Analysis of Operational Impacts and Risks of Airport Security Threats Case Study: Terminal 1 of Lisbon Airport

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Abstract:
The currently practiced high security requirements, in response to emerging threats, opposes to efficiency of airport operations, in which the growth trend of traffic volumes exerts strong pressure.
Facing this problem, the dissertation focuses on structuring and implementing a methodology which allows detailing and evaluating impacts and risks in the departures routine inside the passenger's terminal, generated by threats and consecutive security procedures, in order to assist the decision-making in improving processes efficiency while maintaining the required level of security.
The problem is approached in a semi-quantitative and cause-effect perspective, using the Multipass simulation tool, which was developed by a partnership between Thales and ISCTE-UL. The modelling of variables and relations is based on criteria and assumptions that are transversal to the operation of any airport, pretending a universal use of the tool. When this is not possible, the modulation is particularized for the case of Terminal 1 of Lisbon Airport.
In this case study, a sensitivity analysis is performed for the following scenarios: X-ray equipment failure in the security control and reduction of processing capacity at check-in.
Relatively to the reduction of critical impacts and risks pointed out in the sensitivity analysis, the capacity reinforcement during a perturbation demonstrates a greater effectiveness in its recovery and service levels, while a freer process planning is highlighted in preventing delays and flight cancellations.

Keywords: Risk Analysis, Operational Impacts Analysis, Airport Terminals, Air Transportation Security, Passenger Flow Simulation

INTRODUCTION

Increased globalization coupled with greater development and accessibility to air transport has led to a steady increase in passenger traffic volumes, which requires the increase of operation's efficiency. In order to respond future traffic growth, ICAO Doc 9835 (2013) states that capacity must be increased to improve efficiency, flexibility and predictability of the operation. However, statistics presented by IATA (International Air Transport Association) show that the airport activity has operated under increasingly high load factors, with a global figure above 80% in 2015.

On the other hand, with the increase of terrorism, the airport system has been alert to security vulnerabilities and threats that had not been of major concern up to the first major attack of this kind, the September 11

2001 bombing in New York. In consequence, the security is intensified systematically, causing impacts on the operation, as considerable as the hazards to the security, either by total or partial reduction of the service as by the delay of processes, which means the reduction of the overall airport capacity.
Researches on the subject lead to understand what are the relevant threats in the context of airport security with impact in the operation, due to them high occurrence likelihood and the impacts generated. It is highlighted the considerable likelihood of unauthorized entry of passengers on the air side – air side contamination - due to the numerous vulnerabilities inherent in security control, whether related to screening technologies or to security officials. If such an occurrence is detected, procedures indicate that the air side should be immediately evacuated and all passengers there should be re-screened, which strongly destabilizes the entire operation. Another mutually recurring threat that causes a major impact on the operation is the case of unattended items. In such detection, the area around the item is isolated until the item's hazard investigation is completed, which can cause severe service constraints for a long time.

An effective approach to risk assessment and risk management can lead to better preparation and prevention against acts of unlawful interference and terrorism, either in the security context or in the operational context. This is due to the triple definition of risk - Vulnerability, Threat (probability), and Impact – which gives an influence measure of threats to a certain system. However, the several impact and risk assessment studies in civil aviation and in the airport environment currently used focuses only on the security context and, if there is an operational approach, it is poorly explored and mostly in a conceptual way.
In qualitative methods, besides producing imprecise assessments, infrastructures are analysed in isolation and dependency relations are not addressed, such as the PHA and RVA methods, or if they are addressed, they have limitations, such as the absence of disruptive situations in the case of the BIRR, or the lack of rigor in its definition, ignoring the nature of the relationships considered and the level of detail used.
In the quantitative methods identified, PRA and morphological analysis, although the dependency relations are analysed more rigorously, a consistent database is necessary to evaluate impacts and probabilities, which sometimes is not easily accessible or simply don’t exist. On the other hand, although the PRA has some ability for logical reasoning and prediction of future attacks by the manipulation of logical trees, it is hardly to investigate a wide range of scenarios by them. The morphological analyses, being implemented computationally, provide a deeper exploration of scenarios, as well as an orientated thinking through intelligence.
In a semi-quantitative assessment research, some literature shows the inclusion of fuzzy logic in the evaluation of risk as a way to reduce the imprecision of subjective evaluations in qualitative methods.

