometimes choose not to split sectors in the presence of high traffic volumes. Interviews with ATCOs from Copenhagen ACC, Supervisors and managers combined with storytelling, form the results that show how the professional identity of being an ATCO and belonging to a small group of professionals can relate to sector splits. Student controllers during their education, must show that they possess the ability to call a split of sectors at the right time, in order to show overall competence and thereby get included in the professional group of controllers. This is a difficult task to achieve considering how experienced controllers themselves struggle to make the choice to split sectors or not. In addition, the different views on sector splits and their effect on safety are discussed.

The results indicate a strong dependence on what role you possess in the organisation:

Controller - Supervisor or Manager.

For the ATC system to work it needs to be resilient to the daily variations in traffic demands. The resilience depends upon flexibility from controllers to make the choice to split sectors or not. Sometimes the flexibility means and relies upon the controllers ability to work beyond the sector capacity. The extra capacity created by controllers is appreciated by supervisors and management because it gets the work done. Most controllers enjoy to work in busy traffic and are proud to contribute and create the extra adaptive capacity when needed - by extending the operational envelope buffers.

Table of contents

LIST OF FIGURES

INTRODUCTION

"Should we split the sector?" That question is asked many times during a normal workday in Copenhagen Area Control Center (ACC) - either by the Radar or the Planner controller that in collaboration form a sector team that control the aircraft within a sector. The question to split sectors is raised because the Radar or Planner controller has uncertainty about how the traffic situation will evolve in the near future. By checking in with the other members of the team whether or not to split sectors, the choice can either result in a reduced workload in case of a split of sectors or with the decision to stay with the current sector configuration. The split of sectors requires another two controllers and will approximately half the amount of traffic numbers (depending on the distribution of the aircraft) and involves the redistribution of the traffic in the combined sector into a new sector configuration of two discrete sectors. If there are enough controllers on duty, splitting sectors to reduce workload seems like an obvious choice, if the predicted number of aircraft in the sector is high.

This thesis started out as a curiosity about why controllers often make the choice not to split sectors when the number of aircraft gets high.

The International Civil Aviation Organisation (ICAO) state that ATC is a service operated to promote the *"safe, orderly and expeditious flow of air traffic"* (Gonzalez, 2015, p.2). The phrase "safe, orderly and expeditious" is used commonly in the ATC field and contain the essence of what Air Traffic Controllers learn about the job description at the beginning of their career, often on one of the first days of their training.

The premise is that despite little understanding or acknowledgement, organisations like Air Navigation Service Providers (ANSP) rely on the experience and judgement of professional operational staff, in this case controllers, to fulfil the needs and purpose of the organisation.

Another important organisation when talking about ATC in Europe is Eurocontrol. Eurocontrol is a pan-European, civil-military organisation dedicated to support European aviation. Eurocontrol advises ANSP´s to pay attention to workload, since both high and low workload create challenges for the controllers. (Eurocontrol, 2020)

Due to the increasing volume of traffic in the skies over Europe, shown in Fig. 1 below, there is a massive focus on airspace capacity and to make flights effective. Effective means as little delay as possible and optimising flight paths to save fuel. The ANSP´s delivers this service, a "safe, orderly and expeditious flow of air traffic" by using controllers as sharp-end workers, directly in contact with the pilots flying. Therefore, the question about strategies used by controllers in their choice to split or not to split sectors in Air Traffic Control to deal with workload is important and relevant. Another reason is that sector splits and bandboxing can been seen as an important factor in making the Air Traffic Management (ATM) system resilient. (Woltjer et al., 2015)

> *"As part of the Single European Sky (SES) initiative of the European Commission, the SESAR (Single European Sky ATM Research) program is designing new ATM concepts with the aims of improving fuel efficiency, cost efficiency, safety, and airspace capacity. A large number of technical and operational projects aim to develop concepts (technology and working methods) towards these goals, meaning that new trade-offs between safety, efficiency, and capacity will likely need to be found for future operations. Functional changes and new trade-offs have the potential to make socio-technical systems brittle emphasising the need for Resilience Engineering and Safety-II concepts in ATM"* (Eurocontrol, 2020)

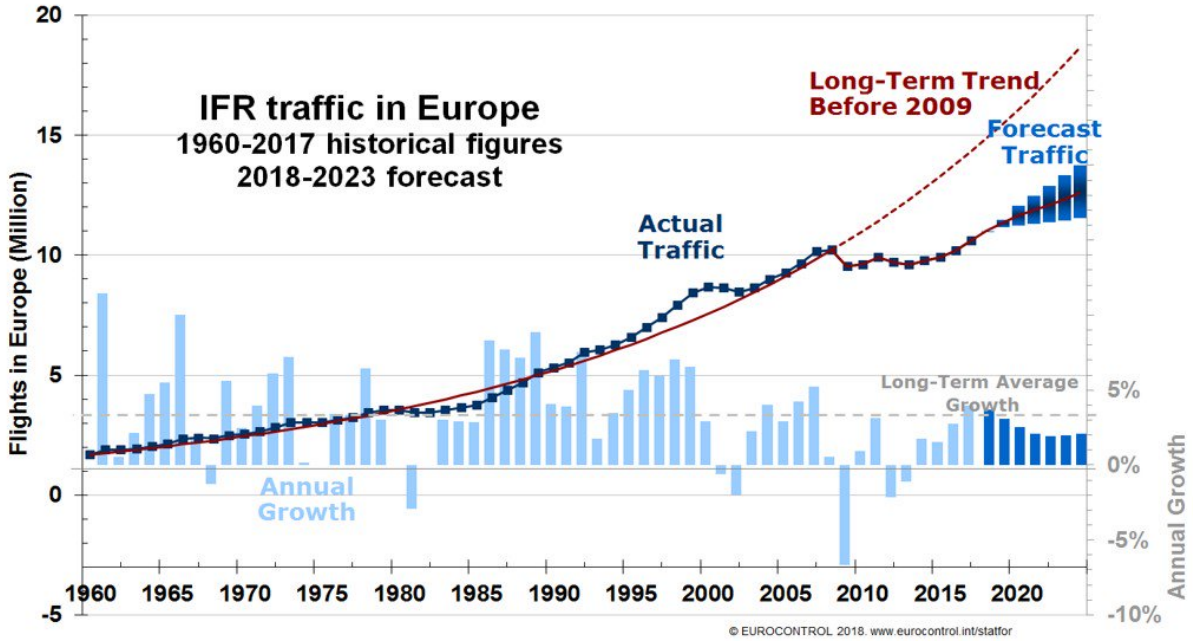

Figure 1. *Development of flights volume in Europe.*

The growth in traffic volume has forced European Aviation Safety Agency (EASA) via Eurocontrol to publish a safety notice "summer scenarios" that states:

"ANSP aims at removing more than 1,000 flights/day from congested areas, either by rerouting them or by level-capping flights." (EASA, 2019) and *"En route air traffic controllers are requested to: avoid giving shortcuts unless essential as they make for congestion problems downstream and keep to the vertical/geographical profile in the filed Flight Plan as far as possible."* (EASA, 2019)

Even a level change different from the filed Flight Level (FL) can lead to an overload situation in downstream sectors in the complex ATM system that the European ATM network has become.

The recommendations from EASA are a clear indication that the European airspace is approaching the capacity limit in peak hours. Air Traffic Management (ATM) depend on the use of airspace and resources available by splitting or bandboxing sectors through the day.

The splitting of sectors is managed differently in each country, depending on the policy and staff situation of each ANSP. In most ANSPs it is up to the supervisors to call a split or bandbox of sectors, based on the forecasted traffic volume. When traffic demand is high and exceeds the capacity of the airspace, sectors that are bandboxed can be split - if there are controllers available to work on the split sectors. Lack of controllers is widespread across Europe. If it is not possible to split sectors, supervisors have the opportunity to impose regulations on air traffic. This is done by setting a maximum number of aircraft in a sector.

Splitting sectors in Copenhagen FIR

In Copenhagen ACC, the supervisors have the responsibility to ensure that on any given day there are enough controllers on duty to handle the forecasted traffic. Supervisors are not usually restricted by the numbers of controllers available, as there are normally enough ACC controllers available to meet the demand of traffic in Copenhagen Flight Information Regions (FIR). Therefore, under normal operational conditions there are no regulations applied and no maximum number of aircraft in ACC sectors. As the controllers are at the sharp end working with live traffic the decision to split sectors or not is administered by them.

Copenhagen FIR is divided into 13 sectors shown in figure 4 below. Each sector can be operated by two controllers: an executive radar controller and a planner controller. On a daily basis the 5 sectors L, V, UV, N, S will be combined into one sector in the western part of the FIR. In high traffic volumes the sector will be split into two new sector configurations consisting of N, S and L, V, UV. The two new sectors will demand 4 controllers or; two executive and two planner controllers. There have been occasions where the traffic volume has reached a high level, that resulted in a split of the combined sector N, S into 2 separate sectors N and S. That split will then require two extra controllers making the demand of controllers 6 in total.

In the eastern part of the FIR there are usual 2 sectors operational. One lower sector B, D, E, I (not all shown in figure 4) and one upper sector A, C, UA, UC. In low traffic volume, the two east sectors can be bandboxed into one sector or in high volume split further into any combination. Typically, a split will be executed so that the sector A, C, UA, UC will be divided into A, UA and C, UC. But the split could also be done vertically in FL 345 resulting in a sector combination of A, C and UA, UC.

As described above the controller may face many possibilities to split and combine sectors - a task carried out every day.

The scope of this thesis is the strategies used by controllers in their choice to split or not to split sectors.

The split and bandboxing of sectors are shown in the pictures below. The first picture is a bandboxed sector with 2 controllers, radar and planner working all East sectors B, D, E, I, A, C, UA, UC.

Figure 2. *East sectors B, D, E, I, A, C, UA, UC.*

Figure 3 below shows the East sectors in Copenhagen ACC split in two.

To the left, sector A, C, UA, UC are combined and to the right the lower sectors B, D, E, I.
4 controllers are needed to work the 2 sectors. The planner controller is missing in the picture far to the right.

Figure 3. *East sectors in Copenhagen split in two*

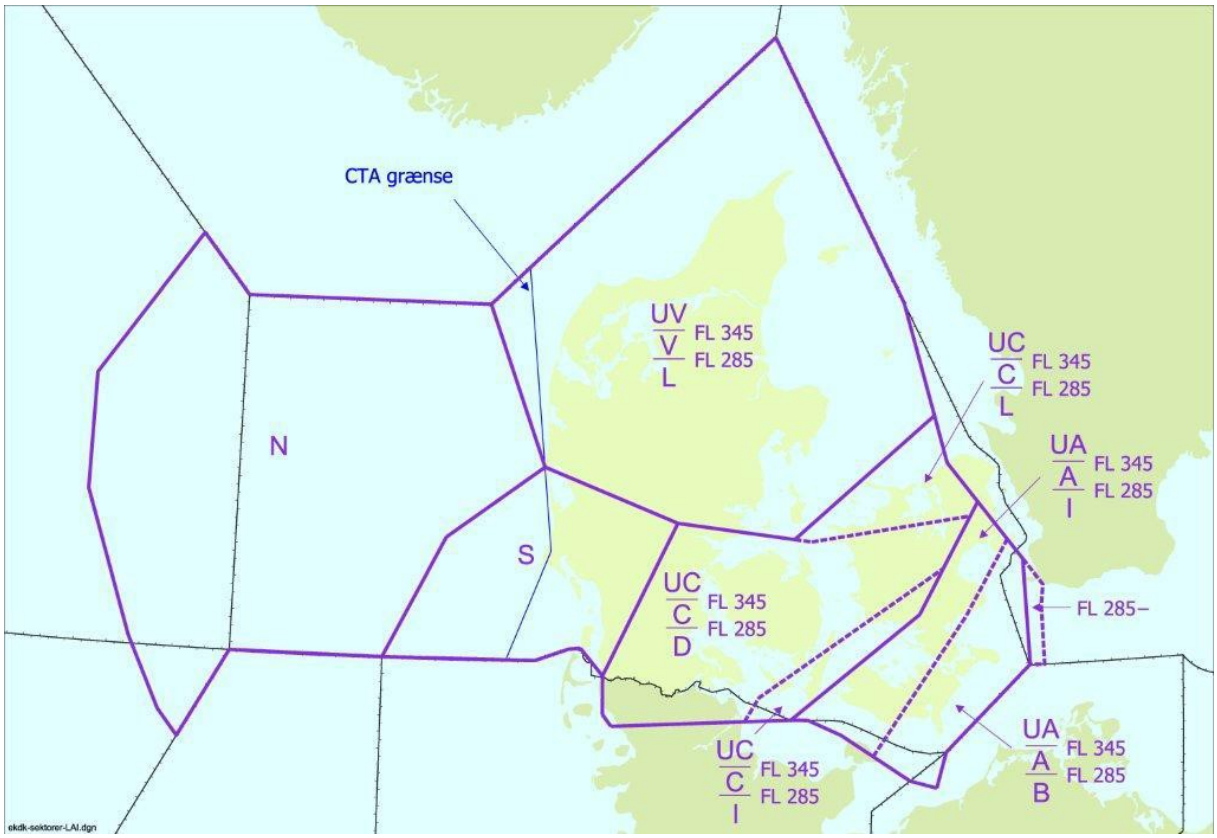

Figure 4. *Sectors in Copenhagen FIR*

The problem of identifying an overload

It is not an easy task to make the choice about whether to split a sector or not, to avoid an overload situation. Even for experienced controllers, the decision seems to be difficult. When to split sectors has been on the agenda in meetings with controllers, supervisors and management the last 25 years. This was confirmed during the interviews with controllers.

ATC is a safety business, actually safety is argued to be the only reason for ATC's existence by some ANSPs. One ANSP the Swiss Skyguide uses the slogan "Safety is our *raison d'être*". (Skyguide, 2020)

The Skyguide slogan corresponds well with the ICAO statement that ATC is a service operated to promote the "safe, orderly and expeditious flow of air traffic"

Overload is defined as:

> *"An occurrence when an air traffic controller reports that he/she has had to handle more traffic than they consider it was safe to do so. An overload could be caused by an inadequate flow management strategy or by over-deliveries or by both."* (Eurocontrol, 2020)

For an ANSP to sustain operation by delivering safety, the above could be read as overload situations should be avoided at all cost, because overload is connected with safety. However, that is not the case in most overload situations. The important feature of an overload is that the overload is a perception noted by the controller after working a busy session. An overload is not defined by a number of aircraft. *"Overload comes not so much from the number of planes that a controller is working as from the complexity of the interactions with the pilot that occur"*. (Weick, 1987, p.121).
A statistical survey from the British ANSP NATS, only showed 2 loss of separation between aircraft in 169 overload situations. This also leads to state that there is no "objective" measurement of how safe an overload is or is not. (Smoker, A. J., (personal communication, 2020)

ICAO provides recommendations for ANSP´s to cope with workload and sector capacity.

> *"The number of aircraft provided with an ATC service shall not exceed that which can be safely handled by the ATC unit concerned under the prevailing circumstances. In order to define the maximum number of flights which can be safely accommodated, the appropriate ATS authority should assess and declare the ATC capacity for control areas and for control sectors within a control area."* (Gonzalez, 2015)

According to the safety manager in Copenhagen, there has only been one incident report produced in Copenhagen ACC during the last three years, that mention an overload situation with a loss of separation, where a potential sector split could have avoided the loss of separation. (Maaløe, A.J., (Personal Communication, 2020)

So, why should we be interested in looking at decision making about sector splits when there have been no major safety problems? One answer is because it is an ICAO recommendation. Another reason is that splitting and bandboxing sectors is a task performed every day in ANSP around the world. The task is part of making the ATM system resilient to variations in traffic demand.

> *"Where traffic demand varies significantly on a daily or periodic basis, facilities and procedures should be implemented to vary the number of operational sectors or working positions to meet the prevailing and anticipated demand. Applicable procedures should be contained in local instructions."* (Gonzalez, 2015)

Based on these ICAO recommendations Copenhagen ACC has made the following SOP (Standard Operation Procedure) for sector split and bandboxing. They are short and state:

> *"When splitting and bandboxing sectors the controllers (EC and PLC) must ensure that all relevant information is passed to the controllers on the new working position, also the time and conditions must be coordinated with the arriving EC before transfer of radio communication is done."* (Naviair, 2020)

If sectors are split beyond the Flow Management Position (FMP) made plan, the Watch Supervisor must be informed. This is to ensure that if sectors are split more than expected, the supervisor needs to provide enough controllers to man the extra sectors (Naviair, 2020).

Decisions to split sectors are influenced by many factors, external factors like weather, military traffic and technical equipment status and also internal factors (private property), such as habit, culture, education, goals, etc. Every traffic situation is different, and it can be hard to predict how the traffic situation will evolve within the next 3 -10 minutes. There are traffic numbers available from Central Flow Management Unit (CFMU) that can help the controller's decision, but the numbers only tell how many aircraft the system predicts will be in the sector, it does not say anything about the complexity of the traffic situation. If, for example most of the traffic is transiting through a sector in level flight, the controller can handle a high number of aircraft, because the traffic situation is characterised by limited task complexity. However, if there are a lot of aircraft that requires climb or descend, typical around an airport, but also en-route when fuel consumption enables aircraft to climb, the complexity increase. In this case the controller can only handle a lower number of aircraft in the sector, because the workload is higher.

Stories told about sector splitting

Three stories told among controllers in Copenhagen ACC illustrate the nature of sector splitting and provides the basis for this thesis, and my desire to learn more about what factors are embedded in the strategies, that leads to the choice to split sectors or not in Copenhagen ACC. The stories differ in actors: student controller, controller and supervisor. But all 3 stories point at the many levels that surrounds the choice to split sectors or not.

The first story is about a controller student working a busy sector combination during the last month of On Job Training (OJT). Traffic keeps building up, and the instructor (OJTI) says to the student "I think we need to split the sectors". The student replies "OK. But how do we do that?". It turns out that the student has never been in a situation that required a split before. The story is told by instructors from the team where the student belonged. One of 8 teams in Copenhagen ACC.

