Proceedings of the Annual General Donald R. Keith Memorial Conference
West Point, New York, USA
May 2, 2019
A Regional Conference of the Society for Industrial and Systems Engineering

Creating a Decision Support Tool for the Stryker NBC RV

Jordan Cascio, Morgan Hale, Amy Owens, Shafer Swann, Andrew Weliver, and José Jiménez

Department of Systems Engineering
United States Military Academy, West Point, NY

Corresponding author: jordan.cascio@westpoint.edu

Author Note: Cadets Cascio, Hale, Owens, Swann, and Weliver are seniors at the United States Military Academy. They will commission as Second Lieutenants in the United States Army in May 2019. Dr. Jiménez is an assistant professor in the Department of Systems Engineering and the advisor for this capstone project. The client for this project is the Joint Program Executive Office for Chemical, Biological, Radiological, and Nuclear Defense (JPMO CBRND), which is the center for CBRN defense and is located in Aberdeen Proving Ground, Maryland.

Abstract: Our capstone team developed a scalable Decision Support Tool that informs commanders on the effectiveness of the sensor suite for the Stryker Nuclear Biological and Chemical Reconnaissance Vehicle (NBC RV) during specific missions. We used the Agile project management approach and the Systems Decision Process (SDP) to guide our project and allow us to continuously make improvements to the model. Through stakeholder analysis and research of the NBC RV's current and future capabilities, we identified sixteen variables that affect the Stryker's overall performance on a mission. We tested the Stryker's performance in several computer designed scenarios with various mission objectives using optimization methods to determine an efficiency score. Finally, our team designed a deterministic model to provide a numerical efficiency output that is robust while maximizing accuracy.

Keywords: Decision Support Tool, Agile Project Management, Stryker NBC RV, CBRN Sensor Suite

1. Information and Background

The Stryker Nuclear Biological and Chemical Reconnaissance Vehicle (NBC RV) has become outdated and with the emergence of new technology, it is no longer as effective in a combat environment (Cress, 2018). Due to The Stryker NBC RV's outdated capabilities (Glynn, 2018), the United States Army is currently exploring options to modernize the next generation reconnaissance vehicle. The Stryker NBC RV utilizes five main sensors for its primary mission: Joint Service Lightweight Standoff Chemical Agent Detector (JSLSCAD), Chemical Biological Mass Spectrometer (CBMS-II), Chemical Vapor Sampler System (CVSS), Radiological Point Detector (AN/VDR), Joint Biological Point Detection System (JBPDS), which can detect Nuclear, Chemical, and Biological threats. These sensors have not been updated in the last fifteen years, but still offer functionality to maneuver commanders in clearing their operational area (Kimmel, 2018). Currently, there is no way to measure the effectiveness of these sensors in different environments, thus there is no clear way for maneuver commanders to fully understand the threat in their area of operations. Our team used the Agile Project Management style to break the project into short-term goals, allowing for close management of the Decision Support Tool (DST) through concentration on tasks and after-action review (we are preparing a separate publication for Agile in decision support).

1.1 Problem Definition

Our task was to create a DST to improve the design of the Stryker NBC RV sensor suite. The client for our project is the Joint Program Executive Office for Chemical, Biological, Radiological, and Nuclear Defense (JPMO CBRND). JPMO CBRND's mission is to "manage our nation's investments in chemical, biological, radiological, and nuclear (CBRN) defense equipment" (Remeto, 2018).

The Stryker NBC RV DST works as a guide for commanders to optimize the sensor suite's efficiency. The DST takes in data provided to our capstone team on the capabilities of the sensor suite as an input. The DST allows the commander to input mission-specific parameters based on intelligence he or she has received. Additionally, the commander will be able to include any additional sensors or resources allocated to that mission into the tool. The result is an efficiency rating for that specific vehicle configuration.