Observing the weaknesses found in the impact and risk assessment in the operational context, the purpose of this study is to bring new knowledge about the subject and propose an innovative way to measure impacts and operational risks by looking at airport processes performances in a linked perspective. The dissertation aims to develop a model for impacts and risks evaluation in the departures process of the passenger’s terminal, due to events against airport security. The model application focuses on mutually frequent and impactful events in the operation. It is intended that such methodology can be used by airport managers and governmental entities as a tool to aid in the decision-making of the design and planning of the operation, in terms of capacity, at its critical points, based on the analysis of the levels of impact and risk to which they are associated, and which is aimed to be controlled by certain reference levels. It is also intended that the implementation of the methodology should be the maximum independent of any specific application case, so that the use in any airport is facilitated. The implementation is therefore based on a level of abstraction or of detail that is only supported by routines and logics which are transverse to any airport environment. When this is not possible, Terminal 1 of Lisbon Airport is considered as a case study.
With this objective in view it is necessary to know the airport processes and to understand the routing of the passengers flows between them. Thus, at the airport, stochastic queuing systems are identified, interspersed by flow accommodation systems. The transfer of passenger flows between systems or related to the global system – dynamic capacity – is dictated by the performance of queuing systems.

The system is, in a given period, in a steady state or in equilibrium when the arrival rate is lower than the processing rate, which means that all passengers arriving at the system are processed, causing no major fluctuation passenger impacts along systems.
The system is in a transient state when the arrival rate is higher than the processing rate, which means that in a given time period, not all the incoming traffic can be processed, making him retained for further processing. In these conditions, the break of dynamic capacity can cause uncontrolled rarefaction and high saturation performances along the systems. According to the Traffic Engineering Handbook (ITE, 1992), due to the portion of retained traffic that is known at any given time, stochastic systems in transient states assume approximately a deterministic behaviour and can be treated, on average, by deterministic modelling. In consequence to the flow dynamics through the system, the static capacity of each system can be addressed, leading to impact analyses. It refers to the occupation state of a given facility or area at a given time, having as reference the physical characteristics of the spaces, generally expressed by the maximum number of occupants it supports.

METHODOLOGY

The problem is structured according to the methodology presented in Figure I, translating a semi-quantitative approach to risk. The occurrences considered pertinent to the study are synthesized by the type of disturbance that induces the operation, through the knowledge of the defence routines, when applied. Subsequently, analysis scenarios are defined by the combination of perturbations with initial states and operational reaction capacities, the latter being representative of the system vulnerability, resilience and redundancy.

Each part of the scenario is quantified in order to integrate a model that, in a first stage, quantitatively calculates the trigger in the operation of the impacts suffered by the main actors in the airport system, presupposing therefore the understanding and measurement of the system behaviour and the values to be defended. In order to calculate the risk, in a second level the model combines the total impact with the occurrence probability of the analysed perturbations, whose evaluation is qualitative and external to the study scope.

Finally, the calculated impacts and risks are submitted in the model to evaluation criteria in order to verify if they are within acceptable limits. If this does not happen, the scenarios can be retested with better operational reaction capabilities until impacts and risks are controlled.