I want to investigate what the story says about sector split and the professional identity of the controller. I also want to analyse how a student controller is formed during training to fit into the tribe of controllers.

The next story is about 2 controllers working with all sectors combined in the eastern part of Copenhagen ACC. The planner controller is busy, and workload is high, so the planner decides to split the sectors, and call for 2 controllers via the pager system to perform the split. When they arrive, the radar controller says, "I do not want to split sectors, if you split, go find another radar controller, because in case of a split, I will not work anymore". The 2 controllers summoned to split sectors, ended up not splitting and just hanged around until the busy period ended. The story leads to questions

about why controllers can have different view on when to split sectors. All controllers receive similar education and training time before validating, so the view on sector splits seems personal and prestigious.

The third story involves management, in operations represented by supervisors. They are responsible for ensuring enough staffing to handle the traffic.

Arriving at the beginning of the shift, a controller is met by the supervisor, that inform the controller that he has been selected to work a busy sector, with estimated traffic volume close to the capacity, and the controller is asked to select any of the other controllers on duty to work with him as planner.

This story is used as a starting point to investigate the mutual social interactions between controllers. The story points to the importance of personal relations and also how supervisors and management are involved in sector splits.

There are more stories told among controllers about sector splits. Stories about splits performed too late, so the split was messy. But there are also stories about successful well timed splits. I believe that there is much to be learned from these stories, by using them as a starting point for further discussions with controllers; discussions which can then be analysed scientifically.

These stories can also be important as learning opportunities in the form of starting points for discussions in the yearly refresher training of Air Traffic Controller Officer´s (ATCO) and in the training of ATCO students. Especially, in the training of students, it is an important aspect in the relevance of making this thesis, since the decision to split sectors is a vital competence that a controller student should possess, in order to be overall competent and qualify for an ATCO license.

My experience as an On The Job Instructor (OJTI) shows that in the end of the 3-year long education of a controller student, just before validating, the instructor team often includes a discussion about the student's ability to make the decision to spilt sectors at the right time. If the student makes the decision to split too early, he/she does not possess the capacity to work as an ATCO and is therefore seen as not competent. If the decision to split is made to late, the student lacks self-awareness and is not able to judge when help is needed, therefore not competent. The skill to call a sector split or not is a vital competence in order to gain an Air Traffic Control license but still an important one.

The research space

The professional identity of a controller begins to form during the 3 years training it takes to acquire a controller license. Especially during the last 6-month On Job Training (OJT) period with live traffic that takes place in the unit where the student will validate and get a controller's license. Indeed, for a trainee to achieve validation there is, anecdotally, an opinion formed by instructors on whether or not the student is able, have the integrity and can be trusted to make band boxing and splitting "calls". The instructors must eventually assess the student controller. According to the Unit Training Plan (UTP) used in Copenhagen ACC, the student must be able to *"Plan and control heavy and complicated traffic on all work positions, safe and appropriate. The student must also be able to assess traffic development and split sectors in due time"*. (Naviair, 2020) The skills described in the UTP must be fulfilled for the student to validate and receive a controller license.

The ability and preparedness to call a split or bandbox is part of forming the professional identity of the controller. A bad sector split can stick to the controller the rest of the career, a career that can last around 35 years, often in the same control room.

Research by Bieder and Bourrier (2013) supports that ATC is a unique environment to train and work in, because ATC lacks the checklists that aviation often is associated with.

> *"Incidentally, we can mention that in aviation, although working together everyday, pilots and controllers do not share the same philosophies and practices regarding procedures. Air Traffic Controllers have few procedures and check lists. Their philosophy is that a controller is trained and educated to work in a specific centre within a specific team. This is achieved through training and tutoring by peers"* (Bieder & Bourrier, 2013, p.24)

The research space for this research is as much the sociology surrounding ATC as it is the technical aspects of controlling traffic.

So, when is it time to split sectors? It is believed that the controllers could answer that question. However, the knowledge might be tacit for the controllers.

> *"There are many different characterisations of knowledge management, but the central assumption is that knowledge is a valuable asset that must be managed". Experts has that knowledge and it is up to researchers to help bring that knowledge to the surface and into the light".* (Wilson, 2015, p.164*)*

One topic of particular interest concerns the use of knowledge elicitation techniques to support the transformation of tacit knowledge into explicit knowledge as part of the cycle of organisational knowledge creation (Shadbolt, 2015)

There are different views on the possibility for a researcher to extract tacit knowledge from experts, ranging from it is impossible to feasible. (Ericsson, 2006) The discussion about whether or not it is possible to extract tacit knowledge from experts will stay in the background of this thesis, and the focus will be on what the controllers think is important factors when choosing to split or bandbox sectors or not. Because the controllers are used to verbalise and discuss the factors surrounding the choice, in order to share the knowledge among colleagues and pass it on to student controllers during OJT. Therefore, tribal knowledge could be used instead of tacit knowledge. "Tribal knowledge" is a term commonly used to describe special knowledge procured through experience, gained over many years. If it is possible to document and share important information learned in practice like how to sector split or not, it could lead to payoffs like improving system performance. (Lin, 2016)

Tribalism is considered an important aspect of group dynamics, that needs to be studied in order to understand subunits and how they connect to each other. (Carillo, 2019) In this study the subunits are controllers, supervisors and management. Where all three groups contribute with their own set of tribal rules.

Work systems are studied to learn about how work is done in the real world. Not as imagined by those making the procedures and rules. *"The gold is not in the documents"* (Shadbolt, 2015, p.4)

Specifically, for ATC, Hayes (2013) added *"despite the enormous number of rules and procedures under which the controllers and pilots operate, it was a myth that the outcomes were clearly determined by these rules"* (Hayes, 2013, p.75)

The study of work can be viewed as a reality check of the imagined and it could describe the gap between work as imagined and work as done. The results can bring valuable feedback to the rules and system designers. Something the experts and management alike are interested in. Another thing all actors are interested in are getting the work done. In ATM this means to be able to cope with uncertainty and surprises. The system must be able to absorb the daily variability in work by having an adaptive capacity, to be understood as the ability for the system to adjust to potential damage and take advantage of opportunities. Sector splits acts as an adaptive capacity and contribute to the resilience in the system. Splitting and bandboxing of sectors is a skill controllers must possess in order to get a controllers license; the skill must be maintained and is a part of the controllers professional identity. Therefore, it is viewed that the professional identity of the controller contributes to resilient performance in ATM among other things by making the choice to split sectors or not.

PREVIOUS RESEARCH

The literature is rich and comprehensive with research on how controllers are affected by workload.

Much research has already been conducted. A search on the research database Scopus with the key words ("air traffic controller" and "workload") shows nearly 600 results.

The aim of much of the research is to explore how the understanding of workload feeds into the measurement of ATC airspace sector capacity(Brooker, 2003).

Sector capacity is more than the application of workload measurement to airspace sectors, often represented by a number of aircraft, that under normal circumstances could and should be handled by controllers. There are many individual factors that affects the daily capacity and workload as described in the "problem with identifying overload" section.

This study is not about workload. I do not want to limit the view on sector splits and bandboxing by making it into a question about workload. I think the subject contains more value if the controllers tell their stories and share their experiences, thereby unfolding the strategy behind sector splits by describing the factors that controllers consider when calling a split or not. I want to know what is important for the controllers in order to make the call - split sectors or not? Secondary, whether the factors towards sector splits, shared by controllers is aligned with management view on sector split. The reason for being interested in how the organisation as a whole view sector split and bandboxing, is that the ability to split or bandbox sectors dynamically can contribute to organisational resilience.

The ATC contains many of the elements that constitute an High Reliable Organisation (HRO) and the ATC system was one of the original organisations considered a HRO. (Weick, 1999).

A HRO typically has a formal hierarchical structure. But organisational processes are flexible and allow responsibility for decision making under high pressure situations to move to experts who are close to the field of action. (Hayes, 2013). Therefore, it makes sense that in the ATC system, the sharp end controllers and supervisors make the decision when to split sectors or not. Paries et. al. (2018) state that HRO and Resilience Engineering (RE) share a common theoretical inspiration.

Resilience.

According to Hollnagel (2009) Resilience in a system requires anticipation of future events, constant monitoring, effective action where necessary and reflection to learn from past experiences.

The concept of resilience fits well in the ATM world.

> *"The complexity of the air traffic system calls for the adoption of a systemic approach that takes into account technical, human, organizational, context, interactions and dynamics. Resilience engineering is not only about analysing risk and failures, but also supporting the organization's ability to be able to respond to both expected and unexpected conditions."* (Herrera et. al., 2010, p.13)

In order to broaden the view of the choice to split sectors or not in this study, I would like to explore the concept of resilience in ATM operations. I will argue that the ability to split sectors is an important part of sustaining resilient performance in the ATM system – what Woods refers to as sustained adaptability (Woods, 2018).

The split of sectors creates a buffer, as a form of adaptive capacity. This buffer can be used to extend i.e graceful extensibility (Woods, 2018) the system in order to cope with the variations in daily work as well as the inevitable performance variation that is a feature of many complex social technical systems:

> *"Graceful extensibility is the opposite of brittleness, where brittleness is a sudden collapse or failure when events push the system up to and beyond its boundaries for handling changing disturbances and variations. As the opposite of brittleness, graceful extensibility is the ability of a system to extend its capacity to adapt when surprise events challenge its boundaries."* (Woods, 2018, p.435)

Rankin et. al. (2014) made a framework for analysing adaptations in high-risk work to focus on resilience in everyday operations. *"The strategies framework can be used as a guide to discuss work practices and work patterns not explicitly available through procedures and other documentation."* (Rankin et al., 2014, p.94)

By observing and examining controllers strategies towards sector split and bandboxing , knowledge can be gained about how the strategies affect, influence or contribute to resilient performance in the ATM system.

> *"From a resilience perspective, the focus is on the system´s ability to cope with increasing demands and compensate for the increased demand by adapting its performance. Hence, adaptations are viewed not only as sharp-end work-arounds to cover for design flaws in technology but as a vital part of system functioning to cope with multiple goals, organisational pressures, and complexity."* (Rankin et. al., 2014, p.81)

Rankin et al. makes this argument about how to maintain a resilient system. *"We argue that observing sharp-end adaptations aimed at avoiding performance breakdowns in everyday operations is critical to identify system brittleness and resilience."* (Rankin et al., 2014, p.81)

Therefore, the daily adaptations performed by controllers are important to study. Malakis and Kontogiannis (2021) states that *"Controllers are expert decision makers who employ cognitive strategies developed over years of operational experience, recurrent training, and shear accumulation of ATC systems knowledge."* (Malakis & Kontogiannis 2021, p.361)
In the same paper Malakis and Kontogiannis (2021) describe how controllers are experts in using their hard earned knowledge to make a course of action that makes a significant impact on the operation of the system. An impact that is proposed here, makes a contribution to the sustained adaptability of the ATC system but is largely under researched and not well understood.

In the summary comparing HROs and RE, Pariès et. al. write:

> *"Reliability is robustness against failures. Resilience is a balanced robustness against variability. This includes the capacity to take benefit of variations to improve performances and to evolve. In other words, HRO advocates are describing how an organization can efficiently prevent failures and safely recover from them, while RE proponents rather focus on how organisations build daily successes (e.g. safety) in spite of - and often with the benefit of – disturbances, and can evolve, readapt and reinforce themselves through disturbing experiences."* (Pariès et. al., 2018, p.510)

The choice of splitting sectors can be argued to be one of the factors or the adaptations that create resilience and contribute to the balanced robustness against variability in ATC.

Choice vs. Decision-Making.

I use the word choice and decision interchangeably to describe how controllers act around sector split, however I think that choice best describes the process. The reason being, is that with choices we face opportunities to select or choose an option. We make choices based on our values, beliefs, and perceptions of where the choice may take us. Decision-making is more a process orientation, meaning we are going through analysis and steps to reach a solution. (Klein, 1999)

Hutton is firm on the statement that experts do not make decisions. Controllers are experts, sharp end workers and use perception in their choices, especially when it comes to sector splits. It is more a matter of how controllers see the world than the knowledge they have accumulated. How they see the world is also how they see themselves, their identity as controllers. (Hutton, 1999)

Choices are more difficult. In a work environment like ATC, where time is a critical factor, we cannot collect all the data, analyse the options, and reach a sound conclusion. A choice to split sectors must be made, or not. The controllers as well as supervisors must then work with the consequences of the choice. The time frame for the choice is around one hour which constitute the time where the two controllers work the sector as a team. When the team are replaced the new controller team can make their own choice to split or bandbox sectors.

Vigilance vs. Workload.

Low workload for controllers poses a problem. The issue with under loading was already addressed in 1987 by Weick *"There tend to be more errors in air traffic control under light traffic load than under heavy load"* (Weick, 1987, p.118). This is also valid today. *"At very low flow rates there would be a concern that the controller "underload" would be reflected in boredom and "coping behaviors", which might result in increased rates of hazardous error"* (Brooker, 2003, p.11)

"Coping behaviors" is connected with the term "vigilance". Eurocontrol describes vigilance and the important role it plays in ATC*:*

> *"Vigilance is a term that refers to an individual's ability to pay close and continuous attention to a field of stimulation for a period of time, watchful for any particular changing circumstances. These changes may be quite small, but their potential effect may be considerable. The speed and accuracy with which we detect these changes (assuming we detect them at all) determines the timeliness of our decisions and actions. Vigilance is greatly affected by our level of alertness, and this is why we can be affected not only by being overloaded but also by being 'under-loaded'." (*Eurocontrol, 2020, p.1)

The advice given by Eurocontrol to controllers is: "*Try to avoid excessively high or very low workload by splitting or band-boxing in good time."* (Eurocontrol, 2020, p.1)

Beside vigilance low workload poses a challenge for the controllers job satisfaction.

> *"People with the intelligence and education of the typical controller seem less willing than they once were to tolerate protracted boredom at work. They want not just a job, but an interesting and satisfying job, and the latter is difficult to reconcile with protracted boredom. While some people may actually welcome boredom at work, few in air traffic control do."* (Hopkin, 1995, p.342)

"Much of the evidence about boredom in air traffic control comes from controllers' complaints." (Hopkin, 1995, p.342)

Controllers are splitting and band-boxing sectors every day to balance workload. The question is what is meant by splitting and bandboxing sectors in "good time"? This thesis will explore if the different actors involved in sector splits, controllers, supervisors and management share the same view and perception of what is meant by "good time" and how the difference in performance between controllers are coped with. The difference in performance is an issue to consider among controllers: "*There are well-known differences between the performances of individual controllers on identical tasks."* (Brooker, 2003, p.11)

High Workload and "Losing the picture".

At the other end of the scale from "under-loaded" is excessively high workload.

Hopkin (1995) discovered that controllers liked to be busy and work hard if given the freedom to choose. *"Most people, given freedom to work as hard as they wish, choose to be busy. Means to reduce high workload that also increase enforced idleness under low workload are flawed and unpopular."* (Hopkin, 1995, p.335)

Controllers like to be busy. However, controllers can get too busy during their work. Sometimes they use the phrase "losing the picture" to describe a situation in high workload where the perceived understanding of the current traffic situation appears lost. According to Isaac (Isaac, 1999) the feeling of "losing the picture" may be accompanied by the perceived loss of control. The startle effect that occurs when exposed to surprising stimuli, comprised of auditory and/or visual inputs resembles "losing the picture". For a controller, this can mean alerts or alarms, that the controller did not expect. (Eurocontrol, 2020).

> *"A controller who suddenly loses the picture of the traffic may have been unable to anticipate that a small increase in workload would prove too much, whereas a controller who reports that the existing workload is so high that it would be impossible to handle more traffic may nevertheless do so efficiently and safely of the necessity arises"* (Hopkin, 1995, p. 334)

How do controllers navigate this space where fine judgment of small changes in workload can tip the balance into the controller "losing the picture"? It is evident that splitting sectors is one adaptive strategy to sustain control of a sector, in so doing managing the connected risk of "losing the picture". However, not all high workload situations incur a high probability of "losing the picture". Malakis and Kontogiannis (2021) suggest that experts gain valuable knowledge through experimentation or trial and error rather than through formal analysis.

In order to learn from experience and gain knowledge, the optimal working conditions for a controller should be targeted somewhere in between the two extremes in a balanced workload. (Eurocontrol, 2020). Controllers can achieve that balance by making the choice to split or bandbox sectors.

Planning vs. IT Algorithm.

Closely connected with workload is planning. Planning is a key word used in much research done, to cope with the increasing amount of aircraft in the sky. Planning is usually done by flow management and is seen by some as the solution to bridge the gap between air traffic flow, capacity management and air traffic control. (Moertl, 2002; SESAR). Others state that Planning is difficult in complex dynamic domains. (Bainbridge, 1997). ATC falls in that category of operating in an environment of conflicting and changing priorities. (Hayes, 2013)

Another solution is the creation of an algorithm that flow management can use to predict when sectors should be split. (D'Arcy, J.-F., & S. Rocco, P. (2001)) The challenge with applying IT to treat a human factor area is that all humans, in this case controllers are considered to have the same capacity. It results in a minimum and a maximum amount of traffic that all controllers should be able to handle safely. Using the IT way to resolve the challenge to split and bandbox sectors, rejects that controllers have different capacity that could lay outside the defined capacity.

In the future a useful IT solution or planner tool might become available. However, it is important to remember a powerful statement by Weick (1987) of ATC *"One striking property of air traffic control is that controllers are the technology, they don't watch the technology"* (Weick, 1987, p.120)

Controllers, Supervisors and Management.

In a Lund master thesis exploring how Air Traffic Controllers manage to make safe decisions facing the increasing time constraints created by increasing numbers of aircraft going through their sector Gissel (2007) wrote *"Another conclusion, that might seem obvious, is that overload / too busy situations need to be avoided"* (Gissel, 2007, p.33) and *"The Controllers do not have a lot of influence on deciding the actual traffic numbers to be handled in a sector at any particular moment, this is flow-management's task"* (Gissel, 2007, p.16).