As part of the verification and validation plan, the DST was tested on two different types of simulation software: the Infantry Warrior Simulation (IWARS) and the One Semi-Automated Forces (OneSAF). The output of the DST served as the input for both simulations to assess its applicability in combat scenarios. The Stryker NBC RV is a valuable asset to maneuver commanders in CBRN environments. The DST simplifies the complexity of a combat mission and gives commanders rapid accessibility to the efficiency and effectiveness of the asset attached to their unit.

2. Functional Analysis

2.1 Stakeholder Analysis

Stakeholder analysis encompassed our team evaluating all the separate entities involved in this project. This evaluation allowed us to create a shared understanding of our task, the Stryker itself, and our client's needs. The analysis allowed us to identify specific requirements for each of the Stryker's functions. The stakeholders that we identified are: CBRN Soldiers, the CBRN School, the Army Maneuver Element, JPEO-CBRND Analytical Framework, the Operations Research Center (ORCEN) and the Department of Systems Engineering (DSE) at the United States Military Academy. Each of these stakeholders brought critical perspectives to the project and called for our team to look at the project through multiple lenses.

2.2 Functional Analysis

In the functional analysis stage, our team utilized the information provided from the stakeholder analysis and broke it down into specific requirements. Functional analysis allows our project team to conceptualize the different facets of the project by displaying them in a logical way, and in the most important system functions. Functional analysis is the foundation for the project team to begin creating a solution for the stakeholder. Our functional analysis improved our team's overall knowledge of the tool as well as helped us move forward with the initial designs of the user interface and optimization parameters for an eventual efficiency rating. The process we used to create our Functional Hierarchy is outlined in Parnell, Driscoll, & Henderson (2011).

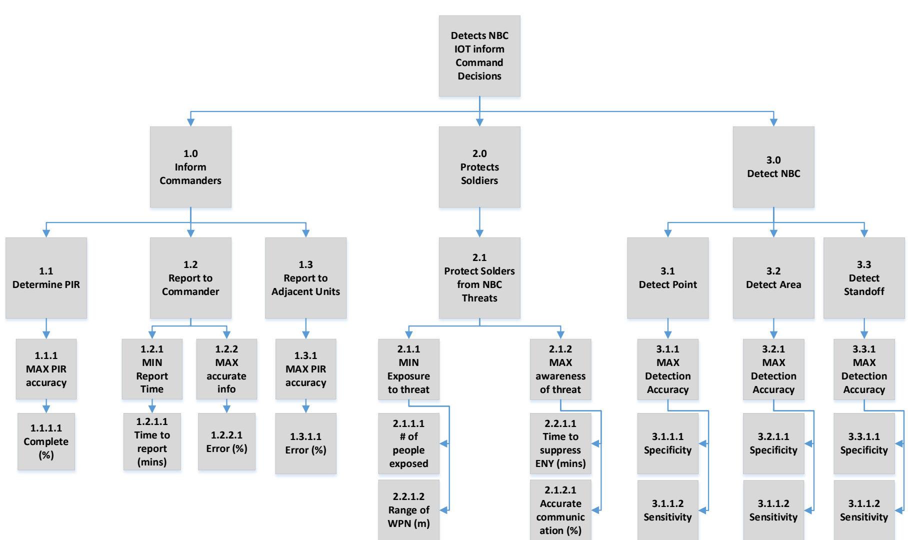


Figure 1: Functional Hierarchy

3. Model Methodology

The DST was created through several development iterations that produced minimal viable products (MVP) or working versions of the tool. The MVP served the function of creating a tool that produced an efficiency score that could be interpreted by our stakeholders in their decision-making process for the Stryker NBC RV. With the inclusion of variables deemed important by our stakeholders we derived efficiency scores that ranged from 0-100 for the Stryker NBC RV's current capabilities within a given simulation. The team derived a design that allowed for minimal user input on the front end while receiving a clear and concise answer on the Stryker NBC RV's efficiency given the scenario. The robust design on the backend of the DST allowed for a multitude of variables to be include in the calculation of the efficiency score.

