Nuclear Smuggling Detection and Deterrence Lifecycle Cost Modeling

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Introduction

Countries around the world use equipment to detect nuclear smuggling.

This equipment is used at borders, airports, and seaports via screening of vehicles, boats, cargo, and individuals.

As equipment is used over time, the performance of each piece needs to be maintained through preventive or corrective maintenance.

Aim

- Determine the global optimal solution of the maximum number of activities based on a budget.
- Corrective maintenance must be done before preventive maintenance.

Objective Function

Decision variables

X_i = indicator variable to perform corrective maintenance

Y_j = preventive maintenance

MAX $\sum_{i,j} C = X_i(d_i * r_i * l) + Y_j(d_j * f_j * l)$

S.T. X_i, Y_j = binary

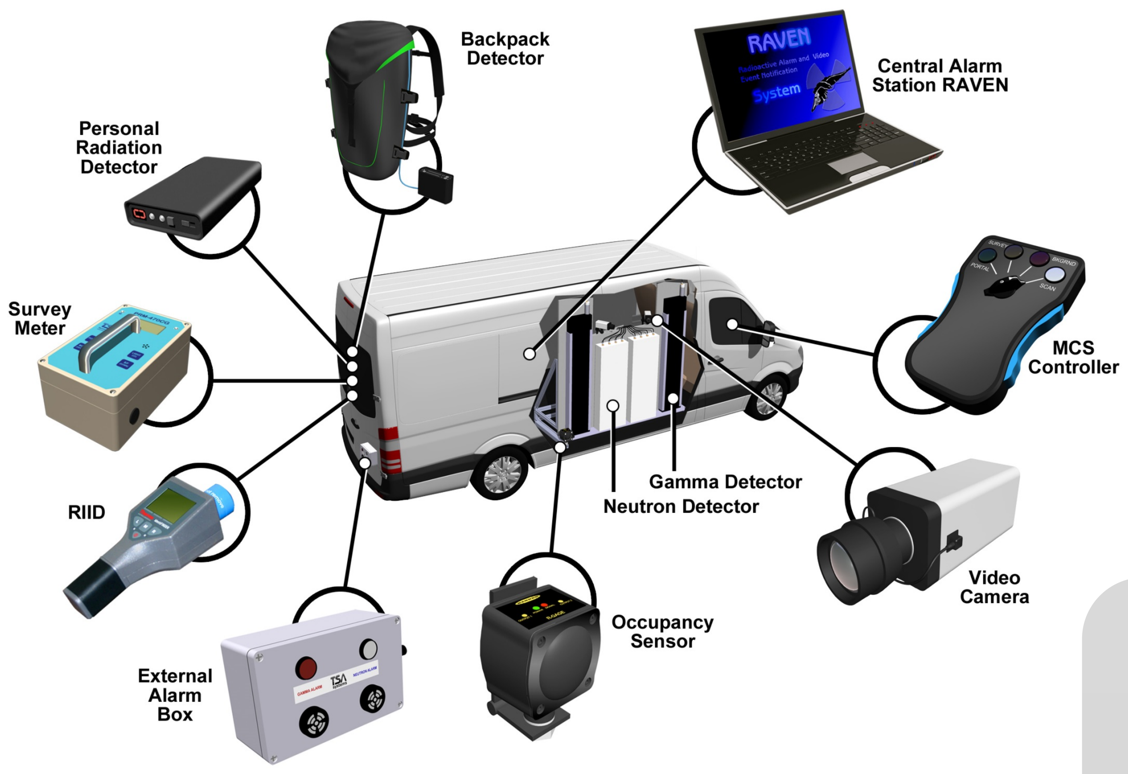
$C < B$, where B is budget ($) and C is the cost

where d_i, dj =activity duration (hrs.), r_i = number annual failures, f_j = frequencies, l = labor cost ($).

Methods

- Microsoft Excel Solver
  - To find the global optimal solution
- Microsoft's Excel What-If Analysis Tool
  - Calculate all budget costs
- Visual Basic for Applications (VBA) Programming on Microsoft Excel
  - Running Solver through loops
  - Color coding each solution based on its feasibility or lack of feasibility

Lifecycle cost of equipment.



Mobile detection system.

Maintenance Types

- Preventive Maintenance:
  - Functional check, Physical inspect
  - Frequencies: 1, 2, 4, 6, 12 times per year
- Corrective Maintenance:
  - Network repair, workshop repair

Results

Given four maintenance types, the maximum number of maintenance activities needs to equal the maintenance budget of $8,000.

- Using the approaches of What-If analysis and using the VBA programming, there were 16 out of 25 solutions that were desirable.
- Other solutions skipped some maintenance activities.

Conclusion

Multiple techniques exist to solve this type of problem. Programming can be used to speed up the solution process. In this case, once generating the feasible solutions was accomplished, the question became: What are the other factors that determine the optimal decision when there are many? In this case, 16 out of 25 were desirable solutions because they did not skip any maintenance activities.

Further Steps

- Consulting subject matter experts on the maintenance equipment is necessary to better understand each country's needs and other decision factors.
- Risk analysis provides each country with possible consequences that may occur if they decide to do a limited number of maintenance activities.

Frequencies for physical inspections	Frequencies for functional checks: 1	2	4	6	12
1	6400	6700	7300	7900	6100
2	6500	6800	7400	8000	6200
4	6700	7000	7600	7800	6400
6	6900	7200	7800	7800	6600
12	7500	7800	7200	7800	7200

Costs for the desirable solutions (yellow), the undesirable solutions (red), and the optimal solution (green).

PackEye radiation detection backpack.

About

Pacific Northwest National Laboratory

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References

Administration, N. N. (n.d.). *Nuclear Smuggling Detection and Deterrence*. Retrieved June 13, 2016, from National Nuclear Security Administration: https://nnsa.energy.gov/aboutus/ourprograms/dnn/gms/nsdd.

Henderson, D., Muller, G., Perkins, C., Sturges, M., Lombardo, N., & Brigantic, R. (2013). *Second Line of Defense System Lifecycle Study.* Research Report.

Michael Perkins (Creator). (2016). *All Types of Detection* [Image], Retrieved from PNNL Creative Services.

Office of the Second Line of Defense National Nuclear Security Administration. (2014). *Second Line of Defense Program Equipment Lifecycle Planning Factors.* Coordinating Draft, Rev. 3.0.

PackEye Radiation Detection Backpack. (n.d.). Retrieved August 11, 2016, from ThermoFisher Scientific: https://www.thermofisher.com/order/catalog/product/FHT1377.

Tutorials. (n.d.). Retrieved June 2016, from MIT Open Courseware Massachusetts Institute of Technology: http://ocw.mit.edu/courses/sloan-school-of-management/15-053-optimization-methods-in-management-science-spring-2013/tutorials/.

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