Modeling Aviation Security Processes: A Group Model Building Approach[1,2]

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Abstract

The US Transportation Security Administration (TSA) is collaborating with a team of system dynamics modelers from three national laboratories to build a model of its security checkpoint operations at US commercial airports. The purpose is to proactively identify high-leverage opportunities for investment to improve system performance. To elicit a broad range of expertise and opinions to better understand the systemic issues facing TSA as it strives to improve its security checkpoint operations, we conducted more than 30 interviews with headquarters and field operations staff; we also hosted a two-day group model building (GMB) exercise. In this paper, we use causal-loop diagrams along with a description of the results of the GMB exercise to present a rich articulation of the issues facing TSA in managing its security checkpoints. We also look at how the complex interrelationships among various factors ultimately impact the effectiveness and efficiency of an aviation security checkpoint.

Keywords: Security, Transportation Security, Aviation Security, Group Model Building

Introduction

This paper describes part of the effort used to develop a Checkpoint Strategy Simulator Model for the US Transportation Security Administration (TSA). The effort focuses on understanding airline passenger screening procedures by using a system dynamics perspective. The screening process, "designed to identify and prevent known or suspected terrorists, weapons, and explosives from being allowed onto aircraft" (GAO 2007, p. 1), is being modeled to identify feedback mechanisms and counterintuitive effects, given changes in policy. The model is based

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1 This paper describes some of the results of a research project to which many people made contributions. The authors wish to acknowledge the participation of George Richardson, David Andersen, Colin Eden, and Fran Ackerman as facilitators of the Group Model Building session described herein. In addition, Gregory Conrad, Michael Samsa, Jim Kavicky, Lisa Moore, Paolo Patelli, and Donatella Pasqualini (all from the national laboratories) participated in the interviews and data collection.

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on the concepts of system dynamics (Forrester 1961; Richardson and Pugh 1981; Sterman 2000) and will help TSA understand how complex interrelationships of various factors impact the effectiveness and efficiency of an aviation security checkpoint. Ultimately, this modeling effort will enable decision makers at TSA to enhance their understanding of the origins of what is perceived as unintended consequences of policy decisions and, therefore, make better, more informed policy decisions, thus avoiding the open-loop mindset that prevents the identification of systemic solutions.

The security checkpoint simulator will contribute to TSA's ability to improve system planning, policy development, collaboration, and problem solving in general. The simulator, to be developed on the basis of the system dynamics approach, will improve TSA's capacity to (1) discover counterintuitive consequences of decisions and plans, (2) identify the data that need to be collected to understand how improvement evolves over time, (3) identify *high-leverage points* in the system (i.e., places where a relatively small effort can yield a significant improvement in system performance), (4) understand the interrelationships between different parts of the system, and (5) multiply and broaden the wisdom of subject-matter experts (SMEs).

The project is being developed by TSA along with three national laboratories that have expertise in system dynamics modeling: Argonne National Laboratory, Los Alamos National Laboratory, and Sandia National Laboratories. Staff from the Office of Risk Management & Strategic Planning of the TSA, with scientists from the national lab team, contacted SMEs at TSA headquarters and several airports throughout the country to collect the data necessary for developing the model. The data collection followed three parallel tracks: (1) review of existing documents, databases, and existing TSA models; (2) interviews with SMEs; and (3) a group model building (GMB) session with security experts from diverse areas of TSA.

The paper is structured into three major sections. First, we present a description of the GMB session. Next, we discuss the initial results, called structural leverage points. Finally, we describe the model sectors, which were evident after the data-gathering stage.

Description of the Group Model Building Session

Theoretical Background

Group model building is a way to construct models with groups (Andersen and Richardson 1997; Andersen, Richardson, and Vennix 1997). Group model building relates to "the processes and techniques designed to handle the tangle of problems that arise in trying to involve a large number of people in model construction" (Richardson 1999, p. 375). In the system dynamics field, a growing body of literature addresses this problem (Martinez-Moyano 2006) and provides insights and guidelines to produce the best results in the least amount of time (Luna-Reyes et al. 2006; Rouwette, Vennix, and Mullekom 2002; for examples of applications see Vennix 1999; Zagonel 2004).

The typical result of a GMB session is in the form of (1) group consensus about the goals and purpose of the modeling effort, (2) group identification of the model boundary and likely results of the modeling effort, and (3) initial model structure related to parts of the model that emerge as crucial to the group through the exercise.

In general, two types of approaches can be used in a GMB intervention (Zagonel 2002). The first approach favors the construction of a model that captures the *true* nature of the system under study: the micro-world approach (Zagonel 2002). In this approach, the evidence of existence of elements in the model is the guiding principle for inclusion in the collective model; empirical validation is the standard for measuring the quality and usefulness of the product. The second approach favors the creation of a model that captures, and sometimes creates, consensus in the group; the main guiding element of the approach is the establishment of a shared conceptualization of the problem. A boundary-object approach (Zagonel 2002) emphasizes understanding the different perspectives of the problem under study as identified by the members of the group. This approach is particularly adept at finding common ground in a multi-disciplinary group that allows the group to decide and move forward with policy recommendations designed to improve the system under study.

Description of the Session

The TSA GMB session followed the standard scripts for group model building as described in the system dynamics literature (Andersen and Richardson 1997; Andersen, Richardson, and Vennix 1997) and incorporated an automated elicitation technique using the Group Explorer software (Bryson et al. 2004; Eden 1994, 2004). In general, GMB sessions begin with brief introductions from the participants, including a brief statement of hopes for the project, as well as fears. These actions allow the facilitators to understand individual viewpoints and provide a list of goals and pitfalls that can be cross-referenced as progress is made.

Later, the modelers present a small concept model (Richardson 2006) based on the one-on-one interviews. This model serves as the springboard from which the session discussions will start. A process of variable elicitation is then initiated; this is the beginning of the consensus model building process. Here participants make sure that the concept model has captured all of the crucial variables.

Once the variables have been determined and prioritized, the facilitators elicit relationships among variables. This effort incorporates both data-driven observations and expert understanding of system behaviors (reference mode elicitation process). The next task consists of eliciting causal structures that potentially explain the behaviors identified in the previous task.

After each round of structure elicitation, the facilitator leads a structured reflection on the group's current thinking. This round helps the modelers to understand the dynamic relationships present in the system under study. This activity also serves to clarify any "fuzzy" or unclear concepts discussed during the session. The process continues until the group feels that the current interrelationships identified and codified are as accurate a representation as can be achieved given the purpose of the modeling effort.

As the session progresses, the modelers collect notes on all the discussions; these materials are then used to formulate a preliminary model. Once completed, the model is presented to the group for final changes and acceptance. The final version of the model produced by the group is generally the initial version of the concept that will be used to formulate a working simulation model.

Schedule

The session took place on January 29 and 30, 2007; the two-day session was organized according to the schedule presented in Table 1.

Table 1 Group Model Building Session Schedule

Time (hr)	Day 1 Activity	Day 2 Activity
07:50	Assemble	Assemble
08:00	Introduction	Review of Day 1 and Introduction to Day 2 Activities
08:30	Problem Definition and Model Boundary	Model Structuring and System Goals
10:15	Break	
10:30	Dynamic Perspectives	
12:00	Lunch	Lunch
13:00	Concept Model	Model Structuring and Policy Priorities
13:30	Preliminary Model Structuring	
14:45	Modeler Feedback	
15:00	Break	
15:15	Scenario Events	
16:00	Adjourn	Adjourn

Participants

In this study, prior to the GMB session, more than 30 interviews were conducted with SMEs from TSA headquarters and selected airports: Reagan National (DCA), Albuquerque (ABQ), San Francisco (SFO), and O'Hare (ORD). After the interviews were completed, GMB sessions were conducted on January 29 and 30 to elicit consensus among the SMEs and to initiate the modeling process with a group-generated set of relevant structures.

The GMB session was held in Washington, DC, with more than 15 SMEs. The session convened outside the TSA facilities in an effort to increase the level of uninterrupted attendance at the session and to be able to deploy the technology used during the session: a secured, dedicated network of laptop computers.

Concept Model Used

As mentioned in the previous section, early in the GMB session, the modelers presented a small model, a concept model, to the group. The concept model is used "to introduce the iconography of the approach and some of its framing assumptions" (Richardson 2006, p. 1) to groups unfamiliar with system dynamics. In addition, the concept model is used to initiate a dialogue among members of the group. Concept models have a number of important characteristics: (1) they realistically relate to the group's problem; (2) they are simple to simulate; (3) they are imperfect so as to stimulate conversation; and (4) they can inspire an endogenous perspective on the problem. Finally, concept models must be formulated by using simple, almost obvious, mathematical relationships to create intuitive behavior. According to Richardson, "the point [of a concept model] is not a good model, but a good start to a conversation" (2006, p. 21).

In the GMB session, a concept model related to "screener" dynamics was presented (see Figure 1). This concept model was presented in three parts to allow the members of the group to become familiar with the iconography of system dynamics and with the main system dynamics concepts (e.g., stocks and flows) while not being unnecessarily overwhelmed with complexity.