However, in Copenhagen ACC the controllers can avoid overloads by splitting sectors. And that is a quite unique opportunity for controllers to possess. In most other ACCs surrounding Denmark, it is up to flow-management and supervisors to make the decision when to split or bandbox sectors, typically based on traffic numbers/volume alone. Beside splitting sectors there are other ways to manage traffic load in real time and thereby avoid an overload for the controller. Departure aircraft can remain on ground, and already airborne traffic can be rerouted via adjacent centers or sectors.

This work will focus on the current situation in Copenhagen ACC, where it is up to the controllers to bridge the gap with changing workload demand, by making the choice to split sectors or not.

Besides controllers there are also several other actors who all have a legitimate interest in the decision to reconfigure sectors either via a split or bandbox. Flow management, supervisors and Manager of Operations are part of the same organisation as the controllers and they are responsible for the overall safety. In a study of operational decision making in high hazard organisations, focusing on operational managers that resembles the role of supervisor and flow manager in Copenhagen ACC, one manager described his job as *"acting as a buffer for the air traffic controllers"*. The buffer was meant to spare the controllers of an overload situation. How the different actors manage that responsibility and make use of the buffer can be disclosed via the stories told in the organisation about sector splits. (Hayes, 2013)

Stories.

Klein devotes a whole chapter to stories "The power of stories" in his 1999 book "Sources of Power". Here Klein claims that we organise the cognitive world of ideas, concepts, objects and relationships and link these up into stories. Klein also states that the most powerful method for eliciting knowledge is to use stories. (Klein, 1999)

Reamy (2002) suggests that storytelling is arguably the best way to transfer tacit knowledge, because it enables experts to convey information and context in a form that is easy to understand. The same view is presented from Weick (1987)

> *"Stories remind people of key values on which they are centralized. When people share the same stories, those stories provide general guidelines within which they can customize diagnoses and solutions to local problems. Stories are important, not just because they coordinate, but also because they register, summarize, and allow reconstruction of scenarios that are too complex for logical linear summaries to preserve. Stories hold the potential to enhance requisite variety among human actors, and that's why high reliability systems may handicap themselves when they become preoccupied with traditional rationality and fail to recognize the power of narrative rationality."* (Weick, 1987, p.125)

Sanne (2008) focus on storytelling in railways, and say about storytelling: *"Storytelling is not restricted to appropriate procedures though; it also extends to the moral and emotional dimensions of unfortunate event such as accidents, incidents, and illnesses"* (Sanne, 2008, p.1212) that fits with my quest to research, an aspect of work that is surrounded with stories, some told to entertain, but most told for a purpose. Storytelling is always biased toward one purpose, although most stories have multiple readings *"biasing storytellers and listeners within the community to experience things in certain ways rather than others"* (Sanne, 2008, p.1212). In other words, there is a lesson to be learned from the stories. A conclusion also supported by Weick (1987)

> *"A system that values stories and storytelling is potentially more reliable because people know more about their system, know more of the potential errors that might occur, and they are more confident that they can handle those errors that do occur because they know that other people have already handled similar errors."* (Weick, 1987, p.113).

Experts.

Dreyfus and Dreyfus (1980) suggested that novices tend to make decisions in a careful, analytical fashion, whereas experts appear to make decisions quickly rather than making serial and exhaustive searches. Similarly, Klein (1989) proposed that, in real-world situations, experienced decision makers learn a large set of patterns and associated responses and that, in general, they do not compare a set of alternatives based on their predicted outcomes but, instead, recognise a situation and retrieve an appropriate response.

The current situation in Copenhagen ACC is that all controllers have more than 7 years' experience, and therefore all controllers could be considered experts or at least proficient according to Dreyfus 5 step scale. Malakis and Kontogiannis (2021) state:

> *"An important aspect of expertise is the ability of experts to notice 'interesting events' that provide opportunities for building efficient courses of action to make a significant impact on the operation of the system. These 'interesting events' are referred to as 'leverage points' that*

become the starting point in building new solutions to problems." (Malakis & Kontogiannis, 2021, p.361)

Professional identity.

Controllers are a group of workers that are viewed as professionals by the public and among themselves.

Hayes (2013) wrote *"Professionalism is associated with qualities such as loyalty within the profession, a sense of vocation, identification with the goals and values of the profession, integrity and public trust"* (Hayes, 2013, p.107)

Being a controller creates a professional identity and that identity is associated with how they perform in live traffic. Especially the ability to handle heavy and complex situations is considered a strength. (Brooker, 2003)

Identity is based on interaction with others and a significant factor in developing occupational identity is in the length of time that the controller has been part of their professions and part of their employing organisations. In Copenhagen ACC, the most experienced controller has worked more than 35 years in Naviair. The youngest more than 7 years. The development of the professional identity is generally understood to develop through socialisation. (Joynes, 2018).

Based on the statements above, it is possible to suggest that the professional identity and professionalism of controllers seems to play an important part of the controllers choice to split sectors or not. This contention will be explored in this research.

To address the professional identity, it is suggested to make a Thick Description to describe and explain elements of work, in this case sector splits. Instead of talking about what culture surrounds a sector split, a Thick Description describes the many elements at play in a sector split and the context. The experience shared in interviews combined with explanations and interpretations add details in order to understand the significant and complex cultural meaning that creates a Thick Description narrative. (SAGE, 2019)

Knowledge gap.

I found that there is a lack of research on the strategies used by controllers to control workload in a complex working environment, by calling for help and split sectors. Probably because in many ACCs the supervisors and flow managers decide when to split and bandbox sectors. To conduct the task supervisors and flow managers mainly use traffic numbers as the benchmark. But what happens when the power to draw the line and decide when to split sectors are handed to the controllers like in Copenhagen ACC? I believe that it is under researched how the individual strategies connect to the terms of adaptive capacity in the system by sector reconfigurations.

This research is made to enhance focus on how controllers perceive and use sector split in a complex work environment to deal with workload and personal capacity. To understand what role storytelling plays in the understanding of sector split at all levels in the organisation and how the choice to split sectors or not relate to the professional identity of being a controller. Also, how the use of sectors by splitting and bandboxing contribute to the overall resilience of the system.

This thesis sets out to investigate what strategies are used by controllers in their choice to split or not to split sectors in Copenhagen Area Air Traffic Control.

RESEARCH METHODOLOGY

The research methodology will draw from different categories of research methods to research different aspects of the specific research question.

1. Knowledge elicitation

The first step is to elicit what is involved in reconfiguring sectors by bandboxing and splitting, how and why it plays such a significant part of the management of traffic. This knowledge elicitation must explore the operational practice from various involved actors' perspective. Then follows a document review to understand what procedures are written down. The results from the knowledge elicitation will uncover the actors and elements role. The information about what surrounds sector splits and bandboxing, together with drawing on Cognitive Work Analysis (Naikar, 2017) will be used to form the questions used in the next step - Critical Decision Method (CDM).

2. Sector splitting and bandboxing strategies via Critical Decision Method

Eliciting various aspects of operational practice to gain an understanding of the lived and shared experience of controllers and others is fundamental in examining the strategies used as well as the rites and rituals associated with sector splitting and bandboxing.

3. Analysis Work Domain Analysis (WDA) content analysis

Decision ladders/abstraction hierarchy will be drawn upon as a means of analysing the data from (1) and (2). (Naikar, 2017). Exploratory interviews and CDM data will be analysed using content analysis techniques drawing from Erlingsson & Brysiewicz (2017)

4. Socialisation and the professional identity within the control room

An ATCO can and is defined by their willingness to split a sector. Trainee sector controllers are defined by the assessment of the students perceived capability to call for a split as well as how they are perceived to work in these reconfigurations. Hypothetically, it is a rite of passage. What does this mean in praxis and why is it so important?

This will be explored through interviews in stratified samples of roles and experience, coded using a coding frame that compares and contrasts the views sought. Interviews are the best way to explore this aspect of the research using sector splitting as the vehicle.

5. Resilient performance in the ATM system

By using a framework for analysing adaptations in high-risk work as analytical strategy together with second order analysis, the perspective of the choice to split and bandbox sectors can be seen in a larger context regarding resilient performamce in the ATM system. (Rankin et. al., 2014)

METHODS

Fundamental in studying work is appreciating that practitioners may very well not be able to verbalise how work is undertaken or what they actually do or how they think about the work they undertake. Human's do not have privileged access to their own cognition. (Richard Cook at a Learning Lab Lund University) This means that post-event interviews by themselves will not yield the validity that we are looking for in order to generalise the results we might take from a small number of cases.

If time permitted an ethnographic study seems like an obvious choice, but this master thesis did not fit into the time frame needed for an ethnographic study, also "ethnography usually works best when conducted by an outsider with considerable inside experience" (Forsythe, 1999, p.130). I am inspired by ethnographic work style concerning fieldwork. But I am an insider working controller doing research inside my own workplace.

The research context – what is it I need to understand, is the rationale behind strategies and decisions around how splits and bandboxing are undertaken and how this practice is socialised within the group of controllers. Furthermore, to include the view on sector splits and bandboxing from the supervisors and management perspective.

There are very exact data available about numbers of aircraft airborne in each sector at any given time. The data is provided from Central Flow Management Unit (CFMU) located in Brussels. Supervisors are able to access all data from CFMU. The controllers have limited access to traffic volume estimated in the sector within the next hour.

There are no records about when sectors are split. Except from a 14 days period every summer during high peak traffic volume, here controllers must inform the Flow Manager Position (FMP) when sectors are split and bandboxed again. That information goes to the network manager, the former CFMU in Eurocontrol. Therefore, it is only possible to compare the amount of traffic and splits for a 14 days period. That comparison could make an interesting quantitative basis for management, if the numbers were accessible for a whole year, but not of much interest for sharp end operators, because the numbers does not reveal any information about the strategies used in the decision to split sectors. Therefore, I have chosen to take a qualitative approach.

The act of splitting sectors is a physical act, involving making input in the system and use physical equipment like microphones, chairs etc. the whole process leading up to the split is something we construct in our minds, a cognitive social construct. Air Traffic Control is done in an environment where the system and humans must interact to create a safe and efficient flow of air traffic. One important element is the controller's decision to split sectors. It is not possible to stop work and ask the controllers what they think right now about splitting or ask them to think aloud during normal work. Any disturbance could have an impact on safety since the decision to split is only relevant in busy high traffic volumes. So, we need to retrieve that information after the split is done. And consider that the knowledge might be tacit to the controller. What method is best suitable to bring the tacit knowledge forward?

Hoffman's advice is *"that one should not rely on any single method"* (Hoffman, 1998, p.263)

It is a difficult choice to select a method, but certain methods appear relevant: knowledge elicitation and storytelling. Beginning with storytelling, meant to elicit controllers experience about sector splits and thereby explore their knowledge. Through storytelling statements made by controllers can be gathered and then these statements can be cross checked with other controllers to gather data about the beliefs, values and ritual that surrounds sector splits. The knowledge gained from storytelling also leads to a system understanding that forms the basis for the interviews.

Interviews are conducted using one method that is evidently suitable - Klein's Critical Decision Method (CDM). With pre constructed questions about episodes where sector splits were particularly

challenging. A description of the full CDM procedure is given in Hoffman (1998) appendix. The procedure is used as described in the research methodology.

The CDM was designed to efficiently gather data on the basis for proficient performance of naturalistic tasks.

> *"It is a theory-driven strategy that is based on the assumption that expertise emerges most clearly during nonroutine events and focuses on these as the prime source of information. The events have actually occurred, so there is no need to develop artificial simulations that are limited in contextual richness and are time-consuming in preparation and validation. The interviews cover prior events, so there is no need to wait for nonroutine events to occur."* (Klein, 1989, p.462)

The researcher has unique access to the operation room at Copenhagen ACC and therefore able to build a picture of the key research lines of inquiry.

The use of semi-structured interviews was used to reveal what the controllers think is important when they make choices about splitting sectors. Open ended questions were used to allow informants an open field for explanation but guided by premade questions. Informants were also encouraged to tell stories about events surrounding sector splits. All questions were asked to get insight information about sector splits. Information that can lead to answer the thesis question.
ATC is a textbook example of where critical decision-making takes place. Features that help define a naturalistic decision-making setting are time pressure, high stakes, experienced decision makers, inadequate information (information that is missing, ambiguous, or erroneous), ill-defined goals, poorly defined procedures, cue learning, context (e.g., higher-level goals, stress), dynamic decisions, and team coordination (Klein, 1999). Copenhagen ACC is a working environment that contains most, if not all, of the elements mentioned by Klein, making CDM a preferred method for knowledge elicitation in this environment.

Hoffman states that *"The CDM is actually a combination of activities selected from the available palette of knowledge elicitation methods (retrospective, responding to probe questions, building a timeline, etc.)"* (Hoffman, 1998, p.264). Therefore, I believe that the method combination of storytelling and CDM will cover my research question:

"What are the Strategies used by controllers in their choice to split or not to split sectors in Air Traffic Control"

> *"Recent laboratory research (Buckner, 1997) suggests that the inclusion of illustrative stories in skills training can facilitate the trainee's recall of task instructions. Work using the CDM has dovetailed with this finding. Case accounts have served to enrich the trainee's knowledge of examples (typical, rare, challenging, etc.), to assist trainees in developing skill at situation assessment and recognition and to help prepare trainees to deal with nonroutine cases."* (Hoffman, 1998, p.259)

A bonus is that the results of making a CDM study often can serve as important training materials. Something I like to gain from my thesis. Since the ability to split sectors when the instructors believe it is the right time to split, is an important aspect in getting an ATC certificate.

Dekker and Nyce (2004) wrote about ATC, with examples of how they believe qualitative research should be carried out in order to make it useful to designers of new systems.

"Researchers must engage in second-order analysis, transforming informant statements about present work into terms designers can use in building future work (Nyce and Bader, 2002)." (Dekker, 2004, p.10)

The scope for this thesis is not to use the findings in order to change or improve how sectors split is performed in Copenhagen ACC or any other Area Control Center, even if the results of the second-order analysis could point at a useful direction. However, the methods for achieving useful results are the same.

"However, interviewing informants without doing higher order analytical work does not result in good qualitative research. Qualitative inquiry has to unpack informant meanings and categories, otherwise it hardly provides designers with helpful input for the creation of future work (e.g. Forsythe, 1999)." (Dekker, 2004, p.10)

Research ethics.

Consulting Lund University's research ethics retrieved from https://www.researchethics.lu.se/research-ethics-information. I found no requirement to obtain an ethical permission for my research.

General Data Protection Regulation (GDPR) issues are covered by using and complying with the content in the consent form.

Consent form.

The consent form was handed out, explained to and the written informed consent was signed by the participants before the interview started. The full consent form is listed in appendix 3.

Limitations.

This study is based on a limited number of participants. While qualitative studies can have high validity by providing in-depth understanding of a phenomenon, generalisability or transferability of the study results to other contexts can often be limited. The interview was performed at Copenhagen ACC and data has been collected from employees at the Danish ANSP. It follows that the findings may not generalizs to other ANSP´s. The 13 participants interviewed in the study only pose 9 % of the workforce in the ACC. Increasing the number of interviews might have strengthened the results of the study.

All participants are coworkers - controllers, supervisors or management with whom the researcher shares daily work in the ANSP. The effects on the studies are considered minimal.

Concerning my own role in the research. A controller researching controllers in our common workplace. There could be raised questions about the ability to stay objective in the research. For me is not possible to stay objective. I bring my professional identity as a controller, as well as my own opinion on sector splits. My original idea was to include field work in the methodology, drawing on my own 25 years of experience as controller. But I have constructed an Analytical Strategy that reduces my own bias in the research results. The possibility to conduct the research in my own workplace - Copenhagen ACC, an industry that is not easily accessible, but where I have exclusive access, was considered more important than the bias coming from my role.

The interviews were done in various rooms in Copenhagen ACC. Interviews were held during breaks or at the end of the shift. No other person was present during the interview besides the participant and the researcher.

The interviews consisted of a 20 to 40 minutes semi-structured interview with each participant. The selection of controllers was done randomly, taking into account who was available for an interview during the period that was devoted to the task. Two controllers who were asked to participate in the interview declined. The participation in this study is voluntary and any participants may choose to withdraw from participating at any time. No one who was interviewed took advantage of that offer.
Ideally the participants should represent a broad range of the controller working group, that consist of 135 controllers divided into 8 teams. The research had no intention to take account of gender, except to include a representative distribution in the interviews. Also, an even distribution between the age of the controllers and part time controllers involved in doing office work was aimed.

The interviews were done in Danish and the citations translated into English by the author. This approach was chosen because the author is a Danish controller and all informants speak Danish. The risk that something is lost in translation was a factor to consider, but the depth and richness of the interviews conducted in the controller's native language was considered more important.

The list of participants are in appendix 2. Normally the list of participants will include the notion of work experience etc in detail. In this thesis the list is made with a spread of work experience in groups of 5-10 years, due to the risk of disclosure of the participant. However, in the thesis it is stated if the quote comes from a controller, supervisor or management.

The information collected during the interview will be kept strictly confidential and available only to the researcher and for the purpose of the research.

The audio recording will be erased together with all notes upon completing the research.

Analytical Strategy.

The analytical strategy was based upon the composition of different elements. First a model of actors was built using post-it notes on a white board to create a multiple perspective of Bandboxing/Splitting. Then informal discussions with all actors controllers, supervisors and management was held. The knowledge and perspective gained from the discussions combined with the researchers own experience led to the question set and interview guide. The analytical framework from Naikar (Naikar, 2017) with a Work Domain Analysis and Cognitive Work Analysis was used to draw a picture in regard to relationships, dependencies and the constraints placed on actors by the social and cultural environment.

The material used in the interview are included in the appendix. The questions asked to the controllers for this research can be found in appendix 1.

