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Criticality Management of Airports

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This paper presents a project Safetec has done for Avinor (a Norwegian state-owned company, and Norway's largest owner and operator of airports) regarding development of a methodological approach as a basis for setting requirements for uptime and availability to infrastructure at individual airports. Avinor has divided its 44 airports into 5 categories. It is crucial for Avinor to have a conscious relationship with resource use at these airports and the balance between resource use and availability. The purpose of this project has been to develop and describe a methodological approach as a basis for setting requirements for uptime and accessibility to the individual airports. This project proposes definitions and KPIs that can form the basis for requirement. It describes a methodology for identifying critical functions and analyses the current situation regarding the performance of the various categories, airports and functions. In addition to the general requirements that are outlined, this provides a basis that can help Avinor set appropriate requirements for the airports and distribute these requirements to the individual functions.

Keywords: Criticality, airport, availability, delays, FMECA, optimization.

1. Introduction

Avinor owns and operates a total of 44 airports in Norway. There is increased awareness of Avinor on operating costs for this airport infrastructure. At the same time, many requirements and expectations are set for Avinor regarding uptime. This is a demanding combination - on the one hand, many stakeholders expect the airports to be available 24/7/365, while this significantly increases the cost impact. It is in this context important for Avinor to have a systematic approach to the question of what airports should deliver (and not deliver) in terms of uptime and availability.

Another challenge is the large differences in size. Avinor have divided their 44 airports into 5 categories:

A. International HUB (one airport)
B. International (three airports)
C. National (six airports)
D. Regional (nine airports)
E. Local (25 airports)

These range from the Oslo International Airport with 25 000 000 passengers annually to the smallest local airports with 10 000. The question is if and how availability requirements should vary based on size.
The purpose of this paper is to develop and describe a methodological approach for defining criticality and uptime requirements. This paper is largely based on a project performed to help Avinor with their challenges regarding requirements for airport availability and the work has been done in close cooperation with Avinor. The objectives of the project can be described as follows:

- Verify overall availability requirements for the 5 airport categories, including impact and probability classes
- Develop and describe methodology for identifying critical functions and infrastructure at airports and setting requirements for these
- Develop and describe methodology for operationalizing the criticality requirements in the form of, for example, design requirements, operating routines, maintenance programs, organizational redundancy, etc.

The project has presupposed that security is maintained at the current level and no financial considerations such as lost revenue etc. have been made.

2. Collection of Information

To ensure a good starting point for the analysis, there were obtained relevant available information. Three areas have been the focus; information from airport operators in other countries, information from other, similar industries and relevant research done in this area previously. However, there were not much information to find. No airport operators from other countries could give us any input. Other similar industries like national railway and tram infrastructure are more focused on increasing availability than balancing the availability with cost. Oil and gas industry have long experience in distributing a system safety requirement down to subsystems. This is done on instrumented safety systems. There are some parts of these methods that can be transferred to aviation.

Some scientific articles were found that were relevant to the project. These included efficiency improvements, system availability, capacity and demand at airports. Even though none of the articles directly provided any benefit when it comes to specific principles for requirements, it was nevertheless interesting to observe that availability of airports is an issue in the academic environment as well.

3. Principles for Availability Requirement

3.1 *Definitions*

When setting requirements for airport availability, a good starting point is to find a useful KPI that is linked to Avinor's main objectives. Availability is not easily defined for airports. There are many individual systems and functions with various degrees of interdependency. Discussions on this topic led to the conclusions that the airport performance should be related to delays of passengers and luggage. Based on this, the following definitions were made:

(i) Avinor's operational objectives:
   a) Passengers / baggage / cargo depart and arrive safely with their aircraft when they are supposed to
   b) The airport has the correct response time for emergency response
   c) Passengers have good experience at the airport

(ii) Airport downtime / unavailability: A time period where Avinor's operational goals are not achieved due to an event for which Avinor is responsible (substract airline contributions).

(iii) Critical Functions: Functions that by failing may result Avinor operational objectives to a greater or lesser extent not being achieved.