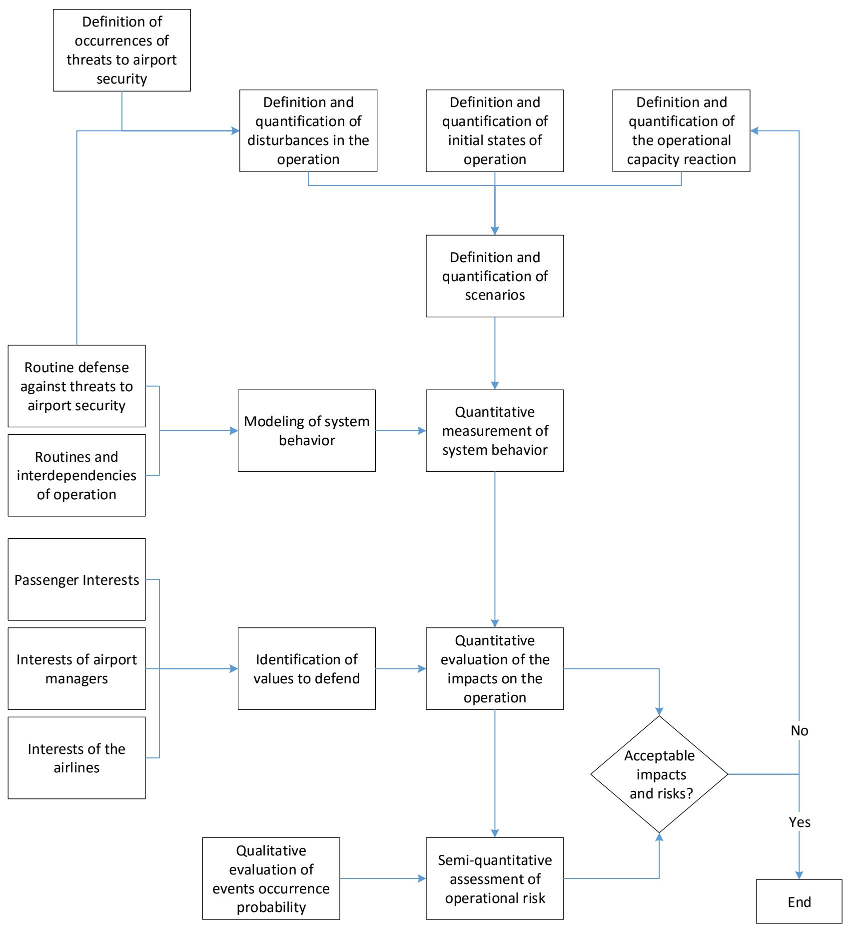

Figure I - Analysis methodology

The model is implemented in the Multipass computational tool that allows the simulation, the measurement and the evaluation of scenarios, starting with the definition and quantification of a relational cause-effect network. The interaction with the user consists in the activation of detections to be simulated, which will impact the network and generate alarms according to its magnitude.

MODEL DEFINITION

In the model construction, it is defined the input variables – perturbations, initial states and reaction capacities –, the output variables – impacts – and how they interact with each other and under what criteria the results are evaluated.

Events of threat to airport security

The definition and the characterization of events are introduced in the simulation by the activation of detections, explained below.

Regarding occurrences in queuing systems, the developed model allows simulating any events that cause processing constraints, such as failure of equipment, the use of more exigent or more time-consuming procedures, or the treatment of unattended items via the isolation of a certain area dimension. The simulation of these events is accompanied by the time definition that elapses until the processing capacity is restored, that is, the duration of the disturbance.

On the reverse side, it can also be simulated events that lead to traffic flow levels above those dictated by demand of the airport, which may represent, for example, air side contamination.

With focus on the intermediate systems, the model gives the hypothesis of simulating events that imply the movement conditionings, generated by the isolation of an area due to the detection of a criminal activity, an unattended bag, among other reasons.

Finally, it should be noted that the simulation of any occurrence in the context of risk is accompanied by the detection of its threat level, that is, its probability of occurrence.

Initial states of operation

The characterization of the initial operating conditions in each queueing system is carried out by detecting occupancy rates/demand levels and delay levels.

System reaction

The reaction of the system to perturbations is defined through the valuation of certain interdependencies between impacts, which makes possible to simulate queues from the perspective of the planning slack, capacity reinforcement after a perturbation and downstream capacity increase.

Typology of impacts: operational and decision-making aspects

Given the general panorama of interests and interactions that coexist within the airport, the model relies on two types of impacts: the final impacts, which respond to the question "What evaluate?" and the intermediate impacts that respond the question “How evaluate?".

Final impacts consist of extremely important parameters for evaluating the service quality of the airport system and its level of security, aiming to serve as a support for the decision-making management of the airport, conducted by airport and government managers. Thus, facing a given perturbation, the simulation converges to the evaluation of the service levels degradation, of its time and space components, and associated risk, as well as the measurement of resilience, recovery and the necessary efforts to revert those impacts. Besides service level degradation in each system and the overall impact and risk, the following variables are addressed: space occupancy, waiting time and delay in system queues, space occupancy in circulation corridors and waiting rooms in accommodation systems, and at last charges to maintain the capacity, since it has been restricted, probability of flights cancelation and recovery time to the initial state.

Intermediate impacts include variables that reflect the operational performance of the various systems, as individual and interconnected, with the objective of simulating the dynamic capacity throughout the system, on which the assessment of the final impacts is based. Thus, intermediate impacts comprise variables that synthesize and combine the influence of events and initial states on the dynamics of flows.

Simulation Architecture

The basis of the effects simulation on queuing systems is the evaluation of their occupancy status, resulting from the weighting between the initial occupancy rate, user-initiated, the degradation of the processing rate and the arrival rate. Thus, for a given period of analysis, the occupation state indicates the proportion of the traffic served, i.e. the dynamic capacity, and detecting the presence of a stationary or transient regime, leads to the measurement of the service level provided there, as well as the proportion of traffic retained. The service quality in queues is also affected by the initial delay level set by the user.

