In Search of a Method: How to Prospectively Recognise Drift into Failure

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Preface

This thesis is the final assignment of the masters course Human Factors & System Safety followed at Lund University, and covers the search of a method to prospectively recognise the phenomenon 'Drift into Failure'.

In retrospect, many incidents, accidents or even downright disasters seem to be subject to a 'drift into failure'– a slow and invisible incremental . Despite this conclusion, the phenomenon keeps reappearing instead of being prevented. This has kept me occupied for a long time and made me start thinking: Are there ways, or even better, is there a method available to prevent a drift into failure or at least recognise the presence of drift into failure? Or is it truly inevitable and are we destined to reach the same conclusions in retrospect: that we have once again fallen prey to a drift into failure.

During the course reading mandatory and selected literature unfortunately no adequate method or tool was discussed that would help to recognise drifting into failure. This made my search even more challenging and made me also look at the available instruments within the field of safety. Are there perhaps methods that can be combined and provide some form of prospective information regarding the fact that drifting into failure is at hand?

In this thesis I will be researching drift into failure and search for a method to prospectively recognise drift into failure. For the research I studied a specific case within my field of expertise: aviation. This case, in combination with the Dynamic Risk Model introduced by Rasmussen (1997) and constructing a narrative, provides valuable data that could lead to prospectively recognising drift into failure.

Summary

Drift into failure only seems to be fully recognised retrospectively, after an incident occurred. In retrospect we are able to connect the dots and see the incremental steps where and when things started to turn and end up in disaster. Hindsight does definitely not equal foresight, but foresight is what we actually are looking for. The safety (science) literature does not offer any solutions to prospectively recognise a drift, before the failure occurs. The literature only offers ways to recognise the drift in hindsight, points out where the mistakes were made, and where the assumptions were wrong.

This raises the question: 'it is possible to make use of the already available Dynamic Risk Model introduced by Rasmussen (1997) in such a manner that we can prospectively recognise drift?' Is there a method to which the Dynamic Risk Model can contribute, possibly combined with another available tool, so that we can be provided with the right data on which to make decisions? When a narrative of all known incremental steps can be drawn out, this might be used in conjunction with the model and visualise a certain trajectory that perhaps could indicate drift. Will this prevent failure? No it will not, if actions are not taken. But it could raise awareness and trigger preventive measures.

The concept of this research is that by applying the proposed method, the trajectory of drift into failure can be made visible. The method itself consists of two sequential steps. For research purposes a third step is added. The first step is constructing a phased narrative, consisting of all the changes that have taken place within a particular organisational process subject to research. What has changed, what made these changes necessary, what steps have been taken, what has been the effect of the changes? This phased narrative serves as input for the next step of the research. The conversion into the Dynamic Risk Model is the second step in the method. Plotting all the milestones from the phased narrative into the Dynamic Risk Model and visually connecting these milestones. After connecting these milestones a trajectory can be distinguished. This trajectory contains information regarding the direction the process is moving. Both steps, the construction of the phased narrative and the visualisation of the trajectory in the Dynamic Risk Model, are performed in the form of interviews with personnel directly involved in changes of the process under consideration.

After going through both steps of the research, one has a composite model with the input of several interviewees. This model can be used to create a combined visualisation of the trajectory of the process under consideration. Is the trajectory moving towards the boundaries of the model? Which boundaries are involved? And above all, is this movement a visualisation of drift? After this visualisation the interviewees indicated they were indeed more aware of the trend and the unwanted direction in which the organisational process - i.e. drift - was moving. They indicated they had a feeling that this trend was present, but could not grasp it. By applying this method, the trajectory becomes visual for the interviewees and therefore it becomes easier to initiate countermeasures.

The third step in this research has been the verification with the participants. What was their opinion regarding the applied method? Does this method make a possible drift into failure visible? The participants approached for this research were in general positive regarding the applied method in prospectively recognizing drift.

In conclusion it is indeed possible to visualise drift as it reveals itself: it is possible to combine the Dynamic Risk Model with a phased narrative in such a manner that we can prospectively recognise drift and by that possibly prevent this from turning into failure.

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Abbreviations and Acronyms

0 Introduction

Nowadays passengers board and deboard the aircraft by walking across a busy aircraft stand, exposed to hazards such as kerosine, jetblast, noise, ground equipment and time pressure. This would not have been thinkable years ago. But why do we allow this to happen today? The search for optimalization and efficiency drives organisations to adapt procedures and make changes in processes like boarding and deboarding of passengers.

For decades it was not considered safe to allow passengers to cross the aircraft stands by foot but only make use of passenger bridges. Nowadays the airport considers the crossing of the aircraft stand by foot safe, otherwise the airport would not permit this. What has changed the airports opinion? Has it taken measures to prevent harm and protect the passengers? Or have the changes been so incremental (and thereby invisible) over the past period that the airport is hardly aware of them, and is the airport gradually creeping towards failure (without realising it)? Aviation passenger bridges were introduced, not from a safety perspective but for comfort reasons. Aviation was a luxury means of transportation and a passenger bridge contributed to that concept by shielding the passengers from the elements of weather and making boarding and deboarding of the aircraft effortless. Aircraft stands gradually became more occupied with functions supporting ground equipment: Multiple vehicles for water services, luggage, catering and mechanics were being added to the already tight and busy aircraft stand. As such, aircraft stand started decreasing in size to optimize the airport layout and accommodate the growing need for more capacity. Airports have also become significantly busier over the last decades. Service roads that need to be crossed if passengers want to reach the aircraft stands from the Terminal resemble highways during rush hour, with vehicles designed only for their specific task, not taking into consideration colliding with humans. In that light, the passenger bridges are not just a luxury and comfort item anymore, but have become more and more a safety measure by shielding passengers from these hazards.

What makes the airport decide to turn back the clock and re-introduce passengers on the aircraft stands to board and deboard the aircraft? Is this a scenario that will lead to disaster, is it possible that this is a 'drift into failure' – a slow incremental decline (erosion of safety margins) into disaster? The incident reports do – so far - not seem to show this is a problem. So is there a reason for panic? But when disaster does strike and a dreadful accident involving passengers on an aircraft stand happens, what will the investigation tell us? In retrospect the conclusion could be that this disaster was incubating for a considerable amount of time: that the airport slowly and subtlety has been drifting into failure by all the little alterations it made along the way, over the past decade. Would it not be far more valuable if the airport is able to recognise this drift prospectively instead of retrospectively, and possibly prevent it from happening?

Drift into failure gradually introduces itself over a long period in time by small incremental changes, slow and subtle adaptations in processes (Berman & Ackroyd, 2006; Dekker, 2011; Dekker & Pruchnicki, 2014; Gould & Fjæran, 2019; Harvey & Sotardi, 2017; Hollnagel, Woods, & Leveson, 2006; Starbuck & Farjoun, 2005). This is why an accident overcomes us by surprise and we never would have guessed this would or could happen. The main problem with drifting into failure is that we only seem to recognise this in retrospect and never seem to be able to do so prospectively. This is why we are caught off guard. In hindsight it is often very clear that mistakes have been made along the way, limits have been overstretched and boundaries have been crossed. Only in hindsight we seem to notice all the incremental changes and start to question the motivations behind these changes: "why did we not see this coming in foresight?" During the actual changes, the motivations all seemed reasonable and based on facts and figures of that moment. We deem ourselves, our processes and changes safe, as long as we have no proof of the contrary. This builds our confidence in the countermeasures being effective. In this sense, the absence of incidents is directly translated to the belief that everything is safe (Busch, 2019). This building of confidence makes it even harder for an organisation to look at what possibly could go wrong. As described by Woods in his contribution in the publication of Starbuck and Farjoun (2005) regarding the lessons learned from the Columbia disaster, "the absence of failure is taken as a positive indication that hazards are not present or that countermeasures are effective" (p.293). Past successes could comfortably be taken as a guarantee of continuation of safe performance (Dekker, 2011). This might be the biggest threat considering drift into failure; Due to the small incremental steps accumulating over a long period in time, we hardly notice the dangers that lay ahead and that hit us by surprise. Drift, then, is the slow movement towards the limits of what is seen as acceptable and safe performance of a system. Rasmussen, a Danish professor in Safety Science researching the dynamic characteristics of processes, has introduced a model in which the limits of acceptable system performance are included and represented. This is the Dynamic Risk Model (1997) a model in which Rasmussen projects a process that is surrounded by three boundaries. These are boundaries of acceptability in the areas, economic, workload and performance. The performance boundary is also referred to as the safety boundary.

All this leads to my central question that asks: "is it possible to recognise drift into failure prospectively, so we can prevent the failure from happening?" Could the Dynamic Risk Model (Rasmussen, 1997) be integrated in a method to recognise drift into failure prospectively whilst the drift is still happening and has not resulted in the failure yet? Or are we doomed to keep repeating history and become victims of again another drift into failure? Is it like the French would say: 'L'histoire se répète', regarding drift into failure? Although we do learn from incidents and accidents, this is mostly retrospective: during an investigation we put together all the pieces of the puzzle and reveal the trajectory towards this particular outcome that was incubating with the accumulation of small, seemingly insignificant, little steps. This once again emphasizes the importance of recognizing drift into failure prospectively.

Using the changes in the passenger handling process at the airport as a case study, this thesis will describe the search for a method to prospectively recognise drift into failure using the Dynamic Risk Model (Rasmussen, 1997). With this thesis steps will be provided to gain more understanding of the ongoing process during changes over a longer period in time and by that give opportunity to make adjustments timely and change trajectories and prevent drift turning into failure.

1 Theoretical framework Drift and Dynamic Risk Model

1.1 Drift

In order to be able to recognise drift into failure, it is necessary to have a clear understanding what drift into failure is. Dekker (2011) provides one definition, "drift into failure is a gradual, incremental decline into disaster" (p. xii). This definition does not mention how drift could be recognised, only that it is a gentle process that takes time to evolve, incubation time (Dekker & Pruchnicki, 2014). With incubation time, it is meant that it has been accumulating over a long period, building up suspense until the moment it pops. Günther Ortmann published an article in Science Direct in 2010 entitled 'On drifting rules and standards'. In this article Ortmann discusses rules and standards, their origins, definitions and conceptual issues based on Wittgenstein and Derrida. But Ortmann also discusses the concept of drift. Despite the fact that Ortmann's article is about rules and standards, his definition of drift is applicable to matters outside this domain. In particular, when Ortmann refers, similar to Dekker (2011) and Rasmussen (1997), that a certain form of drift in relation to rules and standards is visible in situ. Ortmann states:

> "in many cases this is due to contextual and situational conditions and to the local rationality of task fulfilment. On the one hand, drift is a necessary condition of the functioning of organizations. On the other hand, it can be dangerous." (2010, p. 208)

Similar to Dekker (2011), Ortmann (2010) clearly mentions that a certain degree of drift is seen as a necessary condition of the functioning of organisations. Ortmann (2010) provides us with the following: "if a movement that is (a) not intended, (b) slow, subtle and, therefore difficult to perceive, (c) long-lasting and (d) has a certain direction, then I term it a "drift"" (p. 207). In this definition there is no reference on how to recognise drift. Both definitions contain the same elements, namely time and movement in a certain direction.

Primarily, time plays a key role in drift into failure, as Ortmann (2010) emphasises. Especially the fact that due to the slow and subtle changes it is hard to perceive what is going on underneath the surface of a system. The little steps toward optimalisations seem meaningless, however, over time, these small steps accumulate towards a giant leap in the erosion of important (safety) features of the drifting system. This exactly points out the dangers of drift and why this often leads to failure. Signals and dashboards do not indicate something is moving in the wrong direction due to the subtlety of the movement. Due to this subtlety, we do not recognise the danger. Ortmann (2010) refers to this as 'the perception of drift': "Time-frames are important in the perception of "drift". Institutional or cultural or social memory is temporally limited, so where drift extends beyond the relevant time-frame of reference, we have to consider the temporal limitations of drift perception" (p. 209). This refers to 'collective memory', a concept introduced by Maurice Halbwachs in his posthumous book La Mémoire Collective (1980), published by his daughter. Collective memory is in essence a representation of the past projected on the present and is often referred to in relation to organisations or society. Within organisations, however, this is also subject to regular failure. This failure may be due to organisational changes, staff turnover or because there is too much time, months or even years, between certain events for this to be remembered, like Ortmann (2010) states. As a result, the effects of (small) changes within a system become invisible.

It is clear that key elements in drift into failure are time-related and create a movement in a certain direction. Most often this direction is not towards safety, but rather towards increased efficiency of system performance. Rasmussen (1997) refers to this as, "a systemic migration towards the boundary of functionally acceptable performance" (p. 189). In many cases, organisations tend to move towards more efficiency and a better financial situation, by that pressuring the functionally acceptable performance. This can lead to an unintended movement away from the safe side. Moving away from the safety intentionally would not be a healthy strategy for any organisation. This jeopardizes the future of the organisation by causing accidents and financial burdens. However, as explained above, the small incremental steps make the movement invisible and unintended. The unintended part of the movement is also mentioned by Ortmann (2010) in his definition of drift and Dekker (2011) refers to this as well, calling it, "an inevitable by-product of normal functioning" (p. xii). In order to meet targets and keep up with the competitive markets, organisations are obligated to search for optimalization and efficiency. By this, drift into failure is lurking under the surface of seemingly rational system optimalisations. Compared to Dekker (2011), Ortmann (2010) goes even further by stating, "drift is a necessary condition of the functioning of organizations" (p. 208).

Seen in the light of competitive markets, drift is not necessarily a dangerous phenomenon but perhaps a necessity, as long as there is a clear understanding of the boundaries: where are we in the spectrum and in which direction are we moving? This is exactly where the problem lies, as Cook and Rasmussen (2005) mention, "In practice, the precise location of the boundary of unacceptable performance is uncertain. Only accidents provide unambiguous information about its position" (p. 130). The boundaries and the spectrum in which we move, will be further explained in the next section when discussing the Dynamic Risk Model.

As far as other literature concerns, there is nothing that contributes to the recognition of drift into failure prospectively. Available literature refers to drift into failure in retrospect mostly. Only after a failure has occurred drift is identified. Examples are described from various industries i.e. military (Snook, 2000) where two U.S. helicopters were shot down by friendly fire in Iraq due to practical drift. The drift from procedures such that actual performance varies from designed performance, Energy companies (Dembinski, Lager, Cornford, & Bonvin, 2006) who elaborate over the tale of Enron who lost ethics to gain profits. Aviation (Dekker, 2005) explaining how Alaska Airlines crashed into the ocean killing 88 people due to amendments from original maintenance regulations, protocols and programs over multiple years. Since no incidents or accidents occurred regulations were deemed to be correct and maintenance could be stretched even further. To the disaster of NASA's space shuttle programme (Vaughan, 1996) where the normalisation of deviances eventually led to the tragic accident killing all astronauts. More generic literature on accidents rarely explicitly mention the phenomenon of 'drift into failure'. This, despite the presence of key elements of drift into failure (time and direction related elements as outlined above). Accidents that contain such elements are i.e. the Bhopal disaster (Bloch, 2016) where investigation has proven that repeat failures and normalisation of deviances has led to a drift into failure causing the immediate death of 2,850 people. Or the Hatfield train crash (Jack, 2001), where alterations in management, maintenance and inspections eventually contributed to the derailing of the commuter train near Hatfield killing four persons and injuring 70. The Aberfan collapse (Turner, 1976) where years of underestimating, systematically trivialising and ignoring actual risks, despite similar incidents elsewhere, has led to the death of 116 children and 28 adults due to the sliding of the tip of the residue on the slopes above the town. Presumably the list could go on to large extent. All this literature emphasises that no industry is exempt from this phenomenon (often without explicitly labelling it as ' drift into failure'). In retrospect it is often very clear what has happened along the way and how it has been incubating over time (Turner, 1978). But this is only done in retrospect, with knowledge of the outcomes. None of the mentioned literature provides a method to prospectively recognise drift into failure so that pro-active measures can be taken to prevent this from turning into failure. Not that there are no lessons learned, but these lessons do not provide the insight necessary to forestall the drift into failure; i.e. stop the drift resulting into failure.

A parallel with drift could perhaps be drawn with a form of anticipation as cited by Woods in Pariès and Wreathall (2010), although this is more closely associated with resilience. Anticipation is based upon past experiences, adaptation to prevent previous issues. Hence the direct reference to resilience and making an organisation more resilient in order to prepare it for possible disturbances. However, this is based on previous issues. Drift on the other hand is, as mentioned, the slow but steady incremental movement towards the boundary of unacceptable performance. Anticipation is close in line with Requisite Imagination (Westrum, 1991; Wise, Hopkin, & Garland, 2010) which focusses on the proper design of cognitive tasks in relation to man-machine systems. Although the design of such cognitive tasks is assessed and potential risks are identified, acknowledged and preferably mitigated within this design process the presence of potential drift has not been addressed. Anticipation, and in the same sense Requisite Imagination, do not specifically take into account the differences between the current state and the previous design or state of a process. There is no insight in the direction of the movement due to the design. I would argue therefor that neither anticipation nor Requisite Imagination make it possible to prevent drift into failure. The main pitfall in anticipation and Requisite Imagination is the fact that this is based on known previous issues. When issues have not manifested themselves, the idea can arise that the system is inherently safe. However, successes achieved in the past are no guarantee for the future. This can give a false sense of security and as stated by Dekker (2011) this might be the biggest threat considering drift into failure.

It could also be argued that literature related to the High Reliability Theory refers to drift into failure when addressing rich awareness of discriminatory detail (Weick & Sutcliffe, 2006). However, this refers to predicting and mitigating potential risks based only on knowledge and experience gained in the past. Somewhat similar with anticipation and Requisite Imagination mentioned earlier. Rich awareness of discriminatory detail also does not indicate the location of a certain process in the Dynamic Risk Model (Rasmussen, 1997). It has a potential of revealing possible threats. However, it is not possible to gain insight into whether a process is moving towards the outer barriers of the model, thereby increasing the risks. In particular, gaining insight into the movement within the Dynamic Risk Model is required to be able to recognise drift into failure prospectively.