(iv) Criticality measure:
   a) Probability of failure of critical system
   b) Consequence associated with failure
      i) Number of passengers affected
      ii) Duration including recovery to normal state

3.1 *Performance measure*

The conclusion was to use passenger delay hours as an overall KPI for airports. This simply sums up the total delay for the sum of all passengers affected by a malfunction. As requirements will then for example set a maximum limit for the number of delay hours per year. This performance measure directly addresses Avinor's purpose, taking into account both frequency, duration and number affected.
The challenge of using total delay as an indicator is that it is not always easy to estimate how much delay downtime on a given system will cause. Here, there are some assumptions that need to be carefully considered. Below are some examples of system failures that can lead to delays and what kind of assumptions must be used. The assumptions were set in close cooperation with Avinor.

Example 1: 5 flights are delayed 30 minutes due to an undesirable event for which Avinor is responsible:

- Assumption: The aircraft has an average of 100 passengers
- Delay hours = 5 flight x 0.5 h x 100 pax/flight = 250 hours

Example 2: The luggage handling system at arrival is down for one hour:

- Assumption 1: Considered an additional 1 hour before luggage handling is up to normal operation due to delays.
- Assumption 2: There are 1,000 passengers flying per hour at the airport.
- Assumption 3: 30% of the passengers will not be affected during the period (only hand baggage).
- Assumption 4: Your luggage will be forwarded to your resident, and it will take in average 24 hours.

- Delay hours = (1 h + 1 h) x 1000 pax/h x 0.7 x 24 h = 33 600 hours

Example 3: Security is down for 30 min:

- Assumption 1: 30% lose the plane and must take the next which on average is 6 hours later
- Assumption 2: There are 1,000 passengers flying per hour at the airport
- Delay hours = 6 h x 1000 pax x 0.3 = 1 800 hours

Although there are many factors that take into account (e.g. time of day, different sizes of aircraft, frequency of different departures, etc.) this provides an estimate that can provide a sufficient basis for assessing the criticality of different systems against each other.

An important question to determine if delay hours are a good measurement parameter is the following: Is one-hour delay for 10 people about as "bad" as 10-hour delay for one person? If the answer is yes, this parameter works because you do not need to specifically consider duration and number and can settle for one parameter instead of the combination of two. We have concluded that it is sufficient to look at the total number of delay hours regardless of how the duration and number of affected persons are put together.

4. The Current Situation

To later evaluate what functions are critical for the availability of an airport, an analysis of "all" functions and systems at an airport was first made. Figure 1 shows an overview of the identified functions and systems. The figure illustrates a process where we follow the aircraft, passengers, luggage and cargo throughout the cycle from start to finish of the journey. The red building on the left of the figure shows the facilities and infrastructure needed for the airport to function. Each of the functions consists of sub-functions and subsystems.