The taped interviews was transcribed into 13 word documents. The transcription from the recorded interviews to word document. It was done with the inspiration of a notation technique used in ethnographic studies, where comments about the tone of voice used or if a statement was said with humour or irony were added in parenthesis (Seale, 2006). Comments that add meaning to the text and if omitted easily would be lost during the coding process. The guidelines from Erlingsson (Erlingsson, 2017) were used to make sense of the material from the interviews.

Then the condensation and code process began. I looked for descriptions of events that happen almost every time a split of sectors take place, because that information paints a picture of how a sector split looks like most of the time. Then I paid special attention to when the controllers described situations when splits did not turn out as planned - the messy splits. And compared the messy split with a normal one. What stood out?

Next, I looked for words and phrases that were used and repeated by the informants. The results from this sorting created categories that were assigned with a colour. Based on the collared category's themes evolved. The themes was then sorted depending on what group the word and phrases came from: Controllers - Supervisors - Management.

Interview transcribes was reread to retrieve quotes and meaning of the themes. Findings was listed in a spreadsheet – drawing from thematic and actor network analysis. Then I looked for patterns to make sense of the data.

The last step in the initial process was to translate the quotes from Danish to English.
In order to take a step back and view the findings in a resilience perspective, I added a selective coding for resilience. This was done by using the framework suggested by Rankin (Rankin et. al., 2014). This framework will focus on the systemic part of where sector splits fits into the ATM system by adding a content analysis to analyse adaptive behaviour in everyday work.

A picture of Rankins strategy analysis is inserted below figure 5. (Rankin et. al., 2014, p.83)

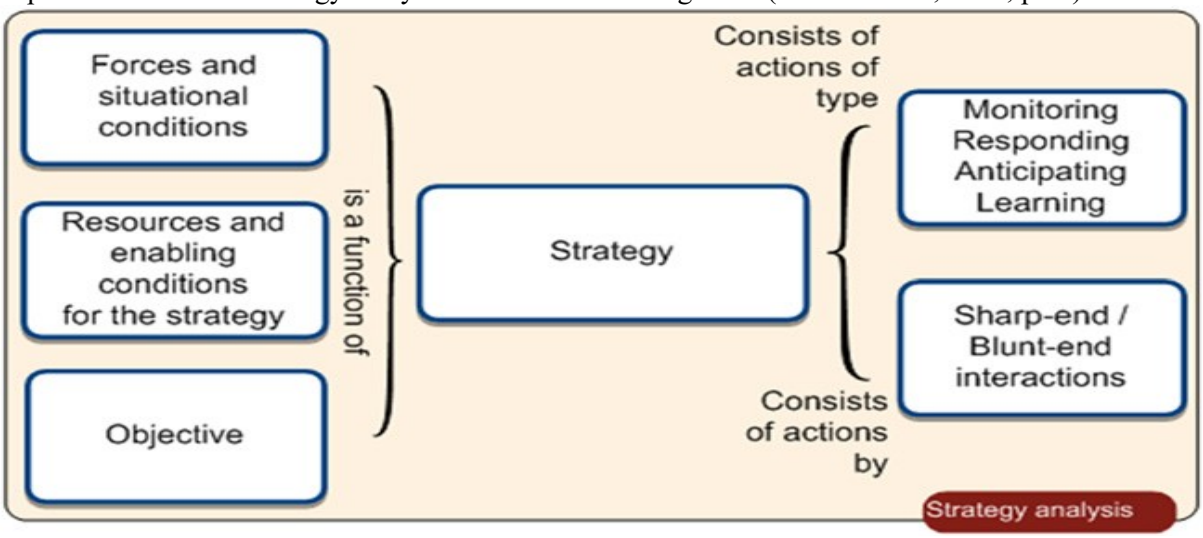

Figure 5 *The strategies Framework*

RESULTS

Air traffic controllers are used to handling variation in workload by making the choice to split and bandbox sectors. Therefore, participant controllers were asked questions about the strategy they use to make the choice. Supervisors and management were also interviewed to retain their view on sector splits in Copenhagen ACC.

During one of the first interviews one Controller said: *"In my 20 years as controller we have constantly talked about sector splits, that we need to split sooner and more often, that talk carries on".* (respondent 4)

When and how often sector splits are performed is not a new thing in ATC and the relevance is still present. The results indicate an interesting different view among actors, about when a sector should be split. Different goals between sharp end workers and management are well known, and arguably the essence of most operational systems. (Dekker, 2014)

The results will be discussed in three chapters, based on the themes found from coding. In the first chapter, controllers views and strategies used on sector split and bandboxing are presented. A second chapter contains supervisors and management view on the subject. With the third chapter being a second order analysis and discussion of the similarities and differences between controller, supervisor and management views on sector splits and explores the question to when and why controllers split sectors.

Context.

Several controllers described the historical change that came in 2006. Before 2006 the ACC control system was manned with one controller on a working position that consisted of a radar and paper strips, with the possibility to call for a planner to help with strips and make phone calls. In the current system 2 controllers are working together (EC and PLC) to constitute a sector. Both having a radar screen available and no paper strips.

The change meant that now two controllers must agree on when to split sectors, when workload and capacity approaches the limit. The split of sectors can also be dictated by the supervisor. Typical if the traffic volume is very high. It is very seldom that the supervisor dictate a split of sectors and that is probably the reason that when it happens, it draws a lot of attention. No matter who calls the split, it requires 2 controllers (EC and PLC) to man the new sector.

During the interviews, the questions listed in appendix 1. were asked to the participants and depending on the answer follow up questions were used to expand the statements. The answers were transcribed and then coded and analysed as described in the methods section.

Themes formed from the coding categories:

- Reasons to split sectors
- Reasons not to split sectors
- Reasons to bandbox sectors
- Stories about sector split
- Radar/Planner, Supervisor and management relations
- Professional Identity - Tribe - Professionalism - Different work teams.

The first three categories contain the reasons to split sectors or not. Then follow three separate categories. First the stories surrounding sector splits, because as argued under previous research, stories are an important source of knowledge. Second relations between all actors involved in sector splits. Last part is about how the professional identity influence sector splits.

The Controllers view of bandboxing and splitting.

Interviewing controllers revealed many statements and opinions, that via follow up questions created a foundation for the findings. *"If the traffic numbers are only high for a short period of 5-10 minutes, it is OK to keep the sectors bandboxed, it keeps you sharp"* (respondent 4). The same controller said *"We have all been in that situation that we should have split 5 minutes ago"* (respondent 4)

The two quotes above serve as a starting point for the results gathered. It indicates that the controllers sometimes choose to keep sectors bandboxed and the choices sometimes lead to situations where the controllers in retrospect wished they had split sectors instead.

Reason to split sectors.

Most controllers agreed on the main reason to split sectors, is to avoid an overload situation with too many aircraft in the sector and on the frequency at a given time. Controllers told that they do not count the actual number of aircraft but are aware that numbers count. All controllers stated that they use traffic numbers in their choice to split sectors. First, they look at the predicted traffic count on the info screen, located in front of every control position. It shows the predicted number of aircraft in the chosen sector configuration for the next hour, divided in blocks of 20 minutes. If the numbers are high, controllers can ask the supervisor to provide occupancy numbers. Occupancy show in more detail how the traffic is spread. Controllers explained that occupancy numbers were a useful tool, used to provide information about if traffic will come evenly distributed. If occupancy shows a high spike, it could be a reason to split sectors. Some controllers also use the sector list on the radar, where they can see how many aircraft the EC has on the frequency, and how many aircraft that will enter the sector within the next 10 minutes.

So, controllers state they have 3 different sets of numbers that they use: traffic numbers on the info screen, occupancy numbers on printed paper and the sector list on the radar screen. Pictures of all 3 are shown below.

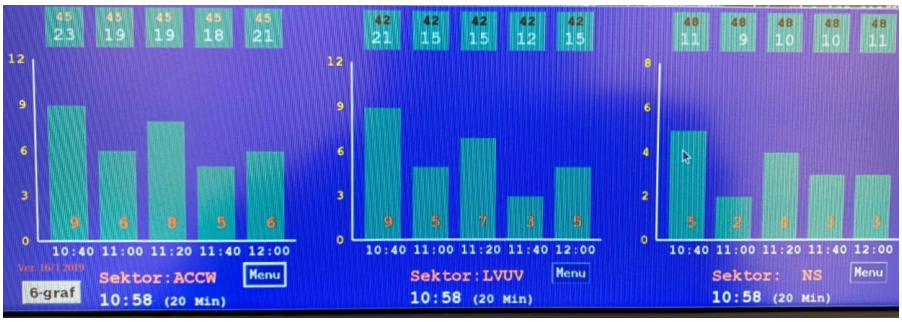

Figure 6. *Traffic numbers from the info screen.*

Figure 6 shows the traffic numbers from 3 different sector combinations on the western sectors. First from the left sectors L, V, UV, N, S combined, called ACCW. Then L, V, UV and N, S split into 2 sectors. Each column shows how many aircraft that are predicted in blocks of 20 minutes. E.g. at time 11:00 at ACCW there are predicted 6 aircraft to enter the sector until 11:20. The sector capacity is set at 45 aircraft an hour. The predicted numbers of aircraft between time 11 and 12 is 19 aircraft, well below the capacity. So, in this case all sectors L, V, UV, N, S would be combined. If the sector L, V, UV, N, S are split into L, V, UV and N, S, the distribution are also shown in picture 5 (15 aircraft on

L, V, UV and 11 on N, S). Note that the sector capacity is different in case of a split. Combination N, S has a higher capacity of 48 aircraft an hour, where L, V, UV only has 42. The sector capacity is decided by a small group, consisting of a few controllers, the flow manager and one supervisor.

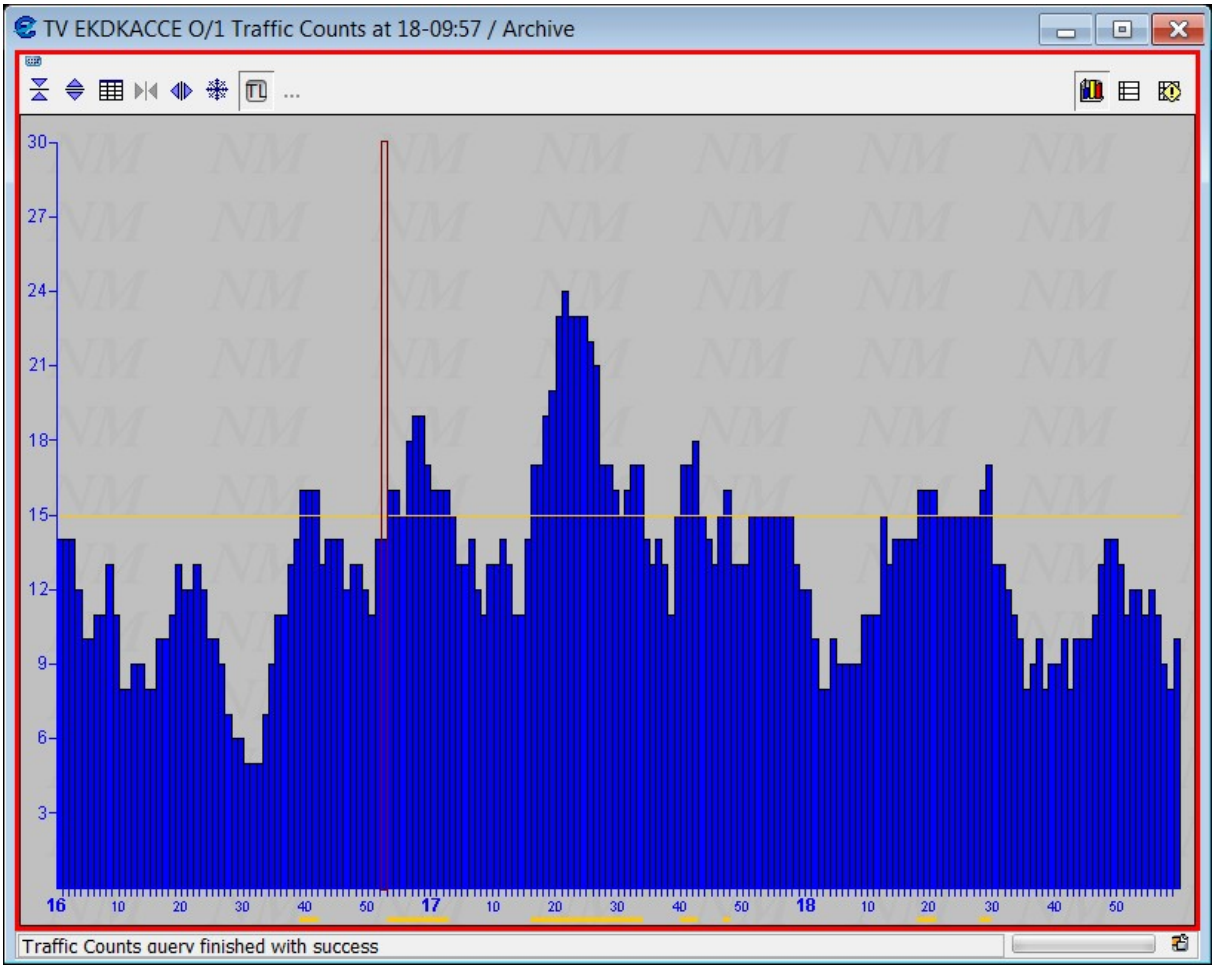

Figure 7. *Occupancy numbers.*

Occupancy numbers (Figure 7) show aircraft for all East sectors A, C, UA, UC, B, D, E, I. The blue columns show the predicted numbers of aircraft inside the sector pr. minute. E.g. time 16:00 to 16:03 there are estimated to be 14 aircraft. Then the number will drop to the lowest at 16:33 with only 5 aircraft.

The yellow horizontal line starting from 15 show the sector capacity, that equals 45 aircraft an hour.

By using the traffic numbers from the info screen and making a comparison with the occupancy numbers, the controller can detect nuances. If the traffic numbers read 19 aircraft in a 20-minute period, that is a little above the capacity. Then the controller will turn to the occupancy numbers to get information about how the aircraft are distributed in the 20 minutes. Is there a spike or is it evenly distributed?

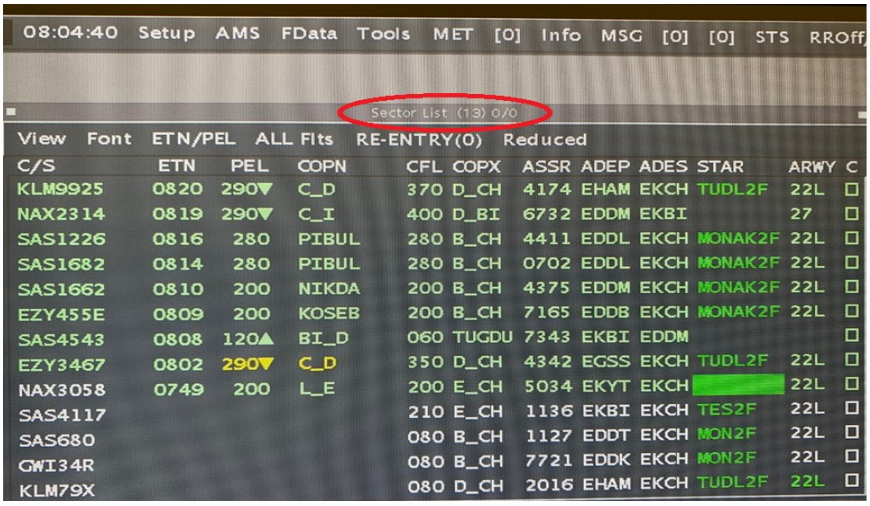

Figure 8. *Sector list.*

The sector list (Figure 8) shows all the aircraft that are on the controllers frequency. If the call signs to the left are the colour white (in this list there are 5), it means that the controller talks to the aircraft. The green call signs (eight in the figure 7) are aircraft that will enter the sector within the next 15 minutes, there are 8 green. The red circle added in the top, shows the total sum of aircraft on the frequency and the ones that will call within the next 15 minutes. Here it is 13 aircraft. The sector list gives the controller an indication of how busy it will become within the next 15 minutes. One colleague described the daily working method towards sector split. *"In the beginning of the working session we look at the traffic numbers and talk about them. Maybe we just wait and see how it will turn out, or agree to split right now, it all depends"* (Respondent 2)

What "it all depends" on is interesting. Controllers agreed that it is a shared responsibility to ensure that sectors are split before the workload becomes too high. Controllers stated that they try to decide the capacity not for the day, but for that next hour where the radar and planner controller is working together.

- Some factors that influence the capacity of the day is weather. Turbulence will decrease the capacity, due to the increased numbers of level changes and time spent on frequency to inform pilots about the turbulence. It is the same with towering Cumulus clouds that will lead more aircraft to fly on headings around the clouds resulting in increased workload for the pilot and the controller. Clear weather brings an increase in photo flights and small aircraft flying according to Visual Flight Rules (VFR). Military exercises take some capacity, due to the blocks of airspace inside the sectors, reserved for military activity.

- All these outside factors and several more, will make controllers split sectors sooner because they know that these factors will add to the pool of uncertainty, increase workload and take up time.

There are also factors on a personal level that leads to an early split. Several respondents mentioned the relationship between the radar and planner and how the level of trust and reliance on the co-worker will affect the capacity and the willingness to stretch the line where sectors are split.

One controller said *"I am willing to stretch the time before calling a split, if my co-worker and I work in the same way and we both are aware that it will get busy."* (Respondent 13). Therefore Radar/Planner relationships was made a theme of its own.

Common for all external and personal factors is that it will affect the workload the given day and it is impossible to predict how big an effect it will have on capacity, because the variation is too high.