First, a stock and flow diagram of the accumulation of part-time screeners in TSA was presented. The total number of *Part time screeners* present at any time in TSA is conceptualized as a stock of people (represented by a box in the diagram). The accumulation of part-time screeners is identified as the difference between the number of part-time screeners hired (*Hiring rate*) over a period of time and the number of part-time screeners quitting (*Part timers quitting*) over the same period of time given a certain initial number of part-time screeners present in the system (in this case, the number chosen for the initial value for the stock of part-time screeners was 1,000 people).

The difference between the two rates (represented by faucet-like icons in the diagram), accumulates over time, having the potential to make the stock grow, to stay the same, or to decline over time, depending on the relative size of one rate versus the other. When *Hiring rate* is greater than *Part timers quitting* over time, the stock of *Part time screeners* necessarily grows because more people are entering the organization (in this case TSA) than are leaving it.

In addition, in the concept model, a goal for the number of people to have in the organization (*Desired personnel*) was made explicit, and the feedback mechanism to control hiring on the basis of this goal was identified. Not shown to the members of the group was a time constant used to control the hiring rate (time to meet the goal), which was set at 12 months. This constant was explained to the group as being part of the model (and the group agreed that it was a plausible value) but left hidden (implicit) to avoid an unnecessary increase in detail complexity in the picture of the model presented to the group.

It was explained to the group that the value for the goal for personnel (*Desired personnel*) was chosen on the basis of advice given by domain experts during the initial interviews to represent what TSA had gone through at its inception. The value for *Desired personnel* was determined to be 60,000 people. Also, it was explained that the initial consideration, without making it explicit in the diagram, for the rate of *Part timers quitting* was set at 10% of the number of *Part time screeners*. This consideration was also identified by the group as a plausible number.

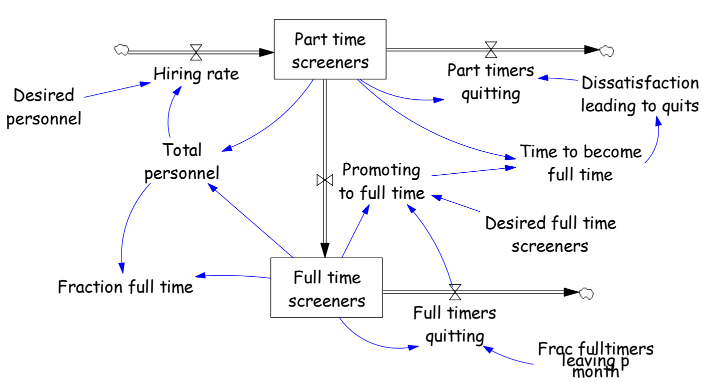


Figure 1. - Concept Model

Results of the Session

Some results of the GMB session are presented next. The GMB session was designed to elicit and obtain consensus on model elements and on the behavior over time of important variables to be included in the model, main sectors to be included in the model, and detailed feedback structure as identified by the members of the group via determination of pair-wise linking of important variables of the model. We followed the Albany Group standard process of elicitation and consensus building as described in the literature (Andersen and Richardson 1997; Andersen, Richardson, and Vennix 1997; Luna-Reyes et al. 2006). Moreover, we used an automated set of elicitation scripts as used by Eden and others in problem structuring interventions (Bryson et al. 2004; Eden 1994, 2004).

Goals and Level of Consensus on Goals

Remarkable unanimity was observed in articulating the goals of the security checkpoint operation. The goals were articulated by the group as:

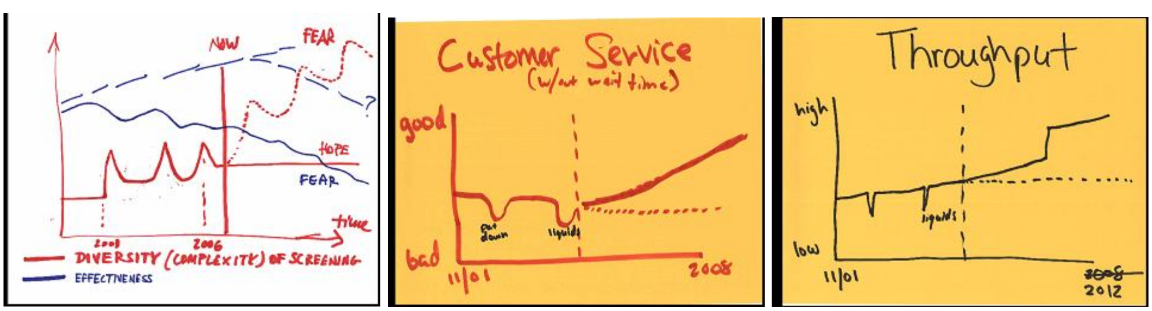
- Security (effectiveness),
- Throughput (efficiency), and
- Customer service.

However, no unambiguous operational statement was discovered that describes what it means to meet these goals. Participants did identify three areas they felt would contribute toward improvement and realization of the mentioned goals. There was a high degree of unanimity regarding the results. The areas are:

- Personnel proficiency,
- Operating procedures, and
- Technology deployment.

Behavior-over-Time Graphs

The elicitation of behavior-over-time graphs was performed by asking the members of the group to organize themselves in pairs and to produce behavior-over-time graphs of as many variables as they could think of. Members of the group were also asked to specify the units of the variables and the time frame of reference that they were projecting. Finally, group members were asked to establish a time pattern into the future, starting that day, that would reflect the variable behavior that they hoped for, the behavior that they feared, and the behavior that they thought would be normal. Some of the results are shown in Figure 2.



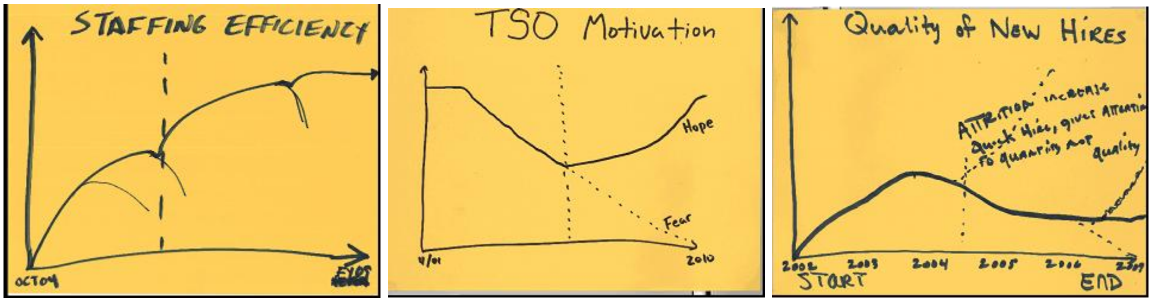


Figure 2. - Behavior-over-Time Graphs Captured during the GMB Session

Initial Results—Structural Leverage Points

Points of intervention have been being identified throughout the interviews and GMB exercise. Specifically, by looking at the feedback mechanisms that emerged during the GMB session, likely high-leverage points of intervention can be determined. These points of intervention are structural in the sense that they are not identified as the result of a simulation of the behavior that the structure produces. These points of intervention represent structural insights (Richardson 2001) derived from identifying elements that have several interacting feedback loops that potentially can change the behavior of the system.

The points of intervention identified will be explored and tested via simulation, when the model is formulated, to generate dynamic insights (Richardson 2006). It is important to validate these tentatively identified insights by formally characterizing them by using mathematics and to infer their dynamic implications with computer simulation to be able to learn more about the system under study. Identification of dynamic insights will be possible when the formal model is finished and analyzed. Only then can specific high-leverage points be identified with higher levels of confidence (Forrester and Senge 1980).

The leverage points are presented in three major areas that are linked to crucial variables that capture transportation security officers' (TSOs') and passengers' interactions. Three sets of feedback structures are presented: the *TSO Morale* structure, the *TSO Skill* structure, and the *PAX*[4] *Awareness* structure. A detailed account of the different feedback mechanisms found in the elicited structure at the GMB session follows. This account is presented to allow the reader to identify each one of the feedback mechanisms by itself in a clear and unequivocal form. This presentation allows for the recognition of the specific components of each feedback loop identified and for its structural analysis. We present 11 reinforcing feedback processes, 6 balancing feedback processes, and 2 full feedback maps.

TSO Morale

TSO Morale seems to be central to improving customer service, security, and throughput. *TSO Morale* is at the center of several feedback mechanisms that influence the results of the security checkpoint process: customer service, security, and throughput (see Figure 3). This figure presents the emergent complexity of at least 9 interacting feedback processes.

[4] Passenger.