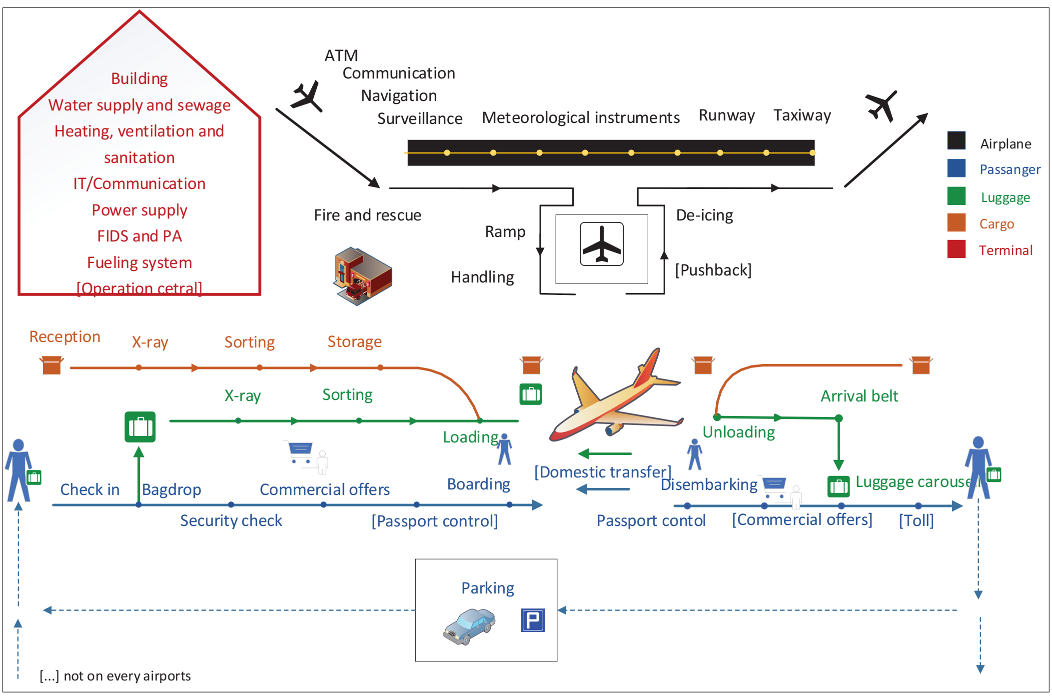

Fig. 1. Airport systems assessed in this project

Ideally, there would be collected data for the different airports giving information on the outage of functions and systems and the resulting effect on delays. This is, however, difficult to obtain. Certain systems might gather data on their performance and the airlines typically collect data on flight delays, but these are not linked together. Data on passengers missing their flight due to airport problems and which system caused the delays is usually not found.

Instead, to assess whether the sub-functions can cause delays and possibly the frequency of delays, FMECA (Failure Mode, Effect, Criticality Analysis) has been implemented for each of the categories. The goal of the analyses has been to estimate the delay hours for an average airport for each category for the current situation. All subfunctions have been analysed with experts in Avinor and assumptions as explained in example 1-3 in Section 3 were set. This gives estimated delay hours for failures of each function. These are summed up to delay hours for each main function and then summed up to delay hours for the airport category. Both passenger delay hours, baggage delay hours, flight delay hours, consequences for emergency preparedness and passenger experience have been considered.

Table 1 illustrates the FMECA with assumptions and delays. Figure 2 illustrates the expected number of passenger delay hours per category. As expected, category A has the largest number of delays hours since there are a lot more passengers at category A than in category E. However, if we look at delay hours per passenger, we see that category E has the largest number, as illustrated in Figure 3. It seems that category C has the best lowest number in both figures.

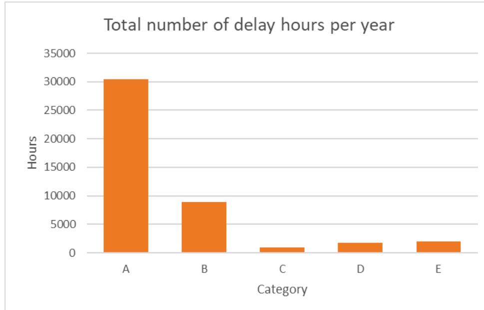

Fig. 2. Total number of passenger delay hours per category

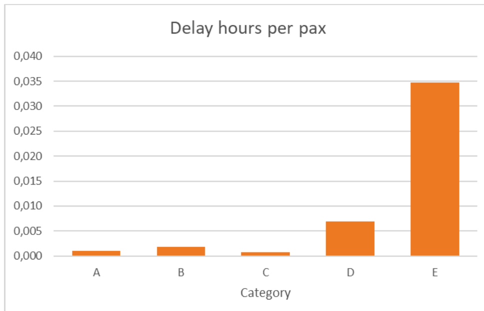

Fig. 3. Number of passenger delay hours per number of passengers at airport for each category

Table 1 Example of FMECA used in this project

Description of system		Description of failure		Effect of failure					Risk	
System	Subsystem	Failure	Assumptions	Passenger delay hours	Baggage delay	Flight delay	Emergency preperadness	Passenger experience	Frequency per year	Passanger delay hours per ye
Disembark	Bridge	The bridge does not go out to the plane	20 minutes delay for one plane. 117 passengers per plane.	39	No effect	20 minutes	No effect	Bad experience for 117 passangers	3	130
ATM systems	ICW	Cannot allow any traffic. Full stop.	All incoming flights must land at a different airport, possibly return. All departing aircraft must wait. Assumes an average of 3 hours delay for passengers. 76 planes are effected. 117 passengers per plane.	26676	-	228	May effect	Bad experience for 8892 passengers	0,003	89