One controller stated *"There could be a thousand reasons for colleague to call a split"* (Respondent 1)

The line or time to split sectors are not visible to others and not even to the individual controller. Therefore, the controllers try to verbalise how they see the line today. Statements like *"I feel great today - bring it on"* (Respondent 2) is used to tell the college that the controller is ready to work hard and will split sectors late. On the other hand, statements like *"I am not on top of things today, so expect an early split"* (Respondent 1) indicate that the controller is not ready for a heavy workload today.

Several controllers mentioned that before splitting sectors, they could use some other measures to delay the decision to split. The measures was indented to slow things down, a controllers used the phrase "to buy some time". Also, a change in how progressive the traffic was handled was mentioned. An example was the use of level separation, when the traffic volume was high, the controllers often choose to use level separation between aircraft, instead of a more complicated solution involving headings, that demands more work and constant monitoring. These strategies correspond well with the theory of resilience, the system must monitor what is going on and respond effectively when something happens.

The controllers own awareness on current workload is important because the time to split is not clear or defined. Controllers state that there always must be an extra amount of capacity left to handle an unusual situation. *"You need a buffer for an emergency, we are in the safety business"* (Respondent 4)

The numbers 5-10% are mentioned as the buffer that must be saved for unusual events. *"You need that extra 5% for if something out of the ordinary happens"* (Respondent 4)

Eurocontrol uses words like "unusual", "emergency" and "abnormal" situations to cover for events that require controller action and sets of checklists has been developed to support the controller. (Eurocontrol, 2020)

But how "unusual" is understood and perceived by the controller is very individual. Controllers talk about and agree that they need to preserve time and capacity to deal with unusual situations. To have extra 5-10 % capacity for the unusual event, out of a capacity that varies every day. Many episodes were mentioned where an unusual or abnormal situation was the trigger for a sector split. Typical where the ATCOs found themselves in a situation they would define as unusual. One example mentioned was with a small aircraft where the controller was not able to make input about the track flown in the computer system that support the operation. The effort took up time, and the situation ended up in a sector split, also because the controller lacks time to solve the other tasks needed. These types of events increase workload and reduce the controllers capacity quickly. Or as controllers mentioned these situations. *"Problems with system input use up our buffer"* (Respondent 9). The buffer is a key element for controllers in their choice to split sectors. In order to keep the buffer intact, the controller could take measures to change the way the traffic is handled (change strategy), by slowing the traffic down using speed reduction or using level separation. These measures/strategies are part of the adaptive capacity of the system.

Controllers use the word "buffer" when they describe the need to maintain and preserve capacity for unexpected events. Gissel (2007) uses the term "Sizing up" to describe the same thing. Using resilience engineering terminology, the "buffer" is associated with "adaptive capacity". So, to stay in the resilience terminology - controllers will split sectors to keep their personal buffer intact and the adaptive capacity of the system.

Reasons not to split sectors.

At any time during the work shift, but especially when traffic numbers exceed the announced capacity, it is up to the controllers to make the choice to split or not. Sometimes they choose not to split.

What is the rationale behind that choice?

One controller said *"It is OK not to split if is only gets busy for a short time like 5 to 10 minutes"* (Respondent 3)

Most controllers also mention that they need to stay sharp, as an explanation for not splitting sectors in the presence of high traffic numbers. One controller answered the question, what does it mean to "stay sharp" for a controller? *"It is a craftsmanship; you need to use it to maintain it and be good at it. It is important work we are doing, so we need to be sharp - the pilots expect it"* (Respondent 9)

Asked what is meant by "staying sharp"? Most controllers gave the answer that it is the ability to control aircraft in a heavy traffic load. Asked why it is important to be sharp, and not just competent, one controller answered. *"If you feel sharp, it is OK to handle lots of traffic, you get to miss that feeling if you only handle low volume of traffic"* (Respondent 9)

The next explanation for not splitting sectors is using a term used amongst controllers to describe a situation where it is some time ago since they handled heavy traffic. In Danish is called "Rusten" translated into English "rusty". To be "rusty" is a common way for controllers to address that they have not been working in heavy traffic for some time. It could be due to leave of absence, long holiday or the most common reason - part time office work. A controller stated:

> *"If a controller says, "I feel a bit rusty today", then all is good. Because the controller is aware of what level he can work on. If he is not aware of his current level, a sector split could be done to late"* (Respondent 5)

In order to get rid of the "rust" controllers say they need to "knock rust". Keeping sectors bandboxed is one way to "knock rust" and is explained by saying that you need to "knock rust" in order to "stay sharp" or become sharp again. *"You lose your sharpness if you do not use it"* (Respondent 9)

To explain the last reason not to split sectors, controllers used the Danish word "Sjovt". Direct translated into English "Sjovt" is "Fun". However, "Fun" does not entirely cover the meaning of "Sjovt".

A controller will use the word "Fun" to describe a situation where controllers are working in heavy traffic and all goes well. Controllers enjoy the busy workload. It is fulfilling and provide job satisfaction. "Fun" should not be understood as entertainment.

Reasons to bandbox sectors.

I included the theme "reasons to bandbox sectors" because it was specifically mentioned by several controllers during the interviews. Controllers bandbox sectors to achieve a higher level of traffic numbers.

Controllers mention that reasons to bandbox sectors are the same reasons why they do not split sectors. They want to avoid boredom. Most controllers mentioned during the interviews that working a busy sector was desirable, because it is "Fun" and time passes quickly. Some controllers even mentioned that they would show up early after a break to replace the working controllers, in order to work the radar position on a busy sector.

Also, controllers mention that bandboxing sectors leads to more controllers on standby. So, bandboxing sectors serves multiple purposes. It keeps the working controllers busy and provides the standby controllers a longer break, as well as it will save resources for later use. Which again, preserve system capacity.

Stories about sector splits (or splitting).

During the interviews, the controllers were presented with the three stories about sector splits mentioned in the introduction section. Almost all controllers interviewed had heard the stories, and all could add more stories to the pool of stories told about sector split. The controllers had strong views on the moral in the stories, either *pro* or *contra*.

I chose to adjust the stories questions after the first interviews, in the direction of what stories the controllers would like to tell the controller students, to pass on the experience from sector splits. The result was clear, most controllers stated that the stories should contain examples on when a situation turned bad because something unusual happened. One controller said. *"Tell the students to remember to include a buffer for the unexpected"*. (Respondent 1)

The quote above indicates that controllers in their work must save time and capacity for unusual events. Because experience shows that it is sometimes needed. This is one example of the nature of buffer capacity in ATM at the sector level.

One other type of story was mentioned, about how sector splits create boredom due to the decreased workload. Controllers see a risk in boredom, it resolves in increased noise on the work positions, because the controllers have time to talk about other subjects than traffic. Boredom affects the controller's vigilance. So, most controllers see boredom as something to be avoided, and therefore adds to the reasons not to split sectors. It is in line with what Weick (1987) says about boredom and errors in ATC as described under previous research.

No stories or episodes about sector splits containing an emergency situation were told. This is an indication of how rare emergency situations are.

When they occur, they need to be dealt with instantly. Controllers tell that usually there is no time to split sectors, even if a split would have been done if the unusual events were known in advance. In emergency situations the controllers use the pager system to call for backup controllers. The same pager system that is used if sectors should be split.

Radar/Planner relations.

Most of the controllers told during the interviews that they have been in situations with disagreement between radar and planner controller, about the choice to split or not.

Most of the time the disagreement ends up with the controllers performing a sector split. The principle of precaution is used, so the rationale is that the lowest common denominator sets the level for the time to split. Asked how they settle the disagreement, most controllers agreed upon that the radar controller has more to say about when to split than the planner. Because the radar controller is in direct radio contact with the aircraft, where the planner takes care of the planning and coordination. So, the radar controller is performing a more time critical job than the planner. However, it is teamwork to control a sector as a controller described.

> *"I have not experienced a situation where the first to call a split is not respected. I have myself been in situations where I was on top of things, but my planner was not. If my planner call a split, I will back that call up, because I want to be sure that I have my co-worker with me all the way"* (Respondent 13)

All three explanations for not splitting sectors "feel sharp", "knock rust" and "fun" are controversial. Because there is a different view on when to split among controllers: *"From the controller that wants to split first to the controller that wants to split last - there are a big gap"* (Respondent 6)

The gap appears to be created by the difference in the view on the above factors. While most controllers interviewed tend to lean towards not splitting sectors or split as late as possible, two controllers interviewed positioned themselves at the other end of the scale. *"We are not here to knock rust" and "I do not work because it is fun, I create safety"* (Respondent 10).

At this end of the scale controllers argue for an early split, as soon as the traffic numbers indicate a split. Still controllers that do not want to split sectors early end up with the feeling of a missed opportunity to "feel sharp", "knock rust" and have "fun" if they are forced to split. Exemplified by a controller *"I can recognise myself when I am working radar position and it just flows, then it is a pity that to split sectors"* (Respondent 2). Followed up with the question: Why is it a pity? The controller answered *"It is the desire to be busy, when traffic flows it is a great feeling to be in control of it all. So, I know the resistance to split sectors, but you must just accept it"* (Respondent 2)

There is ample opportunity to discuss that sometimes awkward situation shortly after the split is performed, since the traffic volume in the new sector configuration is reduced. Most controllers end the discussion by agreeing that the sector split was done at the right time. But during the interviews stories about disagreements about sector split, where the controllers did not come to an agreement were told. Some controllers mentioned that they take extra care when they work together with certain colleagues: this is part of the stories told where some controllers have a reputation of splitting sectors either early or late. One controller mentioned how to deal with these situations. *"My experience tells me that a sector split should not be discussed too much, if I want to split, I just say so"* (Respondent 2)

Others also said that there is no reason in turning the choice to split into a discussion. Nothing good comes out of these discussions. One reason could be that the co-worker are about to "lose the picture" One controller described the impact of "losing the picture"

> *"It comes down to very few occasions where I have lost the picture. When you reach that point, it is not funny anymore. We have the most fun job in the world when we work and are in control. But nobody thinks it is fun to hang on by the fingernails - there are too much at*

stake... Nobody wants to lose the picture; it hits your ego and professional pride"
(Respondent 13)

During the interviews it became clear that there exists disagreement between controllers about when or when not to split, but most of the time the issue resolves itself.

Some controllers mentioned the numbers of controllers on duty has an impact on how often sectors are split. The watch is normally staffed for the worst case scenario, meaning that there are enough controllers on duty to man all new smaller sectors after a split. A scenario that occurs in case of an unusual event like bad weather or a closed runway. Events that will create increased workload for the controllers beyond what is considered normal.

If sectors are not split, there will be a number of stand by controllers in excess on the watch. Some controllers argued during the interviews that the standby controllers should be used to split sectors earlier than usual. Because the lower workload could increase the level of service delivered. Others argued that the presence of standby controllers is a reason to keep sectors bandboxed for longer than usual, because the reassurance of having fresh controllers ready to work on standby, leads to a sense of safety that help is near, only a call away. So, the presence of backup could be used to "feel sharp", "knock rust" and have "fun".

One thing the controllers agreed upon was the situation where there are too few controllers on duty, or just enough to keep the shift running, lead to situations where controllers kept sectors bandboxed for longer than they normally would, in order to facilitate a break pattern and not use up the controller resources.

The importance of having backup in the form of standby controllers was mentioned by most controllers during the interviews. Usually there are backup controllers available in Copenhagen ACC carrying a pager that can be ready to assist and split sectors if needed. When on standby and the pager starts to sound, the controllers only know they are requested in the operation room. They do not know what task that awaits them. It could be to split sectors due to high traffic or to assist with an emergency situation. The uncertainty of what will happen is present for both the controllers working the sectors and for the standby controllers.

Despite the tension between the Radar/Planner about when to split sectors and make use of the standby controllers there are also synergies if we go beyond the individual and look at the relationship between the individual and the system. The system gain an adaptive capacity that goes beyond the static boundary that would exist if the Radar/Planner was not able to make the choice when to split sectors. According to the staff manager in Copenhagen ACC we would need more ATCOs on duty than what we have with the flexible opening and closing of sectors, if we were to open and close sectors using the traffic numbers alone, (Rasmussen, J.R., (personal communication, 2019)

Professional Identity - Tribe - Professionalism - Different work teams.

During the interviews many controllers made comments that connect to the professional identity of the controller. *"We are a breed that are proud of controlling aircraft"* (Respondent 1)

Controllers show an enthusiastic approach to the work they perform. They connect and judge each other's performance based on when sectors are split. One controller said. *"You are a better controller if you can control lots of traffic and do not split"* (Respondent 1) Another: *"If you control lots of traffic and it suddenly becomes above your limits, you are not a good controller"* (Respondent 4)

To be a competent controller you must be able to ensure an orderly, safe and efficient flow of traffic and at the same time be able to make the choice to split sectors before you reach your limit. It is that balance that controllers try to achieve.

In Copenhagen ACC each controller belongs to one out of eight teams, each team consists of 12-16 controllers. During the interviews several controllers' broad up teams, and how the eight teams look different on sector split. A normal watch in ACC will contain 16 controllers mixed from the eight teams.

Asked how team "x" timed sector splits, most of the controllers had an answer on the team performance, either early or late to split. Controllers belonging to a team are anecdotally either early or late to split sectors.

One controller told about a situation where the controllers working informed the controllers on standby with pagers, that sectors properly would be split shortly, when the controllers on standby heard about it, they said. *"Oh no, are we on duty with "splitters" today"* (Respondent 6)

Introducing a new concept "splitter". Controllers that will split sectors earlier than others are referred to as "splitters".

The controller continued to add another perspective on "splitters". *"If you belong to a team where 80 % have the attitude that something called "splitters" exist, then you will move in that direction and accept that "splitters" exist"* (Respondent 6)

A common saying among controllers when they talk about operational work like splitting sectors: *"I have turned the aircraft I need to turn"* (Respondent 10)

The expression is used by controllers that have many years of experience, typically more than 20 operational years, to emphasise that the controller talks about a subject with experience. The many years of experience has contributed to develop the professional identity as a controller.

The results concerning the controllers thoughts and strategies about sector splits will be dealt with later in the discussion section. In order to understand the next part of the results dealing with supervisors and management, it is important to realise that the professional identity of the controller is a fundamental part of the choice to split sectors or not.

Supervisors and Management.

This chapter will address the view on sector splits from the perspective of supervisors and management.

The Supervisor group consists of 19 people, all controller educated. 13 are still active controllers working part time controlling aircraft in combination with supervisor duty. Six supervisors work full time as supervisors. The supervisor duty is split in two. One is working as a watch supervisor (WS) the other as a Flow Manager (FMP). All supervisors can operate both positions. Supervisors have overall responsibility for what goes on in the ACC, they monitor the traffic numbers on the flow position, so they have a legitimate voice about when sectors should be split. Therefore, I have included the view on sector splits from the supervisor perspective.

Supervisors are positioned in the same room as the controllers, the ACC. Still controllers and supervisors point out that there is a mental distance between the two groups concerning sector split.

One controller described the distance as: *"They (SUP) have a different view on sector split than we (ATCO) have, they (SUP) have a "What if it turns out bad" perspective, if not as the only view, then the primary view"* (Respondent 9)

During one of the last interviews one controller reflected upon sector splits and the way is done in Copenhagen ACC and stated:

> *"As controllers we are raised to be conscious about our capacity and our responsibility. We must detect and dare to ask for help when we reach a boundary defined by ourselves. You remove that ability if it becomes a dictate when to split sectors and when not. Supervisor has a responsibility, if they say "I don't want controllers driving so much traffic on my watch" then you have to accept it. But you must have your own limit too. The more you dictate the more people forget to notice their own limit".* (Respondent 13)

This quote contains many of the aspects the different actors face when dealing with sector splits and also point at answers to why and when controllers call for help.

A supervisor pointed out that with more than 120 controllers, every watch is composed with controllers with different capacity and opinions on sector split. Some days the composition of the controllers on duty influenced how supervisors act*: "There are combinations of controllers where I think it is best to provide occupancy numbers more often than usual"* (Respondent 5)

The supervisor elaborated that the extra hand out of occupancy numbers was done as nudging towards controllers to visualise the high traffic numbers to controllers. This is done physical by the supervisor, who will walk down to the controller working positions, with occupancy numbers on a printed paper to raise awareness on the current and coming traffic situation, because the supervisor believed the high traffic counts should turn into a split of sectors, but had doubt that the controllers on duty would split sectors.

I asked the supervisors if they have tried to dictate a split, and if there were a common agreement within the supervisor group on how and when to dictate a split should be done, in order to handle situations where the supervisor felt a split of sectors is needed. While one supervisor had not tried to call a split but used tools like providing traffic numbers more often than usual. The other supervisor interviewed had tried to dictate a split. That event ended up creating one of the stories that are told among controllers about sector splits. The controllers did split sectors when the supervisor called it. After 1½ hour the sectors remained split even if the traffic were very low and would normally be

bandboxed into one sector. The supervisor went down to the controllers to ask why the sectors was split, and the answer was: *"If you call the split, you call the bandbox as well"* (Respondent 7)

Clearly an event like the story above creates an experience for the supervisors. And they have created methods to avoid a disagreement with the controllers. Instead of dictating a split supervisors told that they approach the controller work positions and talk to the controllers working using phrases like. *"How come you still have one sector, is the traffic not complex today?" or "The traffic numbers indicate a split"* (Respondent 7)

The phrases are used by the supervisors when delivering fresh occupancy numbers to the controllers. Leave behind the choice to split or not to the controllers.

Supervisors have monthly meetings, where all supervisors attend, except those on duty. In this meeting the daily challenge with split and bandboxing sectors are discussed.

Also, on a meta level. *"If you overrule a controller that feels he is in control, you mess with his professionalism and pride"* (Respondent 7) Said by a supervisor during the interview. When the supervisor interferes in the controllers work by dictating a split, the supervisor also address the professional identity of the controller. A supervisor mentioned that as supervisor you have an obligation to take care of all controllers in the ACC despite the controllers personal capacity. *"The chain is no stronger than its weakest link"* (Respondent 7)

An argument used by supervisors is that the ACC is staffed with enough controllers to handle worst cases, meaning that it should be possible to split sectors when traffic numbers exceed the chosen limit for the sector combination. Therefore, when working as supervisors the informants said that they would prefer a split of sectors, and let the controllers work in low traffic with the boredom it creates. On the other hand, the interviewed supervisors told that when working as controllers they liked to work in heavy traffic because it is fun and challenging.

