Abstract

CPA—Cost and Performance Analysis—is an architecture that supports analysis of physical protection systems and upgrade options. ASSESS (Analytic System and Software for Evaluating Security Systems), a tool for evaluating performance of physical protection systems, currently forms the cornerstone for evaluating detection probabilities and delay times of the system. Cost and performance data are offered to the decision-maker at the systems level and to technologists at the path-element level.

A new optimization engine has been attached to the CPA methodology to automate analyses of many combinations (portfolios) of technologies. That engine controls a new analysis sequencer that automatically modifies ASSESS PPS files (facility descriptions), automatically invokes ASSESS Outsider analysis and then saves results for post-processing. Users can constrain the search to an upper bound on total cost, to a lower bound on level of performance, or to include specific technologies or technology types.

This process has been applied to a set of technology development proposals to identify those portfolios that provide the most improvement in physical security for the lowest cost to install, operate and maintain at a baseline facility.

1 Introduction

Decision-makers need to know the cost and performance tradeoffs of physical system alternatives at the system level. Decision-makers need to know what the options are and the impacts of those options. Problems-solvers need to know how to identify sets of options so they may expediently evaluate those options. CPA—Cost and Performance Analysis—is an architecture that supports analysis of physical protection systems and upgrade options. Previous work focused on new paradigms for organizing cost and performance data to support both problem-solvers and decision-makers. Recent work has focused on automation in two areas: 1) visualization of performance metrics and 2) evaluation of system enhancement investment alternatives. Visual summaries of system performance assist the problem-solver at the beginning of the analysis process with
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identifying and prioritizing areas of investigation and at the end of the process with communicating results to decision-makers. A new optimization engine has been integrated with an existing performance analysis tool, ASSESS\(^1\) (Analytic System and Software for Evaluating Safeguards and Security), which automates the evaluation of portfolios or combinations of physical security upgrade options. Although this work has currently incorporated ASSESS Outsider analysis as the performance analysis tool, the modular architecture supports the integration of other performance analysis tools. The current implementation offers a suite of 17 new cost and performance metrics to facilitate the examination of analysis results.

2 CPA Architecture

The CPA architecture has been presented previously ([1] and [6]) and is illustrated here in Figure 1. Early work had developed CATSS [\(\mathcal{C}\) in Figure 1] (Cost Analysis Tool for Security Systems), a spreadsheet-based approach to organizing system costs, and PERFORM [\(\mathcal{P}\)], also spreadsheet based, which made performance analysis data from ASSESS available for further analysis. The structure of the Adversary Sequence Diagram (ASD), an icon of ASSESS [\(\mathcal{A}\)], was used to organize life-cycle costs and performance metrics to support comparative analysis in both tabular [\(\mathcal{T}\) and \(\mathcal{G}\)] and graphical [\(\mathcal{G}\) and \(\mathcal{T}\)] formats at both the subsystem or path element level and at the system level [\(\mathcal{T}\)] and [\(\mathcal{G}\)].

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\(^1\) ASSESS was developed for DOE by Lawrence Livermore National Laboratory and Sandia National Laboratories.
3 Data Visualization

The graphic illustrated by @ in Figure 1 is demonstrated in Figure 2. The path elements of a nominal security system are listed to the left. Path-element performance metrics (probability of detection and delay times) are shown for two outsider threat modes of attack (on foot or in vehicles) and two threat tactics (force/stealth and deceit). From this figure analysts can readily examine system attributes and identify potential weaknesses. Long delays are desirable close to the target. Detection needs to occur, with high probability, prior to this delay. Both detection and delay should be balanced; that is, detection or delay times should be of nearly equal value for all the path elements that form a layer of protection. Referring to Figure 2 for the example facility, 1 shows balanced but only moderate detection between the limited area and the protected area. 2 shows both low and unbalanced detection. Minimum detection value at this layer is nearly zero. 3 shows detection probabilities of 0.5 for deceit tactics at the emergency evacuation corral and at the emergency portal. 4 shows balanced delay between the material access area and the vault interior. However, the adequacy of the level of this delay (~ 80 s) can only be determined if the response time is known.

