NAVAL POSTGRADUATE SCHOOL

# Management and Business Knowledge Representation for Decision-Making:

## Applying Artificial Intelligence, Machine Learning, Data Science, and Advanced Quantitative Decision Analytics for Making Better-Informed Decisions

## (Incubator Phase I, WRT-1049.8.3)

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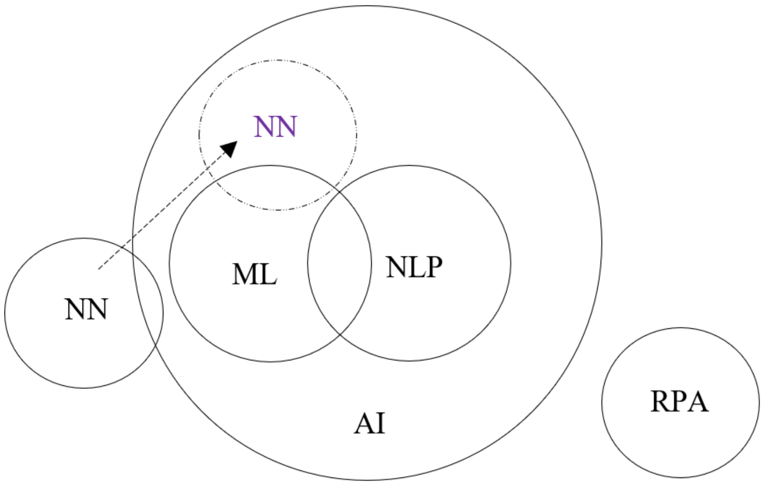
*Quantitative Data Science Risk-Based Stochastic Decision Analytics*

MAY 2023

# BLUF

- Provide decision makers with actionable information and intelligence with visibility into future decision options or flexibility real options, complete with the assumptions that led to certain comparable decisions.
- Researched state of the art in industry pertaining to a decision options register (DOR) related mechanisms.
- Identification and testing of various AI Machine Learning algorithms including classification models, text scraping models, and other related approaches… as well as any issues that may arise.
- Applies a Multidisciplinary Approach: Advanced analytics, artificial intelligence, computer science, decision analytics, defense acquisitions, economics, engineering and physics, finance, options theory, project and program management, simulation and stochastic modeling, applied mathematics, and statistics.
- Predictive modeling (LIMDEP, probability of success), stochastic portfolio optimization, AI/ML, data science, decision options, Monte Carlo simulations of historical data, collating DOR dataset for better predictive power.

# Quick AI/ML Overview




**Artificial Intelligence (AI):**
algorithms exhibiting "smart" behavior

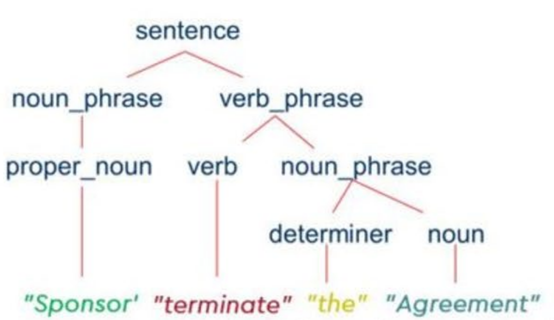
**Machine Learning (ML):**
algorithms that detect patterns and use them for prediction and decision making

**Natural Language Processing (NLP):**
Algorithms that can interpret, predict, transform, and generate human language

**Robotic Process Automation (RPA):**
Algorithms that mimic human actions to reduce simple but repetitive tasks

## NATURAL LANGUAGE PROCESSING IN PROCUREMENT

Identifying parts of a text and their grammatical roles through text parsing.