1.2 Dynamic Risk Model

Rasmussen (1997) introduced the Dynamic Risk Model, which schematically shows three forces acting on a system during operation: finance, workload and safety (the latter was called 'functionally acceptable performance' by Rasmussen). These forces play a large role in the dynamics of any organisation and interact with each other during operation. Too much focus on one particular force will lead to a disbalance within the model, shifting towards the other forces being under pressure and possibly crossing the boundary of what is acceptable for the system to keep functioning. Mainly this is why the term 'safety first' would not be sustainable due to the fact that too much focus on safety would imply that the model would shift towards finance and workload.

The Dynamic Risk Model can be a tool to visualise the constraints and pressure on an agent, the operating point, performing his or her task and, as such, brings an understanding of the dynamics within a system. With this model it is possible to project the (discretionary) space of an agent in any work system while performing his or her task, and the restraints that ought to be respected to meet the performance level required for the specific task. The restraints form the boundaries of the task and limit the variations that are possible for the agent in performing that task. They are presented as three boundaries in the Dynamic Risk Model: the boundary of functionally acceptable performance (i.e. safety), the boundary to economic failure and the boundary to unacceptable workload. The boundaries are visualised in Figure 1.1 below. The perceived boundary of functionally acceptable performance is also referred to as the marginal boundary. This marginal boundary can be interpreted as the boundary where the operation is still acceptable, and is a boundary set by the organisation itself. Exceeding this boundary is seen as unacceptable because it makes the risks too high. Cook and Rasmussen (2005) argue that this boundary is the result of sociotechnical processes and that when this boundary is crossed, mitigating measures will be put into action. However, this also entails the danger of so-called 'flirting with the margin' (Cook & Rasmussen, 2005), whereby the margin slowly creeps out. If the consequences of incidents are minor, this may be interpreted as being acceptable and the boundary will be stretched.

The free space in which the agent works, enclosed by the boundaries, referred to as 'space of possibilities' by Rasmussen (1997), can be translated as the discretionary space or margin of manoeuvring. This is the area in which the performance of the agent takes place and moves. This performance is able to vary during the task or operation, due to small adjustments from the agent. Within the Dynamic Risk Model the operating point is the point where the agent is positioned during the performance of the task. In given circumstances the agent will perform close to the boundary of functionally acceptable performance. In other moments in time the performance of the agent will be in the proximity of the boundary to economic failure, hence the term 'dynamic'. The location varies under influence of the goals that are present for the agent, which implies that the accompanying position of the operating point also varies. Rasmussen (1997) also concludes that the agent is most likely to manoeuvre away from the proximity of the boundary to unacceptable workload by creating circumstances that decrease workload. Management on the other hand, will attempt to move the operating point away from the proximity of the boundary to economic failure and increase revenues. This, "will very likely be a systemic migration towards the boundary of functionally acceptable performance and, if crossing the boundary is irreversible, an error or accident may occur" (Rasmussen, 1997, p. 189).

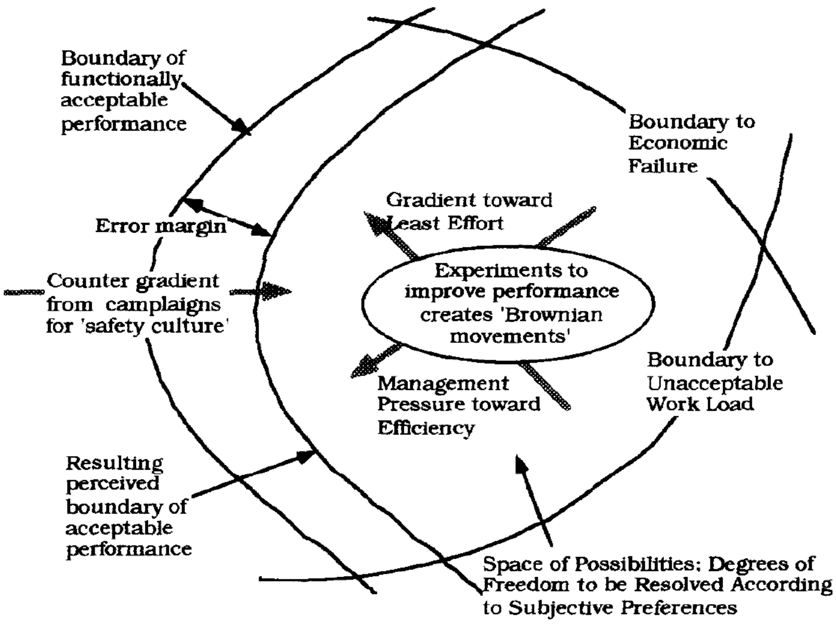

Figure 1.1: Dynamic Risk Model – Rasmussen (1997)

Rasmussen (1997) also points out that there is a hidden danger within the system. Organisations that rely on multiple defences, the defence-in-depth principle, often do not notice the degeneration of defences. This links with drift according to Ortmann (2010), regarding the aspect of slow, subtle and difficult to perceive. Especially over a longer period of time the loss of effectiveness of defences is hard to notice – this is where the model fully overlaps with the concept of drift (into failure), as described in the previous section. This degeneration is not only caused by the physical defence, but also under the influence of external or organisational (optimalisation) pressures, i.e. the introduction of a new item within a system might result in a local degeneration of a defence. The fact that defences have a tendency to degenerate over time can refer to the incubation time mentioned by Dekker and Pruchnicki (2014), "accumulation of these events can produce a gradual drift towards failure" (p. 534). The degeneration of defences could be visualised in the Dynamic Risk Model with an additional boundary within the model, the perceived boundary of acceptable performance shown in Figure 1.1. When defences degenerate, this boundary will slide towards the boundary of functionally acceptable performance, resulting in a decreasing error margin. Degeneration of defences can manifest unnoticed, due to the fact that incidents or accidents have not occurred.

Rasmussen (1997) regards the Dynamic Risk Model in relation to an individual agent. He and does not mention it could also be seen in relation to an organisation. Decisions and changes, adaptation performed by an organisation will, similar to an agent, have an effect on the position of the operating point. The organisation also has room for manoeuvring within the Dynamic Risk Model before reaching the boundaries. In that manner an organisation can be regarded as the agent mentioned by Rasmussen (1997). By concluding this, the operating point can be compared with the status of that organisation during time and be visualised in the Dynamic Risk Model (Rasmussen, 1997). Decisions, changes or adaptations by an organisation express themselves slower in time and could therefore go unnoticed. When interpreting the status of the organisation during multiple moments and plotting each point a trajectory will be visible. This leads to the question: 'is it possible to use the Dynamic Risk Model in identifying drift by visualising shifts in the model under the influence of the boundaries of unacceptability?'

In summary, drift into failure is a gradual movement towards the limit of the maximum permissible under the influence of factors: such as economics, workload and safety. It could be argued, but in essence Dekker (2011) already made a connection with Rasmussen (1997) and the Dynamic Risk Model concerning

Alaska Airlines flight 261, where economic pressure resulted in a migration towards the limits of safety and workload. Rasmussen (1997) mentions, "pressure toward cost-effectiveness in an aggressive, competitive environment" (p. 189). This results in the movement of the operating point away from the boundary to economic failure. He points out that, within a system, there is a tendency of moving towards the boundary of functionally acceptable performance. This directly relates to the definition provided by Dekker (2011) and Ortmann (2010) both referring to drift in relation to normal functioning of an organisation. In order to maintain operation it is necessary to learn and adapt, make processes efficient, adjusting norms and standards. This is common practise in organisations to cope with the economic pressures. Rasmussen (1997) also states the similar in essence, "a systemic migration towards the boundary of functionally acceptable performance" (p. 189).

As Dekker (2011) states, referring to Rasmussen (1997), "the likely result of increasing competitive pressure on a system, and of resource scarcity, will be a systematic migration towards workload and safety boundaries" (p. 37), this migration is an unintended outcome of normal operation. This gradual degeneration is what Vaughan (1996) refers to as 'organizational drift' where the safety goals have changed, due to new values and earlier outcomes. Matters previously seen as unacceptable, or deviances from the norm, are now considered acceptable and pose the new norm, resulting in the sliding of the marginal boundary. The same can be applied to the passenger handling process that allows passengers to walk across the aircraft stand which was unacceptable for a long period in time, but is now becoming more and more acceptable and forms the new norm.

There have been other studies with regard to the use of the Dynamic Risk Model (Rasmussen, 1997). An interesting thesis by Vijayan (2018) researched the identification of factors that contribute to the boundaries of the model and the gradients that push the operating point. This research has been performed in a biomedical laboratory setting. Although interesting and valuable this research does not elaborate considering the Dynamic Risk Model (Rasmussen, 1997) in relation to prospective recognising drift into failure.

In the next chapter, I will outline how this thesis aims to make the invisible gradual changes in passenger handling processes visible by using Rasmussen (1997) model of the Dynamic Risk to visualise the process of drift.

2 Research Design

2.1 Overview of the research setup and methods

The applied research design – that seeks to provide a method for prospectively recognizing drift into failure – is divided into three explicit and separate steps to give substance to the key-elements of drift into failure. The final step is the conformation of the obtained data by discussing the results with the participants of the research. As such, these steps in broad terms will consist of:

(1) constructing a phased narrative of the case;
(2) plotting the trajectory in the Dynamic Risk Model;
(3) conformation of drift discussing the visualised trajectory.

Both the phased narrative (step 1) and the processing of the narrative in the Dynamic Risk Model (step 2), were conducted by interviewing various persons from the organisation under consideration. By applying this interview method, the experience and knowledge of the participants can be used as data. Also, the participants will be able to provide the necessary local rationale behind all the decisions (regarding the passenger handling processes under study) that have been made during the time period. The interviews for the construction of the narrative (step 1) were conducted with two participants. These participants have been selected because of their involvement in, and knowledge of, the development of the passenger handling process over many years. The researcher also contributed his own knowledge of the passenger handling process to the refinement of the narrative. The interviews for the purpose of plotting the narrative (step 2) were conducted with seven participants who all work within the organisation under investigation. The positions of the participants vary, but all are directly or indirectly related to the process. From compliance officer in the field of regulation, process owner who is delegated risk owner and responsible for the entire process, strategic advisor involved in providing safety contributions, process developer responsible for managing the design process, safety advisor assessing changes, manager of the safety and control department, to an expert in the field of emergency response. The conformation of drift and discussing the trajectory (step 3) was conducted with the same participants.

For step 1, the phased narrative, the interviewees were asked what changes or optimalisations within passenger handling processes under consideration they have seen. These optimalisations were noted as milestones and placed on a timeline and broken up in discrete phases together with the additions of the researcher. All responses together form a phased narrative, which is the bases for the second step in the research.

In step 2, the plotting, the interviewees were asked where to plot the operating point in the Dynamic Risk Model for each of the identified phases from the phased narrative. In addition to the physical location of the operating point, the local rationale behind it was also requested. For every interviewee a separate model was drawn to prevent influence from previous plotted narratives. Eventually, this research step provided multiple drawings with multiple operating points, which were combined into one overall Dynamic Risk Model. Based on the obtained overall model, the average movement of the operating point of this organisation during the timeframe was drawn.

Finally, in the third step of the research, the now available artefact – the visualised path of drift in the passenger handling process - was used. This artefact was presented to the participants and asked if it was helpful in understanding and prospectively recognising (potential) drift into failure.

The research was executed by utilising a case concerning the passenger boarding and deboarding process on the airport. This particular process seemed to be an appropriate example for studying the process of drift, as there have been many changes (optimalisations) spread over a long period in time. Large international airports most often make use of the available passenger bridges that allow passengers a comfortable boarding and deboarding experience straight from the Terminal building into the aircraft, shielded from the environmental hazards. But this form of passenger boarding and deboarding is gradually changing. At the airport of study, from the year 2005 until now, several modifications in this passenger process have been introduced. Nowadays, it has become more and more common that passengers do not make use of the available passenger bridge, but board or deboard the aircraft by walking across the aircraft stand and enter or leave the aircraft with mobile stairs.

The design of the study thus consists of three separate sequential steps. In these steps, the prominent research method consisted of: interviews[1] with participants of the organisation (a large airport) under study. More specifically, experts that have somehow been involved in the decision making around the particular process of passenger boarding and deboarding at that airport. The following sections will further describe how the interviews were conducted and facilitated in the individual steps. The sections will also elaborate on how the data obtained from these interviews was analysed and contributed to answering the thesis question.

2.2 Step 1. Constructing a phased narrative of the case

As mentioned before, the first step consists of constructing a chronological narrative of the process of boarding and deboarding of passengers as the case subject to research. By focussing on significant differences within this chronological narrative, it is most likely possible to distinguish several discrete phases in which the handling of passengers changed from one phase to the next phase. This study calls this a 'phased narrative', which will constitute the first step in search of a method to prospectively recognise drift into failure.

In order to create this phased narrative interviews were conducted with two participants from the organisation under study. These interviewees were asked:

- what different phases are to be differentiated regarding the passenger handling process;
- what are the key-moments in time that modifications have been undertaken;
- what details are significant considering the modifications that have been made;
- what has been the effect of these modifications;
- what was the local rationale behind these decisions?

The strength of a narrative is that it contains many layers and is generally richer in data than reports, notices and memos. Cortazzi refers to a narrative as an important tool, "increasing recognition of the importance and usefulness of narrative analysis as an element of doing ethnography" (as cited in Atkinson, Coffey, Delamont, Lofland, & Lofland, 2014, p. 384), because of the way it constructs the context. A phased narrative presents certain events from the perspective of the narrator, in this case the interviewee, focusing on what happened and what the underlying motivation was, the 'local rationale'. A narrative can almost be seen as a glimpse into another person's mind. It shows how the world is seen from the narrator's perspective. That is why Cortazzi (1993), among others, underlines the importance of the narrative. The phased narrative provides insight into the origins and rationality of the modifications (decisions, changes, adaptations) in the process subject to research. This combination creates a historical overview (on the basis of discrete steps) and aims to understand what modifications were made, when they were made and for what purpose they were made.

This phased narrative starts at phase 0, the point at which all aircraft are connected with a passenger bridge, which was the standard at the airport 15 years ago. From there on successive phases are created together with the participants up to the present time. The aim was to identify all modifications and divide these into discrete phases. After the specific phases were established together with the participants during the interviews, additional data was collected by the researcher regarding laws and regulations from the International Civil Aviation Organization (ICAO) and European Union Aviation Safety Agency (EASA). This data consists of information on the market share of the Low Cost Airlines (Vidovic, Steiner, & Skurla Babic, 2006) in terms of airport information, passenger numbers and number of flights. Dimensions of the most common aircraft were also added to the phased narrative. The goal of this additional information was to make sure that the participants had sufficient data about the various pressures that the organisation was under during the various phases.

[1] as a result of the Covid pandemic, these have all been conducted online via Skype and Teams

The hypothesis is that the compilation of a timeline with the distinct phases, gives substance to the time-related elements from Ortmann's (2010) definition of drift. A timeline consisting of concrete phases of the development of the topic of study, paints a picture of the course of events (which can later be used as reference points that). Thus, it can be determined whether these were slow, subtle (incremental) changes, and as such, characteristic of drift (Ortmann, 2010; Dekker, 2011).

The now obtained narrative with the distinct phases, constructed from the interviews together with the additional data, forms the basis for the next step in the research. This narrative was ultimately very comprehensive and contained many details which may be too superfluous for the actual determination of the time-related elements. Excessive details could cause distraction for the interviewees and lead to a focus on side issues and miss the point. For this reason, the extensive narrative was condensed by the author into a more concise form. This was realised by summarising the phases one by one (note that the order and number of phases remain the same).

2.3 Step 2. Plotting the trajectory in the Dynamic Risk Model

The objective of this step 2 is to create a visualisation of the various distinct phases in the Dynamic Risk Model. The end product of this step is a visualisation of the movement and direction of the operating point

Prior to the actual interview, the seven interviewees received an information package with a number of components (see appendix A). An important part of this is an explanation of the Dynamic Risk Model (Rasmussen, 1997). This explanation of the model describes the functioning of the model by means of an example. In addition to this explanation, the information also contained the condensed narrative of the passenger handling case (the product of step 1). The information package also specified what questions were to be asked during the Skype session. In this way, it was possible for the interviewees to prepare themselves for step 2.

For each of the identified phases in the narrative, the interviewees were asked what the impact was on the position of the operating point in the Dynamic Risk Model. Also they were asked if the alterations in operation had an effect on the location of the marginal boundary. And if there was an effect on this boundary what this specific effect was. This was performed in the form of an unstructured interview where the researcher, in the role of moderator, assisted the interviewee through the process and had no part in the decision of the location of the operating points. The interviewees were asked to indicate the exact position of the operating point on a grid of the Dynamic Risk model (see Figure 2.1) for that specific phase according to their understanding of the various Rasmussen (1997) pressures at play during that phase. Does it remain on the same location in regards of the previous phase? Will it move towards or away from a particular boundary of the Dynamic Risk model? The rationale behind this drawing of the operating point by the interviewees was also questioned and noted by the researcher. By repeating this activity of positioning the operating point for all the distinct phases, multiple operating points were plotted within the Dynamic Risk Model. By using a Dynamic Risk Model which is implemented with an underlying grid it ensures that the interviewees location of the operating points can be compared afterwards.