Rank ordering the variables by importance based on our stakeholder analysis and research allowed us to create value measures for each variable. As the project progressed, the model became more robust by including other factors that may affect the Stryker NBC RV's performance in a given situation but were not included in the functional hierarchy. These factors include an *area scanned* variable, denoting the total area scanned by the sensor suite on the vehicle, and *sensor effective rate*, adding randomness to the sensor's performance to make it more representative of reality.

3.1 Concept of DST Model

The model attempts to connect the sensor suite with its environment, in relation to sensitivity of sensors, and give a numerical value that allows for an objective comparison of multiple sensor suite combinations. This is achieved through value modeling that is highly dependent on user specified value measures. The following are the steps to our algorithm:

1. Determine the functions of the Stryker NBC RV, as well as the desired magnitude (Maximize or Minimize).
2. Rank the functions from step one and the sensors in order of descending importance. The sensors will all have a positive magnitude, indicating maximization.
3. Normalize these values to determine the value measures (positive for Maximize and negative for Minimize).
4. Determine the conditions for different scenarios the Stryker NBC RV will be operating in (see Table 1 in the results section for our model, which was determined through our stakeholder analysis).
    a. Categorize conditions so that each condition determines a level of difficulty for that category (our categories are environment, threat level, type, state of threat, and scan method).
    b. Determine the weight for each category. The weights were calculated using the same method of calculating the value measures, ranking them by importance.
    c. Different combinations of conditions for each category should capture the complexity of operational environments for the Stryker NBC RV.
5. Determine the interdependencies of the scenario conditions with the sensor suite and Stryker functions from step 1. These interdependencies should indicate which sensors and functions are active for each condition within every category (1 - active, 0 - inactive).
6. Set the conditions for a single scenario.
7. Using the interdependencies and function value measures, calculate the efficiency of the Stryker using the following linear model:

$$E = \sum_{x=1}^{y} w_x(\sum_{i=1}^{m} (S_i * e_i * v_i) + \sum_{j=1}^{n} (F_j * v_j)) \quad (1)$$

where S_i are if the sensors are used in that scenario (this value is binary where 1 indicates it is used, 0 indicates it is not, *m* representing the number of sensors), with an efficiency rate of e_i and a value measure of v_i (from step 3), and F_j are the functions of the Stryker NBC RV used in that scenario (this value is also binary, *n* representing the number of functions),

ISBN: 97819384961-6-5

with a value measure of v_j (from step 3). All efficiency rates and value measures range from 0 to 1. The efficiency rate for each sensor the Stryker NBC RV were provided by the JPEO-CBRND Analytical Framework. These summations are then multiplied by weight w_x, where y is the different categories for each condition in the scenario. These weights range from 0 to 1. The efficiency rate of the Stryker (E) ranges from 0 to 100.

3.2 Simulation in IWARS

Since the cost of testing the NBC RV sensor suite on a full scale is cost prohibitive, utilizing simulation is an efficient alternative. Our team focused on simulation in IWARS, while the JPEO CBRND Analytical Framework team focused on OneSAF. Our simulation efforts focused on demonstrating the improvements in efficiency that the upgraded Stryker NBC RV would be able to achieve. We used IWARS to build baseline and future scenarios for the NBC RV in two sample missions: Zone Interrogation and Route Recon – thus creating four models. The end goal of creating these scenarios was to demonstrate how the future capabilities would eliminate the exposure time of the manned vehicles.

In our baseline Zone Interrogation mission, the Stryker NBC RV must interrogate a suspected contamination area adjacent to a town. After the NBC RV completes its interrogation, it communicates to the other vehicles in the unit to move around the threat. The future model for the Zone Interrogation shows the NBC RV and the Robotic Extension Node Demonstrator for Reconnaissance (RNDR), the unmanned ground vehicle, spanning apart to scan the area and eventually triangulate on a specific contaminated location. Once this location is determined, the NBC RV team launches its Deep Purple unmanned aerial system (UAS) to interrogate the threat. The Deep Purple conducts the interrogation and communicates its findings to the NBC RV team. The Deep Purple finally returns to the NBC RV and the unit moves around the threat.

