

Integrating human factors in airport passenger security checkpoints: A decision aiding analysis of structural incoherencies

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Abstract

Our study tackles the challenges of adapting a “one-size-fits-all” airport security screening system. To do this we focus on passenger-transport security officers interactions at the passenger security checkpoint. The originality of the study lies in integrating the four elements of Herbert Simon’s (1977) “procedural rationality” (Intelligence, Design, Choice, Review) to the four dimensions of Alexis Tsoukiàs’ (2007) *Decision Aiding Process* (DAP). The method of the study was validated by a series of statistical and ethnomethodological studies involving passengers, transport security officers and civil aviation authorities. The results of our investigation highlight seven incoherencies at many passenger security checkpoints. In the light of this, we put forward three recommendations involving transport security officer empowerment, passenger engagement and increasing an overall sense-making approach via key performance indicators.

Keywords: decision aiding, airport security checkpoint, procedural rationality, coherence axioms

Résumé

Notre étude s’attache à faire évoluer un modèle monolithique (« une-taille-pour-tous ») de filtrage aéroportuaire. Pour ce faire, nous examinons les interactions entre passagers et agents de sûreté (PAX-ADS) au poste d’inspection filtrage. L’originalité de l’étude réside dans l’intégration de la rationalité procédurale (Intelligence, Conception, Choix, Revue) d’Herbert Simon (1977) et du Processus d’Aide à la Décision d’Alexis Tsoukiàs (2007). La méthode de l’étude a été validée au travers d’une série d’études ethnométhodologiques et statistiques sur le terrain. Les résultats qui s’ensuivent mettent en lumière sept incohérences dans le fonctionnement de nombreux postes d’inspection filtrage. Dans ce contexte nous proposons trois recommandations concernant l’encapacitation des agents de sûreté, l’engagement des passagers et l’accroissement de la construction de sens à travers des principaux indicateurs de performances.

Mots-clé: aide à la décision, poste d’inspection filtrage aéroportuaire, rationalité procédurale, axiomes de cohérence



1. Introduction

1.1. Airport security needs

Civil aviation security seeks to prevent the introduction of dangerous prohibited items into aircrafts. This is done by the implementation of various operational measures based on the coordination of technologies, procedures and human operators at different levels. These measures include a focus on passenger screening in order to detect and deter security threats at checkpoints prior to boarding as part of anti-terrorism procedures. We argue for an essentially situational threat detection-based approach to analysing airport passage checkpoints. The term situational is associated with a superposition of, for example, legal, cultural, psychological, economic, “contexts” in a given time and space. In this sense, a situational threat detection-based approach to airport security seeks to create specified “tensions” between a passenger (PAX) and Transportation Security Officers (TSO) involved in a security threat detection process. This is in contrast to, but not in opposition with, a more covert information seeking-based approach to detecting security threats.

In this context, a key challenge of airport security rests in improving the efficiency and efficacy of security checkpoints in a complicated equation made up of different entities at different decisional levels, as each of these entities has its own objectives, dynamic and constraints. From an optimization perspective the central issue can be summarized as follows: How can one reconcile the improvement of security performance levels (i.e. the efficient detection and deterrence capabilities) while facilitating the efficacy of passenger flow (that takes into account the respect of passengers’ dignity and the need to provide value for money)? From this point of view, TSOs at checkpoints can be seen as grassroots decision- and action-makers in their daily task of identifying, analyzing and acting on signals coming from security equipments and procedures. This includes implementing a full body search on a passenger to ascertain whether the person is a security threat, or not.

1.2. Objectives of the study

A scientific framework is thus necessary to prioritize the recommendations of security experts about how to improve security checkpoints at grassroots level, namely those that take into account human factors. Such a framework provides a sufficiently detached viewpoint that enhances the legitimacy of upstream decision makers’ choices when considering regulatory reforms at the political level. This represents an optimization problem at multi-levels that can be modelled as a formal decision-making problem.

The term “*model*” has a specific meaning in this study. Following the founding work of Bernard Roy (2000: 8), in multicriteria decision making, a model designates an “*abstract representation of a class of phenomena*” taken from a specified environment in order to facilitate an investigation and/or social exchanges. A model is, thus, not necessarily an “impoverished or approximate photograph” of a reality but more akin to a “caricature of real-life situations” based on a family of questions for a given observer (Roy, 2000: 9). In this context, the ambit of our study was to create a robust model of an airport security checkpoint based on three issues related to assessing performance regarding:

- the placing of human screeners in an appropriate spot within a designated security perimeter,
- the development of the appropriate performance criteria of human screeners,
- possible improvements to the existing security framework.