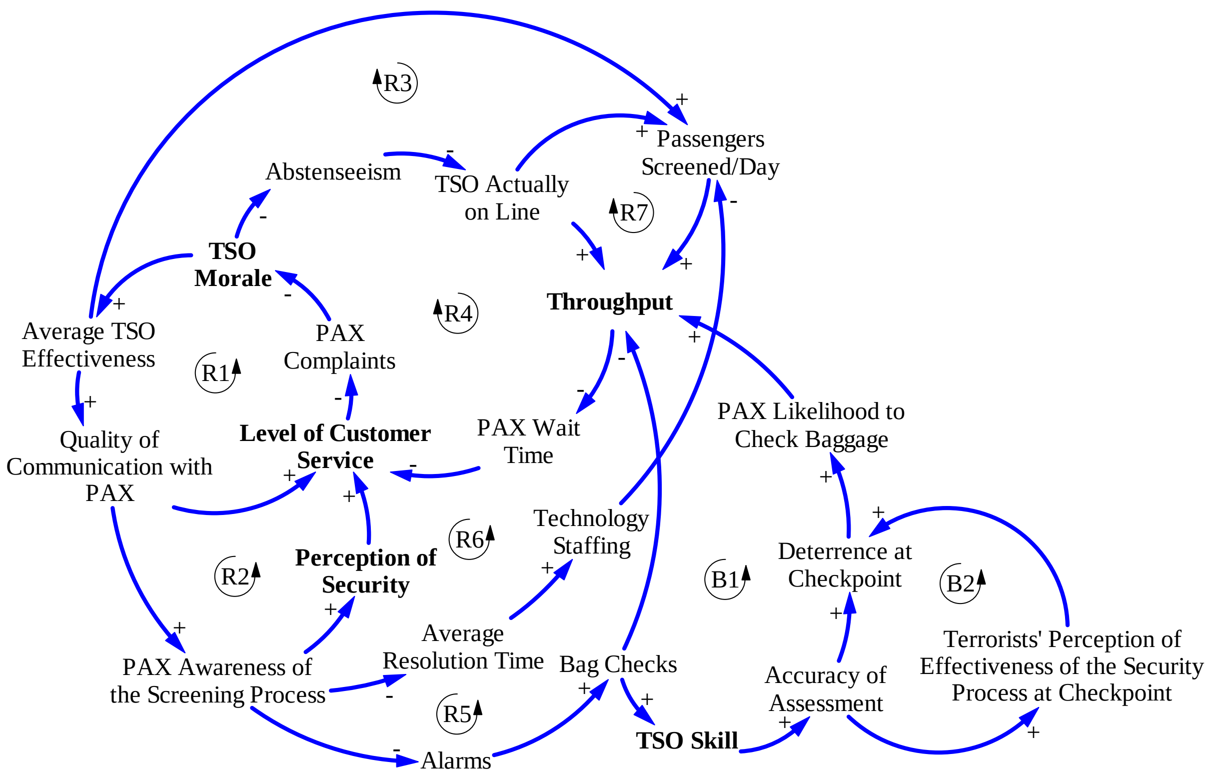


Figure 3. - TSO-Morale-Related Structure

Reinforcing Mechanisms Identified Related to TSO Morale

Reinforcing mechanisms are those that create reinforcing behavior over time. If the variable of interest grows, then, through reinforcing feedback, its original growing tendency is amplified, generating further growth. Alternately, when the variable of interest decreases, its declining behavior is reinforced, creating a decline spiral. Reinforcing feedback (also known as positive feedback) creates the conditions for growth or decline if left unchecked. In complex feedback systems, most reinforcing feedback is coupled with other feedback mechanisms that constrain its effects.

As noted at the beginning of this document, a remarkable unanimity was observed in articulating the goals of the security checkpoint operation; the goals identified by the group include security (effectiveness), throughput (efficiency), and level of customer service. In addition, the group identified a series of feedback mechanisms, centered on *TSO Morale*, that influences these three clearly identified goals.

First, the morale-improves-service reinforcing feedback loop (see Figure 4) links *TSO Morale* with the goal *Level of Customer Service*. This feedback loop shows how the variable *TSO Morale* is influenced by the variable *PAX Complaints* with a negative causal link: when the variable *PAX Complaints* grows, the variable *TSO Morale* declines. The opposite is also true: as *PAX Complaints* declines, *TSO Morale* grows. The sign, or polarity, of the causal link determines the type of relationship that two variables have when analyzed *ceteris paribus* (all other things being equal, or holding everything else constant). In this case, the hypothesis is that *TSO Morale* grows when (holding everything else constant) *PAX Complaints* declines. In addition, by following the identified feedback mechanism, we know that *PAX Complaints* declines as the *Level of Customer Service* grows (see the negative feedback link between *Level of Customer Service* and *PAX Complaints*) and that the *Level of Customer Service* grows when *Quality of Communication with PAX* grows. *Quality of Communication with PAX*, in turn, grows as the *Average TSO Effectiveness* grows. The last grows when *TSO Morale* grows, closing the feedback mechanism.

The identification of this feedback mechanism is important because this reinforcing process can cause extreme damage when, for any reason, *PAX Complaints* increases enough to influence *TSO Morale*, causing the necessary conditions to trigger a vicious cycle in which increased *PAX Complaints* further decreases *TSO Morale*. The morale-improves-service reinforcing feedback loop is also crucial, as it allows us to identify that *TSO Morale* is an important driver of *Level of Customer Service*, via *Quality of Communication with PAX* and *Average TSO Effectiveness*, which influences *PAX Complaints* that further reinforces the behavior of *TSO Morale*.

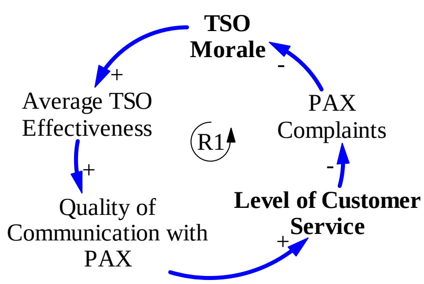


Figure 4. - (R1) Morale-Improves-Service Reinforcing Loop

Besides improving the *Level of Customer Service*, the group of experts acknowledged that *TSO Morale* is linked to security, another main goal identified by the group. As Figure 5 shows, *TSO Morale* improves the *Perception of Security* via improved *Quality of Communication with PAX* and, consequently, an improved *PAX Awareness of the Screening Process*. Passengers are more aware of how to navigate the security checkpoint process and appreciate the security that the process gives them. The morale-improves-perception-of-security loop is a reinforcing feedback mechanism that creates the conditions for improved security and customer service by improvements in *TSO Morale*. According to security experts interviewed, improving the *Perception of Security* improves the *Level of Customer Service* that passengers experience because they tend to equate the effort of going through the security checkpoint with the advantages of being more secure. Through this feedback mechanism, increased *TSO Morale* increases both security and customer service, influencing two of the three most important goals of the security checkpoint process as identified by the group of experts that participated in the GMB session.

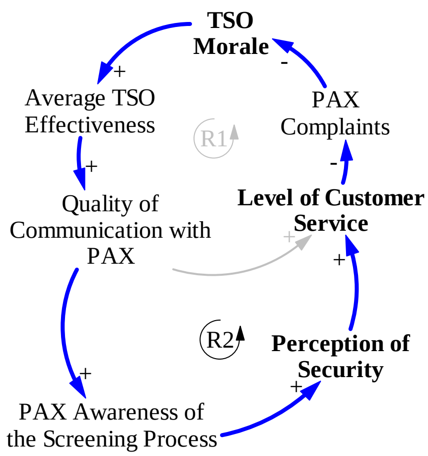


Figure 5. - (R2) Morale-Improves-Perception-of-Security Loop

First, *TSO Morale*, because it consists of four additional reinforcing feedback processes, also influences the last main goal identified: throughput. Figures 6 through 9 clarify these feedback mechanisms. As shown in Figure 6, *TSO Morale* improves *Throughput* via *Average TSO Effectiveness*, which influences the number of passengers screened. As *Throughput* increases, *PAX Wait Time* falls, which improves the *Level of Customer Service* and decreases *PAX Complaints*, thus further improving *TSO Morale*. Through this mechanism, improvements in *TSO Morale* create the necessary conditions for improvement of both goals: throughput and customer service.