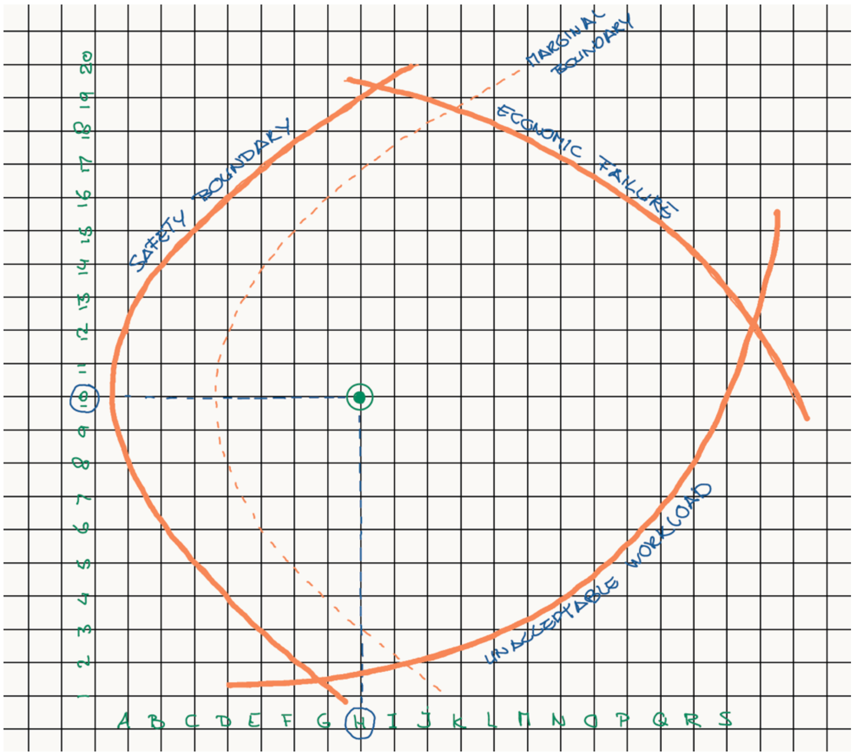

Figure 2.1: Dynamic Risk Model with grid

The starting point in the Dynamic Risk Model is phase 0, which is represented by the green dot in the centre of the model (see Figure 2.1). This location is reached by drawing a line perpendicular to the boundary from all boundaries of the model. The intersection of these three lines is the centre, the green dot. From here, all other phases are plotted against time. In the model (Figure 2.1) that was provided to the interviewees prior to the interviews, the boundary of functional acceptable performance, as Rasmussen (1997) refers to (Figure 1.1), is referred to as the safety boundary for convenience purposes. This made it easier for the interviewees to comprehend and apply in step 2.

Having the interviewees plot the distinct phases as multiple operating points in the model and then connecting these points by drawing a line through them, created a trajectory of the operating point over the subsequent phases (i.e. the chronological development of the passenger handling process over the last 15 years). The goal is to literally make drift visible in the Dynamic Risk Model, as a line that gradually moves towards one of the boundaries of the model (presumably the boundary of acceptable performance presented as the safety boundary in Figure 2.1). The result of applying the described method is that at this moment the direction-related elements can be identified Ortmann (2010).

Besides the actual plotting of the operating point of each phase on the grids of the Dynamic Risk Model, the rationale behind the location of the operating point is of value for the research. In order to understand this, the researcher asked follow-up questions such as: What made the interviewee decide to place the operating point in a specific location in that distinct phase? This created an understanding why the interviewees plotted the operating points where they did. This rationale was noted by the researcher and stored as qualitative data in conjunction with the actual plot in the Dynamic Risk Model. This qualitative data was also included as input in step (3) of the research and contribute to the final conclusions. The noted rationale was compiled and from this compilation an aggregated rationale is distilled. The aggregation itself was done on the basis of a summary of the noted rationale. This is presented in the form of Table 4.1 in which the aggregated rationale can be distinguished per phase.

Since all models are provided with a grid, it is possible to capture all individual operating points in a common model. After conducting all interviews and plotting the individual models, all data obtained was combined in a common model. Each operating point from the individual distinct phase in the narrative was copied and plotted into the common model. All the operating points of the individual phases were grouped together and connected in such a manner that an average became visible. The averages of all individual phases represent the movement of the operating point over time. This common model, with all operating points, is the final result of step 2. This common model was presented to the interviewees in step 3 of the research. They were questioned what this presentation of the common model meant to them and whether they could reach any conclusions regarding drift on this basis.

2.4 Step 3. Conformation of Drift discussing the visualised trajectory

This final step 3 is introduced in the research as verification for the proposed method to prospectively recognise drift: on the basis of the visual plots that step 2 creates, are the participants in step 3 able to see that the process subject to research (passenger handling) is drifting towards the boundary of acceptable performance? As such, step 3 aims to answer the primary thesis question if it is possible, by applying this method, to prospectively recognise drift. Additionally, step 3 aims to learn of this method for recognising drift is able to influence - and possibly change - the participants' general thoughts or perspectives regarding the process subject to research to be an example of a process that is drifting into failure – i.e. do they recognise that there might have been too much optimalisations of the other Rasmussian (1997) pressures (workload and finance) and too little focus on safety?

Prior to this final step 3 additional information was provided to the seven interviewees that participate in step 3 (see Appendix B). This additional information contained a brief description of the definition of drift, containing the key elements, according to Ortmann (2010), a short explanation of the research methodology and finally the overall Dynamic Risk Model that was created in step 2. The provided overall Dynamic Risk Model is the composite model based upon all the data acquired in the individual models. The participants were asked, after they have read the drift definition Ortmann (2010), what they could conclude on the basis of the presented composite Dynamic Risk Model provided. Step 3 was conducted in the form of an unstructured interview, similar to step 2, supplemented by written answers to the questions concerning the recognition of drift provided in advance. The objective was to verify if the creation of a phased narrative and plotting of the distinct phases within the process in the Dynamic Risk Model as operating points visualise a possible trajectory which can be recognised as drift?

3 Results Step 1. Constructing a phased narrative of the case

3.1 Introduction to the Phased Narrative

During the interviews the emphasis has been on searching for moments in the past when changes were made to the passenger handling process. These moments were noted by the researcher and confirmation thereof was given by the interviewees. This data forms the basis of the timeline as the backbone of the narrative, because it now is possible to distinguish different phases in which the passenger handling process changed. A phase is defined as a moment or period that distinguishes itself from another moment or period, due to significant (but seemingly small) changes. Completing this step and marking the changes in time in the narrative gives substance to the time-related elements, which characterise drift into failure.

The narrative hereunder provides insight into the decisions and measures taken by the airport to accommodate the changes in the passenger handling process set aside in time. During the unstructured interviews with the two participants in this step of the research the phases, in meta perspective noted in advance by the researcher, were discussed in detail. The questions the interviewees were asked started whether, apart from these phases, any other phases could be identified in the time period mentioned. The participants indicated that this was not the case, but that these were the phases to be distinguished to their opinion. This is the starting point from where, in conjunction with the participants, the key-moments within these phases were distinguished and noted for the narrative. The interviews provided details as to how the passenger handling process was performed, what changes there had been initiated, and how this manifested itself at the airport.

Finally, together with the interviewees, the rationale behind the phases was discussed; what was the basis for the choices made, and what were the decisions? Based on these interviews, together with additional data provided by the participants and the researcher, six different phases (0-5) have been distinguished in the narrative in detail. This narrative directly emphasises the long duration of the incremental changes that have been taking place over a period of 15 years. There are small differences between the phases individually. However, ultimately, the difference between the first phase and the last phase is recognised by the participants as being significantly large. When asked whether the airport, if it was situated in phase zero, would transfer directly to phase five, both participants replies negatively. This would have been too big a step and would lead to accepting too much risk.

In their definition of drift, both Ortmann (2010) and Dekker (2011) refer to small incremental changes over a longer period in time which play a key-role. The narrative, and specially the defined phases, comply with this definition. All decisions that make up distinct phases were deemed logical by the interviewees and based on the rationale of the specific moment. There was no mentioning of any of the phases being unsafe or irresponsible, and the incident database of the airport does not contain evidence that contradicts this information.

After completion of step 1, a comprehensive narrative was constructed based on the interviews conducted and supplemented with additional data (see appendix C). In retrospect, this level of detail was not necessary for the research. The narrative serves as a guideline for the next step and can contain too much information. The goal of this step of the method to prospectively recognise drift is that the interviewees construct their own story – integrating the forces of the Dynamic Risk Model (Rasmussen, 1997) - and not the one that has been spoon-fed to them by giving too much detailed information. Hence why a concise narrative has been constructed based on the comprehensive narrative.

The comprehensive narrative is solely used as a tool in the method to recognise drift into failure prospectively. It is not an end product in itself and therefore has not been included in full detail in this thesis. The more concise narrative, divided into five different phases which served as input for step 2 *Plotting the trajectory in the Dynamic Risk Model*, is provided hereunder. This concise narrative was presented to the interviewees prior to the interview of step 2. In the following paragraphs, the phases of the story will be presented in the same way in which they were presented to the interviewees.

3.2 The result of step 1: a phased narrative of the passenger handler process

The phased concise narrative presented hereunder is the result of step 1 and will serve as input for step 2.

3.2.1 The Beginning “the original plan for boarding passengers” (*Phase 0*)

The year 2000 marks the beginning, the starting point of this narrative. Passengers use the passenger bridges to board and deboard the aircraft and thus have direct access to the aircraft without having to walk over the service road or the aircraft stand, free of traffic, danger and weather influences. The only places where this process differs is on the Eastern part of the airport on a smaller apron, because of the fleet composition. This starting point will be represented in step 2 of the method to prospectively recognise drift by the operating point in the middle of the Dynamic Risk Model (Rasmussen, 1997).

Total passengers in 2000 are 39,606,925 and the number of flights is 432,483 (Schiphol, 2000).

3.2.2 Growing market of Low Cost Airlines (*Phase 1*)

The market is changing: Low Cost Airlines (LCA), such as Ryanair in 1991 and easyJet in 1995, are conquering an ever increasing market share. The growth of these LCA’s in early 2000 continues to increase (average growth of 45% per year between 1999 and 2004). The airport does not apply any price differentiation, each airline pays the same amount for visiting the airport. This makes the airport unattractive to LCAs because of the high costs. The LCAs are driving the market further and are gaining an increasing share of the regional airports, while the larger international airports are lagging behind. Larger airports are seeing passenger numbers decline in contrast to the smaller regional airports and are forced to respond. Traditional airlines are experiencing more competition from LCAs and are looking for suitable answers.

The aircraft stands at the airport have a wingtip clearance of 7.5 meter, regardless of the aircraft type. This meets the ICAO (2005) requirements for taxiing aircraft. These clearances are on the conservative side, which feels like an inefficient use of the available space.

3.2.3 Countermeasure airport additional ‘low-cost’ pier (*Phase 2*)

To compensate for the declining number of passengers and to meet the demand from LCAs, the airport decided to build an additional ‘low-cost’ pier. In 2005 this pier was built to accommodate LCAs and to meet their need and demand for lower costs in order to be able to add the airport to their network. The airport also benefits from this, considering the decreasing number of passengers, and sees an expansion of the existing network. With the introduction of this pier, the Boarding/Deboarding Rear Stairs (BRS/DRS) process was introduced at the airport. Now passengers walk to a mobile staircase across the aircraft stand, under close supervision of the handler, to board their plane. By not using passenger bridges, the process of boarding and deboarding is very short and reliable, which is necessary for LCAs to remain profitable.

The introduction of LCAs at the airport has direct consequences for other 'traditional' airlines. After all, they are no longer the only players at the airport. They have gained formidable competition and will have to absorb this in some way in order not to succumb to it. Short turnaround times are seen as a means to reduce costs and thus remain profitable.

At the end of 2005, the number of passengers increased by 12% to a total of 44,163,098 compared to a slight decrease in the number of flights (-3% to 420,736) to the previous year (Schiphol, 2005).

3.2.4 Expansion of LCA-handling (*Phase 3*)

In the following years, the market share of LCAs continues to grow from approximately 25% in 2005 to 49% in 2014 (EEA, 2019). More and more routes are added to the LCA networks, making them increasingly interesting for large international airports. The number of flights at the new ‘low-cost’ pier has increased. At certain times the pier reaches its maximum capacity, and it is necessary to divert to other piers. This leads to inefficiencies for LCA, particularly due to the use of the passenger bridge, which lead to higher costs.

To compensate for this, one specific LCA requested to be allowed to use the rear doors and lead passengers across the aircraft stand to the pier. The airport complies with this request in 2014 and makes an exception for this specific LCA to allow handling via the rear door at this location (G02). This is the first introduction of DRS at an aircraft stand where passenger bridges are available.

The increase in the number of passengers transported by LCAs continues to provide competition for other airlines, who are diligently looking for cost-cutting measures in order to keep up. Turnaround times are being reduced again, in order to save costs.

In 2013, passenger numbers increased by 20% to 52,569,200 and the number of flights rose by 1% to 425,565 compared to the previous year (Schiphol, 2013).

3.2.5 Changes in Security regulation (*Phase 4*)

Between 2013 and 2014, amendments to EU regulations have been announced requiring measures that have an impact on the airport. Arriving and departing passengers must be physically separated. As a result, the airport will have to rebuild piers to accommodate this. During the period that the works are being carried out and the physical separation in the piers cannot yet be realised, the so-called bus@gate principle will be applied.

With this principle, arriving passengers leave the aircraft via the passenger bridge and then take the stairs to the aircraft stand, where they are transferred to a bus that takes them to a bus injection point to ensure physical separation. This process takes longer than the standard handling process. Additional supervision is required by the handler to prevent passengers from wandering or leaving Foreign Object Debris (FOD) at the aircraft stand.

During this period, ICAO changes the regulations regarding wingtip clearance (ICAO, 2009). For category 4 aircraft this was reduced to 4.5 meter this allowed aircraft stands to become smaller. This results in less available space while the number of ground equipment vehicles remains the same or increases, due to the increase in passengers on board an aircraft.

The number of passengers increased by 5% in 2014 to a total of 54,987,500 compared to the previous year (Schiphol, 2014).

3.2.6 Efficiency stands (*Phase 5*)

As time passes, the need for the use of the bus@gate process disappeared, particularly due to adjustments made to the gates that now comply with the introduced EU security regulations. In 2015, several airlines requested the use of the rear door in combination with a mobile staircase. These airlines indicated that time savings for aircraft handling would mainly be found in the boarding and deboarding of passengers when this can be done faster. This immediately has a positive effect on the turnaround time. Passengers are escorted by the handler across the aircraft stand to the fixed section of the passenger bridge to enter the pier. This concept is called efficiency stands and is applied at several locations to reduce turnaround times. The efficiency stands use a similar handling concept as the previously realised BRS/DRS, which was set up for a specific LCA (see phase 3).

At the end of 2015, the number of passengers increased again to a total of 58,200,000. The number of flights increased by 3% this year to a total of 450,679 compared to the previous year (Schiphol, 2015).

4 Results Step 2. Plotting the trajectory in the Dynamic Risk Model

4.1 Plotting direction-related data

During step 2 all interviewees were asked what the impact is on the position of the operating point in the Dynamic Risk Model, based upon their interpretation of the presented narrative. The rationale behind the decision as to where the location of the operating point shifts towards is noted for every separate phase.

Some participants expressed some doubt over the plotting process, considering where to plot the operating point in the model: Would the operating point move towards the boundary of unacceptable workload or more towards the boundary of functionally acceptable performance? According to one interviewee, in some cases, the model did not seem to be entirely satisfactory, due to the context in which the modifications took place. A question raised by a participant was: 'Does the increase of workload automatically lead to a decrease of safety and vice versa?' The researcher explained that a shift away from the boundary to economic failure does not automatically imply a shift towards the boundary of unacceptable workload and illustrated this by shifting the operating point exactly parallel to the boundary in question. This helped participants better understand the workings of Rasmussen's (1997) Dynamic Risk model and they felt reasonably confident to plot the various phases on the grid of the DRM.

After plotting all the phases from the narrative as separate operating points, the researcher checked with the interviewees whether this shift was what the interviewee had in mind, and if the location corresponded with their thoughts. If this was not the case, the operating point was moved to a different location in better correspondence with their thoughts regarding the moment in the timeline, considering the phase.

Each phase, now translated into an operating point, has been discussed extensively with the interviewees. The reason for this extensive discussion is to gather the rationale behind the decisions to the locations where the interviewees plotted the operating points. This process of plotting and discussing has been repeated for all the distinct phases of the narrative with all interviewees, which resulted in an overview (Table 4.1) of the rationale for plotting the operating point at a specific position. The following sections and included Figures (4.1-4.7) describe and show the operating points of all interviewees separately together with the corresponding rationale they provided.

4.1.1 Interviewee #1

The Figure 4.1 below visualises the trajectory of the first interviewee and shows a clear trajectory towards the marginal boundary. This trajectory first moved from the starting point (H10) towards the boundary to economic failure as indicated in the added rationale. After touching the initial starting point again in phase 2 the trajectory drawn by the interviewee continues to move towards the boundary of functionally acceptable performance almost parallel to the boundary of unacceptable workload. In phases 3 to 5 the interviewee indicated, as shown in Figure 4.1, that this parallel movement has changed into a movement towards both the boundary of functionally acceptable performance and unacceptable workload.

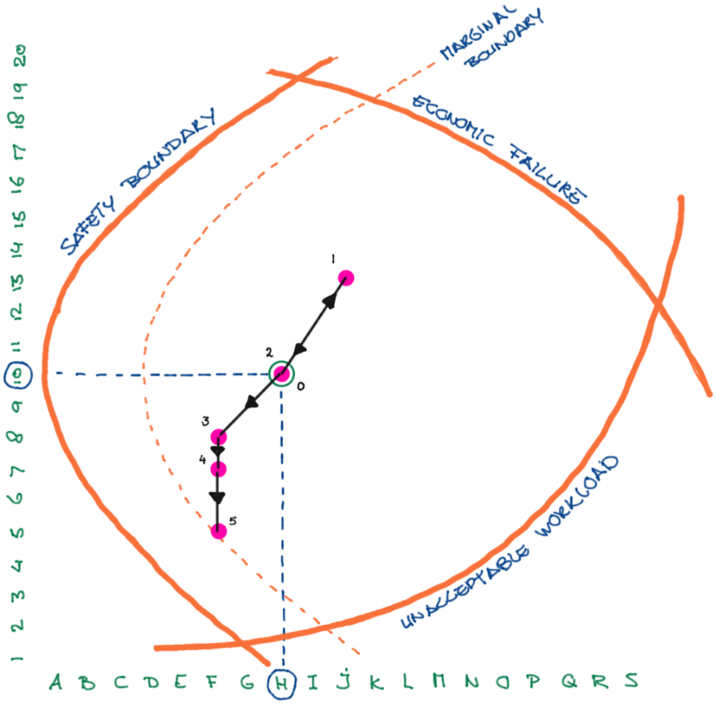

Figure 4.1: Dynamic Risk Model #1

Growing market of Low Cost Airlines (Phase 1): There is a lot of competition in the industry. These circumstances have an impact on the economic capacity and therefore the operating point will move towards the boundary to economic failure. There are little or no implications regarding safety.