In the light of these three issues, three different models are put forward. First, there is a macro-model of the decision making process, based on Decision Aiding Process approach of Tsoukiàs (2008). The aim of the macro-model is to increase the procedural rationality of a given decision making process in explicating its “interconnecting-sense” (i.e. the overall coherence geared to achieving a set objective). The second model is based on a mathematical approach to evaluating a “Problem formulation” (i.e. the “Design” phase of Simon’s procedural rationality, see Table 1, below) within the macro-model. The third model is also mathematically based but focused, here, on the evaluation of solutions to the formulated problem (i.e. the “Choice” phase of Simon’s procedural rationality, see Table 1, below) of the macro-model. The formalization of a robust



alternative “model” of an airport security checkpoint is underpinned by a multicriteria aggregation procedure* approach (Roy, 2000: 9). This procedure enables the decider needs to take into account two or more non-complementary criteria given that the systematic elimination of mathematically “awkward” criteria (due to its ambiguous, paradoxical, or dissonant nature) could effectively invalidate solutions aimed to solve problems focussed on the imperious nature of “real-life situations” (Roy, 2000: 9).

Within this framework, our study puts forward a set of decision aiding Recommendations (see Table 1, below), *i.e.* assertions taken from a sequence of results based on various sets of data and/or sets of working hypotheses (Roy, 2000: 9). Such recommendations are not to be confused with related, but distinct, assertions such as a “road map” (how to navigate around problems in order to go from A to B), technical specifications (how to create an artifact), or an action plan (sequence of steps to be taken in terms of allocated tasks, time horizon and resources).

2. Analysis by the decision aiding

2.1. Decision aiding

Decision aiding is defined by Roy (1996) as “the activity of the person who, through the use of explicit but not necessarily completely formalized models, helps obtaining elements of responses to the questions posed by a stakeholder of a decision process. These elements work towards clarifying the decision and usually towards recommending, or simply favouring, a behaviour that will increase the consistency between the evolution of the process and this stakeholder’s objectives and value system.”

Four major components of this definition can be found in the *Manual Doc9808* regarding “Human Factors in Civil Aviation Security Operations” (ICAO, 2002) notably:

- the stakeholder’s value system that brings together security and human factors,
- security equipment that plays the role of models to “leveraging human capabilities and adaptabilities to enhance overall system performance”,
- the decision process that includes the task of screening all baggage as well as establishing “how much time is required to screen a given number of passengers” during the security checkpoint process,
- the need to increase the consistency of decision that is aimed at “matching the limitations and capabilities of the operators to the technologies that support civil aviation security operations” as well as “making the aviation security system resilient to the consequences of human error”.

In our study, decision aiding is based on four concepts based on the Multicriteria Methodology for Decision Aiding of Bernard Roy (1996). This consists of potential actions, criteria, preferences and robustness. The methodology is divided into four levels:

- The first level, called “Object of the decision and spirit of the recommendation or participation”, establishes the set of potential actions and the selection of a subset.
- The second level, called “Analyzing consequences and developing criteria”, defines a family of criteria that expresses the consequences of the actions by taking into account the factors of imprecision, uncertainty and inaccurate determination.
- The third level, called “Modeling comprehensive preferences and operationally aggregating performances”, is built on an aggregation of criteria.
- The fourth level, called “Investigating and developing the recommendation”, designs the procedures to acquire and process information that leads to solutions to a specific problem. These procedures include the robustness analysis that studies the capacity of the recommendation, notably that of aggregation, in order to remain a solution despite the factors of inevitable variability in real life situations (Roy, 2010).

In this way, the methodology set up its model within the scope of decision theory. At the same time, the methodology helps obtain elements of responses to the questions of the stakeholder about resolving a given problem. This is called a “constructivist” decision making approach.

* **Multicriteria aggregation procedure** :A procedure which allows the systematic comparison any two actions from a set of actions *A* by taking into account (in a comprehensive way) the performance levels of each action according to all the criteria of a given criterion family (Roy, 2000: 9).