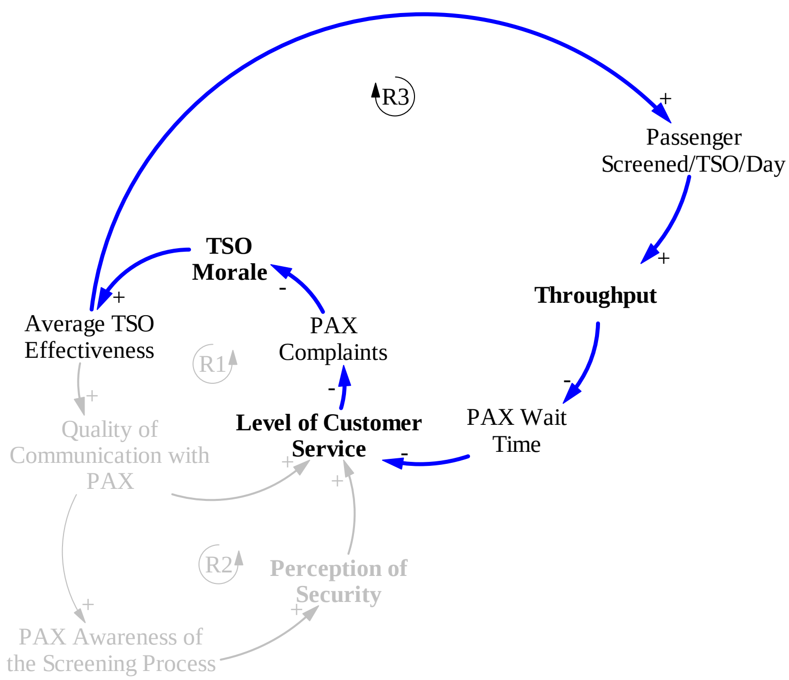


Figure 6. - (R3) Morale-Improves-Throughput Loop

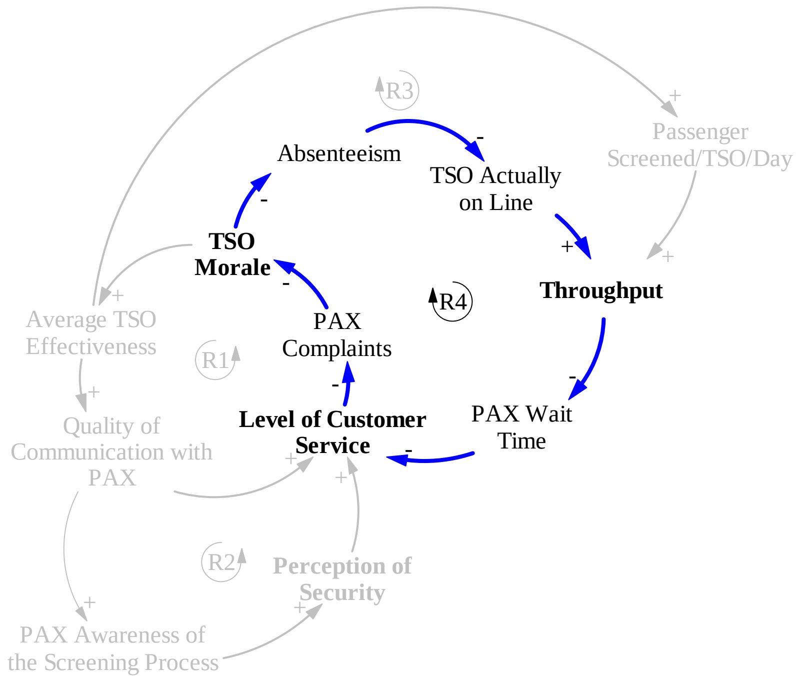


Figure 7. - (R4) Morale-Prevents-Absenteeism Loop

Second, *TSO Morale* also influences *Throughput* by decreasing *Absenteeism*. Figure 7 demonstrates how decreased *Absenteeism* improves the number of *TSO Actually on Line*, improving *Throughput*. As *TSO Morale* improves, *Absenteeism* decreases, which increases *Throughput* and influences *Level of Customer Service* via decreased *PAX Wait Time*. With an improved *Level of Customer Service*, the variable *PAX Complaints* drops, further improving *TSO Morale*.

Third, *TSO Morale* improves *Throughput* via a decreased number of triggered *Alarms* and thus a decreased number of *Bag Checks* (see Figure 8). When *TSO Morale* rises, *Average TSO Effectiveness* goes up, improving the level of the *Quality of Communication with PAX* and then improving *PAX Awareness of the Screening Process*. An increased *PAX Awareness of the Screening Process* decreases the number of *Alarms* at the security checkpoint, bringing the number of *Bag Checks* down, allowing *Throughput* to consistently rise. As explained earlier, an improved level of *Throughput* decreases *PAX Wait Time* and increases the *Level of Customer Service*, ultimately improving *TSO Morale* and closing the reinforcing process.

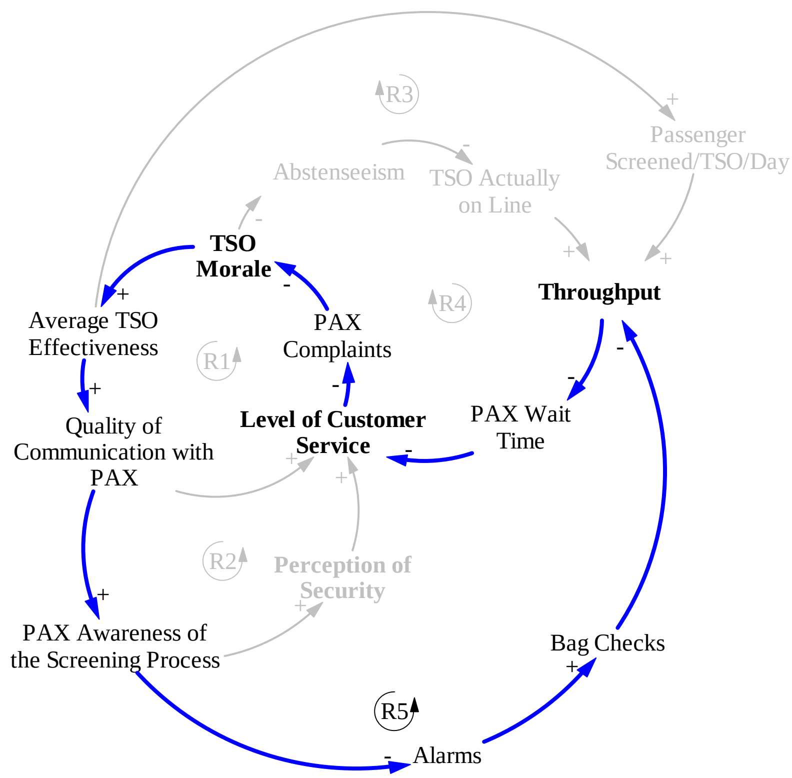


Figure 8. - (R5) Morale-Reduces-Alarms Loop

Finally, as shown in Figure 9, *Throughput* is positively influenced by *TSO Morale* by reducing the *Average Resolution Time* of passengers at the checkpoint, influencing technology staffing needs. High levels of *TSO Morale* create the conditions for increased *PAX Awareness of the Screening Process*, contributing, *ceteris paribus*, to a reduced *Average Resolution Time*.

In summary, *TSO Morale* is part of reinforcing feedback mechanisms that influence the three main goals of the security checkpoint process: security, throughput, and customer service. It is hypothesized that increased levels of *TSO Morale* have the potential to increase the three main goals of the security checkpoint process through varied feedback mechanisms that create a multiplicative effect in the security checkpoint system. *TSO Morale* seems to be a high-leverage point of intervention for improving the effectiveness and efficiency of the security checkpoint process. This insight, structural in nature as described in Richardson (2001), needs to be verified and tested via computer simulation to assess its dynamic plausibility.

As identified in Figure 10, *TSO Morale* is additionally part of a reinforcing process that influences both the *Throughput* goal and the *Level of Customer Service* goal. As *TSO Morale* grows, *Absenteeism* drops, increasing the number of *TSO Actually on Line*, which increases the number of *Passenger-Screened/Day*. When the number of *Passenger-Screened/TSO/Day* increases, *Throughput* increases, bringing *PAX Wait Time* down, increasing the *Level of Customer Service*, creating pressure for *PAX Complaints* to decrease. Finally, with lower levels of *PAX Complaints*, *TSO Morale* increases, and the feedback loop is closed, creating a reinforcing effect in which an initial increase in *TSO Morale* results in additional increases in *TSO Morale* over time.