It is considered that part of the traffic retained in queuing systems moves to the immediate antecedent accommodation system, affecting there the quality of the service, since it is understood that this type of systems act as barriers to changes in operating conditions, and that upstream routine occurs within normalcy. On the other hand, the traffic served in each waiting queue allows knowing the traffic that flows to the next queue and consequently the portion of the initial occupation rate installed there, as well as the flow that may exceed this initial state. All of this information will introduce the simulation of its occupation state.

The model gives the hypothesis of simulating impacts due to the influence of events occurrence - 1^{st} simulation phase - and due to the influence of its resolution - 2^{nd} simulation phase, because the global system can assume different operational behaviors in each phase, as it will be seen bellow.

In queuing systems, the detection of events that limit the processing rate and the definition of its duration lead to the degradation of its occupation state in the first simulation phase. If this state recognizes the presence of a stationary regime, there is no upward movement of traffic and the traffic that moves to the downstream queues remains stationary, so the initial occupancy rate of these systems is not changed. If the occupation state indicates that there is a transitory regime, there is a bottleneck in the service, with a rarefaction of passengers in the waiting queues downstream, as a result of the decrease in the initial occupancy rate, and a more significant flow upstream as greater is the traffic retention.

In the second simulation phase, the resolution of the perturbation is carried out, at first, by the deactivation of the disturbing event and its duration, which cancels all the impacts, estimated by the reduction of the processing rate, and re-establishes the conditions of service before the disturbance occurrence. In order to reproduce in that system the retained traffic from the first phase, which will affect its occupancy state in the second phase by increasing the arrival rate, the user must activate the service normalization event based on that information.

The memory over the retained traffic will now control the running of the entire simulation in the second phase. The dynamic capacity of the normalized system increases for processing the retained traffic, if the system has the capacity to do so, and as the flow decreases in the upstream accommodation system, it increases in the downstream queue, which lead to the recovery of its initial occupancy rate, and a level of demand beyond this level, turned on by service normalization events. If the chain queuing systems is not able to handle the new flow requirements, there are new bottlenecks in the operation, where these systems enter into a transient regime until they process a certain amount of traffic that allows them to recover the station.

The simulation in the security control of downstream traffic confluence, via air side contamination, is homologous to the simulation of the second phase of constraints in the operation, although they are activated by different detections precisely to allow the reproducing of their combination.

From what have been explain, and in similarity to shockwave theory, the perturbations in a queue system can be seen as the epicentre of a flowing wave that grows upstream, and shifts downstream in its maximum magnitude when the system recovers its initial ability.

The occurrence of an event against security in accommodation systems only leads to the quality of service degradation in these systems, due to its function of disturbances damping of disturbances. The resolution of the disturbance only involves the deactivation of the generating event and therefore the annulment of the first phase effects, restoring the initial level of service. Therefore, there is no interference of these systems performance with the others around it, both in the first and second phases.

Finally, it is noted that risk should be assessed whenever impacts are calculated, at one or other simulation phase, so during that analysis the probability of occurrences should be active, even if disturbing events have been disabled.

Impacts evaluation

In the developed simulation, the evaluation of impacts magnitude is also associated with several concepts of capacity. As advocated by the Multipass program, the effect on impacts is staggered in three intervals, associated in ascending order of gravity to green, yellow and red colours, respectively. In the interpretation that is given to the model, the three gravity states and associated colours suggest three distinct states of capacity defined by IATA (International Air Transport Association), described below.

Low gravity (green) – Sustained capacity - indicates a capacity state in which the system can accommodate all the traffic in a sustainable period and within the standards of space and time required by the level of service to be preserved, which must comply with the IATA dimensioning recommendation. Thus, it denotes the maintenance of the dynamic and static capacity in processes, accommodation areas and interconnections between them, in such a way that a level of service is not inferior to C.

Medium gravity (yellow) - Limited capacity - reproduces the maximum traffic flow that can be sustained only in a short period of time but not maintained in the long term due to safety and service levels. It refers to the beginning of a service level D, which corresponds to an alarm situation, meaning a warn that measures must be taken to improve the service, or the situation will degenerate into service levels E or F, depending on the time the system is left in such conditions.

High gravity (Red) – Depleted capacity - accuses an unsustainable disruption of the service even in a short time, with long delays and highly degraded levels of service throughout the system equivalent to service levels E or F, depending on the length of time during which the activity remains affected.