Countermeasure airport additional 'low-cost' pier (Phase 2): The additional pier was specifically designed for this handling concept and therefore presumed safe. Additional measures have been taken; there is guidance of passengers, banklining and instructions are solid. This leads to the fact that the level of safety remains equal compared with phase 1, but there are economic benefits that make up for the losses. Combined, this will place the operating point back into the neutral starting position.

Expansion of LCA-handling (Phase 3): The pier was not designed for this process and additional measures had to be put in place. The fact that passengers are now walking across the aircraft stand is less safe compared to the passenger bridge which was initially designed. This measure has been taken based on economic grounds because airlines receive a discount in charges for remote handling. Combined, the operating point will move away from the boundary to economic failure.

Changes in Security regulation (Phase 4): The building of the new pier has been delayed, resulting in an alteration in the operation and therefore a process change. Large investments have to be made and, despite measures taken, the risk remains, because passengers are present on the aircraft stand where they do not belong. This makes the operating point move even closer to the boundary of functionally acceptable performance and also closer to the boundary of unacceptable workload, due to the fact that passengers need to be guided and this process is more labour demanding.

Efficiency stands (Phase 5): Shorter turnaround times are economically favourable. Despite mitigating measures that have been taken, the holes in the system are still present. The shorter turnaround times lead to an increase in workload, due to the additional guidance of passengers and the added processes (e.g. bust@gate). The operating point will move closer to the boundary of functionally acceptable performance and also the boundary of unacceptable workload.

4.1.2 Interviewee #2

Figure 4.2 below visualises the trajectory that was compiled during and after the second interview. Interestingly this interviewee placed the operating point regarding phase 1 at the exact similar location as the previous interviewee with basically the same rationale. This Figure 4.2 also visualises a clear trajectory towards the marginal boundary slightly different in comparison with the first trajectory, as now the trajectory also moved towards the boundary of unacceptable workload. The overall trend towards the safety boundary, however, is very similar to that of interviewee #1.

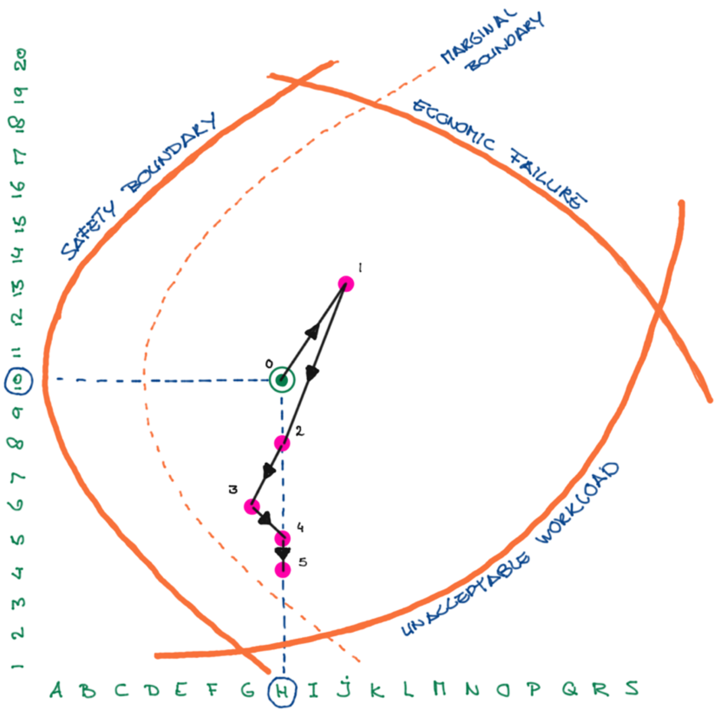

Figure 4.2: Dynamic Risk Model #2

Growing market of Low Cost Airlines (Phase 1): The airport is still growing but at a slower pace. And due to the fact that the airport cannot accommodate the low cost airlines (LCAs) they are also experiencing a decline in revenue. This will make the operating point move towards the boundary to economic failure.

Countermeasure airport additional 'low-cost' pier (Phase 2): There is higher pressure on the handlers regarding turnaround times, commercial pressure due to competition and an increase of traffic intensity, which has a negative impact on turnaround. This leads to an increase in workload. The airport has economical advantage due to the fact that more LCAs means more passengers who provide more revenue. However, shortening turnaround times and increasing workload for handlers has a negative impact on safety. Overall, the operating point moves away from the boundary to economic failure and closer towards the boundary of functionally acceptable performance and boundary to unacceptable workload.

Expansion of LCA-handling (Phase 3): With the introduction of the particular process (LCA-handling) the aircraft stand is operated by way of derogation. Despite the taken mitigation actions, it remains less safe. The workload will increase due to monitoring and guiding the passengers while deboarding and walking across the aircraft stand. There is an increase of economical profit due to the accommodation of more flights. This combined makes the operating point move towards the marginal boundary and closer to the boundary of unacceptable workload.

Changes in Security regulation (Phase 4): Passengers can trip or slip on the aircraft stand or fall in the bus. This provides an additional risk, but only slightly. Due to extra guidance, movements and clearances, and the fact there is lesser space on the actual aircraft stand, the workload increases. This results in the movement of the operating point towards boundary of unacceptable workload almost parallel to the boundary of functionally acceptable performance.

Efficiency stands (Phase 5): Several mitigating measures were conditional; only smaller aircraft were permitted, the aircraft stand has to be clean and tidy, passengers have to walk without obstacles blocking their path and crossing roads is prohibited. These measures contribute to making the process complicated. There is more potential risk involved with passengers walking on the aircraft stand. The shortening of the turnaround times introduces higher pressure and workload for the handling crew. Economically this turns out positive. Shortening turnaround times gives more profit. Overall, there is a slight movement of the operating point towards the boundary of functionally acceptable performance and also towards the boundary of unacceptable workload.

4.1.3 Interviewee #3

The third interviewee, in line with the previous interviewees, indicated that the operating point in phase 1 would move towards the boundary to economic failure with little or no impact regarding safety or workload. The complete trajectory (Figure 4.3), including all phases, indicates a clear trend towards the boundary of functionally acceptable performance. In phase 5, this trajectory moves more away from the boundary of unacceptable workload in comparison to the previous trajectories from earlier interviews.

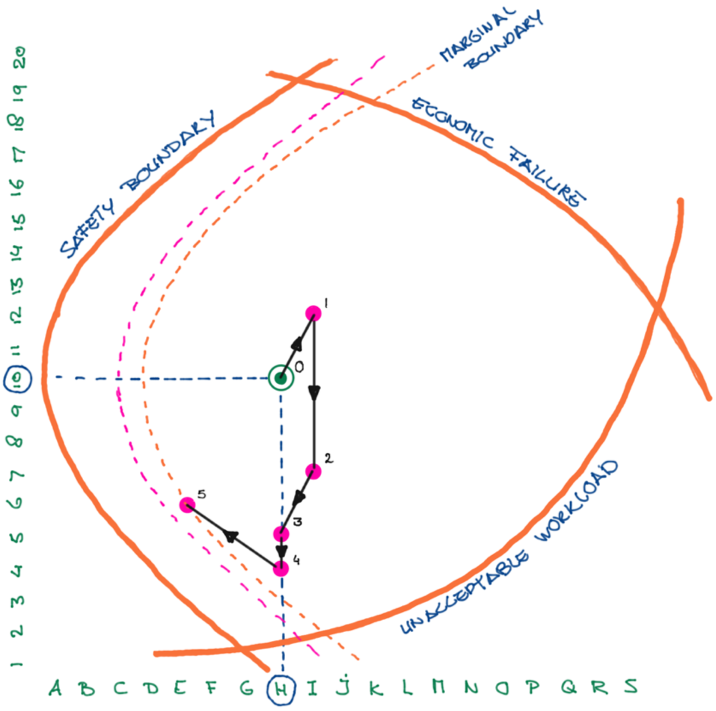

Figure 4.3: Dynamic Risk Model #3

Growing market of Low Cost Airlines (Phase 1): An external threat where no adequate reaction is undertaken, shifts the operating point towards the boundary to economic failure. There have been changes in the periphery of the airport that have an effect on the airport itself. However the airport has got a good foundation and will be able to manage these changes. In general the workload will decrease little.

Countermeasure airport additional 'low-cost' pier (Phase 2): Airlines are destined to shorten turnaround times. This results in increased pressure on aircraft handling. More safety risks are taken with the concept of the low cost pier due to the fact that passengers walk on the aircraft stand. In general, the workload will increase in search of cutting costs to counterbalance against competition. This will result in a movement of the operating point away from the boundary to economic failure and towards the other boundaries.

Expansion of LCA-handling (Phase 3): Regarding the entire airport, these are just minor changes and relatively dedicated to this specific aircraft stand. This leads to a small economic advantage. With the constant pressure and emphasis on turnaround times, the workload increases. This brings the operating point closer to the boundary of functionally acceptable performance as well as the boundary of unacceptable workload.

Changes in Security regulation (Phase 4): The airport is forced to this adaptation under pressure of European law. The decreasing dimensions of the aircraft stand is having an increasing negative effect on safety. The workload increases due to additional ground equipment movements, and personnel having to perform multiple tasks. Regarding safety the aircraft stands are getting busier and by this becoming less safe, which would imply a movement towards the limits of acceptability. All this results into the operating point moving closer to the boundary of functionally acceptable performance and the boundary of unacceptable workload.

Efficiency stands (Phase 5): This seems like a move back to phase 3. However, there is less space due to the fact that the aircraft stand sizes have been reduced. This increases the risk of incidents. The workload is, compared to phase 3, more positive and improved. There is a slight push away from the boundary to economic failure and from the boundary of unacceptable workload. This makes the operating point move closer to the boundary of functionally acceptable performance.

4.1.4 Interviewee #4

In Figure 4.4 the trajectory of the fourth interviewee also presents a clear path to the boundary of functionally acceptable performance. This interviewee is under the impression that the marginal boundary has shifted towards the boundary of functionally acceptable performance, reducing the error margin in phase 3. The reason for this shift is the acceptance of passengers walking across the aircraft stand while there is a passenger bridge available. The aircraft stand where this process is currently allowed, was initially not designed to accommodate this process, and therefore it justifies the shifting of the boundary: accepting the previously unacceptable. The trajectory is in line with previous trajectories which all indicate a trend towards the boundary of functionally acceptable performance, after an initial 'curve' towards the boundary of acceptable workload.

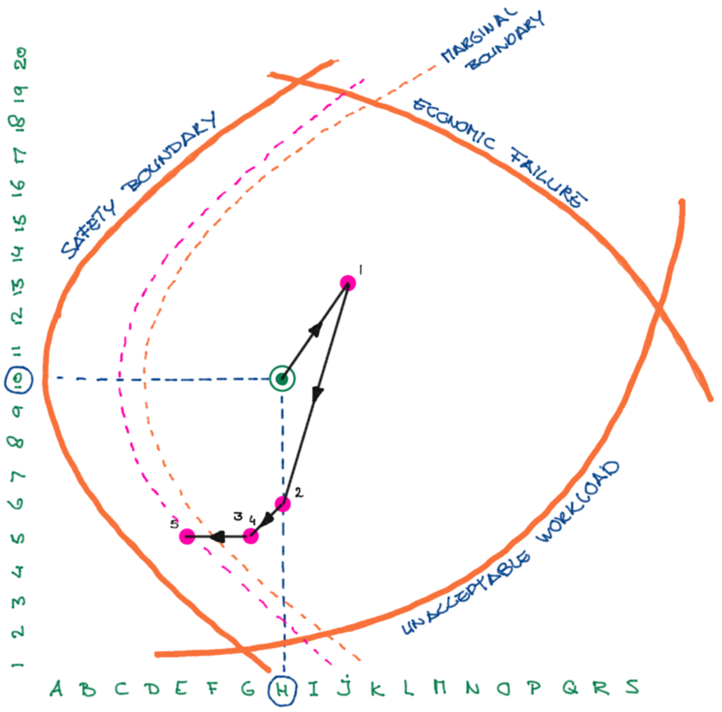

Figure 4.4: Dynamic Risk Model #4

Growing market of Low Cost Airlines (Phase 1): The airport is missing income due to decreasing passenger numbers. This has no impact on safety and the workload stays even, due to the fact that there are less passengers.

Countermeasure airport additional 'low-cost' pier (Phase 2): The new additional pier means extra economic benefits. It also means an increase in workload in the form of guidance, extra personnel and an extra phase in the process. Regarding safety this changes results in a slight decrease, due to the fact that passengers are walking on the aircraft stand now, where they can wander, are exposed to the weather elements and could create Foreign Object Debris (FOD). The main reason for not applying a passenger bridge was commercially driven. Passenger bridges were not deemed reliable by LCAs, where the turnaround is time critical. This combined, shifts the operating point towards the boundary of functionally acceptable performance and the boundary to unacceptable workload.

Expansion of LCA-handling (Phase 3): The financial position benefits from this change in operation. The workload has increased at other locations, due to the competitive nature of the industry. Regarding the safety component it is clearly less safe by using stairs and guiding the passengers over the aircraft stand. This phase 3 has more impact on the safety compared to phase 2, because in that phase the new pier was designed for the process and in phase 3 this was not the case. Altogether, the operating point will move away from the boundary to economic failure and towards the boundary of functionally acceptable performance. This is also the point where, according to the interviewee, the 'marginal boundary' moves towards the boundary of functionally acceptable performance, by introducing this handling method on an aircraft stand where an operational passenger bridge is available.

Changes in Security regulation (Phase 4): At this point there is no commercial incentive. The revenues remain equal for the airport. This change however, does increase the workload on the aircraft stand by introducing additional guidance of passengers. Regarding safety it can be pointed out that the aircraft stand was not designed for this process, which leads to changes in procedures. This is less safe compared to the former step 3, however, not a lot. Therefore the operating point will move towards the boundary of functionally acceptable performance.

Efficiency stands (Phase 5): This phase 5 is similar to phase 3. There are economic benefits, more profit can be realised. Workload remains more or less equal in comparison to phase 3. However, the aircraft stand has not been designed for this usage and therefore it is not optimally equipped, leading to an increase of risks during handling. This combined makes the operating point move towards the boundary of functionally acceptable performance.

4.1.5 Interviewee #5

Figure 4.5 below visualises the trajectory of the operating point regarding the fifth interviewee. This trajectory has a slightly other pattern in comparison to the previous trajectories. The main difference is to be found in the location of the operating point of phase 2 and phase 3. In contrary to the other interviewees, this interviewee states that, because the additional pier has been designed with the process of passengers walking over the aircraft stand in mind, this does not pose any additional safety risk. This does result in a change in the negative way with regard to workload. Hence the shift towards the boundary of unacceptable workload. Phases 4 and 5 on the other hand, do match with the average of other interviews.

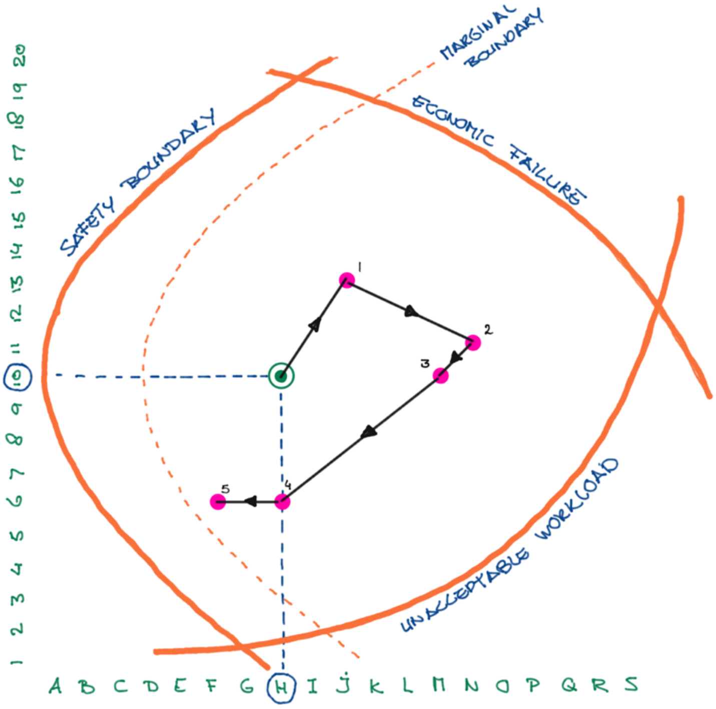

Figure 4.5: Dynamic Risk Model #5

Growing market of Low Cost Airlines (Phase 1): The airport was dropping ranks in the top-10 best airports in Europe which led to changes in approach and more focus on return on investment instead of quality. The operating point shifts towards the boundary to economic failure, due to decreasing number of passengers and destinations. There is hardly any impact on safety nor workload.

Countermeasure airport additional 'low-cost' pier (Phase 2): Regarding the economics nothing really changed, but the other components did. The workload increases, due to conflicting objectives and stress. There is an impact regarding safety. However, this impact is more about the wellbeing of personnel, thus the distance to the safety boundary can remain roughly similar The operating point will move strongly towards the boundary of unacceptable workload.

Expansion of LCA-handling (Phase 3): Workload is not affected clearly. However, the surrounding environment is affected. Other airlines are pressured into more cost effective operation thereby increasing workload. There is a growing demand for deviations from 'standard' operation which leads to the introduction of different procedures, leading to new risks and a less safe process. The operating point will move slightly towards the boundary of functionally acceptable performance.

Changes in Security regulation (Phase 4): Workload does not really change a lot. Regarding safety there are smaller margins: bigger aircraft, different procedures and more exposure to risks, such as stairs, busses and service roads. This makes the operating point shift dramatically towards the boundary of functionally acceptable performance.

Efficiency stands (Phase 5): By introducing this process the total pressure on the system increases. The proverbial 'last straw' that breaks the camel's back. The chances increase which leads to the movement of the operating point closer to the boundary of functionally acceptable performance.