This graphic provides the problem-solver with an overview of the system. The graphic can also be useful in showing the decision-maker where improvements need to be made and why. For example, referring back to group 2, any investment to improve the detection probability against force/stealth tactics at the emergency portal will have a minimal effect on system performance unless detection probability is also improved at the ventilation ducts, the building walls and roof.

Figure 2 Metrics of path-element performance illustrated for a nominal system.
4 Automated Tool

The new tools do not replace the analyst. They do, however, greatly facilitate the data entry and analysis processes. Prior to invoking these tools, the analyst must develop the baseline ASSESS facility file and identify placeholders in that file for the enhancements (upgrades) for consideration. The analyst needs to develop the life-cycle cost and performance estimates for each upgrade. Finally, he needs to define the ASSESS Outsider analysis (e.g., threat types and capabilities and response times). Having done these things, he is now ready to take advantage of the new automated analysis capabilities.

The automated tool: 1) enables analysts to efficiently consider all possible combinations of upgrades; 2) enables analysts to assess the relative value of those combinations based on a menu of decision criteria such as total cost to the site after five years, improvement in system performance, and fitness (a ratio of performance to cost); and 3) delivers a summary of portfolios that meet the selection criteria for further sorting and display.

The automated process, illustrated in Figure 3, can be described as four major and separable functions: 1) design the analysis, 2) run the analysis, 3) extract the results, and 4) display and manipulate the results. The current implementation is built upon the ASSESS Facility definition and Outsider analysis models. The methodology is not, however, limited to the ASSESS performance analysis model.

In the first function—design the analysis—the user identifies the filename of the ASSESS Facility file that defines the baseline facility and identifies the list of enhancements to be considered by the analysis. The user interface offers a drag-and-drop approach to placement of the enhancements in the baseline facility definition. The user is prompted to modify existing performance metrics and to enter lifecycle cost data for each enhancement. The methodology supports the modeling of cost and performance penalty factors to reflect the impact of inadequate or no action (e.g., inadequate maintenance) on the future performance of the current system. Finally, before completing the design of the analysis, the user identifies the filename of the ASSESS Outsider file that contains the threat definitions to be used for the analysis.

![Figure 3. Data flow of the automated process](image)
The second and third functions—Run analyses and Extract results—are transparent to the user and are encapsulated by an optimization shell. At the press of a button, the run analysis function automatically generates the required facility (.PPS) files to analyze all possible combinations of enhancements against the threats defined in the ASSESS Outsider file. The Outsider analyses are run automatically and results extracted and archived, again automatically. A database supports all of the data management.

This automation of ASSESS Outsider analysis offers a very powerful capability to expedite analysis of alternatives. The user defines a single baseline facility and placeholders for N enhancements. The automated process takes the facility file and the N enhancements and generates a maximum of $2^N$ ASSESS facility (*.PPS) files to be analyzed by ASSESS Outsider using the previously defined threats and safeguard conditions for the analysis. The process automatically cycles through the $2^N$ Outsider runs and automatically saves the results of each analysis through the Extract module. All PPS files and all results extracted from the ASSESS *.OUT files are archived. For each ASSESS run, a suite of 17 new system-level metrics are stored in the database for viewing, sorting and exporting to an Excel spreadsheet through the Display module. The 17 metrics are summarized in Table 1.

### Table 1 Summary of Cost and Performance Metrics

<table>
<thead>
<tr>
<th>Performance Metrics</th>
<th>Current</th>
<th>5 yrs</th>
<th>10 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of Interrupt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mean</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Expected Delay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mean</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cost Metrics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development Investment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This year</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Life-cycle Cost</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Fitness** — a ratio of performance to cost

Probability of Interrupt is a familiar metric from ASSESS. It is dependent on response force time (RFT). It is computed for each threat defined in the analysis, for each RFT and for each of 10 most-critical paths. The minimum and mean are computed over the entire ensemble of analyses for each portfolio. Expected value of delay is a new metric that is independent of RFT. It is a measure of the minimum (mean) system delay after detection, weighted by the minimum (mean) preceding detection probability. The penalty factors can model degradations of system performance over time. They can also model an associated increase in cost over time. Although installation costs are typically non-recurring, recurring costs (operational and maintenance costs) result in an accumulation in costs over time. For these reasons, both performance and cost metrics are reported as a function of time. Fitness is a ratio of Mean Expected delay to Life-cycle
Cost, both taken at five years. It represents a measure of "bang for buck". If a set of upgrades causes performance to improve or costs to decrease, the fitness metric increases.