The baseline Route Recon mission has three Stryker NBC RV vehicles moving along a linear route (a road). Upon spotting an NBC threat, they move through and interrogate the threat as a team. In the future model of the Route Recon mission, the NBC RV team conducts the same method of scanning and triangulation with the RNDR followed by deployment of the Deep Purple, but instead, along a linear route. While the time on mission varies per situation, the future models both successfully demonstrate the elimination of manned vehicle contamination.

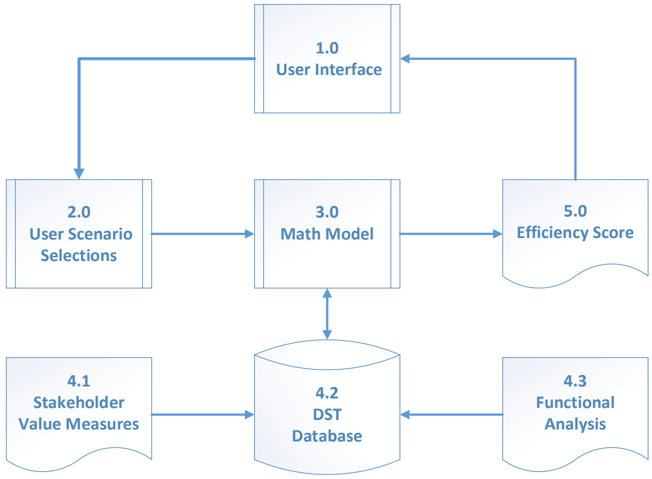
4. Results

Our team performed testing on all the possible input combinations within the DST Model. This resulted in 516 different scenarios with specific numerical efficiency scores. The model was developed using data provided by our client and our functional analysis. The data provided had no associated probabilities, therefore, the testing results were deterministic. However, our model has the capability of accepting probabilistic data for analysis. Figure 1 shows the process that our model runs through to calculate the NBC RV's efficiency score. Beginning with step 1.0 (User Interface), the user inputs the environment, threat level, threat type, state of threat, and type of scan of their specific scenario. Once the factors are selected (step 2.0), they are entered into the mathematical model (step 3.0). The mathematical model calls upon the DST database which stores information from the stakeholder value measures and our team's functional analysis (steps 4.1, 4.2, and 4.3). The efficiency score is then calculated by the algorithm and the formula provided in the methodology section.

Our model includes the different types of sensors within the Stryker NBC RV as well as the 16 different value measures from our Functional Hierarchy. Each sensor and factor were given an overall score based on their effectiveness. Each NBC RV sensor has specific capabilities pertaining to the threat type, scan type, and the state of threat. The model will only call upon the specific sensors and factors that pertain to the given scenario. Table 1 shows a sample of 4 scenarios (out of 516 possible scenarios). The results demonstrate the effects that the 5 user inputs have on the efficiency of the NBC RV.

5. Conclusion and Future Work

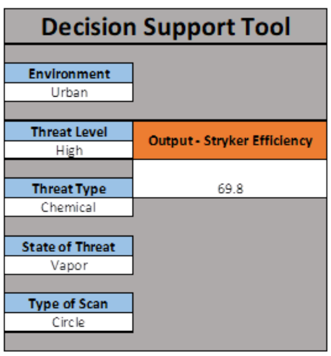
Upon completion of the DST, our team performed output testing for all possible scenario settings. In total, we ran 516 tests giving our team a matrix of outputs highlighting the best performance variables for the NBC RV. The Stryker NBC RV operates best in a desert environment. This result was expected as a desert environment offers the least amount of



Inform Commanders	Weights	Rank
PIR Complete Percentage	0.0515	10
Time to Report	0.0588	9
Info Accuracy	0.0662	8

Protect Soldiers	Weights	Rank
Soldiers Exposed	0.0074	16
Communication Accuracy	0.0441	11
Fire Superiority	0.0221	14
Speed of Vehicle	0.0368	12
Armor Strength	0.0294	13
Reliability of Stryker	0.0809	6