3 TERM
3.1 This Agreement shall commence on the Commencement Date and shall continue, unless terminated earlier in accordance with this Agreement, for the Term. On the expiry of the Term, this Agreement shall terminate automatically without notice.
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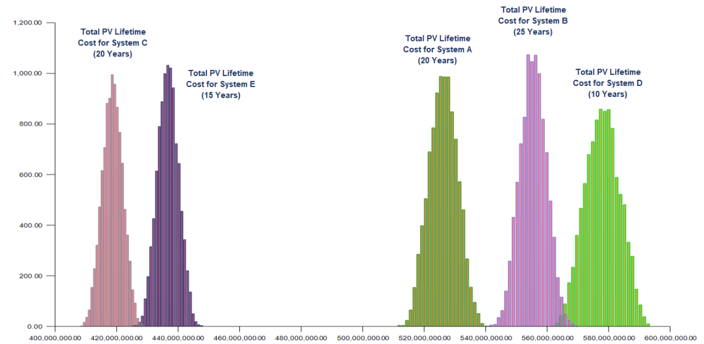
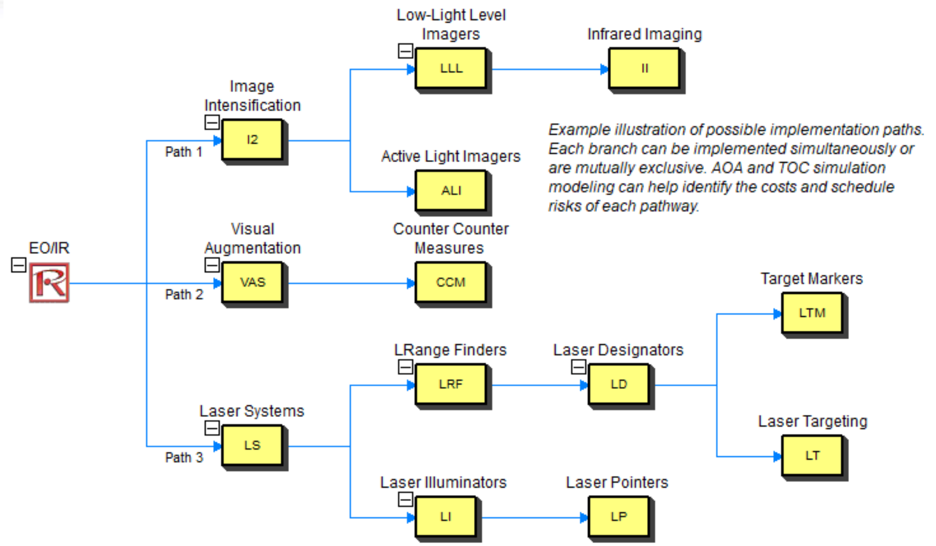
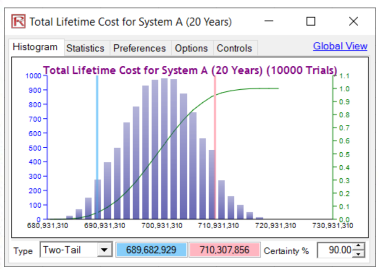
Tag colors:

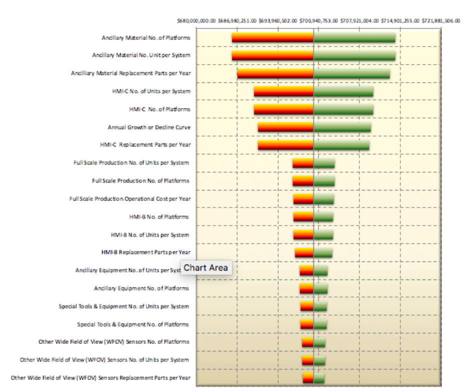
ACTION | ITEM | ORGANIZATION | LOCATION | TIME | MONEY

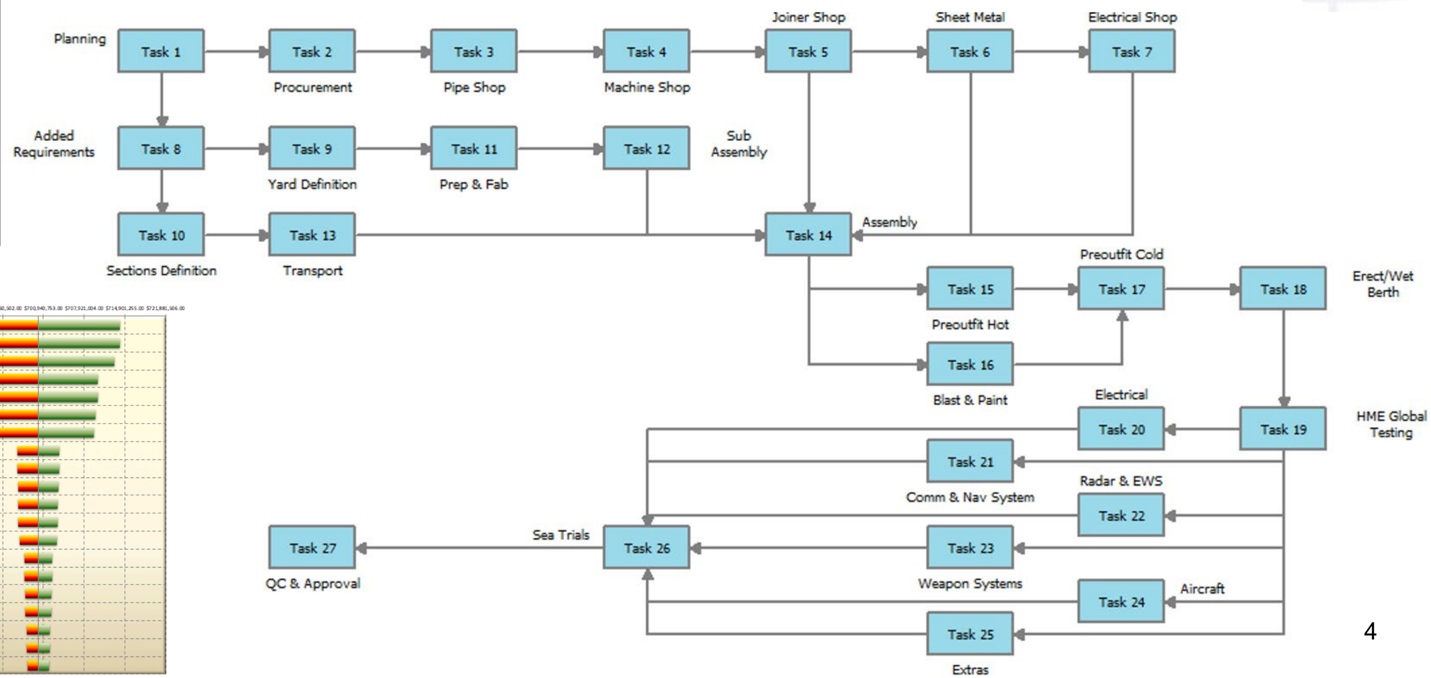
# Decision Analytics (AOA & Options)



# Lifecycle and TOC: Cost & Schedule Risk

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Project Management | Applied Analytics | Risk Simulation | Options Strategies | Options Valuation | Forecast Prediction | Dashboard | Knowledge Center

Ship Building | ICT Navigation | Weapon Systems | Aircraft | Electrical Systems | Radar Systems | Extra Systems | Support Processes | Portfolio Analysis

Select the Project Schedule & Cost Risk Model to use: ○ Sequential Path ◉ Complex Network Path Project Name/Notes:

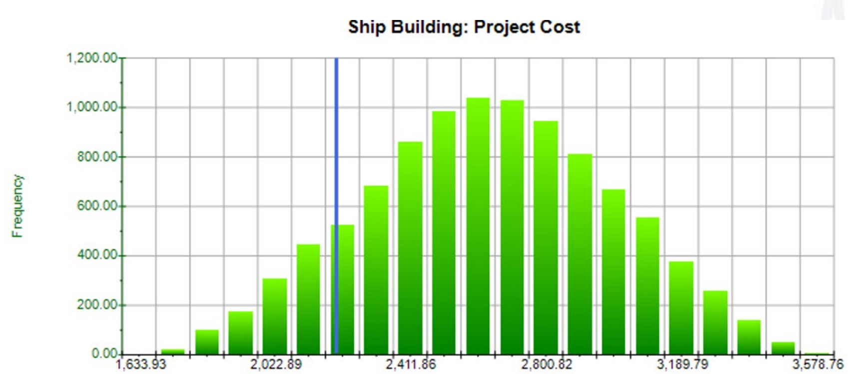
Network Diagram | Schedule & Cost

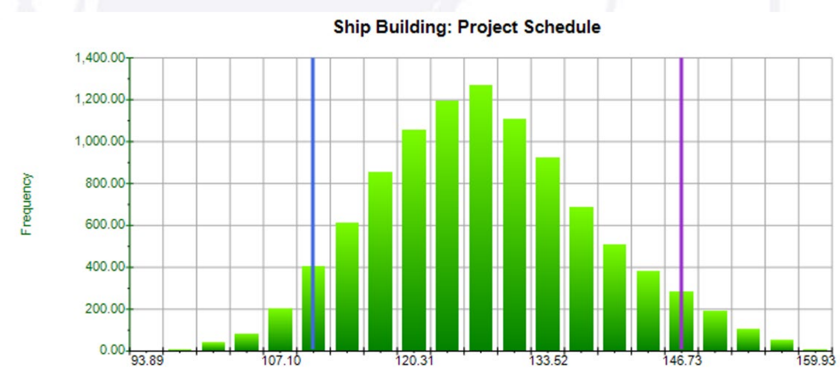
☑ Include Schedule-Based Cost Analysis ☐ Include Probabilities of Success of Each Task and Model Their Impacts

☑ Include Budget Overrun & Buffers ☑ Perform Risk Simulation Run | Run All Projects

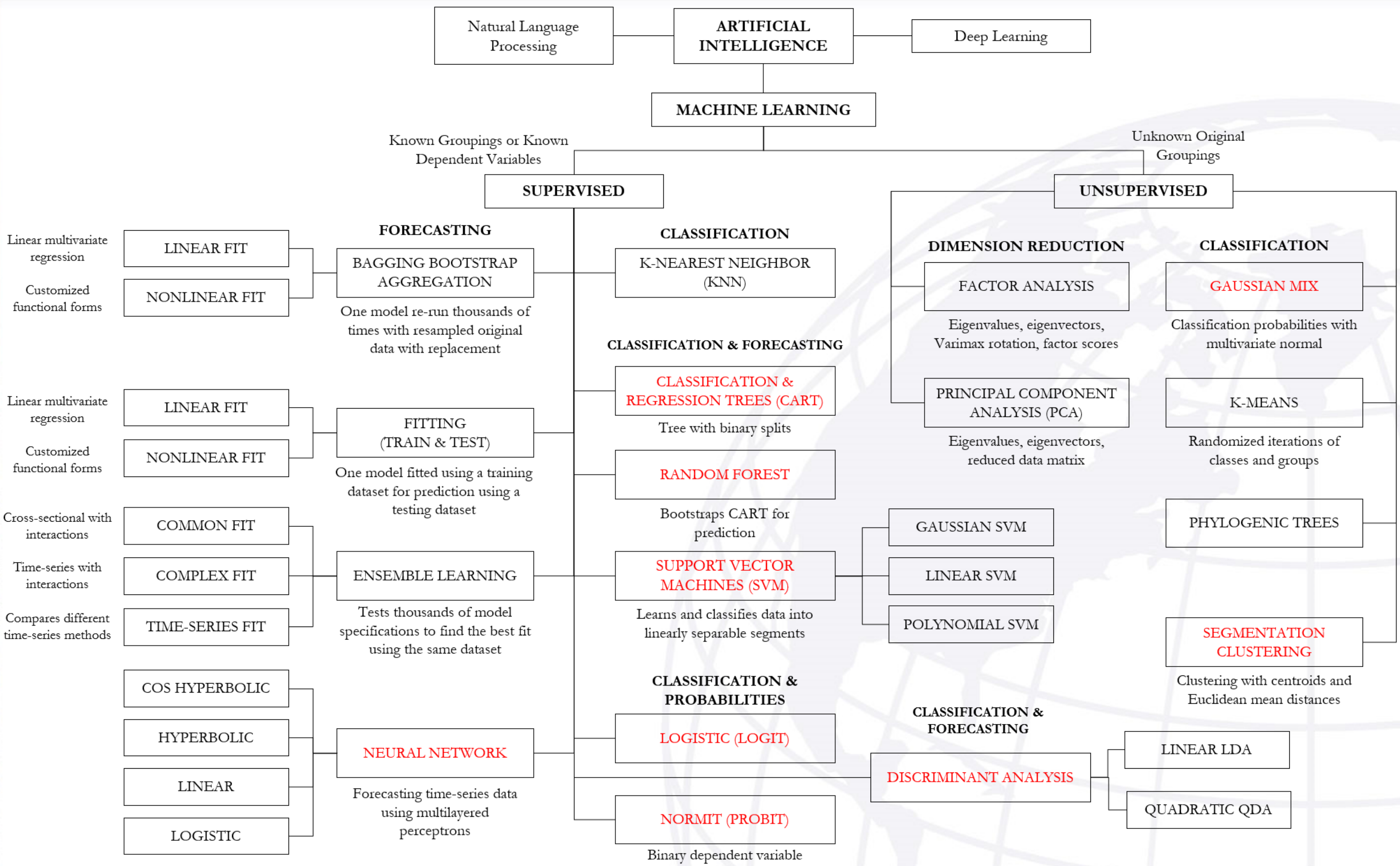
Show 27 Tasks with Weekly Simulation Trials: 1,000,000 ☑ Apply Seed Value: 123 Triangular