5 Display Module
The Display module allows the user a broad range of options to control both the data selected for viewing and the metrics viewed. The user controls these options through a series of windows.

The window titled "Results Selection Options," shown in Figure 4, allows the user to limit portfolios for which metrics will be reviewed to those that meet user-defined criteria. In the upper portion of this window, the user is offered three opportunities to constrain the search based user-defined boundaries placed on up to three of the 17 metrics. In the central portion of this form, the user has the opportunity to force inclusion or exclusion of upgrades (enhancements) by name or by group. Enhancements are listed by name in the center upper box and by group in the center lower box. If they are moved to the left or right column, the selected enhancements will be included/excluded from the portfolios viewed.

![Figure 4. The Results Selection Options window is used to screen the data](image-url)
The example in the figure shows in the upper portion that only those portfolios resulting in a Mean $P(I) \geq 0.7$ and a 5-year side cost $\leq$ $55M will be considered. In the central portion the search is further constrained to force inclusion of the three enhancements named Support 1, Support 2 and Support 3 in all portfolios considered, and to force exclusion of all enhancements that belong to the group labeled “info” from all portfolios considered. The lower portion of the form supports additional viewing constraints that are beyond the scope of this paper.

When the user is satisfied with the selected constraints, pressing the “view” button will open the Results Details window, Figure 5. In the previous window the user selected metrics to constrain the search. In this window the user again uses the metrics to determine how the remaining data will be sorted and which metrics will be viewed. These view/sort options are listed across the top of the window.

The enhancements are listed down the first column of the matrix by ID name and down the second column by descriptive name. The metrics selected for view/sort are listed by name and value across the first three rows of the matrix. Each column of the matrix represents one portfolio of enhancements, that is, one ASSESS facility (PPS) file run through ASSESS Outsider for analysis. The "X's" identify the enhancements that make up the portfolios. In the example, the data are sorted by Mean E(Td) – Mean Expected Delay Time. The other two metrics selected for viewing are five-year site cost and Fitness. In the example in Figure 5, the portfolio in the first column has the greatest value of Mean E(Td) = 2423 s and associated values of five-year site cost = $48,415K
and Fitness = 19.48. The enhancements that make up this portfolio are Active Delay 4, Exterior Intrusion Detection 1 and Active Delay 2. Note that Support 1 (Technology Base), Support 2 (Testing and Evaluation), and Support 3 (Technology Transfer) are always included because their inclusion was enforced in the previous Results Selection Options window. The user is free to modify the view/sort criteria and to toggle back and forth between the Results Details window and the Results Selections Options window to modify the selection criteria. It is not the intent of this tool to make decisions. It is the intent of this tool to organize data into information to support decision-making.

When the user is satisfied with the selection criteria and the choice of sort metric, the results of the optimization can be exported to an Excel spreadsheet to retain a permanent record. The spreadsheet contains portfolio membership by ID name and the values of the three metrics selected for view/sort-by.

6 Summary

New software has been developed that automatically 1) generates all possible combinations of "what-ifs" in ASSESS Facility (PPS) files; 2) analyzes each PPS file through ASSESS Outsider; 3) extracts data from the ASSESS Outsider results; and 4) computes a new suite of metrics from those data. This suite of tools integrates life-cycle costs into the analysis and organizes a large amount of data in a way that facilitates sorting and viewing for the decision-maker.

The automated optimization tool has been successfully applied to the evaluation of ten potential security enhancements at a fictitious (baseline) facility. That evaluation produced and analyzed 1024 ASSESS PPS files, a task that could not have been accomplished in a reasonable amount of time without automation! Various modules are currently being applied to address issues at several real facilities. Next steps will focus on the integration and automation of ASSESS Insider analysis.

References