Assess NBC Threats	Weight	Rank
JSLSCAD	0.1103	2
CBMS-II	0.1176	1
CVSS	0.1029	3
AN/VDR	0.0956	4
JBPDS	0.0882	5
Mission Time	0.0735	7
Area Evaulated	0.0147	15



Total Area Scanned		
Type	Distance(m)	Total Area (m^2)
Point	2000	2000
Cone	1000	267940
Circle	500	785398.1634

Effective Rate of Sensors	
JSLSCAD	99%
CBMS-II	95%
CVSS	70%
AN/VDR	100%
JBPDS	85%

Figure 2. DST Process Flow, User Interface, and Database

Table 1. DST Efficiency Scores

Environment	Threat Level	Threat Type	State of Threat	Type of Scan	Output (0-100)
Urban	Known NBC in AO	Chemical	Gas	Point	38.8
Urban	Known NBC in AO	Chemical	Gas	Cone	49.8
Desert	Moderate	Biological	Vapor	Circle	65.4
Urban	Moderate	Nuclear	Solid	Point	22.3

ISBN: 97819384961-6-5

obstruction to the NBC RV's sensors. The Stryker also operated well in the wooded environment but received the lowest score in the urban environment. The test results showed our team that our initial predictions of the Stryker's operating capabilities held true. Our initial assumptions stated that the Stryker NBC RV would operate best in a hazardous chemical environment due to the reliability of chemical detection sensors and the ability to train often in hazardous chemical situations. The results demonstrate that in any given chemical scenario the Stryker performs at its best. The DST is currently functioning in Python computer language but will be updated by our team to a more user-friendly interface to support ease of access. Furthermore, the DST could use more data on sensors and operating environments to make the tool more robust and effective to CBRN units in the operating force by providing performance accuracy measures.

Future work for the model includes three main areas. First, the user interface needs to be improved for user-friendliness and robustness of the model inputs. Currently our DST is modeled with Python code, which allows for flexibility but is not user-friendly. Next, the cost of the components should be linked to the scenario so that the commanders who use the DST not only get an efficiency rating but also a component cost which they can compare to other scenarios. Lastly, the ability for the back-end of the tool to be more accessible and easily managed to allow for more data and systems to be added to the model while it continues to produce an accurate result. With these future improvements, the model will be a great tool for commanders to use and adapt to the battlefield.

6. References

Agresti, A. (2007). *An Introduction to Categorical Data Analysis* (Second). New Jersey: Wiley & Sons.
Blanchard, B., Fabrycky, Wolter J. (2006). *Systems Engineering and Analysis* (Fourth). New Jersey: Upper Saddle River.
Smith, Roger, "OneSAF: Next Generation Wargame Model," U.S. Army PEO-STRI: 20 August 2007.
Creswell, J. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (Third). California: Sage.
Cress, M. (ECBC Technical LNO to U.S. Army CBRN School). personal communication. July 24, 2018.
Glynn, D. (Technical Representative to U.S. Army CBRN School). personal communication. August 31, 2018.
Highsmith, J. R. (2009). *Agile project management: creating innovative products*. Pearson Education.
Karlesky, M., & Vander Voord, M. *Agile Project Management (or, Burning Your Gantt Charts)* (2008). Agile project management. *ESC*, *247*(267), 4.
Kimmel, S. (Deputy Commandant of U.S. Army CBRN School). personal communication. November 7, 2018.
Picard, D., Levandouski, M., & McJessy, J. (2018, September 27). Introduction.
Parnell, G. S., Driscoll, P. J., & Henderson, D. L. (Eds.). (2011). Decision making in systems engineering and management (Vol. 81). John Wiley & Sons.
Remeto, L. (2018, September). *Analytical Framework (AF) Collaborative Environment for the JPEO-CBRND*. PowerPoint.
U.S. Army (2010). M1135 Stryker Nuclear, Biological, and Chemical Reconnaissance Vehicle (NBCRV)," *Army Programs*
U.S. Army Materiel Systems Analysis Activity. "IWARS User Guide," Version 5.1.2. December, 2014.