In adjoining the four activities of procedural rationality (Intelligence, Design, Choice, Review cf. Simon, 1977, see Table 1, below) to the Decision Aiding Process (DAP) of Alexis Tsoukiàs (2007) the constructivist approach that we put forward involves the following key elements. As shown in Figure 1, below, we argue that a DAP can be conceptualised effectively as a partition of the set of potential solutions \mathbb{A} established through the Problem statement \mathbb{II} (e.g. the best choice, an allocation to categories or a particular ranking) and representative points of view \mathbb{V} . Potential actions \mathbb{A} are numerically represented by alternatives \mathbb{A} based on criteria \mathbb{H} . This numerical representation comes from a selection of points of view \mathbb{V} expressed as a numerical dimension \mathbb{D} taking value from a set of scales \mathbb{E} . The family of criteria \mathbb{H} provides a synthesis of \mathbb{D} sufficient to express an improvement to the decision *via* comparisons. The synthesis is guaranteed by three properties called coherence axioms: non-redundancy, cohesion and completeness. “Completeness” designates a family of criteria that represents all the elements that are significant in a given reality in order to differentiate potential actions. Given that a set of criteria identifies a preference for one potential action over another, the concept of “cohesion” indicates that a criterion has the same distinguishing trait of revealing a given preference whether it is referred to on an individual or collective basis in the family of criteria. By “non-redundancy” is meant not having two criteria, in a given family of criteria, that differentiates in the same way potential actions. The cross-matching of these three axioms enables the observer to pinpoint incoherencies within an operational framework when representing the tensions of a given reality. Two concepts complete the evaluation. First, the representation of uncertainty \mathbb{U} completes the evaluation, which takes into account imprecise and undetermined information. Second, the aggregation operator \mathbb{R} introduces a representation of global preferences as a combination of criteria. The final recommendation $\mathbb{\Phi}$ refers to the final decision that a decision maker should apply. A robustness analysis can be seen as the study of the reverse link from $\mathbb{\Phi}$ to \mathbb{R} .

Table 1. Correspondence between the Decision Aiding Process (Tsoukiàs, 2007) and procedural rationality (Simon, 1977)

Procedural rationality	Decision Aiding Process	Decision aiding concepts
Intelligence	Problem situation \mathcal{P}	Participants \mathcal{A} Stakes \mathcal{C}
Design	Problem formulation \mathcal{I}	Engagements \mathcal{S} Potential actions \mathbb{A} Points of view \mathbb{V} Problem statement \mathbb{II}
Choice	Evaluation model \mathcal{M}	Alternatives \mathbb{A} Dimension \mathbb{D} Scales \mathbb{E} Criteria \mathbb{H} Uncertainty \mathbb{U} Preferences aggregation \mathcal{R}
Review	Final recommendation $\mathbb{\Phi}$	

DAP thus proposes an extension of decision aiding concepts given that the problem formulation \mathcal{I} is linked to an independent representation \mathcal{P} , which assembles the major issues of the decision problem. The stakes \mathcal{C} designates the objectives and constraints introduced by the identified participants \mathcal{A} of the decision. The participants’ declared engagements \mathcal{S} express the accepted relations between participants and stakes.

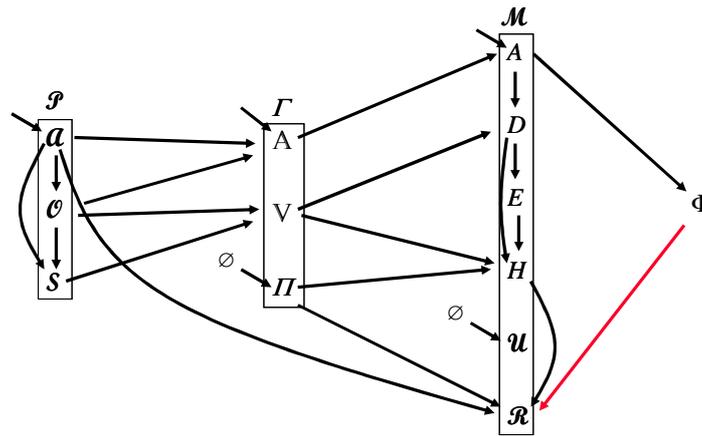


Fig. 1. Decision Aiding Process in the constructivist approach.