5. Proposed Requirement of Availability

To present proposed models for availability requirements, the current situation is used, together with some general principles. The question is whether delay hours per passenger should vary with the size of the airport or be constant / independent of category. Should more downtime be accepted at smaller airports? No matter how we look at it, there are two basic principles that need to be considered:

- Principle of equality: The idea that the likelihood of a passenger delay should be fairly equal regardless of airport size
- Principle of Optimization: The idea that we want to minimize the total sum of delay hours for a network of airports, e.g.: for all Avinor airports

These principles cannot both be fully upheld as they are contradictory. The principle of equality means in practice that passengers should be able to walk into an airport and experience the same expected delay whether they are flying from a small or a large airport. The challenge with the principle of equality is that it causes many more delay hours in total than necessary. This is because category A has so many more passengers than all category E airports combined. If Avinor allows more delay hours per passenger at the smaller airports compared to the larger ones, the total number of delay hours will go down drastically. There is little doubt that it is profitable with a certain disparity between the categories.

In order to take into account both the equality principle and the optimization principle, delay hours are divided into two factors: the probability of being delayed and the duration of the delay:

- Probability of a given passenger being delayed. This can be the same for all categories to satisfy the principle of equality. In other words, it is equally likely that you experience a delay whether you are traveling from a large or small airport.
- Expected duration of the delay. This allows us to decrease for larger airports to satisfy the optimization principle. Such an uneven distribution reduces the total number of delay hours.

This has resulted in 3 different models establishing principles for availability requirements:

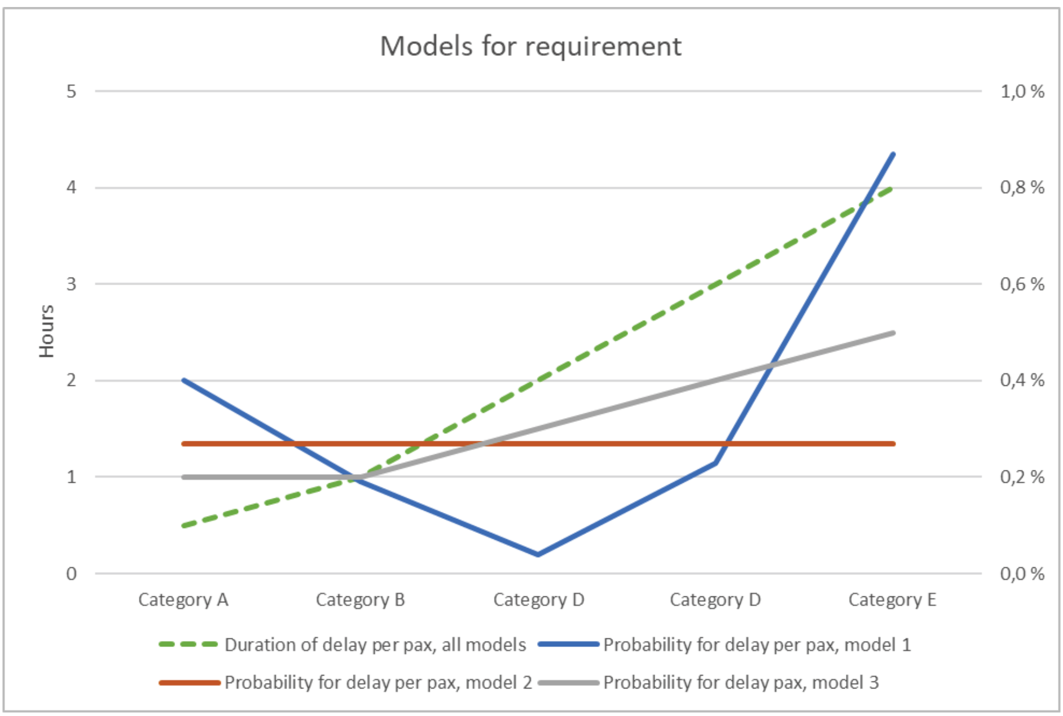

Fig. 4. Illustration of models for requirements

1. Requirements that reflect the current situation
2. Equal probability of delay per passenger
3. Probability of delay per passenger increasing for smaller airports

Model 1 is not focusing on equality principle or the optimization principle but tries to reflect the current situation as assessed in the FMECA results. However, the principle of decreased duration of the delay for larger airports are kept. The probability for delay per pax is adjusted to make the total number of delay hours corresponds to the FMECA result per category.