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Task 6 | Sheet Metal | 19.70 | 24.62 | 29.55 | 27 | 1.27 | 2.00 | 2.73 | 0.04 | 10.00% |
| Task 7 | Electrical Shop | 19.70 | 24.62 | 29.55 | 29 | 3.17 | 5.00 | 6.84 | 0.40 | 10.00% |
| Task 8 | Added Requirements | 2.36 | 3.07 | 4.76 | 4 | 2.53 | 4.00 | 5.47 | 0.16 | 10.00% |
| Task 9 | Yard Definition | 2.63 | 3.41 | 5.29 | 4 | 2.53 | 4.00 | 5.47 | 0.16 | 10.00% |
| Task 10 | Sections Definition | 2.89 | 3.75 | 5.82 | 4 | 1.27 | 2.00 | 2.73 | 0.16 | 10.00% |
| Task 11 | Prep & Fab | 1.84 | 2.38 | 3.70 | 4 | 3.80 | 6.00 | 8.20 | 0.16 | 10.00% |
| Task 12 | Sub Assembly | 21.01 | 27.25 | 42.33 | 31 | 2.53 | 4.00 | 5.47 | 0.24 | 10.00% |
| Task 13 | Transport | 13.13 | 17.03 | 26.45 | 20 | 1.90 | 3.00 | 4.10 | 0.24 | 10.00% |
| Task 14 | Assembly | 31.51 | 40.88 | 63.49 | 47 | 3.17 | 5.00 | 6.84 | 0.40 | 10.00% |
| Task 15 | Preoutfit Hot | 13.13 | 17.03 | 26.45 | 20 | 1.90 | 3.00 | 4.10 | 0.24 | 10.00% |
| Task 16 | Blast & Paint | 3.15 | 4.09 | 6.35 | 5 | 1.90 | 3.00 | 4.10 | 0.24 | 10.00% |
| Task 17 | Preoutfit Cold | 2.63 | 3.41 | 5.29 | 4 | 1.27 | 2.00 | 2.73 | 0.16 | 10.00% |
| Task 18 | Erect/Wet Berth | 39.39 | 51.10 | 79.36 | 57 | 1.90 | 3.00 | 4.10 | 0.24 | 10.00% |
| Task 19 | HME Global Testing | 55.14 | 71.54 | 111.10 | 87 | 6.33 | 10.00 | 13.67 | 0.79 | 10.00% |
| Task 20 | Electrical | 4.40 | 11.05 | 17.70 | 20 | 17.07 | 44.00 | 70.93 | 0.16 | 10.00% |
| Task 21 | Comm & Nav System | 19.64 | 47.07 | 74.50 | 61 | 19.40 | 50.00 | 80.60 | 0.16 | 10.00% |
| Task 22 | Radar & EWS | 158.16 | 385.70 | 613.24 | 435 | 23.28 | 60.00 | 96.72 | 0.16 | 10.00% |
| Task 23 | Weapon Systems | 514.54 | 1,262.38 | 2,010.21 | 1,397 | 18.62 | 48.00 | 77.38 | 0.16 | 10.00% |
| Task 24 | Aircraft | 24.56 | 61.54 | 98.52 | 71 | 13.97 | 36.00 | 58.03 | 0.08 | 10.00% |
| Task 25 | Extras | 18.03 | 45.24 | 72.44 | 52 | 9.31 | 24.00 | 38.69 | 0.08 | 10.00% |
| Task 26 | Sea Trials | 42.01 | 54.50 | 84.65 | 74 | 5.06 | 8.00 | 10.94 | 1.59 | 10.00% |
| Task 27 | QC & Approval | 26.26 | 34.07 | 52.91 | 38 | 1.90 | 3.00 | 4.10 | 0.24 | 10.00% |