4.1.6 Interviewee #6

Figure 4.6 below visualises the plotting of the sixth interviewee. Similar to the previous models, there is a clearly visible trajectory towards the boundary of functionally acceptable performance. The most striking difference between this model and the previous ones, is the multiple shifting of the marginal boundary. In several phases this interviewee argued that the marginal boundary has moved, due to the acceptance of previous unacceptable activities within the process of passenger handling. The main reason behind the decision to shift of the marginal boundary lies in the fact that, in the eyes of the interviewee, there are safer alternatives at hand. Also an interesting deviation of the previous plots is the move towards the boundary of unacceptable workload in phase 5, whereas most other interviewees saw phase 5 moving away from this boundary.

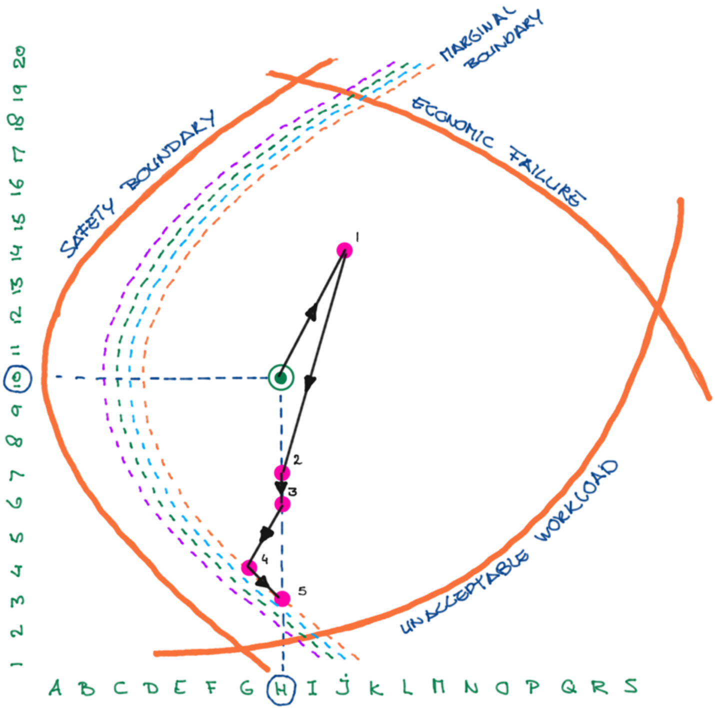

Figure 4.6: Dynamic Risk Model #6

Growing market of Low Cost Airlines (Phase 1): There are no issues besides the growing market of LCAs. There have been no changes in the approach of safety and for workload it has had no effect. The only change is the movement of the operating point towards the boundary to economic failure.

Countermeasure airport additional 'low-cost' pier (Phase 2): The absence of passenger bridges and less luggage provides an economic benefit, but on the downside this leads to a decrease in safety. From a safety perspective the use of stairs is less safe compared to the passenger bridge. This also applies to passengers walking on the aircraft stand. LCAs earn their money flying, so turnaround times have to be short and effective. This led to the introduction of focus on on-time performance (OTP): The occupancy of the aircraft increased, more passengers using the stairs, more passengers on the aircraft stand. This results in the operating point moving away from the boundary to economic failure and towards both the boundary of functionally acceptable performance and the boundary of unacceptable workload.

Expansion of LCA-handling (Phase 3): Handling is comparable to phase 2, but only one stairs in use. This makes this phase 3 a little less unsafe. However, still less safe compared to previous handling on this aircraft stand only using the available passenger bridge. The workload does increase on other areas of the airport, due to competition and the growing demand in shortening the turnaround time. Combined, the operating point will move a small step towards both the boundary of functionally acceptable performance and unacceptable workload. Besides this movement, the 'marginal boundary' has also moved towards the boundary of functionally acceptable performance. Decreasing the error margin due to the introduction of this process on an aircraft stand where passenger bridges are available.

Changes in Security regulation (Phase 4): The 'marginal boundary' has been moved again towards the boundary of functionally acceptable performance. There are more movements of equipment on the aircraft stands and the service roads, due to busses transporting passengers. More equipment is needed, due to the increasing size of aircraft and its capacity. The aircraft stands are getting smaller, so the space of handling is decreased while intensity is increased. Due to the shortening of the turnaround time, the handling processes are no longer sequencing but overlapping, creating more workload and higher risks. Norm times (OTP) become more important applying extra pressure on working staff. The operating point will move closer to the boundary of unacceptable workload and towards the boundary of functionally acceptable performance at the same time.

Efficiency stands (Phase 5): More focus on OTP realising more workload and creating shorter turnaround times. This leads to simultaneous processes instead of separate processes. Aircraft stands are getting smaller and OTP is becoming more important. More ground service equipment occupies the stands. Risks are being introduced, even though a safer alternative is available. According to the interviewee phase 4 is now not applicable anymore the plotting of phase 5 is based on the movement from phase 3. This makes the operating point move towards the boundary of functionally acceptable performance in comparison with phase 3. Again, the marginal boundary will slide closer to the boundary of the model due to acceptation of these modifications.

4.1.7 Interviewee #7

The visualisation of the trajectory of the seventh interview is presented in Figure 4.7 below. Similar to all previous trajectories, the operating point moves strongly to the boundary of functionally acceptable performance after a short run up to the boundary to economic failure. This model indicates the movement of the marginal boundary multiple times. The interviewee argued that the first introduction of the new passenger handling process in phase 2 shifted the marginal boundary towards the boundary of functionally acceptable performance. However, this shifting of the marginal boundary continues throughout the following phases 3 and phase 5. In general, the trajectory of the operating point is in line with the previous trajectories.

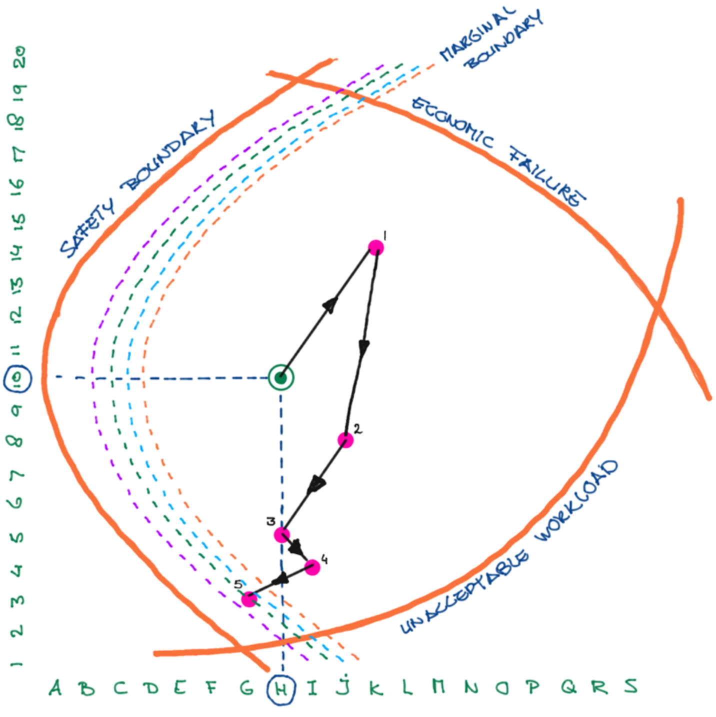

Figure 4.7: Dynamic Risk Model #7

Growing market of Low Cost Airlines (Phase 1): Due to the economic impact of the changing market, the operating point will move towards the boundary to economic failure. Regarding safety there are no changes, so the operating point will move parallel in comparison with the boundary of functionally acceptable performance

Countermeasure airport additional 'low-cost' pier (Phase 2): With the introduction of the low cost pier and the new concept 'passengers on the aircraft stand', the airport accepted new risks. With this, the marginal boundary has moved towards the boundary of functionally acceptable performance. The boundary to economic failure pushes the operating point away towards the boundary of unacceptable workload, which will slightly increase.

Expansion of LCA-handling (Phase 3): This is a new process on an existing aircraft stand where passenger bridges are available. This triggers the second move of the marginal boundary towards the boundary of functionally acceptable performance. Now there is a larger impact regarding safety by guiding passengers over the aircraft stand and the lack of mitigating measures. The operating point will move even closer to the boundary of functionally acceptable performance.

Changes in Security regulation (Phase 4): The 'marginal boundary' has been moved due to introduction of extra busses and extra stairs. The risk increases slightly as passengers have to take additional stairs and board a bus that brings them to the Terminal. The workload will increase, due to that fact that more guidance and monitoring of passengers has to be performed. This leads to the movement of the operating point towards the boundary of unacceptable workload.

Efficiency stands (Phase 5): This process is a copy-paste from phase 3 performed in a different location at the airport. Passengers have to use stairs twice during the process. There is more pressure on the turnaround times, which increases workload in comparison with phase 3. During this phase the marginal boundary again moves towards the left and so does the operating point, shifting more towards the boundary of functionally acceptable performance.

4.2 Combining the individual results

4.2.1 Combined movements Dynamic Risk Model

After conducting all separate interviews and obtaining multiple Dynamic Risk Models, the next stage in the research is combining all this data into one overall Dynamic Risk Model. This overall model, Figure 4.8, visualises the distribution of the operating points. In this overall model an average trajectory can be distinguished. This reflects the general thought of the participants regarding the location of the operating points during the different phases. It becomes visible that the interviewees do not differ much from each other, with a few exceptions. These exceptions are all related to one specific interviewee and apply to phase 2 and phase 3. Here the interviewee stated that in phase 2 the movement is more towards the boundary of unacceptable workload and less in the direction of the boundary of functional acceptable performance. In phase 3 the interviewee is under the impression that the operating point moves towards the boundary of functionally acceptable performance but still not in the same range as the average locations. Except for the mentioned exceptions the overall rationale indicates that the general opinion is equal during all the phases of the discussed narrative. Figure 4.8 reveals that the focal point - from phase 3 onward - in the model is near the boundary of functionally acceptable performance.

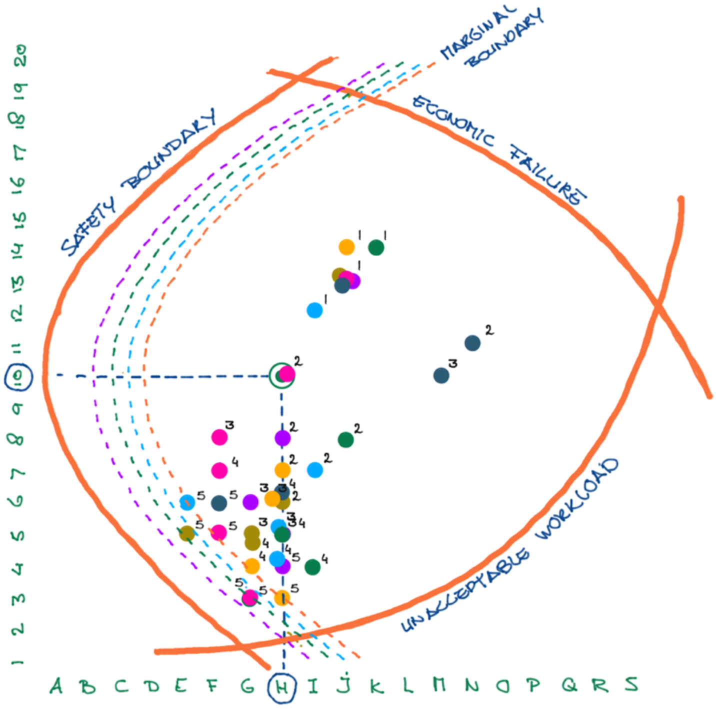

Figure 4.8: Overall Dynamic Risk Model

The overall Dynamic Risk Model shows the distribution of the operating points, but due to the large amount of points the readability is moderate. To increase readability and provide greater clarity on the trajectory, the individual operating points in Figure 4.9 are grouped as averages. The exceptions have been left out of consideration. The results presented in this way show the general movement of the operating point within the Dynamic Risk Model over time. Gradually but convincingly in the direction of the boundary of functionally acceptable performance or the safety boundary in this specific used version of the model.

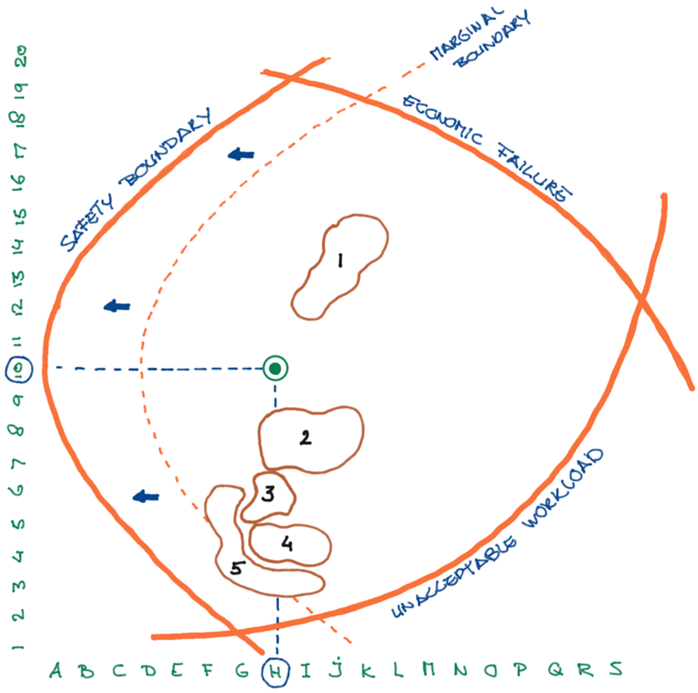

Figure 4.9: Combined Movements Dynamic Risk Model

Figure 4.9 visualises this total movement as a collection of average moves. The first movement is towards the boundary to economic failure, mainly due to the fact that in phase 1 external factors changed and had a negative impact on the competitive position of the airport and airlines. After this movement, the average operating point shifted towards the boundary of functionally acceptable performance, represented by the second movement, due to the introduction of the new passenger handling process. The subsequent movements show a similar pattern which continues towards the bottom of the model where the boundaries of functionally acceptable performance meet the boundary of unacceptable workload.

When phase 5 is compared with phase 0, it can be stated that the interviewees are unanimous in their drawing. A gradual movement – a 'drift' - in the direction of the boundary of functionally acceptable performance can be distinguished. It can clearly be seen that the operating point is moving further away from the boundary to economic failure, and the operating point is approaching the boundary of unacceptable workload. This is in line with the local rationale provided by the interviewees (as described in more detail in section 4.2).

4.2.2 Combined rationale overview

Table 4.1 presents the aggregated overall rationale provided by the interviewees during the plotting of the various phases in the narrative. An overview is generated, from which the main reasons behind the decision of the plotting location can be distilled.

Phase	Rationale for drawing the operating point at a particular location
0	Passengers board and deboard the aircraft via the passenger bridge, shielding them from the environment and separating them from operation on the aircraft stand. This was first seen as a measure for the comfort of the passenger, providing a premium method of boarding and deboarding the aircraft. As time evolved, activities on the aircraft stands and service roads increased, therefore the passenger bridge also was seen as a safety measure.
1	The fact that the overall market share of LCAs is expanding on regional airports, leaving the International airport with a decrease in number of passenger and flight, results in an economic downfall for these international airports. Thus, the operating point will move closer towards the boundary to economic failure. There are little to none implications regarding safety during this phase.
2	The construction of the additional 'low-cost' pier and with that the introduction of LCAs to the airport cause an increase in revenues, resulting in the operating point moving away from the boundary to economic failure. At the same time, the implemented process regarding passenger handling, although designed, has a safety affect. Passengers are now walking across the aircraft stand and are exposed to the present dangers. This results into the operating point moving closer towards the boundary of functionally acceptable performance. Simultaneous, the traditional airlines experience commercial pressure and are destined to shorten turnaround times, resulting in an increase of workload by which the operating point will move closer towards the boundary to unacceptable workload.
3	During this phase, the handling process principle is introduced for the first time at an aircraft stand where passenger bridges are available. This is against the basic design and therefore changes to the aircraft stand are required. This results in a less safe situation compared to the use of only passenger bridges. It will have minimal economic benefits and with regard to the workload it also has minor effects. The operating point shifts towards the boundary of functionally acceptable performance.
4	The introduction of a bus into the passenger handling process, whereby the passengers have to make an extra movement on a staircase, is by definition a less safe situation compared to the previous method. This shifts the operating point to the boundary of functionally acceptable performance. In terms of work pressure, more guidance and supervision are needed than before, which has increased the work pressure. The aircraft stands have become smaller, meaning that there is less manoeuvring space available for ground handling equipment. Within this smaller space, passengers have also been introduced, making the operation more complicated in comparison to the previous method. This combined results in a movement of the operating point closer to the boundary of functionally acceptable performance and closer to the boundary of unacceptable workload.
5	This handling process was introduced to reduce the turnaround time and thus achieve an economic advantage. Additional measures and requirements have been drawn up and implemented, such as restrictions on aircraft type, condition of the aircraft stand, constant supervision and so on. But now passengers are walking through the aircraft handling process on the stand where time is an important factor. All interviewees indicate that the operating point is moving closer to the boundary of functionally acceptable performance. Opinions differ as to whether or not the pressure of work is increasing and therefore shifting towards the boundary of unacceptable workload.

Table 4.1: Overview combined rationale moving operating point

During the interviews, it was opined that the marginal boundary must have shifted based on past events. If it is argued that the marginal boundary indicates the minimum acceptable level, this statement seems to be correct. In the initial situation, phase 0, it was unacceptable for passengers to walk across the aircraft stand. However, this has been changed in phase 3 on aircraft stands where a passenger bridge is available. Extra measures have been introduced, such as the deployment of additional personnel, bank lining and various architectural modifications. But it remained clear to the interviewees that what was previously considered unacceptable has become acceptable during phase 3, with the introduction of passengers leaving the airplane via the rear and walking across the stand. This justifies the shift of the marginal boundary and with that decreasing the error margin in the Dynamic Risk Model in phase 3. Some interviewees also pointed out that the shift of the marginal boundary did occur even more often and is not only reserved to phase 3. This is visually presented and Figure 4.6 and 4.7.