The procedural rationality structures exchanges between DAP and the decision process. First the decision process is structured through four interacting activities defined by Simon (1977):

- the intelligence that collects the elements of knowledge regarding the designated problem,
- the design that develops possible courses of actions,
- the choice that selects particular courses of actions from those designed,
- the review that assesses the coherency between the chosen actions and past choices.

Second, in an abstraction phase, DAP is superposed on the decision process in order to provide a global and synthetic representation. Such a representation identifies useful complements given by the concepts of decision aiding. In a concretization phase, the new abstract knowledge is integrated into the decision process and the value system (Fig. 2 below). In the interaction between DAP and procedural rationality, there is no one entry point. In a fact this means, one can enter at any of the four stages of DAP. This is a crucial point to stress as in our study we focus on the analysis and improvement (see below) of the security framework.

In this way the concepts of our constructivist approach can be used to describe, analyze and improve the decision process and the value system. Such an approach is called a descriptivist approach.

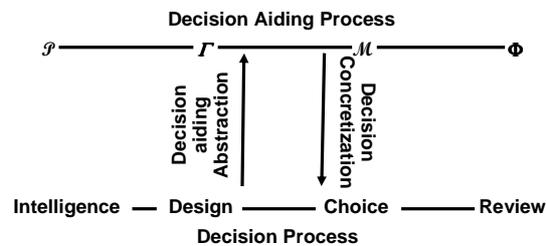


Fig. 2. Exchange between DAP and the decision process.

2.2. Checkpoint context

The project takes place within the context of the manual Doc9808 that defines the basic demands of the role of human factors. These demands guide the abstraction phase of the decision process. The concretization phase, which follows, aims at better integrating security equipment and newly prescribed procedures.

In this light, the decision process concerns the security checkpoint process that can be modelled in terms of the four activities of procedural rationality:

- Welcoming: checking boarding cards, advising passengers on the security procedures,
- Preparation: loading bags onto the conveyor belt, monitoring passengers,
- Searching for prohibited articles: X-ray screening of bags, full body search,
- Filtering: passenger to access to the restricted boarding area or calling the police.



3. Analysis of incoherencies

A total of 16 meetings, presentations and field studies were conducted to develop and validate the analysis of incoherencies. This process involved a series of top-down and bottom-up exchanges, between June 2011 and October 2013, involving PAX, TSO and representatives of civil aviation authorities. The studies were based on generating and analysing statistical and ethnomethodological data. DAP and procedural rationality reveals seven basic structural incoherencies in the passenger screening situation. The first incoherency refers to the manual Doc9808 where the PAX are not explicitly mentioned and, coupled to this, the TSO are viewed as the origin of “human error”. The lack of visibility, especially concerning the PAX, underplays the interaction of grassroots participants in the dynamics of real-life situations. The importance of such participants is effectively highlighted in the Annex 17 to the *Chicago Convention on International Civil Aviation*. In article 4.4.1, the Annex states that “Each contracting State shall establish measures to ensure that originating passengers of commercial air transport operations and their cabin baggage are screened prior to boarding an aircraft departing from security restricted area”. To clarify this incoherency, seen as a violation of the completeness axiom, it is proposed to introduce the PAX as an active participant in \mathcal{P} (Fig. 3).

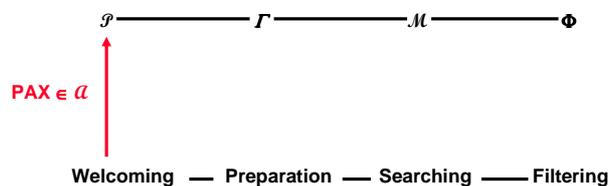


Fig. 3. Introduction of the PAX in the problem situation.

The second incoherency concerns the lack of clearly stated PAX-TSO engagements. Given that the TSO is also a participant in \mathcal{A} , both the PAX and the TSO have the security issue as a mutual concern in \mathcal{C} , albeit from different perspectives. In this sense, DAP reveals an inconsistency about the lack of a clearly defined efficient operational allocation of resources to this mutual security concern. The absence of an explicitly stated allocation leads to undefined “front office” engagements between the PAX and TSO in \mathcal{S} (Fig. 4). The tension that ensues is linked to a violation of the completeness axiom. To resolve the tension, induced by this inconsistency, it seems useful to introduce a new mutual security concern to clarify both existing concerns and allocation of resources to them *via* clearly stated engagements \mathcal{S} between participants.