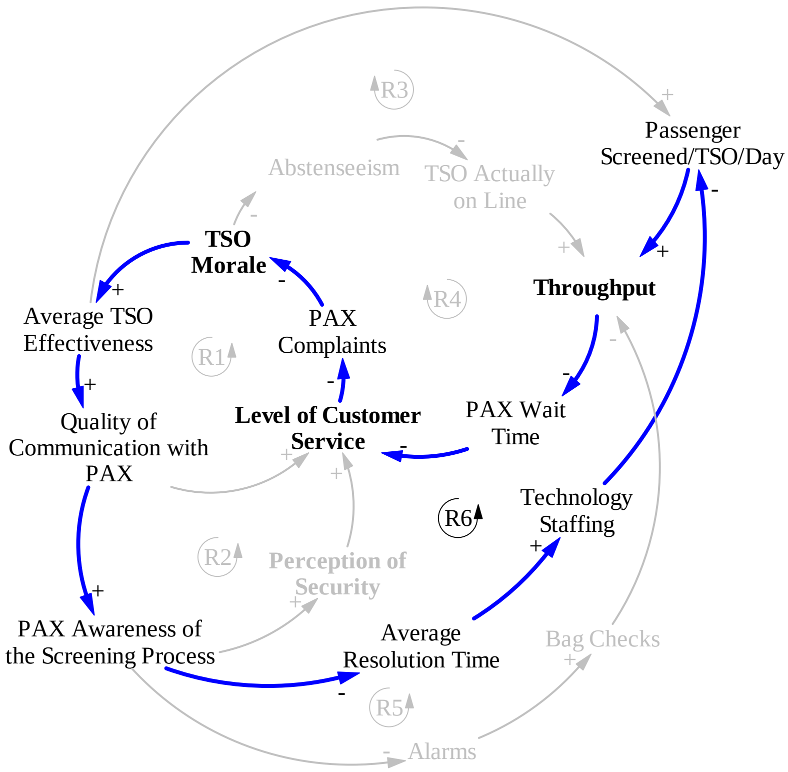


Figure 9. - (R6) Morale-Improves-Resolution-Time Loop

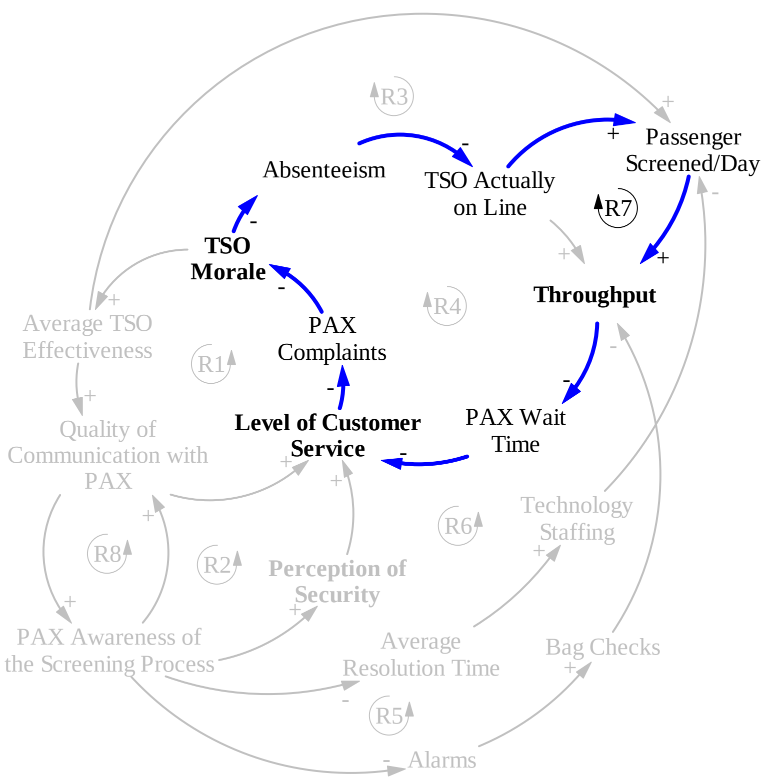


Figure 10. - (R7) Morale-Influences-Throughput Loop

Balancing Mechanisms Identified Related to TSO Morale

Not only does *TSO Morale* participate in reinforcing feedback mechanisms in this complex system, it is also part of two balancing feedback mechanisms that add to the dynamics of the system. Figures 11 and 12 show the two balancing mechanisms one by one to help clarify the precise structure of these processes. First, high levels of *TSO Morale* reduce opportunities for continued *TSO Skill* development and learning, harming the security checkpoint operation (see B1 in Figure 11). Another counterintuitive effect of high levels of *TSO Morale* is the deterioration, *ceteris paribus*, of *TSO Skill* over time. When high levels of *TSO Morale* exist, *Average TSO Effectiveness* grows, increasing *Quality of Communication* and *PAX Awareness*. As *PAX Awareness of the Screening Process* grows, the number of triggered *Alarms* declines, bringing *Bag Checks* and the opportunity for *TSO Skill* to develop down. If *TSO Skill* suffers, *Accuracy of Assessment* suffers, making *Deterrence at Checkpoint* and *Likelihood to Check Baggage* decline, which affects *Throughput* in a negative way (i.e., lowering *Throughput*). Once *Throughout* declines, *Passenger Wait Time* increases, bringing the *Level of Customer Service* down and putting pressure on *Passenger Complaints,* making *TSO Morale* decline and the response of the system compensatory in nature. As *TSO Morale* grows, the normal tendency of the system is to produce pressures for *TSO Morale* to decline over time. This means that if there is a planned intervention to increase *TSO Morale*, and if the high-morale-reduces-learning-opportunities loop has a high relative strength, the system, if left unchecked, will respond, counteracting the effect and bringing *TSO Morale* down and defeating the purpose of the intervention. Depending on the strength of the described feedback process, the response of the system can keep *TSO Morale* from growing as much as it should, given the policy intervention; can cause *TSO Morale* to return to its original level; or in an extreme case, can cause *TSO Morale* to go down to a lower level than it was in the first place (i.e., before the policy intervention was put in place).

In complex systems, the interaction of reinforcing and balancing feedback mechanisms can create counterintuitive overall system behavior (Forrester 1958, 1961, 1975). According to Forrester, in real systems, the ratio of balancing feedback processes to reinforcing ones is approximately 10:1, causing what is known as policy resistance in complex systems. Policy resistance refers to the natural response of systems to counteract policy interventions by balancing effects throughout the system, causing policy interventions to be “delayed, diluted, or defeated by the unforeseen reactions of [other] people or nature” (Sterman 2000, p. 3).

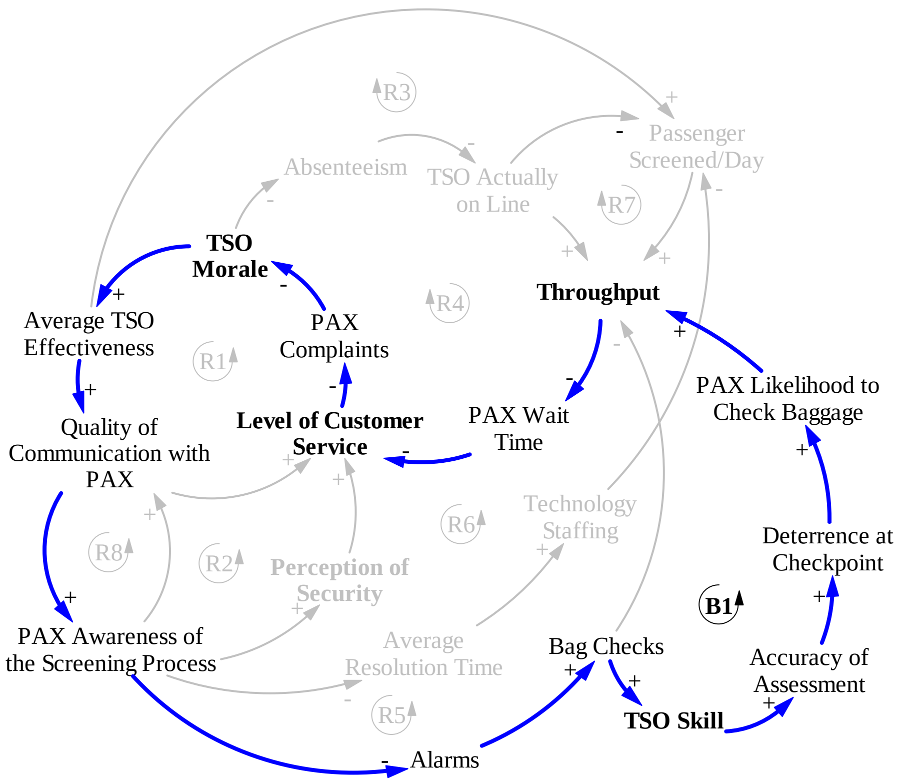


Figure 11. - (B1) High-Morale-Reduces-Learning-Opportunities Loop

Second, high levels of *TSO Morale* can eventually lead to decreased security perception (see B2, the high-morale-could-decrease-security-perception loop, Figure 12). Increases in *TSO Morale*, as explained before, lead to increases in *TSO Effectiveness* and *Passenger Awareness*, bringing *Alarms* and opportunities for learning down and creating the opportunity for *Accuracy Assessment* to suffer. If *Accuracy Assessment* erodes over time, the *Terrorists' Perception of the Effectiveness of the Security Process @ Checkpoint* is likely to decline, lowering deterrence levels at the checkpoint and bringing downward pressure on the *Likelihood to Check Baggage*, thus creating *Throughput* problems. Once *Throughput* starts to suffer, it unchains a series of effects that brings down *Levels of Customer Service* and brings up *PAX Complaints*, causing *TSO Morale* to decrease in a compensatory way. In this process, the natural response of the system to an increase in *TSO Morale* is to create pressures for *TSO Morale* to come back down via decreased perceptions of security.