One interviewee indicated that this shift in the marginal boundary was already realised in phase 2, with the introduction of the additional pier. Despite the fact that this pier was explicitly designed to accommodate this process, the opinion is that the previously unacceptable has become acceptable in this phase, and that the boundary therefore has shifted. If this shift actually took place prior to the shift in phase 3, the space between the marginal boundary and the boundary of functionally acceptable performance has become very small. The main risk is hidden in the fact that this shift goes virtually unnoticed and will most likely only manifest itself when an incident occurs.

Regarding the local rationale for the decisions that emerged in phases 0-5, it can be concluded that the movement away from the boundary to economic failure is predominant. According to the interviewees, the main drivers for the changes have been decreasing passenger numbers and economic loss. This brings the operating point closer to the boundary of functionally acceptable performance and the boundary of unacceptable workload. To compensate and counteract this pressure, the airport has developed an additional 'low-cost' pier and accommodated the change in passenger handling. These preventive measures taken by the airport, seem not to have convinced the interviewees to draw the operating point ever closer to the boundary of functionally acceptable performance.

5 Results Step 3. Conformation of Drift discussing the visualised trajectory

In order to determine whether drift can be recognised by using the method described, the former seven participants were again approached and asked for their cooperation. This was done partly via e-mail and partly via Skype. Prior to this the participants were sent seven questions together with the overall Dynamic Risk Model which was the result of step 2 of the research (see Appendix B). The purpose of this step is to verify the method used in recognising drift and whether this method has achieved the expected result.

The seven interviewees who participated in step 3 indicated that prior to the interviews and the showing of the Dynamic Risk Model (see Appendix B), the general perception was that the changes in the treatment process had been made consciously. Although there was a strong sense of some movement towards the limits of safety, it remained mainly a feeling and was difficult to substantiate. When asked if they had estimated the eventual movement in relation to the passenger handling process in advance, they indicated that they had an inkling but could not directly substantiate it. According to the participants, the use of the Dynamic Risk Model and the presentation of this completed and elaborated model (see Appendix B), thus visualising the movement, changed this.

According to all seven interviewees, the method used provided insight into this movement in the form of the visualisation presented. Thus, the interviewees concluded that it is possible to recognise drift by applying this method. One interviewee replied: 'the pictures do indeed show that there is drift, especially in the model with the three clouds' (see Appendix B), although this method of presentation can also be interpreted as subjective and leading. This interviewee suggested not using clouds, but taking a more statistical approach and calculating the standard deviation and mean in a more scientific way. Other reactions of the interviewees to the applied method were, 'this definitely visualises drift', and as one interviewee replied, 'not a possible drift, but a clear drift to the boundary'.

During the interviews with the participants considering their projected trajectory, they indicated that the movement could be regarded as a slow gradual movement towards the boundary of functionally acceptable performance. This despite the mitigating measures taken by the airport. Some interviewees believe that the marginal boundary itself has shifted towards the boundary of functionally acceptable performance. The shift towards the boundary of functionally acceptable performance has not occurred without certain additional measures. For example, adjustments were made to the aircraft stands and new working procedures were introduced. Despite these measures, according to all the interviewees, the general operating point has moved towards the boundaries of functionally acceptable performance and unacceptable workload. One interviewee mentioned, 'this shows me that during the design phase we will have to prevent this from happening, we should perhaps consider putting up even stricter marginal boundaries that prevent us from crossing the actual boundaries as a warning'. In other words, by setting stricter requirements during the design phase, we need to avoid pushing the boundaries and protect ourselves against necessary cutbacks that affect our location in relation to the boundary in a later stage.

After being presented the combined Dynamic Risk Model (see Appendix B) and discussing the trajectory an interviewee mentioned that the collective memory (Halbwachs, 1992) of the organisation has not been maintained properly due to personnel changes over time, together with the fact that the changes are part of a long-lasting adaptation process. This is a contributing factor in the formation of the trajectory.

The visualisation of the combined Dynamic Risk Model (see Appendix B) and discussion afterwards has led to some interviewees reflecting on the fact that the airport did not look back over a longer period of time when making changes to the handling process. The introduction of new measures has not been compared to and evaluated with earlier measures. This leads to an accumulation of small incremental steps over a longer period of time with little historical background, which is a key element in drift. The collective memory (Halbwachs, 1992) of the airport is gradually changing, experienced staff has left the organisation for various reasons. New staff is starting to build up memory from arrival day and have little or no knowledge of past decisions. Documentation has not been kept up to date and therefore is not always correct reference material. If this is projected onto the Dynamic Risk Model and the midpoint is interpreted as the starting point of the model, new personnel will most likely place the current state at this starting point. By projecting the current state into this specific point, we consider ourselves safe and accept previously made decisions. This relates to what Vaughan (1996) calls “organizational drift”. The acceptation of deviations because there is little or no knowledge that these were deviations in the first place. The absence of incidents reinforces this, false, sense of being safe. Using the plotting of multiple operating points in the Dynamic Risk Model to provide insight into the measures and changes by presenting a trajectory of the process, this may prevent earlier deviations from being considered acceptable. The researched method could be a helpful tool.

In summary, the interviewees concluded that by applying this method, the key elements of drift as outlined by Ortmann (2010) can be substantiated. Therefore it is possible to prospectively recognise drift into failure. One participant considers that it is even possible to visualise the unintentional element. ‘In the case of an intended, and therefore known effect on the change, you make a conscious decision, that means that your line is interrupted and then shifts to another boundary instantly’. The main disadvantage in this matter is the knowledge of the current location of the operating point within the Dynamic Risk Model. When there is no knowledge of the current location of the operating point the implications of initiated changes on the location of the operating point are unpredictable. The participants were enthusiastic about the applied method. The question that immediately arose by all interviewees was: “how can this method be operationalised and at what moments can it be used to make strategic decisions?” Or as an interviewee stated, ‘useful, but a challenge to make it effective, now mainly looking back and the question is how do we look forward?’.

During the interview a participant stated the following:

> ‘By applying the researched method and plot multiple operating points, we do look back in time to some extent, however due to this plotting it is possible to recognise the direction of the movement. This recognition can be used to our advantage by readjusting our tactics or altering decisions based on this revelation. Thus, it is possible to operationalise the method used.’

Another reaction by a participant reflecting on the small incremental steps that are rooted inside the drift during the interview was:

> ’Small incremental decisions where little amount of safety loss is taken, but not added up in the drift. Therein lies the challenge, but also the greatest opportunity of your model. How do you ensure that during the process the partial decisions can count in the drift movement, and not in retrospect?’

This is where the method can be of value. If during the process the trajectory can be recognised, it can raise awareness and become part of the decisions that can alter the trajectory, and contribute to the prevention of drifting into failure.

Overall, the interviewees agree that the applied method is not only applicable for the airport and this specific passenger handling process. The applied method could be useful for other processes at the airport as well. To quote one interviewee, ‘Yes, this method can be useful with more processes and even within other industries, because it gives a clear visual presentation of the trajectory’. By visualising the trajectory over a longer period in time this can be a valuable tool in making strategic choices regarding a process under consideration.

6 Discussion

Of course, like any method, the method researched to prospectively recognise drift into failure is not immune to limitations. Limitations which are such that it is not possible to gain insight into the possible movement of the operating point and therefore not be able to prospectively recognise drift into failure. The main limitation is the lack of insight into the changes that have occurred within the process that is subject to this method. When it is not clear what the changes are within a process and it is unclear where the starting point lies, then it is very difficult to draw a picture of the movements the process undergoes. Without that starting point, subsequent positions of the operating point cannot be plotted in the model. This due to the fact that the subsequent positions are dependent of the previous positions of the operating point. It is therefore necessary that there is a clear and lucid view of the starting points of the process to subject to this method. It has to be clear what the design principles were at the time; what was the aim when the process was created. Only when this is clear a comparison can be made with a phased narrative over time.

The collective memory mentioned earlier has an important role in the proposed method. Perhaps this should even be regarded as a condition for being able to apply the method described. When regarding collective memory, it is meant the pool of shared memories within a group of people or organisation. It is not only a question of having people who are familiar with the situation and the context, but also of having documentation available. It is important for any organisation that documentation is stored and things can be reproduced. In addition to physically building and maintaining this archive, it is important that this is actively shared with the newcomers. In my opinion, this is probably the main limitation or threat to the method. And not only for the application of this method, but also in a general sense within society and organisations. Humanity tends to build up a very selective memory, positive things are remembered, the same applies to strongly negative things. Details, however, are unfortunately all too often forgotten and there is a tendency to fill in the gaps according to our own imagination. Successes prevail in memory and this can lead to parts of a storyline being incorrect or incomplete. Returning to collective memory, one limitation is that within organisations it is often encouraged not to stay in a particular position for very long. The fear of 'getting stuck' is often put forward in this regard. The advantage is that this allows many people to be deployed in many different ways and creates a strong bond with the organisation. The disadvantage, however, is that staff move on to other jobs and often take their own archive with them. And the sharing of experiences is not, or only partially, done due to work pressure or ignorance. A good transfer of information can offer a solution here, but in my personal opinion and experience, this only happens sporadically. This creates the chance that not only staff leave the function, but also the experiences go out the door and thus gaps in the collective memory occur. This makes it very difficult to estimate the location of the operating point in the Dynamic Risk Model (1997), with the result that the method studied can be used less effectively as a tool for the prospective recognition of drift into failure. New personnel have the tendency to place the operating point in the centre of the model presuming it is a solid safe state and use this as a reference point for future changes or decisions.

As a limitation, it could also be stated that the method as such cannot prevent the phenomenon of drift into failure, it is not a ready-made solution. However, the method can contribute to recognising and acknowledging that a certain form of drift is active. However, if no further mitigating actions are taken, this method will not prevent drift. The method should therefore be regarded as a tool for making drift visible and this insight may contribute to the decision making process to prevent drift into failure. Whether this should actually be considered a limitation of the method can be debated.

It could be claimed that not only the operating point within the Dynamic Risk Model (1997) moves, but that the boundaries themselves are also subject to movement. As stated earlier in this thesis the marginal boundary can move, as was also mentioned by a number of interviewees during the research (pp. 18, 19, 22, 23, 25). Woods (2018) believes that the boundaries themselves can also be moved by agents or organisations by setting different limits. This is referred to as graceful extensibility and it is seen as the opposite of brittleness. Brittleness refers to the sudden collapse of a system when it is pushed to, or just beyond, the limits of its capacity. This is comparable to a digital system where there are only two options: *on* or *off*. Woods (2018) indicates that from a resilience point of view, a system should be more flexible to make itself more resilient. More analogous compared to digital. There is a space between *on* and *off*, and it is precisely this space that Woods (2018) refers to, indicating that a system can adapt in situations when it is pushed beyond the boundaries without immediately collapsing. The most difficult part remains that an estimate must be made of the location of the boundaries and especially an estimate of the location of the operating point in relation to the boundaries. And it is this latter aspect in particular that is currently lacking. This is exactly what Cook and Rasmussen (2005) indicate is the problem regarding drift into failure. Where, within the model, is the process located, how does the location of the operating point relate to the boundaries?

If the boundaries of the model are considered to be the maximum permissible limits, then I believe that they cannot actually be moved. Perhaps it would be better, comparable to the marginal boundary, to set such an additional boundary for all boundaries within the model (see figure 6.2). When looking at the use of a so-called standard 5x5 risk matrix (see figure 6.1) in which likelihood and consequence are plotted and classified, one could say that the unacceptable risks coloured red in the matrix, indicate the extreme limits of the system. This could be equated to the boundaries of the model. But before these boundaries are reached, there are risks that already indicate boundaries within an organisation, boundaries of admissibility or acceptance. These additional boundaries can shift in the course of time comparable with the marginal safety boundary. This phenomenon of moving marginal boundary has also occurred at the airport. The marginal boundary has slowly shifted; in the early years it was not acceptable for passengers to walk across the apron during handling operations, but nowadays it is. This indicates the shifting of this marginal boundary.

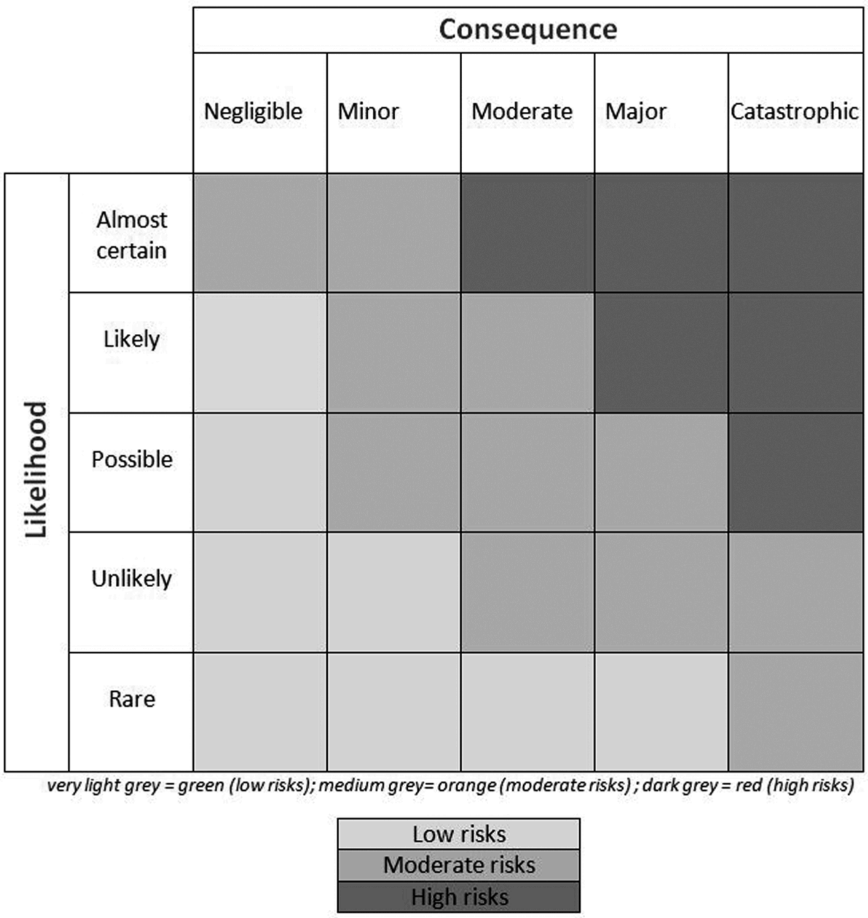

Figure 6.1: Standard 5x5 Risk Matrix (Kaya, Ward, & Clarkson, 2019)

Returning to the use of a risk matrix in combination with the Dynamic Risk Model (1997), it might also be possible to incorporate the use of the terms 'low, moderate and high' risk in the Dynamic Risk Model (1997). Within the broad field of risk matrices used in various industries there is a certain commonality. High risks are mostly considered not acceptable. These risks could therefore be regarded as beyond the outer limits of the Dynamic Risk Model (1997). Low risks are mostly considered to be acceptable and could be regarded as the centre or middle of the Dynamic Risk Model (1997). Low, moderate and high risks could be incorporated in the Dynamic Risk Model (1997) a possible way to do this would be to classify everything within the centre of the Dynamic Risk Model (1997) as low risk, everything beyond the marginal boundaries as moderate risk and everything outside the outer boundaries as high risk. By applying this the model would be presented as below.

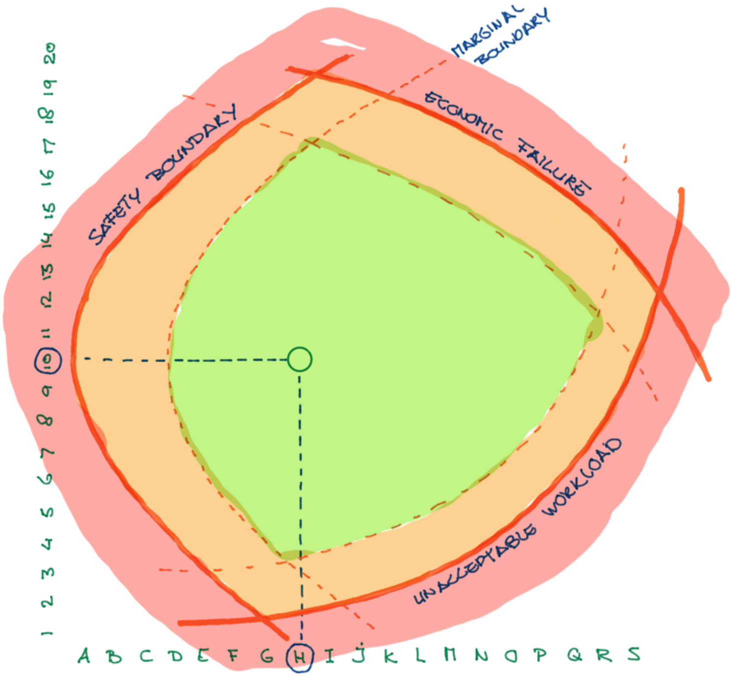

Figure 6.2: Combination Dynamic Risk Model (1997) with standard 5x5 risk matrix

This possible combination could be researched further for possible application. This way, the already existing Dynamic Risk Model (1997) can be used in several ways.

7 Conclusions

This thesis describes the research into the question whether it is possible, by applying a proposed method, to prospectively recognise drift into failure in order to prevent failure from occurring. The research focused on whether this can be realised by applying a method which uses the Dynamic Risk Model (Rasmussen, 1997), in combination with an extensive phased narrative. The core principle of this research is that it is theoretically possible to recognise the key elements of drift by means of plotting various incremental developments of a process onto a grid of the Dynamic Risk Model (Rasmussen, 1997). As such, in order to be able to prospectively recognise drift into failure, it is necessary to first determine these key elements.