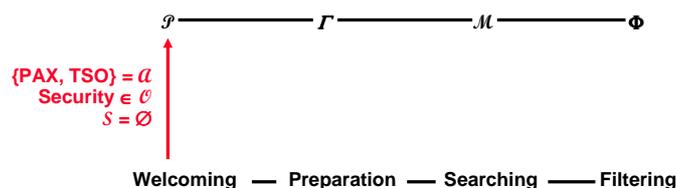


Fig. 4. Lack of engagements.

The third incoherency comes from the checkpoint seeking prohibited objects, represented by the viewpoint \mathcal{V} (see Fig. 5, below). This inconsistency includes the need to put the PAX in a controlled threat detection-based situation. This implies placing the PAX under tension, *i.e.* under sufficient discomfort as a way to analysing and detecting a threat to security. This is akin to what Ansoff (1990) calls the detection of “weak signals”. In this sense, security screening is considered as the controlled ability of putting the PAX offender in a threat-revealing situation by playing up the contradictory effort of transparency-dissimulation related to a violation of the cohesion axiom. In effect, the central issue is deciding if a traveller falls either within the “transparency” (not a likely threat), or the “dissimulation” (a likely threat) category. In the case of an all-clear transparency decision the traveller is considered as a PAX. Inversely, if the dissimulation decision is applied, the traveller is judged as a security threat. This dichotomous transparency-dissimulation decision making, however, can have an undesirable effect on the PAX. The traveller can consider such decisions as unacceptable in that they appear to be arbitrary judgements based on apparently ethnic, religious or cultural preconceptions. It needs to be stressed, here, that it is the “appearance” of arbitrary decisions that is problematic (“Why me, and not someone else?”),



and not necessarily the decision *per se*. In short, what the TSO considers as a “discretionary” decision, the PAX sees as an “arbitrary”, or even “discriminatory”, action. To limit this tension, the security framework needs to regulate what, how and when it communicates relevant information to the PAX on security issues.

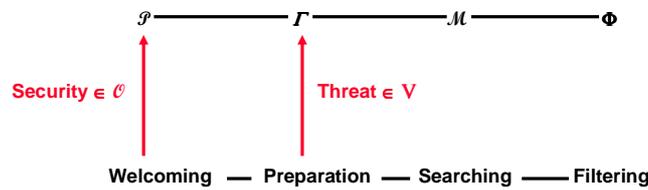


Fig. 5. Contradictory situation for the PAX.

The fourth incoherency occurs when the PAX is placed in a washback (or backwash) situation that occurs when the person is screened as an alternative A in the evaluation model \mathcal{M} (Fig. 6). (The washback effect is classically highlighted in a didactic situation as the (unintended) “influence of testing on training and learning”, Shawcross, 2007). The anticipatory washback screening situation can be either positive or negative depending on the state of the PAX’s security readiness. The incertitude concerning the (readiness of the) PAX includes the passenger’s concerns about personal dignity and respect when being screened. This point refers to a violation of the completeness axiom (see above). Such tensions can be regulated by offering adapted information to the PAX at the appropriate moment in anticipation of the security screening process.

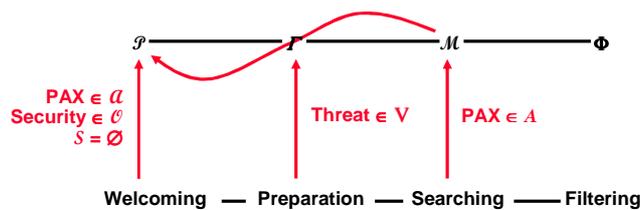


Fig. 6. Washback effect.

The fifth incoherent situation arises from the dynamic nature of a security threat, which varies while it is being evaluated through the static criteria H given by security equipment (Fig. 7). This situation is associated to a violation of the completeness and cohesion axioms (see above). An extension of the concept of robustness analysis, from \mathcal{M} to Γ , can reduce this contradictory situation. Contrary to the present state of affairs, an initial analysis of technical robustness that studies the variations of threat detection in real *in vitro* grassroots situations can but improve the efficiency of identifying prohibited objects. Moreover, the ongoing collection of operational data can contribute to this type of robustness analysis in order to fine tune the technical capacities of security equipment according to the needs of a particular situation and its attending (legal, economic, cultural, ...) contexts.