GENERAL INSIGHTS OF THE MODEL CALIBRATION

In the calibration phase it is approached the quantitative measurement of the variables as well as the relations between them, for application to the Lisbon Airport. Nevertheless, whenever possible, the calibration was carried out in the case of general application to any airport. The calibration therefore uses assumptions, service level and dimensioning criteria and impact knowledge in relation to the operation of airports. It is given in this section some highlights of the logic that comprises the calibration phase.

The study focuses on the detection and evaluation of situations that exceed the dynamic capacity limits that are consistent with a service level C, indicating the eminence or even the presence of transitory states in queuing systems and possibly along the entire airport. Considering this objective, the calibration often refers to the deterministic model presented in the Figure II, which is representative of the study panorama. Based on that model, impact calculations are mainly around the measurement of the retained traffic, referenced to the specified criteria.

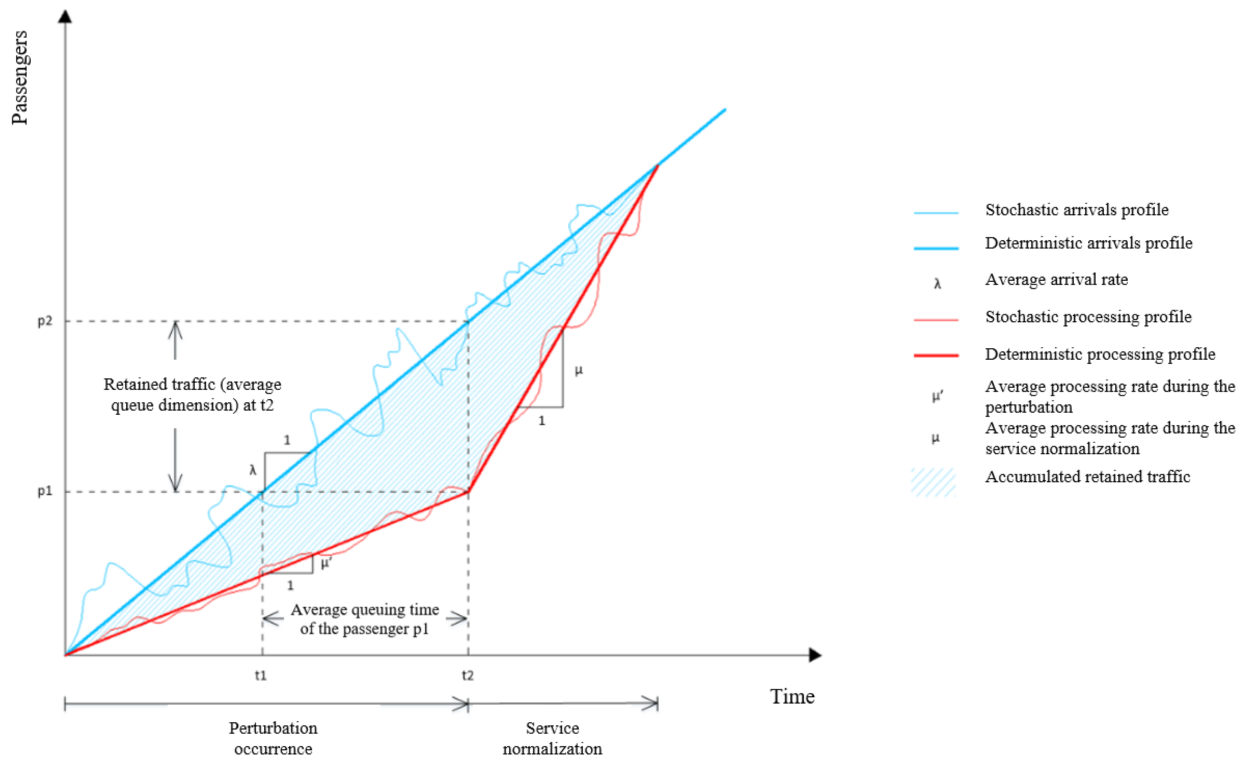

Figure II. Deterministic model adopted to study queues in transient state queuing systems.