The implemented method to determine the key elements of drift relies on two successive steps, namely firstly constructing a phased narrative and secondly plotting the trajectory by connecting the phases with each other. After completing these successive steps, it is possible to visually present drift in the Dynamic Risk Model (Rasmussen, 1997). The visualisation of drift, thus, prospectively – before failure occurs – allows being able to adjust the trajectory and initiate mitigating measures to prevent failure. *'A picture is worth a thousand words'*, the adage that implies that complicated and complex matters are explained by the means of one relatively simple visual presentation, clearly conveys the essence of the case compared to a heavy report.

The first step of the applied method is to identify the time-related elements from Ortmann's (2010) definition of drift. The aim of this step is to give substance to these time-related elements, namely: slow, subtle and long-lasting. By creating a narrative and establishing distinct phases within the time period subject to research, it is conceivable to draw up a timeline. With this timeline it is possible to determine if alterations within the process meet the label slow and subtle. When composing the phased narrative, it is advisable to use the knowledge available within the organisation where the research is being performed. This can be by conducting interviews, but is not strictly reserved for this form. During this research the phased narrative has been created after conducting several interviews. The gathered data from these interviews has been compiled into a detailed timeline where significant changes have been noted as distinct phases. The process subject to research has been incrementally changing over a time period of well over 15 years. The alterations individually and successive are small, but regarding the total, it has been significant. Finally, this timeline gives substance to the time-related elements of the definition of drift, and with that it completes step (1) of the research. This forms the basis of the second step in the research.

The second step in the implemented method is to determine the direction-related elements of Ortmann's (2010) definition of drift. This can be achieved by using the results obtained in step (1) of the method and processing them in Rasmussen's Dynamic Risk Model (1997), using this to visualise the movement. By connecting the mutual operating points by drawing a line, a direction becomes visible and one of the direction-related elements, namely a certain direction, is given substance. During this research it is assumed that a movement of the operating point towards the boundary of functionally acceptable performance is unintentional and is not a conscious strategy of the organisation. Because with this, the risks for the organisation become too extensive and the chance of failure increases, which jeopardises the organisations' interests. Step (2) gives substance to the direction-related elements. Together with the time-related elements, this gives content to all elements of drift according to Ortmann (2010).

In the interest of this research, the results were discussed and evaluated with the interviewees. Does the proposed method provide an answer to the central question that asks: "is it possible to recognise drift into failure prospectively, so we can prevent the failure from happening?" Could the Dynamic Risk Model (Rasmussen, 1997) be integrated in a method to recognise drift into failure prospectively whilst the drift is still happening and has not resulted in the failure yet? The interviewees were asked whether, in their opinion, the applied method provided insight in the gradual movement of the process subject to research, and if this visualisation within the Dynamic Risk Model (1997) indeed represents drift. In general, based on feedback from the participants, it can be concluded that the interviewees are indeed under the impression that drift can be visualised by applying this method. The interviewees believe that they have an insight into the current status of the operating point and, in particular, its movement. In this sense, drift can be recognised prospectively - looking ahead - before it results in failure, providing an answer to the main research question.

By recognising drift in an early stage, potential failure can be avoided by taking preventive measures and thus changing the trajectory. The method offers the possibility not to have to rely solely on the insights we gain in hindsight of an incident, but being able to intervene before an incident occurs. The method described can be a valuable tool for any industry and is not exclusive to aviation. Any process in any industry can be traced back to its starting point and from there a phased narrative can be drawn up in which the changes are made clear. With this, after plotting in the Dynamic Risk Model (1997), a trajectory can be discerned and a potential drift into failure can be visualised, from which conclusions can be drawn. Based on these conclusions preventive measures can be taken.

In conclusion, returning to the question initially posed as to whether it would be possible to use the already available Dynamic Risk Model introduced by Rasmussen (1997) in such a manner that we can prospectively recognise drift, the short answer is ‘yes, such a method does exist’. When following the steps described in this research and using a phased narrative in combination with the Dynamic Risk Model introduced by Rasmussen (1997), it is possible to visualise drift and by that recognise drift prospectively. By using the existing Dynamic Risk Model and replacing the agent in that model with a process, plus plotting multiple operating points in this model, it is possible to visualise a movement. The now visible movement represents the slow drift. From here it can be concluded whether there is indeed a movement towards the boundaries of the model. Since it is not possible to know exactly where the boundaries of the model are until they are exceeded (Cook & Rasmussen, 2005), visualising a trajectory can be helpful in making decisions. Therefore, the described method can be meaningful in making strategic decisions. It is possible to change the direction of the trajectory by taking mitigating measures. It can be concluded that a possible drift into failure can be recognised prospectively before the actual failure has occurred.

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Appendices

Appendix A: Information Package Interviewees

Appendix B: Additional Information Interviewees

Appendix C: Rich Narrative

Appendix A: Information package Interviewees

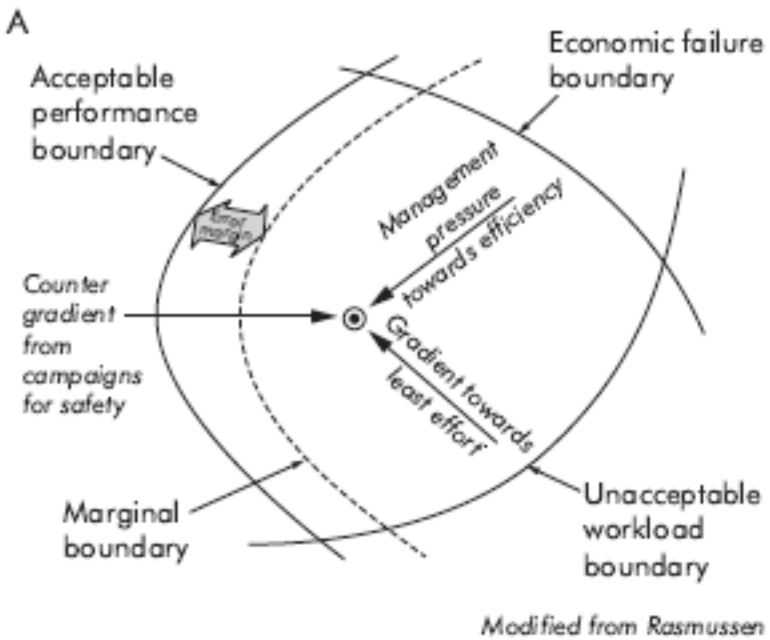
Dear colleague,

As you may know, since 2019 I have been studying for a master's degree in Human Factors & System Safety at Lund University. This is a two-year master's programme and for this the intention is that I conduct a research and conclude it with a final thesis. In order to complete this, I need input from our wonderful company [redacted] and I am appealing to you in the hope that you will help me do this.

I cannot give away the research question of my thesis in advance because this might influence the results and that is exactly what I do not want. What I would like is for us to complete the model together via Skype or Zoom and for you to explain your arguments to me. Once I have gathered all the information I need from everyone, I can draw some conclusions and incorporate them into my final thesis.

Explanation Dynamic Risk Model

In preparation, I would like to briefly explain the model used, so that you can possibly already think about it. The model was created by Jens Rasmussen and is called the Dynamic Risk Model (DRM) and looks as follows:



In this model, the forces that exist within a system can be visualised. Three hard lines and a dotted line can be distinguished here. These hard lines (safety, workload and economy) can be seen as the outer limits of the model. It is not possible to step outside these boundaries without suffering a failure. As indicated, these lines (boundaries) exert pressure on the sphere in the middle of the model. This dot is the so-called 'operating point' and can be seen as [redacted] indicating the position at that moment. The dot will move in the course of time under the influence/pressure of safety, work pressure or economy, in short one of the boundaries. The dotted line is a special one and is only present in the vicinity of the safety hard line. This line can be regarded as a warning line. If we were to put this in the safety matrix, everything to the right of this dotted line is still acceptable but things to the left of the line start to become unpleasant. Left of the hard safety line it is unacceptable. The other lines (economy and workload) cannot be crossed within the system either.

An example is striving to work more efficient in order to reduce the work pressure. This will exert pressure on the dot (operating point), causing it to shift away from the limit of work pressure. It is now up to safety and economy which direction the dot will shift, but in any case away from the line of work pressure. Is it at the expense of safety or is it at the expense of finances, or does it follow the line of finances and only have an impact on safety? If highly restrictive measures are drawn up based on safety, this can result in pressure on finances due to reduced income or other restrictions and, as a result, the dot will shift closer to this boundary. A reaction may then be to push back, which will have an impact on work pressure. In this way, the dot keeps moving through the model.

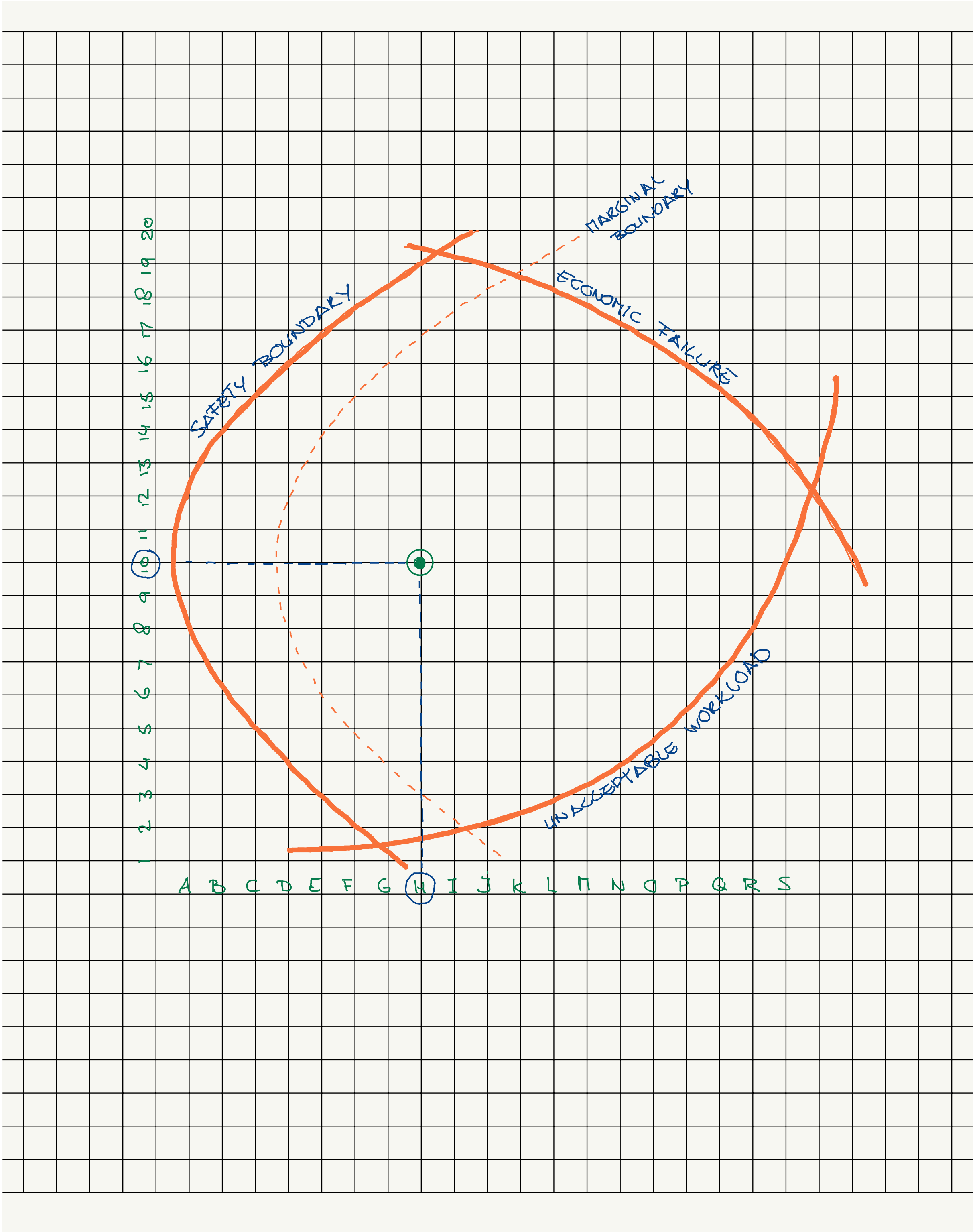
Concrete question

What I would like to ask you to do in concrete terms is to go through the timeline with a number of phases (explained in more detail below). Based on these phases, you may indicate where the dot goes: does it stay put? Is it moving towards safety or towards another boundary? What forces influence the dot? Why do you think the dot is moving towards safety and not to another boundary? In other words, what are your motives? Everything from your own point of view. I am looking for the location of the dot and the reasoning or explanation behind it. I want to do this for all six separate phases in order to generate a picture through time of how the dot is shifting.

Eventually, I will compile this from all of you to generate an overview and possibly determine an 'average'. It will be interesting to see whether we all share the same opinion. In the final thesis, the input given by you will not be traceable to an individual, as this does not matter at all. What matters, simply put, is how the dot behaves over time. I am looking for the trajectory.

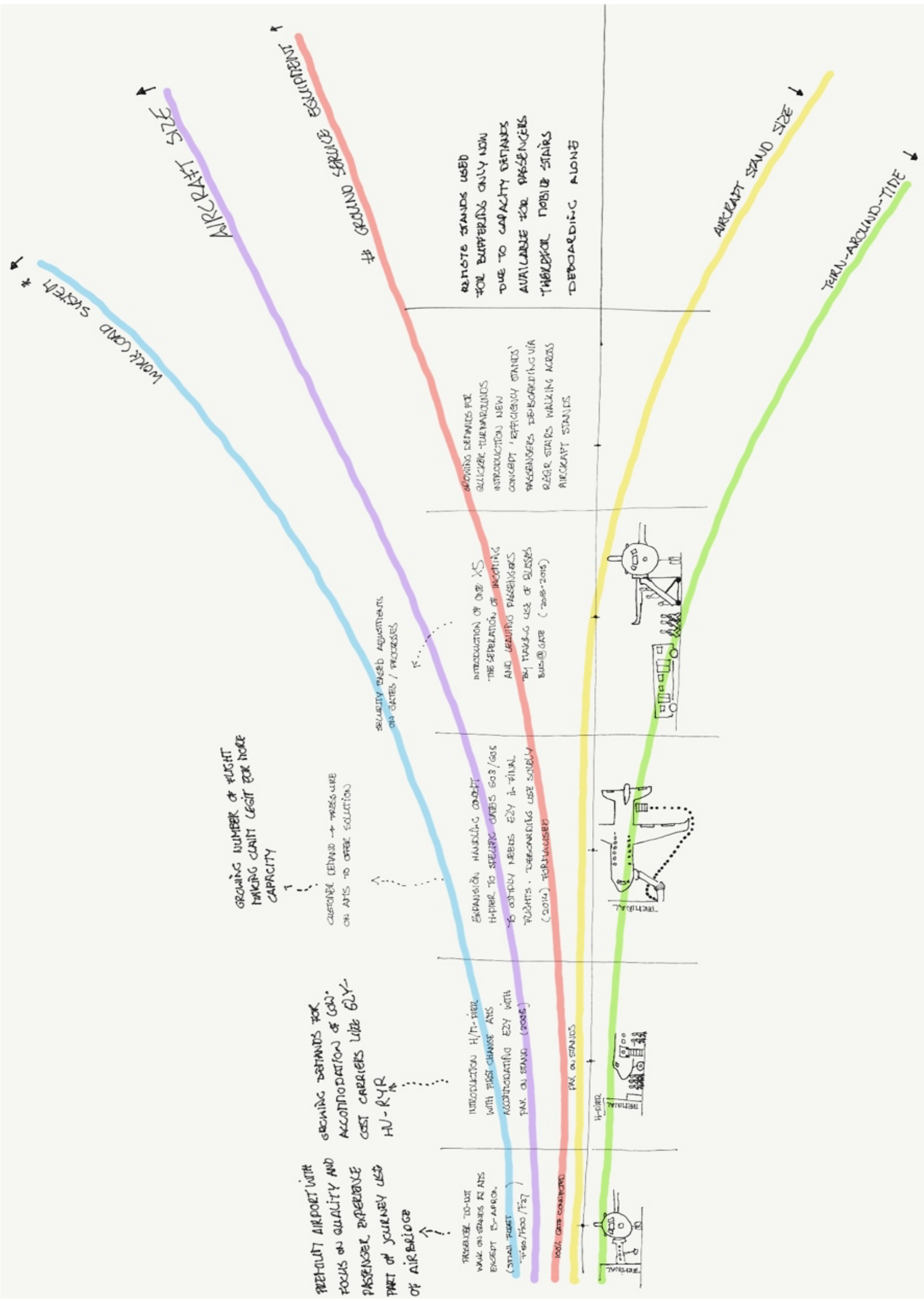
On the last page is the model that we will fill in together. I have provided this with a grid so that the points are the same for everyone and so that I can make a good comparison.

The model to be filled in:



Timeline - narrative

Based on a number of interviews conducted earlier, a narrative from 2000 to 2019 is constructed. This narrative contains a number of clear phases that can be distinguished in the handling of aircraft with extra attention for the principle of Boarding/De-boarding Rear Stairs (BRS/DRS), which is the boarding and de-boarding via the rear door by means of a mobile staircase. I will describe these phases in more detail and, based on these descriptions, will ask you to work together to give the operating point a place in the Dynamic Risk Model. To ensure that you are well prepared and can participate in our Skype or Zoom session, but especially to be able to form your own thoughts, here is a description of the individual phases.



Visual presentation of the narrative

Appendix B: Additional Information Interviewees

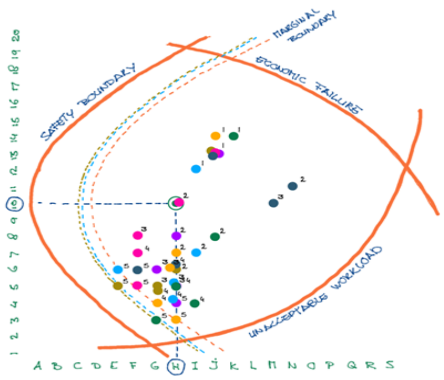
In December, we discussed the BRS/DRS in the context of my thesis. My research focuses on the prospective recognition of drift into failure using a 2-step method, namely 1) drawing up a detailed timeline in which milestones can be identified and 2) plotting this timeline in Rasmussen's Dynamic Risk Model (1997). The latter is what we have done together and some have also been approached for step 1. By connecting the individual points in this model, a line is created that moves in a certain direction which could indicate a possible drift.