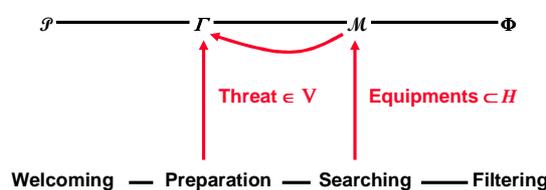


Fig. 7. Technical robustness.

The sixth incoherency is related to the washback effect where the security issue is not allocated to any participant. But, given that the TSO is part of an overall security system, the actions of a TSO constitutes a set of criteria for assessing potential threats. Formally speaking, this gives: $\text{TSO} \in H$ (Fig. 8). This occurs when the TSO is under- or over-focussed on a task that prevents the individual to take into account dynamic washback effects of a screening process. In this situation, it is probable that an instrumental bias is at work that discourages an efficient detection of a security threat. The incoherency is the source of “human error” referred to in the manual Doc9808 when the TSO is not attributed explicitly recognised discretionary powers. Such incoherencies



can be reduced by introducing an additional security concern as mentioned in Annex 9 to the *Chicago Convention*. In this case, the discretionary facilitation issue can balance out the problem situation \mathcal{P} by a clarification of PAX-TSO engagements.

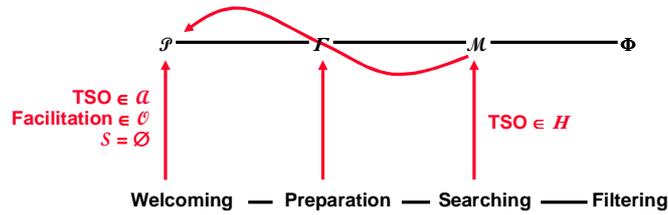


Fig. 8. Instrumental bias for the ADS.

Finally the seventh incoherency concerns the operational quality of performance indicators. Current performance indicators tend to provide an external evaluation that is not connected to declared operational actions or improvements. Such performance indicators can be considered as an operationally “abstract” dimension D , rather than criteria H anchored to specified actions (Fig. 9). In such a case, dimension-based indicators are devoid of basic structures of preferences.

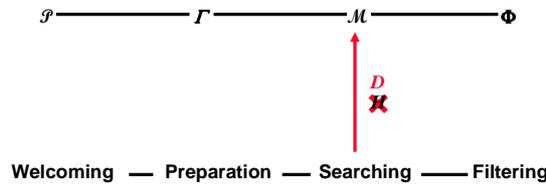


Fig. 9. Evaluation separated from improvement.

4. Problem setting

4.1. Problem situation

All the basic information given by the operational situation and the *Chicago Convention* can be expressed by the descriptivist problem situation (Fig. 10a). At least two objects of concerns are to be considered when allocating resources to two participants without clearly defined engagements between them. The issue of security, rather than that of facilitation, has a slight priority because it is of a more general nature. Added to this, the security equipment provides assistance to the TSO in the detection of prohibited items. Based on these elements, a new problem situation can be defined in a constructivist approach (Fig. 10b) where:

- $\mathcal{A} = \{PAX, TSO\}$
- $\mathcal{C} = \{\text{security, facilitation}\}$
- $\mathcal{S} = \{(TSO, \text{facilitation, PAX}), (PAX, \text{security, TSO})\}$

The interactions in \mathcal{S} imply engagement whereby the TSO provides facilitation and in exchange the PAX provides security. Operationally, this engagement necessitates evaluations of facilitation as a way of balancing out the problem situation (Fig. 10b). From this point of view, the problem setting situation lends itself to the circulation, and thus transformation, of objects of concern both for the PAX and the TSO within the communication space of airport safety in a manner that is compatible with the demands of airport facilitation for the PAX.



Fig. 10. Descriptivist (a) and constructivist (b) problem situation.