During the interviews with controllers, the role of supervisors came up frequently. All controllers agreed upon, that if a supervisor called for a split of sectors, then the sectors would be split. Supervisors have the power and authority to dictate a split. However, there were frequently comments about the lack of authority the supervisors have when it comes to dictate a sector split. One controller framed the controller-supervisor context as: *"A supervisor is just a controller that sat down in another chair"* (Respondent 1).

On step up in the management hierarchy, above supervisors is the manager of operation (MO). The MO is a former ACC controller who has been working in management for more than 10 years.

The MO participating, described during the interview, that the procedure to let the controllers make the choice to split or not, is based on the operational situation where the traffic is not regulated in Copenhagen ACC. It is a choice not to regulate, which means not to delay traffic in peak hours. Management in Copenhagen ACC have that opportunity as a build in buffer to handle most situations, because there are enough controllers available to cope with the traffic load by splitting sectors. A situation different from many other ANSP´s in Europe where there is a lack of controllers and therefore regulations are in force. So, according to the MO the choice to split sectors lies best with controllers working the sectors in a non-regulated working environment.

To support the choice when to split sectors, traffic numbers are available as a support tool that should help the controllers in their choice. Based on that tool the MO feels safe by delegating the choice to split sectors to the controllers. But points at cases where sectors kept bandboxed in the presence of high traffic numbers. To the MO it seems like an unnecessary act, since there were enough controllers to split sectors. The MO said that the challenge is not that controllers handle too little traffic, but too much. MO wonders why sectors are not split 10 minutes before the controller knows that sectors need

to be split. So, the split can be performed in a quiet and calm way. By splitting earlier, the two arriving controllers that perform the split can be working while traffic builds up.

The MO stated that to him controllers wanting to "stay sharp" by "knocking rust" has no place in the ACC. All controllers should be competent. *"We have made a baseline; below that line the controller should be able to handle the traffic. Above the line there are some issues that we need to take a closer look at"* (Respondent 12).

One way to deal with the issues of handling traffic above the baseline, is to use simulator training. If there is a need for capacity training in order for the controller to "stay sharp", then the training should be performed in a simulator. MO uses the phrase "knock rust" to explain the use of simulator training for controllers. MO suggests that maybe there should be an upper limit to how much traffic in numbers the controllers should be allowed to handle on a given sector combination, before sectors must be split. To ensure a level of safety and service and to protect the controllers, supervisors and management from ending up in an overload situation. MO pointed out that a high level of traffic numbers leads to increased frequency time. And then stated*: "What if something happens"* (Respondent 12).

Supervisors and management stated that they are aware that controllers have different capacity and therefore split and bandbox sectors at different times and levels of traffic volume. Supervisors extend their service to controllers by fitting the delivery of traffic numbers to the individual controller on duty. By doing that the supervisors support the controllers, so the controllers are able to make the choice to split sectors or not on a more informed basis. The interaction between supervisors and controllers also illuminates the organisational adaptive capacity created by the cooperation between actors.

This ends the results part of the thesis, where the data from the interviews was used. Now we move on to the discussion part.

DISCUSSION

The results section was divided in two groups of actors, the controllers and supervisor - management. Each group gave their view on sector splits.

In this discussion section, the findings from all actors will be combined in order to explore why the actors gave answers the way they did during the interview. The benefit of combining the results is to gain a systemic view on sector splits and to shed light on connections not clearly visible to all actors. Also, second-order analyses will be used in this section of the thesis.

Help.

A basic question that calls for an answer is: what makes a professional worker like a controller call for help?

For a controller help is to split sectors some time before workload exceeds an acceptable level. But who and how defines what an acceptable level is?

Controllers describe the training before validating as they are being "raised" or "brought up" to be conscious about capacity and the responsibility to call a split. However, for the controller student most focus is on building capacity. Capacity in the way that controllers use the term is the ability to control a high number of aircraft safely. When the level of capacity and safety is considered as suitable by the instructors during OJT, the student is nominated for validation. The validation is where the controller student receives an ATC license and marks the point from where the controller can work alone. It is not enough that the student is able to work hard and possess a high capacity. To pass final evaluation and test, the student must show competence in self-awareness about capacity and call a split of sectors when needed.

After receiving their ATC license the new controller gets included in the "tribe of controllers". The tribe relies upon that all members are aware of the responsibility to call a split when needed. As mentioned by Hayes "Inexperienced controllers have a tendency to take on too much (traffic)" (Hayes, 2013, p.93). Anecdotally it seems true also in Copenhagen ACC, that new controllers take on too much traffic in the time after validating. When they call for help it is more often late than early. So even after validating, the identity of the controller continues to develop and will end up fitting into the tribe of experienced controllers that during their work life has developed a professional identity.

The professional identity of a controller is connected to the ability to control a high traffic volume without splitting sectors. One controller framed it as: *"We are a breed that are proud of controlling aircraft"* (Respondent 1)

The quote was used to explain why controllers take on a heavy traffic load instead of splitting sectors. If the situation turns out well, without any incidents, the controller has proven high status in the tribe of controllers.

One argument for this is that controllers are constantly trying to optimise their performance and through this, the system's performance. *"As experts refine their knowledge and optimise their responses, they remain open to new information and are not afraid to take the extra mile and risk in order to discover new responses." (*Malakis & Kontogiannis, 2021, p.365). The use of the phrase "the extra mile" is highly relevant to the way that controllers perceive their role. The willingness to go the extra mile is part of the identity and professionalism that encircles and shapes the controller's controlling work.

But the self-awareness of capacity, and the ability to call a split is still as valid for experienced controllers as it is for students. If a controller fails to split sectors and ends up in an overload situation, it can have an impact on the controllers own perception of professionalism, but also how the rest of the controller group view the controllers ability to perform safely. If the group assess a weakened ability it will translate into a lower status in the controller tribe. Trust from the tribe cannot be underestimated.

So, the answer to the question why a professional worker like a controller calls for help is, that the controllers own desire to maintain their professional identity is what makes them call for help. This is concordant with Malakis & Kontogiannis (2021) description of how experts are changing the infrastructure of the system of work to overcome obstacles in a permanent way. In this case controllers change, by reconfiguring the operational structure by splitting or bandboxing sectors. In doing so, these strategies are illustrative of adaptations in the work system that contribute to sustaining resilient performance.

The controllers define the right time to call for help by drawing a line to acceptable workload level. Calling for help could also be described as the controllers tool for not "losing the picture". Klein (1999) has written about how experts makes adoptions in their work, so based on the results, I have made the subject into a sub-category about "losing the picture". Because for the controller, the ability to detect when you reach a self defined boundary is vital. If not, it could turn into an overload situation. Some of these situations will create a story that is told and shared in the controller tribe.

Supervisors support the controllers by ensuring that there are enough staff on duty, so the controllers can split sectors when they want to. If controllers choose to keep sectors bandboxed, most supervisors will accept the choice. Especially if the choice was made in coordination with the supervisor.

If the controllers do not coordinate or inform supervisors that they will keep sectors bandboxed, supervisors will sometimes use nudging by bringing occupancy numbers more often to the controllers they have observed splitting late. The supervisors interaction with controllers can be seen as an attempt to create an intentional movement away from the boundary of acceptable performance. The challenge is that gradients are long lasting and the drift towards the boundary will resume. (Cook, 2014)

"Losing the picture".

One controller explained a situation where the feeling of "losing the picture" was present. *"I chose to call colleagues to split sectors because I started to lose the picture. I was not sure of the situation, I had doubt whether I had overlooked something"* (Respondent 13)

Outside the tribe of controllers, the phrase "losing the picture" could sound like it had a big influence on safety and must be avoided at all costs. But that is not always the case. Klein (1999) describes how experts use the feeling of "losing the picture" to make adoptions in due time.

> *"Experts are not only better at forming situation awareness and seeing the big picture, but they can detect when they are starting to lose the big picture. Rather than waiting until they have become hopelessly confused, experts sense any slippage early and make the necessary adaptations"* (Klein,1999, p.158).

With the current controller workforce in Copenhagen ACC, where all controllers have more than 7 years' experience, all controllers can be considered experts according to the Dreyfus 5 step scale. (Dreyfus, 1980) . To act on a feeling and split a sector based on that feeling is well known to experts. It is a normal reaction for experts to act on senses - they develop intuition, an ability controller builds over time (Klein, 1989). Still experts can find themselves in situations where the "picture is lost".

When controllers push to the boundary of how much traffic they can handle, for the reasons found in the results part of the thesis: "feel sharp", "knock rust" and have "fun". Controllers describe the obvious unpleasant situation to feel that things fall apart, those situations also have an influence on the ego and professional pride, that seems to be an important part of the controller tribe.

The importance of confidence for the controller in order to produce is addressed by Weick (1987) *"It is important to remember that confidence is just as important in the production of reliability as is doubt"* (Weick, 1987, p.119). The controllers confidence is supported by the perceived feeling of "being in control". What is meant by "being in control" is the controllers ability to control the situation. When situations occur where the controller loses the feeling of "being in control" it does not mean that safety is compromised, but the professional identity of the controller is affected. To the controller a blow on the professional identity hurts almost as much.

Malakis and Kontogiannis (2021) has an explanation for why expert controllers sometimes "lose the picture" :

> *"Under time pressure, expert controllers make assumptions in order to build a coherent explanation of the situation and accept them as true until there is reason to doubt them. Unfortunately, some assumptions may remain 'hidden' and never get tested as controllers may be unaware of them."* (Malakis & Kontogiannis , 2021, p.375)

For a student controller confidence is also important to focus on. The interviews with the controllers were partly focused on controller students and how students learn the skill to split sectors or not. The challenge will come with future student controllers. In order to validate as a controller, the student must show the ability to sense and act when it is time to split sectors. It has been more than 7 years since there has been controller students in Copenhagen ACC.

The challenge for students is framed by a controller who said. *"It takes experience to know when to split, it is a stomach feeling decision"* (Respondent 2)

Students do not have the experience built over time that creates a stomach feeling that enables them to act timely before they start to "lose the (big) picture". Also, they have opposing goals. On one hand students must prove that they can handle a high amount of traffic in order to validate and earn their place in the controller tribe. On the other hand, students must also show that they are aware of their own limitations and call a split before they lose the picture. The different narrative told on the team the OJT student belongs to about sector splits, e.g. "splitters" will affect the student and the student's perception of when to split sectors or not. A perception that could lead to an overload situation because the student does not want to be considered a "splitter".

For experienced controllers another narrative exists. They possess the stomach feeling build over time to detect an emergent overload situation.

Kontogiannis (2012) describe the experts stomach feeling

> *"Experts develop better mental models of the relationships between aircraft speed, wind or weather conditions and the resultant rates of ascending and route profiles. This knowledge is not captured in written documents but is built up from daily experience and feedback from on-the-job learning"* (Kontogiannis, 2012, p.17)

Malakis (2013) points to the intuitive feel built over time, to explain how controllers get the answer to a problem - and call a split.

> *"Controllers have spent considerable time learning their airspace, and they have developed certain expectations of traffic that flows through their sectors. One aspect of the learning process involves understanding the peculiarities of the airspace—controllers learn to recognise subtle cues in a stable environment that give them an almost intuitive feel for an answer to a particular problem".* (Malakis, 2013, p.225)

As a controller you do not suddenly "lose the picture". The feeling develops gradually and for the expert there are many clues before it happens. This provides time for the controller to act on the clues, either by slowing the traffic down or by splitting sectors. However, as Hopkins observes (Hopkins, 1995) finely adjudged discrimination of the potential workload where small increments of workload change can lead to a controller "losing the picture" is an indicator of the nature of controller judgment, working with uncertainty in changes of tempo in dynamic traffic situations or challenges and surprises. That few controllers interviewed for this research mentioned it as anything other than a feature of the nature of the controlling task as something to be acutely aware of but rarely experienced indicates the existence of a capability to adapt that contributes to sustained adaptability and resilient performance. Day in and day out. It represents a tacit indication at the micro level of the system's state, that is brought into play regularly as a facet of typical sector operations.

Buffers.

The awareness amongst controllers of losing the picture showed itself during the coding process. The talk of losing the picture was used in connection with having a buffer. The controllers said that the buffer must be maintained, to have some extra capacity left for unusual situations. Which is interpreted as situations that arise suddenly or emerge over time. Hopkin (1995) described the difference as the anticipation of a small increment of workload as opposed to the peak or high instantaneous workload levels. This implies some material difference between the two.
It also illustrates the nature of the adaptations that controllers and sector control teams engage in. It is through these that reconfiguration of sectors represents graceful extensibility (Woods, 2018, Woods and Branlat, 2011). This is similar if not representative of higher graceful extensibility, where a system has the capability to *"Anticipate bottlenecks ahead, to learn the changing shape of disturbances / challenges prior to acute events and possess the readiness-to-respond to meet new challenges"* (Woods , 2018, p.435 citing Woods & Wreathall, 2008, Woods et al. 2018). This characteristic is an intrinsic element of resilient performance in complex socio-technical systems.

A split of sectors could protect or sustain the buffer. I considered making the buffer a theme of its own. But decided to leave the buffer in the discussion section. The buffer is a well-known factor that is considered when ANSP´s set the sector capacity. E.g. NATS (UK ANSP) uses DORATASK to calculate the capacity. Here the sector capacity is set by total task load plus a parameter indicating the proportion of time necessary for controller recuperation, i.e. this parameter ensures a match to acceptable workload. (Booker, 2003) So, an extra parameter - the buffer is included.

The buffer or buffers are used every day, controllers know this from experience, it is only a question of when the controllers need to extend the buffer. The informants provide a naturalistic and real world perspective on buffers, how buffers are understood and feel. One controller described the buffer as something that has an 'extent'. The buffer has a beginning described as a soft boundary. *"You know you have reached that soft boundary, when you consider a sector split for the first time"* (Respondent 13). The concept of a border or a point where experts notes and realises something is well known. Klein (1999) describes it as "leverage points". When experts reach a leverage point in their work it indicates an opportunity for making changes. A small change that can make a large difference and can turn around a situation.

Malakis and Kontogiannis (2021) state that *"Experts seem to have acquired a large set of responses or practices that can be used in connection with leverage point to get the system to a desired direction"* (Malakis & Kontogiannis, 2021, p.361). What is intriguing about this statement is that it can be seen to be an expression of Ashby's assertions around complexity and the significance of requisite imagination that 'The complexity of a control system must be equal to or greater than the complexity of the system it controls."(Ashby, 1956).

The import of this is that the margins and boundaries are constantly changing, reflecting the dynamic nature and temporal element of the controllers workspace.

It was commented on by the informants that there is an area where "you start to lose the picture". This area exits before you reach the end of the buffer, described as the hard boundary. *"The hard boundary is where a split must be performed in order not to lose the picture"* (Respondent 13)

Behind the hard boundary you can end up in a situation that Klein (1999) describes as "hopelessly confused". The buffer appears to be the tool, the extra capacity controllers can make use of, to avoid ending up in a hopelessly confused situation where the picture is lost. Based on the data from the controller interviews, the choice to split sectors or not are made inside the buffer, somewhere between the soft and hard boundary. When working in workload situations below the soft boundary, the controllers will not think or talk about splitting sectors.

When controllers talk about the "buffer" they describe the concept as something personally. But there is another aspect of the buffer concept and that is the buffer of the system as opposed to the individual, team or sector buffers. For the ATM system to work it needs to be able to absorb and adapt to the variations and fluctuations that occurs every day, every hours.

The use of sector splitting and bandboxing based on experience to preserve the buffer fits well into the description of a resilient system. *"Resilience engineering focuses not only on creating resilient systems but also on maintaining and managing system resilience."* (Rankin et al., 2014, p.94)

As discussed above, the controllers ability to finely judge changes of tempo and future traffic states in terms of the shape of the system and potential of workload, business and difficulty is one example of what Rankin et al. discuss.

While controllers contribute to resilience with focus on their personal buffer, supervisors and management are also focused on maintaining resilience in the system. This is seen because supervisors and management during the interviews have expressed focus on the important aspect of saving time and capacity for "something" and that could be achieved by splitting sectors sooner than generally seen. Wieck (1987) used the word "slack" instead of "buffer" to describe the same ways of acting.

During the interview's controllers mentioned that the buffer is not only viewed as an extra capacity the controller can activate when needed. The buffer also consists of contingency such as controllers on standby, that via pagers can be called upon to assist or split sectors when traffic numbers get high or an unusual situation occurs. The reassurance of possible help if needed, adds to the controllers buffer and increases the controllers willingness to work at high workload.

The number of controllers on duty is planned months in advance based on traffic forecast and comparison of traffic numbers on the same day the year before E.g. if there were 1865 flights on April 4 last year, the number 1865 is used as the benchmark for April 4 this year. Supervisors decide the number of controllers needed on duty any given day based on the benchmark. But the controllers partly decide the use of the overall number of controllers on duty by splitting and bandboxing of sectors. If sectors are kept bandboxed, there will be a number of controllers on standby. They are available on call if or when sectors should be split.

Supervisors and management view the excess of controllers on duty as an opportunity to split sectors well before traffic numbers are getting high and maintain sectors split during the watch. The lower traffic volume on the split sectors could be used to provide a better service to the aircraft. Brooker (2013) calls this better service a "luxury" service e.g. provide expeditious routing and better climb/descent profiles. The service ANSP provides is safe and expeditious flight and that service can, according to supervisors and management, be provided better by controllers working with split sectors than by bandboxing sectors. To achieve the supervisors and management goal of having sectors split more often than the controllers themselves would prefer, supervisors are using strategies like nudging by providing occupancy numbers to controllers, when the supervisor thinks a split of sectors is called for. The reason that the supervisor rarely dictates a sector split can be attributed to a work culture where top down decisions made by management are not well seen by the sharp end when it has a direct influence on front line workers. Especially when the front line workers are not involved in the decision. One example is the story where a supervisor dictated a split and the controllers continued to work with the sectors split long after the traffic volume had dropped to a level where the sectors could be bandboxed.