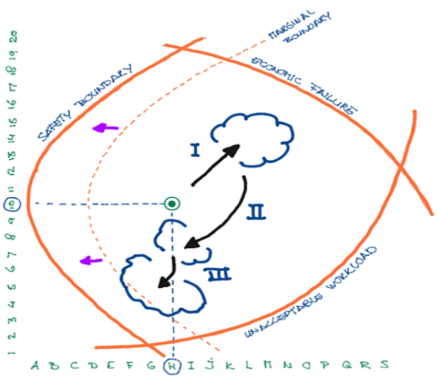
In the available literature, drift is mainly referred to as something that is initiated gradually over a long period of time, with small incremental steps. Searching for articles etc., in my literature review led me to Ortmann (2010), who indicates that drift is characterised by a number of key elements, namely slow and subtle, long lasting, unintended and in a certain direction. I have combined these elements and have come to two categories, namely 1: time-related (slow and subtle and long lasting) and 2: direction-related (unintended and certain direction). Drawing up the previously mentioned timeline fits category 1 and filling in the Dynamic Risk Model fits category 2. Only unintended cannot be explained in a model, and unintended in this sense means that it is not conscious that the movement is towards the boundaries of the model. In my opinion, there are very few organisations that consciously look for the boundaries of maximum permissible work pressure and safety, because the risk involved is too extensive.

Now I would like to ask you something else concerning this explanation: what does this visualisation represent according to you?

- When you look at the images, do you think they represent drift, the gradual movement towards the safety boundary? Not so much that it goes wrong immediately and actually leads to failure, but the movement towards the extremes of the model. The aim now is to ascertain whether the visualisation, based on the data obtained in step (1) and step (2) together, forms a trajectory and whether this is meaningful to you.
- Did you have a presumption beforehand of such a visualisation in relation to the interview? When looking at the process of BRS/DRS did you have this movement in mind?
- Does this correspond to the image you had of the entire handling process prior to step (2) or is this an unintentional movement towards the boundaries of the model?
- What does this process mean to you?
- Does it reflect a possible drift (into failure) in this form?
- Does it conform to the terms used by Ortmann (2010) to define drift? (i.e. can the characteristics be distinguished: slow, subtle, prolonged, unintentional, certain direction)
- Is the method used applicable to other processes within the airport and perhaps other industries?

For clarification, I have added the models in which all your results are included.





Appendix C: Rich Narrative

The Beginning (the original plan for boarding passengers) (Phase 0)

Exposing passengers to the dangers that are present at an aircraft stand such as i.e. industrial vehicles, flammable jetfuel, jetblast, noise and time restraints. Today, in contrary to earlier moments, the airport allows passengers to board and deboard aircrafts by using the rear doors of the aircraft and walk across the aircraft stand during in the handling of the aircraft. Some years ago this would have not been likely to have happened.

At Schiphol until the year 2005 all aircraft stands where equipped with a so called passenger boarding bridge or simply called passenger bridge (https://www.skybrary.aero/index.php/Passenger_Boarding_Bridge) . Only two dedicated places deviated from this concept. The motto during that period was 'Schiphol is 100% gate connected'. The rationale behind this motto was mainly passenger comfort there was no regulation in place regarding this method.

A passenger bridge is a construction that provides direct access to the aircraft from the terminal building. So passengers would gather in the pre-boarding area in the terminal and enter the aircraft via this passenger bridge. As mentioned there were only two locations at Amsterdam Airport Schiphol that had a different operation namely Schiphol East where the smaller general aviation planes are located. This is where business jets are being handled where the traffic numbers are low. The second locations is the B-apron this is where the smaller fleet of commercial planes is located consisting mostly of planes of maximum code C (wingspan up to 36mtrs) called commuters.

By making use of passenger bridges passengers were not exposed to the outside environment and shielded from the influences of the weather. This was the standard for many years on larger airports and can be traced back to the exclusiveness of aviation. Many years traveling by aircraft was considered as luxurious and along that idea passengers should not be exposed to cold, wet or windy conditions on an aircraft stand but board an aircraft comfortably straight from the terminal.

As traffic and passenger numbers during the years increased more and more equipment was necessary for the handling of the aircraft. More catering for the passengers during the flight, more water on board, more luggage to be transferred. Commercial aircrafts proved to be very useful to carry postal services and freight. And with all these activities surrounding the aircraft the amount of vehicles and movements increased reasonable. This created an intensification of traffic on the service roads that surround the piers and lead towards the aircraft stands. So using passenger bridges to provide direct access toward the aircraft now gently transferred from being purely for passenger comfort purposes to a more safety related aspect.

As described a passenger bridge prevents passengers to walk onto the aircraft stand and enter the operational environment consisting of ground handling vehicles needed for the proper handling of the aircraft. This can increasingly be seen as a safety feature shielding passengers from the aircraft operation. It can also be seen as a premium quality feature making sure passengers are not exposed to the weather conditions.

Regarding the usage of passenger bridges from a standpoint of safety and passenger comfort as the starting point and projecting this into the dynamic model introduced by Rasmussen this would provide the operating point in the middle of the model.

If the year 2000 is regarded as the starting point the total amount of passengers during this year has been 39.606.925 with a total amount of flights of 432.483.

Growing market of Low Cost Airlines (Phase 1)

As the years passed by from the introduction of commercial aviation the industry has been evolving. The exclusiveness and luxuriousness of aviation is gently but steadily being replaced by a new business model that makes aviation accessible for common people. This change in business model has been created with the introduction of Low Cost Airlines (LCA's). These are airlines that emphasize on delivering flights at minimal costs. In the early days these LCA's relied on smaller, regional airports. The handling fees of the large international airports would not make the operation on these airports profitable. The market share of the LCA's grew exponential since the founding of Ryanair in 1991 and easyJet in 1995 these airlines have obtained a substantial market share in the aviation industry of Europe. An average growth of 45% per year in the period 1999-2004 (Vidovic, Steiner, & Skurla Babic, 2006). The expansion of LCA's in the early 2000's continued and more and more LCA's entered the market posing a serious threat to the traditional airlines. Not only a threat to the airlines but also to the larger airports due to the fact that they suffered the effect of a decline in passenger numbers. In the early years Schiphol only had one model of handling fees and no differentiation in these tariffs. However due to the competitive nature of the industry and the continuous growing numbers of LCA's and amount of passengers on the regional airports these LCA's generated, and by that a decline in passenger numbers on the large international airport the large international airport had to respond. This allowed a shift in the approach to tariffs and handling fees. Schiphol was forced towards the economical boundary and was compelled to introduce different, lower tariffs for LCA's in order to provide a sustainable model for LCA's to persuade them to also visit Schiphol.

The current wingtip clearance at an aircraft stand did not make a distinguish between different types of aircraft. At Schiphol the maintained clearance was 7.5mtr which had its origins at the clearance that was mandatory for taxiways and taxilanes according to ICAO regulation. This clearance was rather conservative due to the fact that smaller aircraft types would have lots of margins left what resulted in a rather inefficient use of available square metres.

Countermeasure airport H/M-pier (Phase 2)

The accommodation of LCA's was, as mentioned, for a long period of time not part of the strategy of Schiphol however that was subject to change. As time passed Schiphol adjusted its strategy towards the accommodation of LCA's and provide a solution. To accommodate this search in minimizing costs and making Schiphol more attractive for these airlines Schiphol decided to provide a special pier. This pier would accommodate LCA's and provide little of the comfort that was traditionally offered by Schiphol. In 2005 the H/M-pier was finished and operationalized. This pier, in contrast to the regular piers at Schiphol, is fully dedicated to the needs of LCA's. In the pier itself there are minimalistic facilities, no shops, little or no chairs all the inventory is kept basic and sober to cut costs in search of lowering the overhead costs to keep the airport fees as low as possible and by that attractive to LCA's. The H/M-pier is generally speaking operationalised and furnished for use by easyJet. The preference of this carrier is not to use passenger bridges to keep turnaround times as low as possible. This also allows them to keep their operation very efficient what contributes in the cost efficiency. And with lower airport fees the operation at Schiphol can be realised profitably. With the introduction of the H/M-pier Schiphol introduced the first pier without the traditional passenger bridges and by that allowing the passengers have to walk across the aircraft stand and enter the aircraft making use of mobile stairs connected to the front and back doors of the aircraft. This particular process is called boarding and deboarding rear stairs (BRS/DRS).

The introduction of the H/M-pier can be seen as a mitigating measure on the approaching economic boundary and by this pushing the operating point away from this boundary in the dynamic model of Rasmussen.

Now that LCA's are introduced at Schiphol and are accommodated on the special H/M-pier this provided economic and workload pressure on the traditional airlines. Persuading them to reduce costs in order to compensate for the declining number of passengers and growing competition from the LCA's. This adaptation from the traditional airlines can be seen as a push away from the workload boundary in the dynamic model of Rasmussen.

When putting this phase into the dynamic model of Rasmussen the moving of the operation point becomes clear and can be seen moving toward the marginal safety boundary. The marginal safety boundary itself has also been subject to chance. Cook and Rasmussen (2005) refer to this as marginal creep. Operation beyond the marginal boundary that is considered acceptable sets the new location of the marginal boundary. Schiphol regarded passengers walking on the airport stand as acceptable at this moment in time. In contrary to the past decades where this was found unacceptable and was only allowed on two different locations. But based on experiences of LCA's on other regional airport where they apply this operating model did not indicate any overt accidents and therefor is presumed to be safe. This results in a shift of the marginal boundary toward the safety boundary.

The number of passengers has increased in combination with the realisation of the H/M-pier. By the end of 2005 there was an increase of 12% with a total of 44.163.098 passengers. Despite this increasing number of passengers the number of flights decreased to a total of 420.736 (-3%) this could indicate that the occupancy rate of the aircrafts has increased and/or the size of the aircraft is expanded.

Expansion of LCA-handling (Phase 3)

In the years after 2005 the number of LCA's kept on growing and their contribution to the network of the airports continued to grow from a market share of roughly 25% in 2005 to a share of 49% in 2014 increasing to +50% in 2017 (EEA, 2019). More and more routes where being deployed and the number of flights rapidly increased as aviation expanded. This directly led to the increasing need for aircraft handling capacity at the airports. At Schiphol this was no different. The LCA that operates from the special H/M-pier expanded their number of flights which ultimately led to additional late flights that could not be accommodated at the H/M-pier. Schiphol then provided an aircraft stand with passenger bridge. This however meant that the LCA could no longer use both doors of the aircraft for deboarding passengers. Which results in an increasing handling time and would therefor lead to more expenses for the LCA. This eventually led to the request of the LCA to use the rear door of the aircraft in combination with mobile stairs to shorten the handling time. By making use of the rear door and the mobile stairs the passengers could leave the aircraft from the rear door and walk across the aircraft stand towards the terminal building. Prior to accommodating this operation a safety assessment was ordered by the airport. The final conclusion of this assessment was not to provide this service due to the fact passenger bridges are safer and keep passengers and operation on the aircraft stand separated also the cost of the needed additional measures would be too high and not guarantee that all risks would become acceptable. The second recommendation was that if the decision was made to accommodate DRS at these aircraft stands disregarding the first set of recommendations additional measures had to be taken to make it safer for the passengers.

The airport decided, in conjunction with the LCA, to provide the requested service and put in place the additional demand measures making DRS able. The additional measures consisted of the filling up rain ducts to prevent passengers from tripping, providing handrails for the stairs, the use of extra personnel to monitor passengers, bank lines to guide passengers over the aircraft stand, and more smaller adjustments. This was the first introduction of deboarding rear stairs (DRS) at a pier where passenger bridges also are provided. The boarding of passengers is still via the traditional passenger bridge solely due to the fact that before the departure of an aircraft there is much more activity around the aircraft compared with an arriving aircraft. This change was formalised and first introduced in the year 2014 and has still been in operation afterwards. Fortunately no incidents in the sense of injuries have occurred with regard to the passengers that walk across the aircraft stands. This however does not immediately imply that the operation as being performed should be valued as 'safe'. It does simply state that until now the operation as being performed has been free of the manifestation of incidents. However as mentioned before Cook and Rasmussen (2005) would refer to this as flirting with the marginal boundary and eventually allowing the boundary to be moved ever closer toward the safety boundary.

By 2013 the number of passengers had increased by 20% and was now up to 52.569.200 passengers. This increase of passengers forces the airlines to use more ground handling equipment and process more luggage, catering, water, toilet services, cleaning and so on. The number of movements on the aircraft stands increases due to the fact more processes are combined and overlap each other in order to realize shorter turnaround times.

Changes in Security regulation (Phase 4)

Since the partly introduction of the BRS/DRS principle on aircraft stands where there is a passenger bridge available other airlines requested this format to their own aircraft handling. The main driver for these requests is the urge to shorten the earlier mentioned turnaround time. There is an efficiency and financially driven motivation behind these requests. The airport however did not provide the service on other aircraft stands but kept this exclusive to the LCA located on the H/M-pier still regarding this form of handling not intended for overall usage on the airport.

In the period between 2013 and 2015 new EU regulation regarding security on airports was introduced. Due to numerous terroristic attacks and threats the security levels at airports were sharpened. This led to major adaptations within the terminal and pier structure at Schiphol. The new EU regulation made a much stricter separation between arriving and departing passengers based on their origins and destination necessary. The level of security screening outside the European Union was different and therefor passengers arriving from countries outside the EU were not allowed to come in physical contact with departing passengers to avoid passing of prohibited goods. To comply with this EU regulation Schiphol had to execute several structural adjustments on the piers. Because this was time consuming in combination with an operational active airport temporary measures were set in place. The airport developed a special concept called 'bus@gate' to overlap the period until the structural adjustments were in place. This meant that arriving passengers disembarked the aircraft via the passenger bridge however they did not enter the pier but instead left the bridge on the aircraft stand and entered a bus that was ready to transport the passengers to a so called bus injection point. By doing so the airport could guarantee that arriving and departing passengers never had physical contact. This operation however was more time consuming in comparison to the 'normal' operation which directly impacts the workload of the aircraft handling to maintain the short turnaround time critical for the operation.

The airport at the same time had to maintain the status within the competitive airport industry and offer more aircraft stands to realize more options and comply with the growing demands from the industry to provide the necessary aircraft stands. Many airlines ordered new aircraft with winglets which led to bigger wingspans. Schiphol had to react and re-configure the aircraft stands to comply with the needs and facilitate these new generation of aircrafts. During this re-configuration of the aircraft stands the airport relied on the then current ICAO regulation which stated that aircraft stands for the particular aircraft type should have minimal wing clearances of 4.5mtr.

Comparing this with the formerly used conservative clearance of 7.5mtr this leaves 3mtr less room for the handling of the aircraft but is an advantage for the airport that is constant in search of more space.

In order to keep up with the LCA's the traditional airlines intensified the handling and went in a search for time reducing measures. The quicker the turnaround of an aircraft can be realised the more profitable. The introduction of the bus@gate concept due to sharpened EU regulation forced the airlines to take appropriate measures to provide extra guidance for the passengers. This meant that the pressure on the personnel conducting the handling and turnaround of an aircraft gained considerable. A contributing factor in this is the fact that the size of the actual aircraft stand was reduced by several meters due to the re-configuration of the stands in order to comply with regulation and facilitate the new generation aircrafts. This combined manifests in the moving of the operating point closer towards the workload boundary forcing the airlines to take appropriate actions. Also the marginal safety boundary again has been gradually moved toward the safety boundary. Passengers are now allowed to walk on other airport stands not solely for the purpose of accommodating the LCA but due to EU safety regulation.

In 2014 after the introduction of bus@gate the total number of passengers again increased with 5% in comparison with 2013. The number of passengers by the end of 2014 was 54.987.500.

Efficiency stands (Phase 5)

As time progressed the necessity of the usage of the concept bus@gate was largely no longer needed for this purpose due to the introduction of architectural adjustments on the terminal building providing the needed separation between departing and arriving passengers. Only in rare circumstance this is still used in case of an arriving airplane from a so called 'dirty' country security wise. Airlines however now requested the continuation of the concept introduced in phase 3 for the LCC due to efficiency reasons. Making use of mobile stairs to let passengers depart from the rear door and guide them across the aircraft stand and lead them up the stairs into the terminal building would shorten turnaround time compared with the sole use of the passenger bridge. The time it takes for passengers to disembark an aircraft via two doors is far less compared with the sole use of the passenger bridge. And a short turnaround time is necessary in the strong competitive market of aviation. A turnaround time of several minutes less could eventually mean that an airline could have an additional flight at the end of the day creating more revenue. Schiphol now called the stands where this was operational 'efficiency stands'. So again a new aircraft handling concept was introduced.

The major difference between phase 5 and phase 3 is the fact that the particular aircraft stands of phase 3 are designed for large aircraft the so called wide bodies that have a large wingspan and therefor need more space but are used by smaller aircrafts. The aircraft stands are approximately 62mtrs wide compared to the aircraft stands of phase 5 which are approximately 42mtrs wide. This will have an effect on the manoeuvring of the ground service equipment used for the handling of the aircraft during turn around.

To perform this concept of operation (efficiency stands) airlines had to provide personnel to guide the passengers and guard them making sure the passengers were safe. After all this is an industrial environment which they entered. This could overwhelm some passengers who could wander off or create picture opportunities on dangerous locations or invite passengers to light up a cigarette after a flight. To prevent this airlines have to make sure passengers walk in a designated area marked by tens barriers and keep permanent oversight on the passengers until they reach the passenger bridge and merge with the other passengers. All this leads to an increase in workload however this is the answer in order to fulfil the demand of continuous shortening the turnaround times.

In order to realize this concept of operation the airport made small adjustments on the aircraft stands. These are the same adjustments that have been realized when first introducing BRS/DRS at specific gates for the LCA (i.e. railings on stairs, usage of closed steps, tense barriers, filling up rain duct, etc.).

By the end of 2015 when efficiency stands were introduced the number of passengers had increased with 6% and now reached 58.200.000 in total.