4.2. A three-fold recommendation

This new problem situation can be implemented by a combination of three basic recommendations:

- The quality of the PAX-TSO relationship is especially important at the passenger preparation level as one of the key components of an overall efficient screening process. The key idea here is to create a climate of *passenger engagement* (Kiesler, 1971) in which a PAX will willingly cooperate with a TSO in order to enhance both the security system and the passenger's needs.
- The question of *empowering* (McDonald, 2012) a TSO is a crucial but delicate issue. On the one hand, security agents need to abide to official procedures for security, legal, economic and ethical reasons. On the other hand, if TSOs abide over-rigidly to standard procedures they risk falling into a predictable routine of over- or under-focussing on tasks that discourages them from identifying “weak signals” (see Incoherency #6, above). This is counter-productive given that one of the features of airport security threats is its unpredictable nature. Empowering TSOs thus involves enabling them to use their discretionary powers as grassroots decision- and action-makers of walking the fine line between knowing when to go beyond standard procedures (when encountering a potential security threat) while still respecting the law and ethical norms. This form of empowerment requires a security information system that enhances the vigilance of security agents based on team work and the capitalization of “lessons learned” from the field by experienced security agents.
- It is necessary to measure the performance of the security system as a way to evaluate and to *make sense* (Wieck, 1995) of improvements. To do this it is necessary to establish key performance indicators when evaluating TSOs. Such an approach contributes to a maturation and resilient process that examines a set of data in order to better identify “weak signals” (Ansoff, 1990) of an emerging security threat.

4.3. Resilience

The combined recommendations (above) contribute to improving the resilience capacity of airport security screening checkpoints as a dynamic ecological system (Walker, 2006) within a decision aiding framework. A classical representation in numerical decision models expresses the problem as a domain that corresponds to all the possible configurations of evaluation of numerical objects. This domain is divided into two parts:

- the feasible domain of all and every constraints of the problem that are formally satisfied,
- the non-feasible domain as the complementary domain.

By the very nature of the modelling process (see above) all the elements of a targeted reality cannot be inevitably taken into account. Some phenomena are not known (? see Fig. 11), cannot be represented (... see Fig. 11), or are not stable. In these cases, in consequence, several studies are conducted in order to assess the stability of the model in terms of:

- the principal of the sensitivity analysis that verifies the reliability of the solution to remain in the feasible domain when the parameters of the model are perturbed,
- the principal of the robustness analysis, which can be seen as an alternative way of presenting the concept in 2.1 (above), assesses the capacity of the solution to revert back to the feasible domain when unexpected variations, caused by grassroots external reality, pushes temporarily the framework into the non-feasible domain.

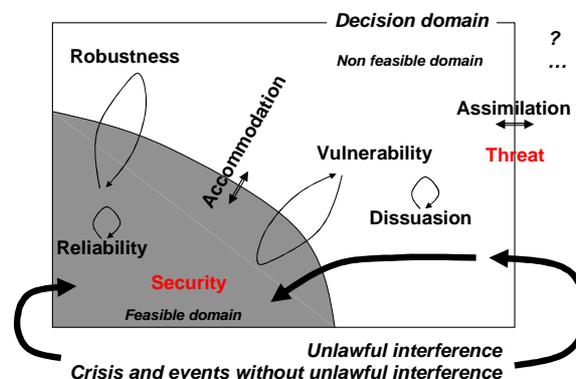


Fig. 11. Application of the concept of resilience.



Threats to airport are not just a complementary element to airport security. The analysis of such threats cannot be reduced to the particular preoccupations of airport security, it is also needs to be seen from a larger societal perspective. This entails examining threats from the angles of vulnerability and dissuasion, which can be seen as the analysis of the non-feasible domain in terms of robustness and reliability factors. When combining this approach with a decision aiding approach, it is possible to study the exchanges between feasible and non-feasible domains when managing the assimilation of new, rare and unknown events in the ongoing adaptation of security procedures. In this sense, new “real” or “potential” events can be represented as alternatives linked to “real actions” that can be analyzed as being part of either the feasible or non-feasible domains. Vulnerability and dissuasion can be seen as the analysis of the non-feasible domain in terms of robustness and reliability factors.

5. Conclusion

In a nutshell, our study tackled the challenges of a standard “one-size-fits-all” overall security screening system, based on a PAX “equal-risk” approach, to a more “risk-based” model by focusing on more dynamic PAX-TSO interactions. To do this we identified seven incoherencies at passenger security checkpoints. Three recommendations are put forward involving transport security officer empowerment, passenger engagement and increasing an overall sense-making approach via key performance indicators. The implementation of these recommendations implies closer collaboration between management and engineering sciences and social sciences, such as the Information and Communication Sciences.

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