Model 2 has equal probability of delay per passenger independent of traveling through large or small airport. Together with increasing duration of delay, the delay hours per passenger will increase for smaller airports.

Model 3 has both increasing probability of delay and increasing duration of delay for smaller airports. This model favourites the large airports with many people.

Figure 4 illustrate these three models. The green line illustrates the average duration of delay per pax and are similar for all models. The other lines represent the probability for delay per pax.

Figure 5 shows the total number of delay hours for the different models. The numbers are the sum of all airports and all passengers. Figure 6 shows the delay hours per passenger for the different models.

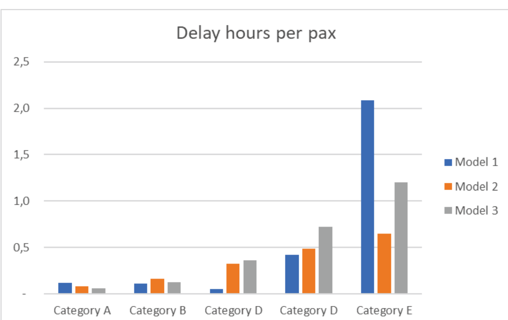

Fig. 5. Effect of the models on total number of delay hours

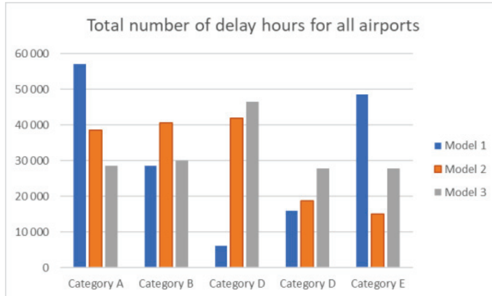

Fig. 6. Effect on the three models on delay hours per passengers

When an airport in a given category has a requirement for a maximum number of delay hours per year, it is desirable to distribute this requirement over the various functions. Then those in charge of the various functions can know what to do with them. Delay hours are a good measurement parameter at the airport level but not at the functional level. The person in charge of a function will usually not have a clear understanding of how many delay hours the unavailability of the current function will cause. Category-level delay hours must therefore be translated into function-level downtime. Fortunately, the 'translation' of delay hours to downtime is not a major challenge as the FMECA clearly shows the relationship between downtime and delay hours for various functions. You just have to go the opposite way from what you have done in the FMECA.

6. Discussion and Conclusion

This paper has outlined a framework for measuring airport performance and setting requirements. The implementation must be done by each individual airport. This is done in several steps:

- Choose a model for availability requirements as given in Section 5.
- Find the performance of the specific airport. This can be done by simply adjusting the numbers from the general airport category FMECA. If, however, the general FMECA is not sufficiently representative for this particular airport, it might be necessary to redo the FMECA.
- Compare airport performance with requirements. If they are not met, work to identify the areas where the most gain for the least cost can be obtained. Use the FMECA

that shows the relationship between system downtime and passenger delay hours. If performance is significantly better than required, look for possible ways to save costs by cutting resources.

- When airport performance is aligned with requirements, identify ways to make it more cost-efficient. This can be done in a workshop going through the individual functions and systems. Given the constraints of the requirements, there may be possibilities to increase contribution to delays for one system and reduce for another to create a better balance and save costs.

One challenge with the implementation is to choose the reasonable requirements. Note that Section 5 outlines a model but does not recommend specific numbers. It is not up to the authors of this paper to tell the airport operator what is good enough or required. The operator must choose a reasonable quantitative requirement themselves with the suggested models as guideline. But they would often have a sense of what a reasonable value would be when they are able to get an indication of current performance from the FMECA. It might also be helpful to see their performance in perspective by comparing with delays caused by other factors than the airports themselves, such as flight companies and suppliers. In this project, statistics were obtained demonstrating that only about 7-8% of all delay time was caused by the airport.

On one hand, the airport could argue that their proportion of blame for delays is so small that it is not their obligation to improve. On the other hand, airports availability must be evaluated on its own merits, since stakeholders, customers, authorities and third parties would be more concerned with actual operational performance than relative performance compared to other entities.

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