Some controllers see the excess of colleagues on duty as an opportunity to keep sectors bandboxed for as long as possible. It is the ideal conditions for controllers to "feel sharp", "knock rust" and have "fun". Because controllers know that if they choose to split sectors, it can be done quickly by standby controllers, just a call away. In this environment some controllers will seek out opportunities to remain and reinforce the feeling of being sharp. To the controller the need to "feel sharp" is important because they work in the presence of uncertainty in a complex system. Situations emerge that take up time and capacity. Traffic numbers will vary, and unusual situations will occur, it is only a question of when and how severe these situations will affect the traffic situation. The controllers want to be sure that they are sharp, so they can handle any emerging situations, at least until a sector split can be performed. It is not possible to calculate or predict when those situations occur, where sectors should have been split some time before the situation occurred. Only in retrospective will these situations be visible.

The importance of having a buffer was also mentioned by a controller during the interview, when the talk was about what stories student controllers would benefit from hearing during their training. *"Tell the students to remember to include a buffer for the unexpected"* (Respondent 1)

The expert controller knows the importance of having a buffer, something a student controller needs to build with experience. It takes time to build experience and the students do not have that time, because the controller education is, mainly for cost and efficiency reasons, compact. The main focus from instructors and students is to develop a high capacity, that consist of the ability to control a high number of aircraft safely. Except just before validation, where the student needs to show self-awareness of capacity and split sectors before reaching the boundary of own capacity. The student must prove to the instructors that they have a buffer, are aware of own limits and show ability to call a sector split before the buffer is used up.

Buffers are about adaptive capacity and resilience. Each controller has an own buffer, not visible or measurable, but the buffer is not only an individual object since ACC controllers work in pairs, it involves teamwork and contains a social dimension. In training controllers student controllers, the essence of resilient performance is introduced through the development of a controllers model of system dynamics and the means to adapt to manage and cope with challenges that stress the system. Developing tactical strategies that exploit buffers and a system’s adaptive capacity is a fundamental for ATM system resilience.

Teamwork.

Salas et al. (2000) defines teamwork as *"a set of two or more individuals interacting adaptively, interdependently and dynamically towards a common and valued goal"* (Salas et al. 2000)

This arrangement of individuals that work towards a common goal can be seen in many sociotechnical systems, e.g. healthcare, maritime operation and aviation. However, the nature of teamwork in ATC is different from other teams in aviation e.g. the flight deck. Controllers are trained and educated by peers to work in a specific centre within a specific team (Bieder & Bourrier, 2013)

Teamwork is inherently argued to be an integral part of ATC sector operations, Centre operations. Sector teamwork, as found here transcends the notion of teamwork that has been introduced in EU2017/373. Indeed, the paucity of the nature of team work on sectors is not accommodated in terms of sustaining resilient performance in ATM. (EASA, 2021)

Two controllers working together form a sector team. The buffer is a part of the teamwork the radar and planner controller constitute together. Each carrying out a separate function that overlaps in mutually supportive ways. Despite that there could be different perceptions about sector splits and each controller has their own buffer limits, the two controllers form a mutual buffer. We are in this together - seems to be the common perception of teamwork. The team forms a common ground, a combined buffer that is used during the time where the team is working together.

Teamwork is part of the mandatory Team Resource Management (TRM) training for controllers that came with the EU regulation EU2017/373. In the TRM guidelines from Eurocontrol concerning teamwork, it is stated that controllers beside teamwork should receive training in team roles, in order to describe the formal and informal hierarchical structures in the ATM environment. Also training in communication is mandatory to identify the functions of communication and to analyse how communication is performed within teams and how it can affect safety. (Eurocontrol, 2020)

We should not become too enthusiastic and expect positive changes in the teamwork by introducing TRM training for controllers. It would be better to listen to the controllers experience and needs. This is the conclusion of a study of medical teamwork, where the evolution of safety science towards teamwork is under critical review. In the following quote "medical staff" could be replaced by "Controllers".

> *"Recognising power dynamics at the workplace in an effort to understand team processes and guide the serious allocation of resources will certainly address current challenges faced by frontline medical staff more thoroughly than the application of normative frameworks. Before rating their 'sharpness', we should harness their narratives and listen to their current needs."* (Neuhaus el al. 2020, p.24)

Teamwork in Copenhagen ACC consists of actors that possess great experience in working together as a team. Listening to the controllers during the interviews, it became clear that informal hierarchical structures are at play in sector teamwork. The Radar controller has a stronger voice about sector splits than the Planner. If the Radar controller wants to split, the split is done with no questions asked from the planner. Here the radar buffer determines the standard and the time to split.

The other way around, where the planner calls a split or asks if sectors should be split, it seems more accepted that the radar says no. The no to split, the Radars rejection to split sectors will in most cases be accepted by the planner. With the rationale that if the radar feels in control and wants to "feel sharp", "knock rust" and have "fun" it is fine. All controllers want that at some point, so the planner is willing to extend the buffer to please the radar. The power gradient is tipping towards the radar controller. But only to a certain extent. If the planner starts to "lose the picture", backup controllers

will be called, and a sector split will be performed. The value of having functioning teamwork in ATC is connected to safety.

It is evident based on the interviews, that the planner and radar controller are looking out for each other, even though they have discreet separate role, functions and tasks - they are a fluid team. They need to succeed as a team. In order for the team to be as effective as possible both the planner and radar controller adapt their work to accommodate each other. A skilled planner can make the difference between a "glad it is over" and "that went great" traffic scenario. It appears creating a narrative about what "good" radar skills includes are more easy done than planner skills. The planner skills are more difficult to learn for a student controller. This is linked to the reality that planners skills are harder to teach than radar skills for the instructors. But, more significantly, there is no precise role design or description of the planner task. Therefore planner controllers develop their own planner modus operandi. Flowing from this has developed a discreet professional identity of the planning controller which has established and acknowledged ways of supporting the radar controller. This is one aspect of resilient performance not just at the sector level but at the macro level.

The teamwork the controllers constitute when working together plays a significant role in the creation of the buffer, that enables graceful extensibility and adaptability that affects resilient performance in the ATM system. In this research the strategies behind sector splits has been harnessed. Derived from this study of controllers strategies towards sector splits, knowledge of how to train controller students and continuation training for already qualified controllers was desired. Controller students would benefit from training that includes the perspective of resilient performance and adaptation. But at the same time, not prescriptive such that it narrows the scope of adaptive behaviour (Dekker & Lundström, 2006) . It is viewed that there is much more knowledge to gain from listening to the controllers narrative and current needs, before turning to TRM training in relation to teamwork. Especially because TRM training is limited in the sense of providing resilience. Resilience is created organic in the mutual overlap between the planner and radar and an important part of what the teamwork should culminate in.
Hopkin (1995) found that:

> *"Shared attitudes are effective means to develop and sustain professional ethos, norms and standards. To be fully accepted in a team, each controller must not only conform with its ways of behaviour but also adopt its attitudes. The team, the watch, the facility, or the profession has a view on most relevant matters and speaks with a common voice about them. When challenged, controllers are expected by their peers to close ranks and present a united front. This is not an artifice, but a sign of identification with a profession and of belonging to it."* (Hopkin, 1995, p.345)

Years of experience in teamwork has shaped and perfected controllers teamwork to a degree where it becomes tacit knowledge.

> *"With experience comes greater depth of knowledge and insight into one's own tasks and those of the colleagues, supervisors and assistants who interface with them, so that teams function efficiently and smoothly as entities. Experience brings the tacit understanding of peers—their roles, practices, preferences, presumptions and attitudes—that is a hallmark of professionalism*." (Hopkin, 1995, p.330)

The daily task of splitting and bandboxing sectors has been fine tuned by the controller team. In the few cases where the teamwork fails in some way, a disagreement between actors could occur that results in a late or messy sector split, a situation that could turn into a story. Because to split sectors is

a practical performed task undertaken with implicit cooperation - teamwork and a visual part of the controllers professional identities in action.

Stories.

The three stories presented in the introduction (p.12), served as an icebreaker during the interviews. Each story served the purpose to explore different views on sector split, depending upon what role you possess in the organisation, controller, supervisor or management. The stories contain episodes from the boundary conditions of sector splits. Situations where the split turned out to be messy or a reaction from a colleague that differs from what is included in the professional identity of a controller. The stories show the extremes that surround sector splits and most of the actors had only heard about the stories, not witnessed situations or even something similar in their daily work. This shows how rare a messy sector split that contains something out of the ordinary occurs. For controllers, sector splits are a normal daily event, that in very few cases contains an event that turns into a story. Therefore, it was difficult to foster an opinion from controllers about how stories could or should be used in the organisation to shed light on a topic like sector splits.

Still there are many stories told among controllers, and during the interviews some of the stories containing sector splits were mentioned. The stories seemed to fulfil the purpose of reminding the controller how an unsafe situation feels like. Often a situation where the controller was starting to "lose the picture". The experience is made into a story that can be shared with peers to point at possible directions of action when similar situations arise. The use of stories based on a feeling corresponds to what Hayes (2013) discovered in the investigation of three safety critical industries including the Australian ANSP.

> *"All interviewees were very clear that they could tell whether a given situation was safe or unsafe, but they were unable to describe how they made that judgement or articulate what are the differentiating features. This appears to be because the judgement is based much more on how a given situation makes them feel, rather than on their analysis of it"* (Hayes, 2013, p.110)

Stories are present in the organisation at all levels - from the beginning of the students´ training and all the way to the most experienced controllers with more than 35 years' work experience. Storytelling is an important way for controllers to keep learning by turning the feelings and emotions they experience during sharp end work into stories. The stories contribute to socialisation and learning in ways which are not captured in bureaucratic systems of for instance incident reports and formal investigations. (Sanne, 2008)

The words and expressions used in the stories differ in use and meaning depending upon where in the organisation it is used. E.g. "knock rust" can have a positive significance to controllers working in live traffic because it is needed to remain sharp and competent, to management is a phrase that only should be used in a simulator.

Time, Boredom and "Splitters".

Most of what the informants have to say about sector split refers to time in some form. The word "minute" was one of the most used in the interviews. While time is a constant factor moving forward, the rest of what surrounds a workday for a controller varies greatly. The workload, colleagues and

supervisors change throughout the day. So, it is only natural that time becomes an anchor to describe the surroundings from. Concerning sector splits time is also a central point for controllers and management. Supervisors and MO can sometimes witness sector splits performed late, too late in their opinion.

The controllers view the situation as a split performed late because the controllers agreed to split late to stay sharp, knock rust or have fun. The choice not to split sectors could also have been made at first, but then the choice was reversed. Resulting in a late split. The controllers choice to split sectors late correspond well with Hopkins (1995) findings that controllers gain great job satisfaction from controlling air traffic and the controllers are aware that the satisfaction comes from applying their knowledge, skill and experience in the presence of high workload.

All three actors in Copenhagen ACC: Controller - Supervisor - Management agree upon the purpose of operating is to satisfy the airspace users by providing safe and expeditious flight through airspace.

But how to provide a safe and expeditious service is viewed differently between the actors.

In ATM the airspace users are represented by pilots. It is the pilots with whom the controllers have direct radio voice contact with, sharp end to sharp end. Pilots are considered the customers by controllers.

Supervisors and management talk about good service as something that is best delivered by controllers when they work in normal to low traffic volume. Not in high traffic. Controllers on the other hand address good service as controllers that are sharp and able to work in high traffic volume. The difference seems to originate from the controllers created professional identity, where to be sharp and sometimes work in the presence of high traffic numbers is an important part of the identity. The ability to work in busy traffic is something that is already introduced as a necessity to possess for a controller student in order to validate. Busy traffic becomes equal with good service for the controller. Hayes (2013) finds that professionals *"sometimes feel a self-imposed pressure to produce. Interrupting operations can be seen as professional failure – letting the system get the better of you"* (Hayes, 2013, p.109). This seems most valid in ATC. Management did not talk about the controllers role in creating efficiency in the overall ATM system. It can be interpreted as a sign that the system operates at a satisfactory level. However, there are situations where supervisors are willing to set aside their goal of good service and focus on system capacity. In peak hours supervisors sometimes need the controllers adaptive capacity to get the work done.

If high traffic is one end of the scale, the other end of the scale is boredom. Boredom is present in situations with low traffic volume and is an interesting subject, because all actors - controllers, supervisors and management mention boredom in the interviews.

Management view boredom as a part of the working conditions for controllers and something that the controllers should be able to cope with in the presence of low traffic numbers. Boredom is seen as an opportunity to provide a good service.

Controllers as a group do not like boredom and will prefer to work with sectors bandboxed to avoid boredom and work under load. However there exists an area of disagreement amongst controllers. The majority of controllers interviewed believe that sectors should remain bandboxed for as long as possible. A smaller group of controllers believe that in case of surplus controllers on duty, the surplus should be used to split sectors despite that it could lead to boredom. The small group´s opinion matches management´s view that split sectors equals a better service to the aircraft. The numbers of interviews conducted was not enough to establish the distribution of opinions on how the surplus should be used, but enough to determine that the difference exists. There was a correlation between the controllers that supported a split of sectors in case of surplus and the controllers that stated, "I have

turned the aircraft I need to turn". The correlation indicates that the controller has established a professional identity and has nothing to prove by taking on a heavy traffic workload but prefers to split sectors. The "splitters" are self-conscious that they constitute a minority among the controller tribe. The reason that the 2 groups can coexist without any visible disagreement is most likely due to the number of years the "splitters" has worked as controllers. More than 20 years. If a young controller with less than 10 years' experience declared him or herself a "splitter", the tribe of controllers would have big trouble accepting that decision. Because young controllers still has to prove membership and loyalty to the tribe.

Supervisors are divided in their view on boredom. When working as a supervisor or on the flow position, supervisors encourage controllers to split sectors in the presence of high traffic numbers and surplus of controllers. Supervisors are aware that it will create boredom among controllers but view the split as a safety aspect as well as a way to provide a better service to pilots. Something that they as supervisors must recommend. Supervisors on the other hand stated during interviews that when working as controllers, they enjoyed being busy with lots of traffic, just like the rest of the controller group.

Here it is important to pay attention to the different roles supervisors possess, a set of dual professional identities and how it relates to sector splits. When working as supervisor the view on when to split sectors must reflect the management view. The view is visible by the actions the supervisor performs, to inform the controllers about high traffic numbers and as a last resort dictate a split. When on duty as a controller the supervisor still carries the management view on sector splits, but at the same time the supervisor must be a part of the controller tribe and balance the view they possess as supervisors with the view controllers possess regarding sector splits.

The double-sided role of supervisors also being controllers requires a strict balance between the two roles. Their dual professional identities were not seen as an issue of conflict by either group, controllers or supervisors. However, the different view on sector splits was identified by both sides during the interviews. But instead of creating gaps and conflicts the two groups co-exist, and work based on the common understanding of the purpose for an ANSP - to provide safe and expeditious flight. The reason is possibly related to the professional identity associated with qualities such as loyalty within the profession and common goals and values. Also, the desire to fulfil the expeditious goal to produce adds to the common understanding.

The findings observed in Copenhagen ACC correspond with the results from Hayes (2013) where professional relationships with peers, other members of the operating team and organisational superiors are stated as important relationships in making the best decisions in the face of uncertainty in complex systems. The professional relationship is in play and at stake when the decision to split sectors or not must be made. The desire to maintain relationships among peers often exceeds other goals - except safety.

The fact that all supervisors and management have a background as operational controllers, and some are still active controllers leads to an understanding of the different terms and phrases used in the organisation. Like story telling it is also of value to pay attention to the terms and phrases used in the organisation. The interviews revealed some phrases and sayings in ATC, that can be useful to pay attention to. "Splitters" said about controllers or teams that have a reputation for splitting sectors sooner than the rest of the group, is an example of such.

To be a "Splitter" does not fit well in the professional identity of a controller, because it tells the story that you split sectors sooner than the rest of the group.

Management and supervisors dissociate from using phrases like "Splitters" and so do some controllers. The use of negatively charged words, terms and phrases create differences not togetherness.

But sometimes situations arise in ATC, where there is a need for controllers that have the ability and desire to work heavy traffic. Like the third story described in the beginning of the thesis. Where a controller is asked sector by the supervisor to select a colleague to work together with as a team on a busy. In situations like that all actors work together to solve the situation. The knowledge about who is a "Splitter" and who is not - can be part of the solution to a difficult situation. A situation where the controllers are required to work beyond the normal boundary to absorb variations in workload. In most cases the controllers will gladly work hard because it emphasise their professional identity. Supervisors and management also appreciate the extra effort from controllers. This day to day problem solving is a demonstration of adaptive capacity in action and is a part of what it takes to get the work done.

Hopkin (1995) wrote about human factors in ATC, and made this passage about controllers that indicate that some parts of the controller identity is at odds with management:

> *"Perhaps air traffic controllers are a difficult workforce to manage. Their selection and training together are intended to produce people who weigh evidence carefully, reach decisions promptly, implement them and abide by their consequences, possess cherished skills and knowledge which they seek to apply, are accustomed to responsibility and some independence, identify closely with their professional norms and standards and professional ethos, defend their profession against outside challenges from any quarter, and do not take kindly to being told peremptorily by others what they should do. Such attributes may be desirable in the air traffic controllers. They are not, however, the attributes of a docile and pliable workforce."* (Hopkin, 1995, p.352)

Expertise and Competence.