In the variables definition the following considerations stand out:

- The initial occupancy rate is defined according to two schedules: peak hour and off-peak hours;
- The flows are introduced and manipulated in the simulation not by their absolute dimension but by the quotient between their size and the total capacity of each queuing system - occupancy rate - allowing the independent simulation of each airport's own traffic volumes;
- In the presence of a disturbance in a queueing system, the model assumes the reallocation of the flows by the available counters in order to standardize the conditions of service to all traffic;
- The model identifies the scenarios in which the increase duration does not lead to negative impacts, discarding its simulation;
- Considering that queuing and accommodation systems are dimensioned to provide the same level of service by a given dynamic capacity, the impact induced by the same flow addressed to each system is the same.

SENSITIVITY ANALYSIS AND FINDINGS

For the Terminal 1 of Lisbon airport, a sensitivity analysis was developed for disturbances in the security control and in the check-in. In the first case of analysis, it is explored a particular occurrence, the failure of X-ray equipment in the security control, while in the second case the disturbance may be representative of any occurrence, if it is carried out by the model simulation moulds.

The sensitivity analysis of the first case demonstrates that, even with a little or no slacks in operation, X-ray equipment failure up to a minimum number that leads to the operation instability beyond 1 hour, generates impacts and risks within acceptable limits, although they must be controlled so that they do not reach critical thresholds.

On the contrary, the sensitivity analysis related to disturbances in the check-in shown results of high criticality, which allowed highlighting some conclusions regarding the effectiveness of the capacity reinforcement in reaction to occurrence vs. the slack increase in the processes planning. The reinforcement of capacity demonstrates itself more efficient in reducing the impact of most of the analysed variables, with the exception of the variables that measure the delay and the ones that depend directly on it, in which a looser planning has more satisfactory results. Moreover, in the presence of initial delays, the reactive action through the reinforcement of capacity cannot absolve the part of the delay that is already consumed in the system, which can be achieved with a slacker planning of the operation that leaves room for the downstream processes to do it. In choosing one or another solution, or a combination of the two, should be taken in account the vulnerabilities and potentialities highlighted, as well as the availability of technical and human resources, necessary for the capacity reinforcement.

CONCLUSIONS

The created model arises in an innovative way in the airport context by allowing to overcome weaknesses in the studied methods of risk assessment, as also to be complemented with their potentialities, largely due to its semi-quantitative evaluation character, as explained below.

- The dependencies between processes are represented by variables and cause-effect relationships, which are detailed and quantified, leading to the analysis of disruptive situations and to the robust evaluation of the cascade and system resilience impacts, whose qualitative methods have a lack of development.
- The exploration of a large number of scenarios, which is an arduous task in logical trees, is facilitated by the type of simulation introduced in the cause-effect network, which is allowed by the Multipass computational tool. In order to optimize the input information, the scenarios decided to be simulated can still be constructed through morphological and intelligent analysis.
- The logic and principles used in the definition and calibration of the model variables and relationships are as distant as possible from the application to a specific airport or to a specific disruption, aiming a maximum independence of internal standards knowledge or experimental/ historical data, which is a recurrent difficulty in the quantitative evaluation methods. It should be noted that only the calibration of the variables "Initial occupancy rate" and "Occupancy space rate per person in a waiting queue" depends on the each case in particularly.

Finally, the aspects that are not contemplated or less explored in the work carried out are identified below which, therefore, represent an opportunity for future developments.

- Validation of the model, and consequent adjustments to the calibration, should be a priority in the next steps, since they permit the constructed model to be applied and the achievement of the objectives it proposes with.
- The evaluation of occurrence probability is done by methods not included in the simulation, being integrated into the model only as a qualitative input parameter in order to carry out the risk assessment. Future improvements could include the manipulation of probabilities from subjective evaluations through the mathematical formalism of the Multipass, which can be complemented with fuzzy logic in order to reduce the ambiguity and imprecision inherent in evaluations.
- Although dependencies between processes are included in the simulation, the traffic passage between queuing processes can be exhaustive and confusing, since it is executed manually and

assumes the conversion of the upstream processes simulation results. It would be interesting to study a way to do this automatically, without the need of interaction with the user.

- With relevance to the calculation of impacts and risks arising from threats to airport security, in addition to the operative part explored in the model, the security aspect is also identified, and it can be incorporated in the model as a way to assess the damage in human lives and assets, costs of contingency plans, bomb risk, among others. Thus, such developments will allow the improvement of defence routines as risk prevention strategies, which in the current model are not contemplated. On the other hand, the fact that most security threat events are false alarms means that the security risk is in general low and therefore does not justify the high degree of operational risk they generate. This issue emphasizes the importance of an analysis encompassing the two contexts, which would allow balancing the operational and security criteria by reducing the impacts and risks inherent in each aspect.

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