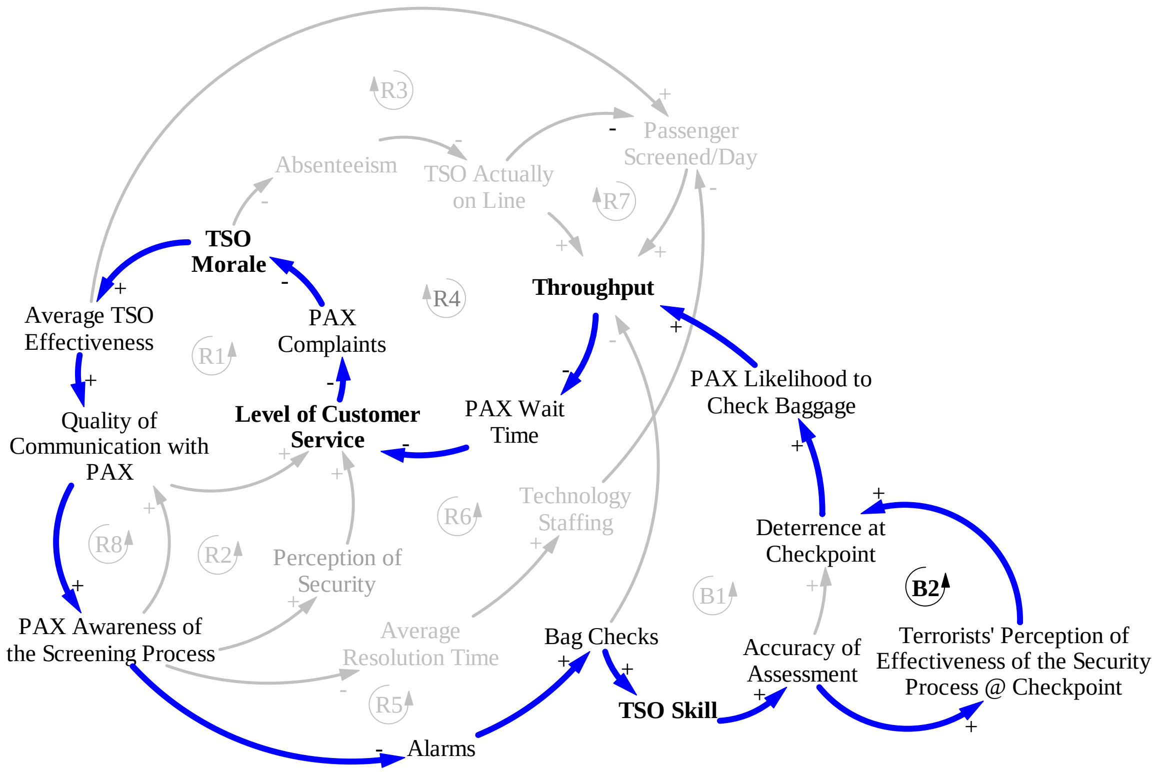


Figure 12. - (B2) High-Morale-Could-Encourage-Terrorist-Attempts Loop

TSO Morale seems to be central to influencing the efficiency and effectiveness of the security checkpoint process through six reinforcing and three balancing intertwined feedback mechanisms. The combined action of these and other processes that involve TSO skill development, TSO career advancement, changes in and deployment of standard operating procedures (SOPs), and technology implementation create complex dynamic behavior at the checkpoint.

TSO Skill

Another area of intervention is the creation of *TSO Skills*. Figure 13 shows a complete causal map of the intertwined feedback mechanisms that influence *TSO Skill* development. This diagram presents the complexity of a few feedback processes to show how rapidly the detail and dynamic complexities of a real feedback system, such as the security checkpoint process, arise. As discussed in the introduction, it is important to validate these tentatively identified relationships by formally characterizing them by using mathematics and to infer their dynamic implications with computer simulation to be able to learn more about the system under study.

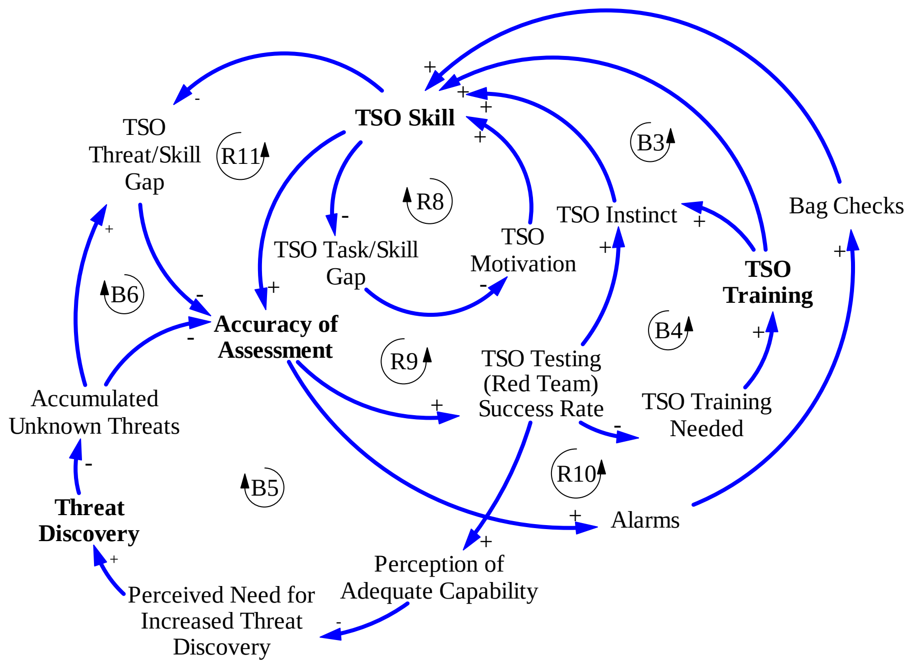


Figure 13. - TSO-Skill-Related Structure

Reinforcing Mechanisms Identified Related to TSO Skill

TSO Skill development is identified as a function of *TSO Motivation*: the higher the *TSO Motivation*, the higher the potential for *TSO Skill* development. In addition, as *TSO Skill* grows, the *TSO Task/Skill Gap* is closed, creating adequate conditions for further increases in *TSO Motivation* and *TSO Skill* development (see R8, the skillfull-TSOs-are-more-motivated loop, Figure 14).

The skillfull-TSOs-are-more-motivated reinforcing feedback mechanism (loop R8) describes a process of improvement and increased motivation, as skills are developed and the task/skill gap is closed. Unfortunately, this same feedback process can become an engine of lack of motivation and decreased skill development, as task or skill gaps widen and motivation is lost as a result. Reinforcing feedback processes, depending on their polarity, can become either engines of growth and improvement in the system or engines of despair and regression.

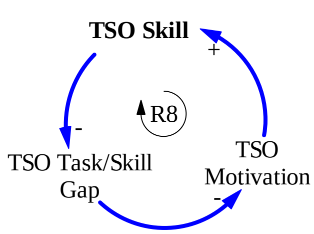


Figure 14. - (R8) Skillfull-TSOs-Are-More-Motivated Loop

TSO Skill is also linked to *Accuracy of Assessment* and *TSO Instinct* via *TSO Testing (Red Team) Success Rate* (see loop R9, the skill-improves-instinct loop, Figure 15). As *TSO Skill* grows, *Accuracy of Assessment* increases, helping *TSO Testing (Red Team) Success Rate* to increase and improve *TSO Instinct* over time. Increases in *TSO Instinct*, in turn, create the conditions for further improvement in *TSO Skill*, closing the reinforcing feedback process of increased *TSO Skill*. Combining R8 and R9, *TSO Skill* gets a multiplicative effect: once it starts moving forward, it creates momentum because of increased *TSO Motivation*, increased *Accuracy of Assessment*, and increased *TSO Instincts*. The result of the interaction of these feedback processes is a more motivated, accurate, and skilled workforce.

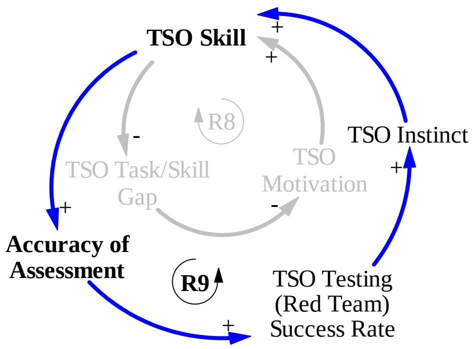


Figure 15. - (R9) Skill-Improves-Instinct Loop

Furthermore, a TSO with high levels of *TSO Skill*, by improving *Accuracy of Assessment*, detects more problems, increasing *Alarms* and *Bag Checks* and providing more opportunities for skill development and increases to *TSO Skill* levels (see R10, Figure 16). In this cycle, the higher the *TSO Skill*, the higher the detection capability, allowing for more opportunities to practice the skill, creating a reinforcing process. This process, in a real system, would be limited by the availability of events/artifacts to detect the creation of opportunities for skill development as well as the TSO capacity to absorb new skills. Furthermore, as in the case of previous reinforcing processes, this cycle, when turned around, can become a significant source of problems as *TSO Skill* declines, bringing the *Accuracy of Assessment* down, reducing the number of *Alarms* and *Bag Checks*, and canceling opportunities to develop *TSO Skill* over time. This process can become a "detection trap," as described in Andersen et al. (2004) and formalized in Martinez-Moyano *et al*. (Forthcoming). A detection trap settles when *TSO Skill* drops low enough to make *Accuracy of Assessment* virtually incapable of detecting any threat, leading to the realization that no *TSO Skill* is actually needed as no threat objects are detected. This realization is false. The true cause of low levels of detection is not the lack of events/artifacts to detect but the lack of detection capability (*TSO Skill* and *Accuracy of Assessment*).

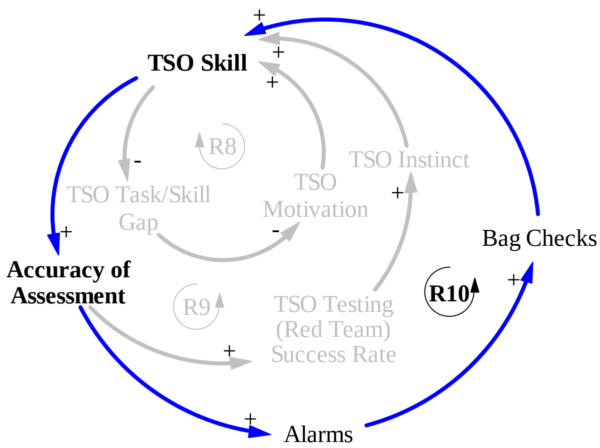


Figure 16. - (R10) Skill-Increases-Alarms Loop

In addition, as *TSO Skill* increases, the *TSO Threat/Skill Gap* decreases, increasing the *Accuracy of Assessment* influencing the two paths previously identified in R9 and R10 (see R11a and b in Figure 17).