The three concepts "feel sharp", "knock rust" and "fun" are fundamental reasons not to split sectors for controllers. The desire to work in high workload could be seen as the controllers attempt to create a bigger buffer. The buffer limits can be challenged and explored by working in the presence of high traffic, close to the controllers limit. But that is only possible when the controller feels safe, are confident and knows that it is possible to get help in the form of workload relief delivered by standby controllers that are able to split sectors quickly. From experience in working in high workload the controllers also gain a higher capacity, or at least a self-conscious on the capacity level.

Malakis and Kontogiannis (2021) describes how expert controllers note and use leverage points for themselves in praxis, to make changes to different elements of the work system. In high workload conditions controllers must make use of many different leverage points to complete the task and sustain the operation. If the work gets done in a satisfactory way, and it does in most cases, the controller can add another well done session to a long list of successes, that is part of forming the professional identity of the controller. It is through such mechanisms that agility through adaptation is deployed – controllers and the ATC control task adapts.

Lundberg and Johansson (2015) build a model of Systemic Resilience which uses as a justification for adaptations in complex work systems the ability of systems to cope with situations. They argue that, drawing on Ashby's law of requisite variety, *"that only variety can destroy variety, i.e. when facing a dynamic situation, we must be able to respond before the situation gets out of hand."* (Lundberg & Johansson, 2015, p.4). Inferring that situations need a response, need to be managed before control is lost. Systems may not possess or have the resources available for variety when needed, to match what will occur. The ability to adapt is central, *"responding is the ability to take action during an unfolding event"* (Lundberg & Johannson, 2015, p. 2). Controller's interviewed value that they have to anticipate or recognise when adaptations are needed as tactical plans and strategies unfold. That

they have the capacity and ability to take action. Controllers often cite not building a plan "A" but plans "B", "C" & "Z". Splitting sectors is normally not one of the first options on the plan list. The freedom to select between different plans has a positive impact on job satisfaction. Hopkin (1995) connected high workload performance by controllers with job satisfaction. *"High workload brings benefits in job satisfaction and interest, in the maintenance of skills through opportunities to use them."* (Hopkin, 1995, p. 335)

All in all, fine-tuning takes place after every split, no matter when the split was done, controllers evaluate the outcome of the split. Exemplified by a controller. *"If the split was done too late or not at all and I end up in a bad situation, I will for sure split earlier next time"* (Respondent 1)

Outside the tribe of controllers, the use of the words and phrases "feel sharp", "knock rust" and "fun" to describe the feeling controllers experience from working in heavy complex traffic situations with sectors bandboxed, is not considered well seen. Controllers seem aware of this and talk about the concepts with remorse to outsiders. Still controllers feel that it is useful to work exactly that way. It makes sense to them. Because over time it has shown them that working inside the buffer close to the boundary of acceptable performance will create valuable knowledge and experience.

Based on way controllers are selected, trained and formed by peers in an operative environment, there is a clear link between the controller, professional identity, adaptive capacity and resilience of the ATM system.

ICAO rules state that "*ATC service shall not exceed that which can be safely handled… under the prevailing circumstances"* (Gonzalez, 2015, p.4). In order to fulfil that rule the controller must know the boundary and detect when the workload approaches the safety limit. It only makes sense if the controller is permitted to experiment by working in that border area. While rules are sufficient to outlay the operational envelope in ATC, they are not sufficient to describe how controllers shall work to stay inside the envelope. Over time the way controllers are working has led to highly effective operations - by constant adapting to retrieve a consistent outcome. *"Often what produced the stable outcome was continuous change, not continuous repetition"* (Weick, 1987, p.119).
The strategies used by controllers to keep working inside the operational envelope has been examined and discussed in this thesis. There are many elements and factors that unfolds before the controller makes the choice to split sectors. The choice to split sectors can be seen as the last resort for the controller to avoid "losing the picture". Before making the choice to split sectors, the controller usually tried to slow things down as Weick (1987) describes. If that is not enough or the change comes fast, like an unusual or emergency situation - the sectors will be split.

> *"When environments become unstable, then people need first to make meaning in order to see what, if anything, there is to decide. When there is swift change, you either label the change to see what you should be paying attention to, or you take action in an effort to slow the change so that you can then make a rational decision".* (Weick, 1987, p.123)

The controllers choice is based on experience and awareness on the factors uncovered in this research and is fundamental to the ATC system in order to work. Because the buffer it creates by expanding the system capacity is needed regularly.

During the interviews questions were asked about if sector splits were done too early, too late or at the right time. While supervisors and management predominated the view of late splits, controllers had few examples of late splits that turned out messy, simply because it rarely happens. But when they do, it gets a lot of attention and could explain the focus the few late split cases get from supervisors and management.

To avoid messy splits the time to split sectors could be made by supervisors. However, if the choice to split sectors is removed from controllers and given to supervisors, it will affect the controllers professional identity and over time result in a lack of consciousness about the controllers current capacity level. A situation that could lead to two opposite directions. Controllers that will split sectors earlier and create a need for more controllers on duty or late split that could lead to an overload situation. A high price to pay, considering that the system occasionally depends on the controllers ability to work beyond the assigned capacity of the system. The controllers are the engine of the system. The adaptive capacity the controllers add to the system, is what gets the work done. How do the controllers do that and what is it that they add? They create a balance in the system, by using trade off strategies. The strategies the controllers use together with the other actors are informal measures by which the system achieves what it does, any attempts to formalise this often leads to a reduction in the overall system capacity.

The task of splitting and bandboxing sectors is an example of adaptation in a complex social system. When and how to split and bandbox sectors are decided by controllers based on expertise together with the professional identity that controllers develop through time starting from the beginning of their ATCO training. The professional identity created, shaped by peers cannot be underestimated, it is vital, it becomes the engine of the resilient performance of the ATC system – created by controllers adaptive behaviour. Controllers create resilience day-in-and day out for the benefit of the whole ATM system. Management and supervisors know that they have to let controllers do their thing, otherwise the overall system effectiveness will be reduced.

Reflections.

After completing the writing of the thesis, some reflections would be appropriate. First did I answer the research question? I think that the foundation where the strategies to split sectors or not has been displayed. The reader will gain a broad understanding of factors besides workload that surrounds the controllers choice, including goal trade-offs, professional and tribe identity together with blunt end interactions with supervisors and management. Deeper knowledge from one specific ANSP unit is harvested. The value in form of knowledge the controllers gain from experience by working in busy traffic is considered vital. Not only for the controller but for the whole ATM system. My own combined role of being a controller colleague and researcher at the same time was more of a challenge than I imagined. The professional identity build over 25 years was hard to push in the background. However, it also gave some advantages in where to look for answers. Covid19 has reduced the traffic volume considerable. However when the traffic numbers returns to a more normal state, the need for controllers adaptive ability is considered vital for the ATM system. Therefore it makes sense to look into the factors that supports the controllers willingness and desire to work in busy traffic.

Future research.

Future research regarding the controllers buffer, what does the buffer consist of and is it possible to enhance the buffer? The results could be used to make training more specific during the yearly refresher training of controllers and in the training of controller students. Also, the research could be used to make the ATM system more resilient.
The number of stories in the ATC community is high. The study of the origin, content and meaning of the stories could uncover underlying tacit knowledge in the ATC world.

The Covid19 situation with the steep drop in air traffic volume occurred after the thesis was planned and all interviews was conducted. So, the effect of much lower traffic was not considered in the thesis. The effect of Covid19 on controllers ability to cope with raising workload and how a long period of low traffic effects the professional identity of the controller would be interesting to investigate. Also, a

comparison of the Covid19 and the effect the financial crisis in 2008 had on workload and professional identity in ATC could be useful knowledge to soften the effect of future crisis.

CONCLUSIONS

This research looked at the strategies controllers use when they choose to split sectors or not. The findings show that the choice depends on the social aspect, the identity of the controller, as much as it depends on the technical aspect including workload and number of aircraft controlled.

Beside to balance workload controllers choice are embedded in the professional identity that surrounds the controller at an individual level. But also, the expectations from the tribe and subtribes that exist in the controller community will affect the choice to split sectors or not. The professional identity of the controller is at stake in the choice.

The strategy used by controllers includes risk and benefit in the choice, factors not visible to an observer, but well known in the tribe of professional workers that face the choice every day. They share the knowledge in form of stories that contain learning for the whole group, from the student to the most experienced controller. The stories also illuminate the risk and benefit of splitting sectors or not. Risk includes ending up in a situation with high workload, that the controller loses the picture and calls for help too late. A situation that leads to a messy sector split sometimes ends up in a story that could stick to the controller for an entire career. Benefits for not splitting sectors, includes job satisfaction by giving the controller the feeling of being in control, staying sharp while having fun in the presence of high traffic numbers and a place at the top of the informal hierarchy among controllers.

The professional identity of the controller permeates many of the tasks the controller performs on a daily basis, including the choice to split sectors or not. It is not an individual performance; the controllers work in pairs. So, the choice to split sectors no not must be aligned between the radar and planner controller. The controllers must have confidence in all traffic situations, especially in high traffic volumes. In this environment the controllers gain job satisfaction and maintain the hard learned skills by using them. They must feel in control and feel "sharp". To achieve that feeling, controllers push to the limits of the operational envelope and work in high volume traffic. In this busy and complex environment, the controller receives feedback through "gut feeling" and instinct as well as a confidence built from years of experience. This experience leads to near continuous development of new meta-skills. Skills that are used in the choice to adapt to the inherent performance in ATC; a series of adaptations that strives to optimise capacity and efficiency in order to deliver to the customers a "good service". All achieved through the choice of splitting sectors where and when it is considered appropriate.

Supervisors and management follow the controllers choice to split sectors or not. Differences amongst actors have been discussed. The gap between the actors´ view on sector splits appears not to be deep or broad. All actors have an operational background, so they are aware of each other's point of view. The difference seems to origin from what position the actor currently holds in the organisation and the responsibilities that are embedded in the role. All need to remain loyal to the tribe.

Still the three actors view on sector split: controllers - supervisor - management are unanimous - the choice to split sectors or not should be made by controllers.

For the ATC system to work it depends upon flexibility from controllers to make the choice to split sectors or not. Sometimes the flexibility means and relies upon the controllers ability to work beyond the sector capacity. The extra capacity created by controllers is appreciated by supervisors and management because it gets the work done. It makes the ATM system resilient by adding adaptive capacity to the system.

Splitting and bandboxing is an adaptive strategy, it works because of the social processes and group identity of controllers that have evolved and have been able to be sustained over time.

Most controllers enjoy working in busy traffic and are proud to contribute to create the extra capacity when needed. A capacity that all actors appreciate because it gets the work done, keeps a high capacity and is an important factor in making the system resilient to absorb the constant changes the ATM system is subject to everyday.

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I have spent almost 25 years as an operative controller in the Danish ANSP Naviair. In that time, I have met many inspiring people in the aviation industry. But the ones that had studied the Master program: Human Factors and system safety at Lund University made a special impression on me. One characteristic they all possess is the ability to wonder and ask relevant questions about human factors and safety - not only provide answers. Something that I value in people.

I am thankful for working in a company - Naviair that has been supporting me in my journey for new knowledge. Beside working as a controller, I have been part of the Naviair training organisation for the last 20 years. The Head of Training supported my participation in a learning lab at Lund University in 2017. The learning lab was run by Dr. Johan Bergström and Dr. Anthony Smoker. It was a truly mind-blowing experience and I felt lucky to enrol in the Master program in 2018. Again, with the support from Naviair.

My own professional identity as controller has been challenged during the last two years. Beliefs and values have changed, some still stand. Thanks to classmates for great discussions and to Dr. Smoker who became my supervisor for this thesis and evolved into a mentor during the process. His background as a controller combined with academia provided me with the best learning opportunity.

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

Word list

ACC Area Control Center

ANSP Air Navigation Service Provider

ATCO Air Traffic Control Officer

ATM Air Traffic Management

CDM Critical Decision Method

CFMU Central Flow Management Unit

EASA European Aviation Safety Agency

EC Executive Controller (Radar)

FL Flight Level

FIR Flight Information Regions

FMP Flow Management Position

ICAO International Civil Aviation Organisation

NATS National Air Traffic Agency

OJT On Job Training

OJTI On Job Training Instructor

PLC Planner Controller

RE Resilience Engineering

SOP Standard Operation Procedure

TRM Team Resource Management

WS Watch Supervisor

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https://www.skybrary.aero/index.php/Startle_Effect

https://www.skybrary.aero/index.php/Toolkit:Systems_Thinking_for_Safety/SESAR_Resilience_Guidance_Material_for_Safety_Assessment_(SRM)_and_Design

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Appendix 1 Guiding questions used in the Semi-Structured Interview:

1. "What stories have you heard about sector split?"
2. "Do you have any stories about sector splits that did not go as planned?"
3. "What does the stories try to tell us?"
4. "This statement comes from a colleague..., what do you think about the statement?"

    "We normally split at the right time".

    "We often split too late".

    "Most controllers agree on when it is time to split".

    "Sometimes I choose not to split sectors, even when traffic counts are high"

5. Is it OK to say no to split sectors, if a colleague wants to split?" - "what about if a supervisor asks you to split?"
6. "When is the right time to split the sectors?"
7. "How many % of the sector splits are done too late, in your opinion?"
8. If you should learn a controller student when to split sectors, what would you talk about?"
9. "If you should tell a story about sector split to a controller student, what would it be?"
10. "What information do a student need to have, in order to make the decision to split?"
11. "How do when we split sectors connect with the identity of being a controller?"
12. "How does your choice to split/not to split sectors differs from the controllers that work part/full time?"
13. "How did you learn when to split sectors?"

Appendix 2 List of participants.

Informant	Controller / Supervisor / Management	Years of experience
1	Controller	10-15
2	Controller	5-10
3	Controller	15-20
4	Controller	20-25
5	Controller/Supervisor	20-30
6	Controller	5-10
7	Controller/Supervisor	20-30
8	Controller	10-15
9	Controller	5-10
10	Controller	20-25
11	Supervisor	20-30
12	Management	25
13	Controller	15-20

Appendix 3 Consent form.

Informations Brev

Kære Sir/Madam,

Jeg er i gang med en uddannelse til MSc i Human Factors and System Safety på Lund Universitet.

Min specialopgave omhandler sektor split i ACC.

I den forbindelse har jeg brug for din hjælp, i form af din deltagelse i et interview hvor jeg vil stille spørgsmål, der kan hjælpe mig med at give svar på det emne jeg har valgt at undersøge.

Emnet er "Strategier flyveledere bruger når de vælger eller fravælger at splitte sektorer i ACC"

Til at belyse emnet har jeg designet et kvalitativt studie, der gennem en række spørgsmål skal forsøge at indsamle opfattelser og erfaringer af sektor split, samt afdække de strategier vi bruger dagligt, når vi enten vælger eller fravælger at splitte sektorer i ACC.

Din deltagelse er vigtig for at jeg kan indsamle materiale til brug for min analyse og vil forhåbentlig føre til, en øget forståelse for de strategier, der ligger til grund for vores valg af sektor split. En forståelse der også kan bruges i uddannelsen af kommende flyveledere i ACC.

Inden jeg kan bruge informationen fra interviewene i min opgave, har jeg brug for dit samtykke. Det vil ske i form af din underskrift på et dokument, som bliver fremlagt i forbindelse med interviewet.

Med venlig hilsen

Carsten Bie, MSc Human Factors & System Safety (candidate), Lund University

Supervisor

Dr. Anthony Smoker, Lund University, Sweden

Assessor

Dr. Johan Bergström, Lund University, Sweden

Baggrund og formål med specialet:

Hvornår og hvordan vi splitter sektorer i København ACC, er en vigtig del af flyveleder arbejdet. Vi er en af de få kontrolcentraler hvor valget om at splitte sektorer eller ej i stor grad ligger hos flyvelederne.

Formålet med specialet er at undersøge og indsamle opfattelser og erfaringer af sektor split, samt afdække de strategier vi bruger dagligt.

Hvem deltager i studiet?

Primært ACC-flyveledere, idealt 16 fordelt med 2 pr. vagthold. Derudover indhentes baggrundsviden fra supervisor, flow manager samt MO.

Hvad vil der blive spurgt ind til?

Under interviewet der forventes at vare 60-90 minutter, vil der blive stillet en række spørgsmål, som er forberedt på forhånd, alt efter svarene vil der blive stillet uddybende spørgsmål.

For at sikre kvaliteten og detaljerne af interviewet vil jeg optage samtalen, samtalen vil blive slettet senest en måned efter interviewet.

Risiko:

Alle interview forbliver anonyme, derfor ser jeg ingen risiko ved at deltage.

Fordele:

Ved deltagelse i interviewene får du som flyveleder mulighed for at give udtryk for og dele din viden og opfattelse om sektor split. Din viden og ekspertise kan bidrage til en større forståelse og diskussion af de strategier der omhandler sektor split.

Frivillig deltagelse/udtrædelse af studiet:

Din deltagelse i studiet er frivilligt og du kan trække dig ud af studiet på et hvilken som helst tidspunkt, hvis du ønsker.

Fortrolighed:

Informationerne fra interviewene vil blive behandler fortroligt og kun brugt af mig i forbindelse med studiet.

Kontakt til mere information om studiet:

Hvis du har spørgsmål eller bekymringer som du vil tale om i forbindelse med studiet, er du velkommen til at kontakte mig:

Carsten Bie

Flyveleder og chefinstruktør Naviair

cab@naviair.dk

Naviair Allé 1
2770 Kastrup

+45 xxxxxxxx

Samtykke:

1. Min underskrift er min accept af at deltage i overnævnte studie.

2. Jeg har modtaget baggrundsinformation om studiet.

3. Jeg forstår at jeg kan nægte at deltage i studiet og interviewet, samt at jeg kan trække mig fra studiet på et hvilken som helst tidspunkt.

4. Jeg modtager ikke nogen økonomisk kompensation for at deltage.

5. Jeg accepterer at interviewet bliver optaget.

Navn og underskrift Deltager----------

Navn og underskrift Carsten Bie ----------

Making the choice to split or not to split sectors in a complex Air Traffic Control environment

Carsten Bie

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