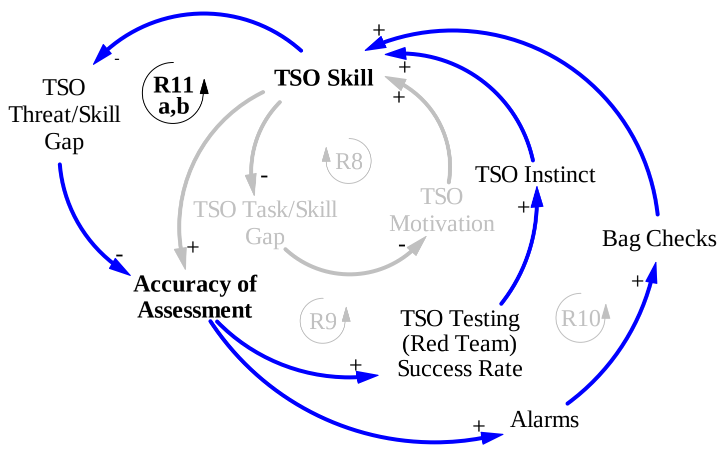


Figure 17. - (R11) Skill-decreases-Threat/Skill Gap Loop

Balancing Mechanisms Identified Related to TSO Skill

TSO Skill was also identified as part of two balancing mechanisms: One involves *TSO Training* activities, and the other involves *TSO Instinct*. First, as recognized in the management literature for decades, *TSO Skill* is influenced by *TSO Training* activities (see B3 in Figure 18). In general, the higher the *TSO Training* activities, the higher the *TSO Skill* level developed. This relationship was identified in several interviews as being crucial to TSO development and to increased effectiveness and efficiency of the security checkpoint process. It is clear that at TSA, training is highly regarded as a viable mechanism for increasing capabilities and improving process operations. Moreover, it was recognized in the interviews and during the GMB intervention that *TSO Training* is difficult and takes time and effort to enhance effectiveness in the security process.

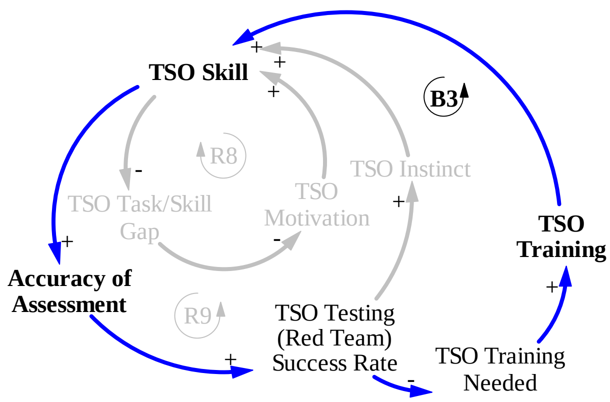


Figure 18. - (B3) Skill-Influences-Training Loop

In B3, the skill-influences-training loop, as *TSO Skill* grows, *Accuracy of Assessment* grows improving *TSO Testing (Red Team) Success Rate*. As *TSO Testing (Red Team) Success Rate* increases, *TSO Training Needed* declines, making *TSO Training* erode over time; *TSO Skill* also declines as a result. In other words, the system responds to an increased level of *TSO Skill* with a compensatory action that brings *TSO Skill* down as a result of being successful in testing activities (identifying red team activity); therefore, the system is assessed as not needing new training. This behavior could generate “waves” of training activity over time as the level of accuracy of the assessment fluctuates over time. This behavior is typical of complex systems with delays in the measurement and reaction processes. Figure 19 shows hypothesized behavior-over-time graphs produced by members of the group during the GMB session, characterizing training activities in the described cyclical behavior.

Figure 19. - Hypothesized Training Behavior

In addition to influencing *TSO Training* via the skill-influences-training loop, *TSO Skill* is linked to *TSO Training* and *TSO Instinct* in another balancing feedback mechanism (see B4 in Figure 20): the skill-instinct loop. In this feedback process, as *TSO Skill* grows and *Accuracy of Assessment* improves (which reduces the demand for additional training), *TSO Instinct* erodes as no new *TSO Training* is provided. In turn, *TSO Skill* declines with an eroded *TSO Instinct* level, creating an additional compensatory process that will keep *TSO Skill* low as a result of previous demonstrated successes.

The feedback process captured in B4 can create a cycle that can become what Reppening and Sterman (2002) characterize as a dynamic capability trap, limiting the ability to detect new threats at the checkpoint when the only driver of additional training is the ability/inability to recognize red team activity. Making a reasonable case out of this trap is difficult, as it is challenging to make the case to invest resources to develop the capacity to fix problems that do not yet exist and that, if successful, will never materialize (Repenning and Sterman 2001).

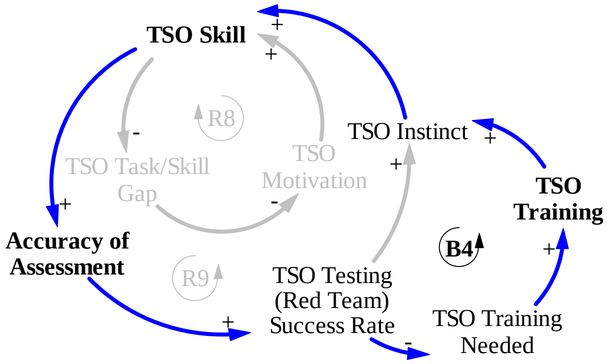


Figure 20. - (B5) Skill-Instinct Loop

The group also identified two additional feedback structures related to *Accuracy of Assessment*. *Accuracy of Assessment* is part of two balancing feedback processes linked to *Threat Discovery* (see B5 and B6, the increased-accuracy-prevents-threat-discovery loops, in Figure 21) that pose an interesting counterintuitive structural insight. In these feedback mechanisms, as *Accuracy of Assessment* improves and *TSO Testing* (*Red Team) Success Rate* increases, the *Perception of Adequate Capability* increases, bringing the *Perceived Need for Increased Threat Discovery* down. As the *Perceived Need for Increased Threat Discovery* decreases, the process of *Threat Discovery* erodes, allowing the *Accumulated Unknown Threats* to grow. The growing number of *Accumulated Unknown Threats* has a twofold effect. First, *Accuracy of Assessment* becomes a more difficult endeavor, as it is hypothesized that higher levels of *Unknown Threats* make it more difficult for assessment to be truly accurate. Second, the *TSO/Threat Skill Gap* increases negatively influencing *Accuracy of Assessment*.

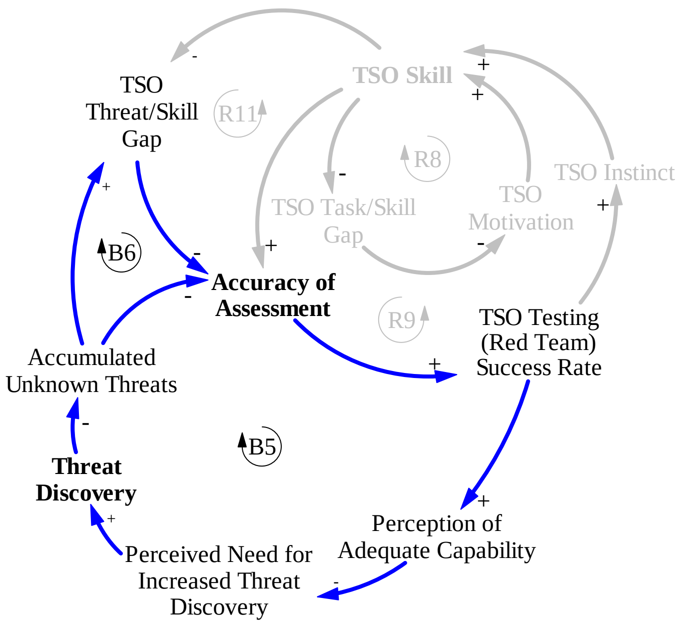


Figure 21. - (B5 and B6) Increased-Accuracy-Prevents-Threat-Discovery Loop

Elicited Structure

The process to elicit structure is theoretically quite simple; in practice, however, it is very complex and delicate (see pages 307-314 on Luna-Reyes et al. 2006). Starting with a set of variables elicited from the group, the facilitator of the meeting guides the participants through a process of connecting concepts and understanding interrelationships, while keeping the endogenous perspective in mind, to help the group to close as many feedback loops as possible. After progress is made, another modeler, the reflector (Andersen, Richardson, and Vennix 1997), presents slightly modified versions of the elicited structure; this effort brings added rigor and formalizes the work of the group without taking ownership of the process and the model from the group. The group facilitator is primarily concerned with maintaining the group in the process and keeping the product true to what the group produced. The reflector, on the other hand, is concerned primarily with providing modeling expertise and rigor to help the group improve its understanding of the problem at hand. The interaction between the group facilitator and the reflector is crucial. Figures 22 and 23 show part of the elicited work during the GMB session and feedback provided by the reflector.

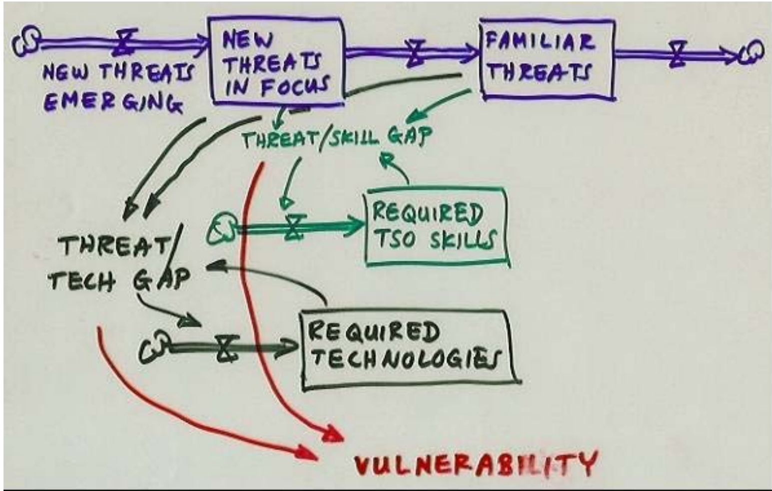


Figure 22. - Threats-Related Structure

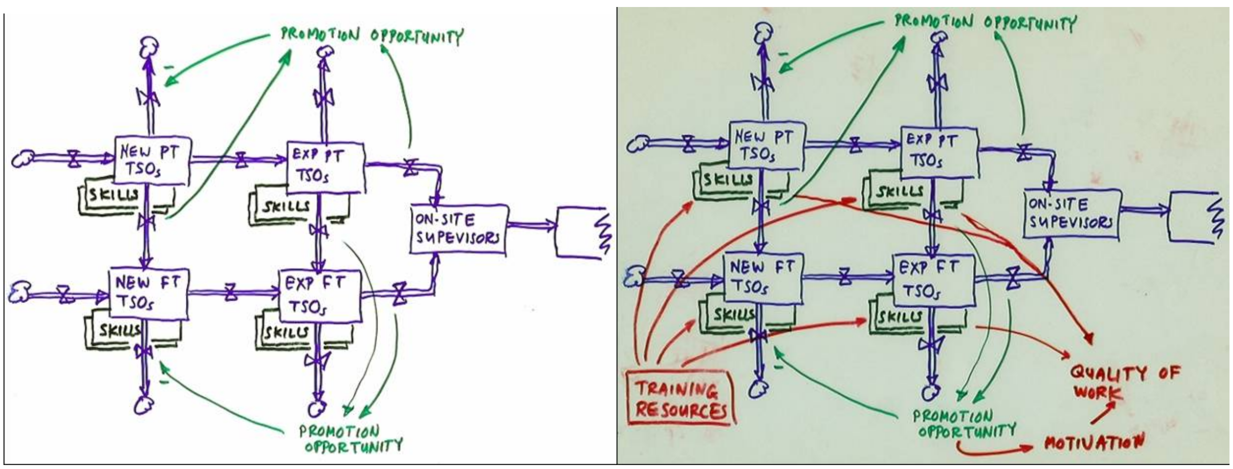


Figure 23. – TSO Aging-Chain Structure

Model Sectors

After the GMB session, in preparation for the formulation of a formal model that captures the dynamics of the security checkpoint process, a sector diagram for the model was developed. The formal model under development has seven sectors that constitute the complexity identified in the aviation security checkpoint process. Figure 24 shows the sectors and the main interactions identified. The main sectors identified are:

- Human Resources Sector,
- Technology and Operations Sector,
- Demand Sector,
- Testing Sector,
- Training Sector,
- Threat Sector, and
- Financial Sector.

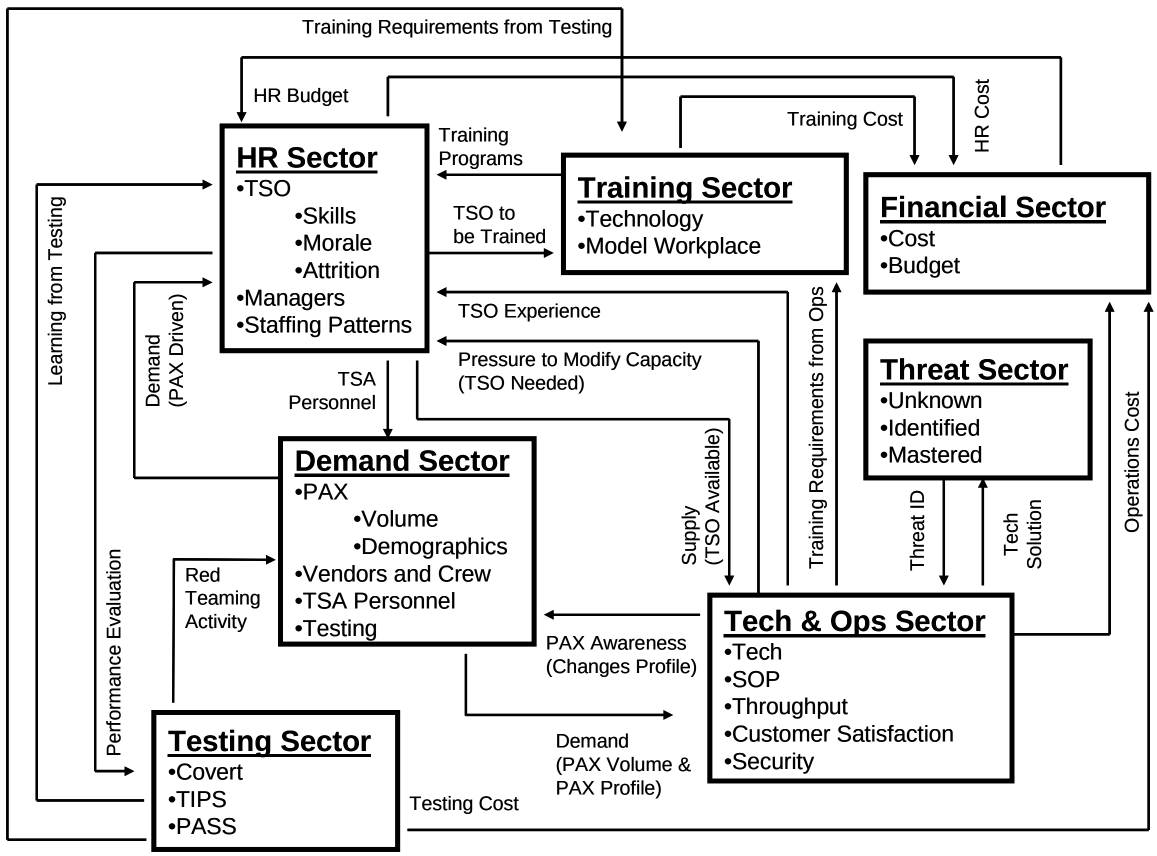


Figure 24. – Sector Diagram

The interaction between the sectors is identified by using connecting arrows. The number of interactions between sectors is evidence of the high level of feedback mechanisms present in the aviation security process.

The Human Resources Sector captures the dynamics related to TSO skills, morale, attrition, hiring and firing, etc. In this sector, manager interaction is also modeled. The Human Resources Sector provides people to the Technology and Operations Sector to conduct screening. In the model, as in the real system, in order to have a person screened, personnel, technology, procedures, and demand must be in place. If any one of these four elements is not present, the model cannot produce screened individuals. The Training Sector interacts with the Human Resources Sector and the Technology and Operations Sector via training activities and by receiving and processing training requirements. In this sector, personnel learning processes are captured. By receiving requirements from the Testing Sector, the Training Sector also captures the learning mechanisms triggered by feedback received from covert operations, such as Red Team activities.

In the Demand Sector, demand characteristics are identified and stated. Four main drivers of demand are identified and characterized. First, passengers are identified as the main source of demand for screening. Passengers are characterized by volume and demographics. The second element of the Demand Sector is composed of vendors and crew members. The number of vendors and crew members is proportional to the size of the airport and to the number of flights served. Vendors, in particular, seem to be an interesting source of demand for screening services because this population is native to the airport and goes through the process repetitively. The third source of demand is TSA personnel. TSA personnel themselves are subject to the screening process so that they can access the sterile area and conduct their day-to-day activities. The last source of demand, which is minimal when compared with the others, is related to testing activity at the checkpoint.

TSA personnel learn through training, testing, and experience gained through their day-to-day activities. The overall system, in turn, learns through a process of threat identification captured in the Threat Sector. Finally, the Financial Sector captures all associated costs and provides budgetary information and constraints for operations and activity in general.

Next Steps

We are currently in the process of using the information obtained from our interviews and the GMB exercise to build a system dynamics flight simulator according to the sector diagram (Figure 24). In addition, we will be iterating with TSA SMEs to obtain feedback on the various model constructs we are building to represent the dynamics of their system. We will also be helping them to internalize the insights about their security checkpoint operations through hands-on interaction with the simulator.

Acknowledgments

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