# AI/ML Methods



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# Decision Options Register I

**Decision Options Register**

| | | | |
|---|---|---|---|
| Project Name: | | | |
| Project ID: | | | |
| Sponsor: | | | |
| Division: | | | |
| Program Manager: | | | |
| Contact Details: | | | |
| Starting Year: | | | |
| Ending Year: | | | |
| Project Status: | | | |
| Project Type: | | | |
| Project Area & Purpose: | | | |
| Main Decision Trigger: | | | |
| Acquisition Cost ($M): | | Monthly FTE | |
| Annual Oper. & Maintenance ($M): | | Complexity Level (1-100) | |
| Total Lifecycle Cost ($M): | | Strategic Value (1-100) | |
| Annual Savings ($): | | Value to Command (1-100) | |
| Total Lifecycle Savings ($M): | | Overrun Ratio | |
| Return on Investment (%) | | Length (Months) | |
| Project Constraints & Limitations: | | | |
| Project Risks & Uncertainties: | | | |
| Project Comments: | | | |
| Project Communications Thread: | | | |

Project Status:
- Pre-Proposal
- Proposal
- Funded Awaiting Start
- Work in Progress
- Near Completion
- Completed
- Other
- Not Funded/Failed

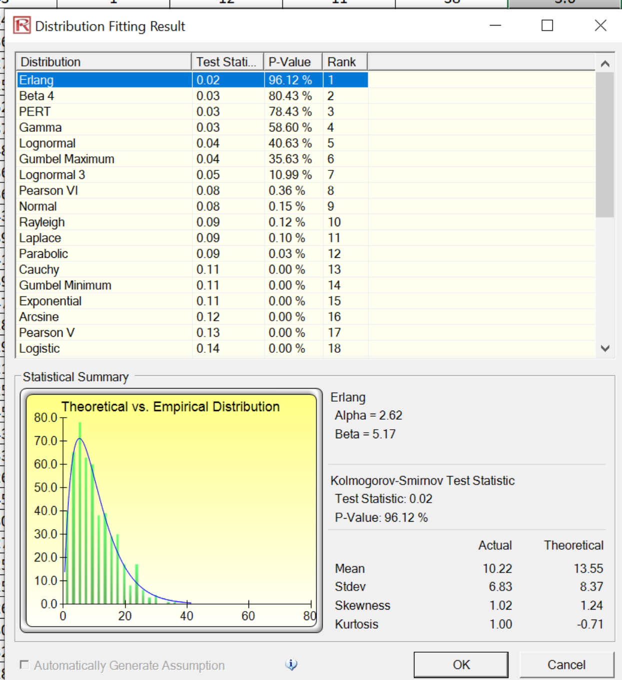
Decision Trigger:
- Cost Savings
- Efficiency Improvement
- Future Needs
- Other
- Policy Decision
- Process Improvement
- Required for Ongoing Support
- Return on Investment
- Strategic Decision
- Other:

Project Type:
- New Work
- Continuation
- Related
- Competitive
- Other:

Project Area and Purpose:
- Arms Control & Conflict Resolution
- Assure Access to the Maritime Battlespace
- Autonomy and Unmanned Systems
- Autonomous Systems Augmenting Military Operations
- Bilateral & Multilateral Security Building
- Border Security
- Capable Manpower: Matching Mission Essential Competencies
- Counter Weapons of Mass Destruction
- Cyber Performance Improvement
- Data-to-Decisions: Shorten Cycle Time from Data Gathering to Decisions
- Domestic Politics, Political Economy & Regional Security
- Electromagnetic Maneuver Warfare
- Electronic Warfare & Protection
- Emergency Management
- Engineering Resilient Systems
- Enterprise and Platform Enablers
- Expeditionary and Irregular Warfare
- Expeditionary Maneuver Warfare
- Force Health Protection
- FORCEnet: C4ISR, Networking, Navigation, Decision Support
- Human Systems: Improve the Fusion of Humans and Systems
- Information Dominance
- Justice & Law Enforcement
- Modeling Future Conflicts
- Platform Design and Survivability
- Post-Conflict Reconstruction
- Power and Energy, High Energy and Pulse Power
- Power Projection and Integrated Defense
- Public Health & Safety
- Sea Basing: Sea Basing Logistics, Shipping, and At-Sea Technologies
- Sea Shield: Missile Defense, Anti-Submarine Warfare, Mine Countermeasures
- Sea Strike: Weapons, Aircraft, and Expeditionary Warfare Technologies
- Security Applications of Emergent Technologies
- Space Technology
- Special Operations & Irregular Warfare
- Strategic Stability
- Terrorism & Counter-Terrorism
- U.S. & Allied Security Policies, Planning & Strategy
- Warfighter Performance
- OTHER (Not Listed)

# Decision Options Register II

| Status (D) | Monthly FTE | Complexity Level | Strategic Value | Value to Command | Length in Months | Program Cost | Overrun Ratio | Annual Cost Savings |
|---|---|---|---|---|---|---|---|---|
| 1 | 41 | 3 | 17 | 12 | 176 | 9.3 | 11.36 | 5.01 |
| 0 | 27 | 1 | 11 | 6 | 31 | 17.3 | 1.36 | 4 |
| 0 | 40 | 1 | 15 | 14 | 55 | 5.5 | 0.86 | 2.17 |
| 0 | 41 | 1 | 15 | 14 | 120 | 2.9 | 2.66 | 0.82 |
| 1 | 24 | 2 | 2 | 1 | 28 | 17.3 | 1.79 | 3.06 |
| 0 | 41 | 2 | 5 | 5 | 25 | 10.2 | 0.39 | 2.16 |
| 0 | 39 | 1 | 21 | 9 | 67 | 30.6 | 3.83 | 16.67 |
| 0 | 43 | 1 | 12 | 11 | 38 | 3.6 | 0.13 | 1.24 |
| 1 | 24 | | | | | | 1.36 | 3.28 |
| 0 | 36 | | | | | | 2.78 | 2.15 |
| 0 | 27 | | | | | | 0.18 | 0.09 |
| 0 | 25 | | | | | | 0.25 | 0.94 |
| 0 | 52 | | | | | | 3.93 | 2.47 |
| 0 | 37 | | | | | | 1.72 | 3.01 |
| 0 | 48 | | | | | | 3.7 | 5.4 |
| 1 | 36 | | | | | | 0.82 | 3.4 |
| 1 | 36 | | | | | | 2.92 | 3.81 |
| 0 | 43 | | | | | | 1.18 | 4.29 |
| 0 | 39 | | | | | | 0.56 | 2.91 |
| 0 | 41 | | | | | | 0.1 | 0.34 |
| 0 | 39 | | | | | | 1.15 | 0.51 |
| 0 | 47 | | | | | | 0.59 | 1.82 |
| 0 | 28 | | | | | | 0.43 | 2.17 |
| 0 | 29 | | | | | | 0.4 | 2.24 |
| 1 | 21 | | | | | | 0.24 | 2.64 |
| 0 | 25 | | | | | | 2.14 | 3.49 |
| 0 | 45 | | | | | | 0.71 | 3.92 |
| 0 | 43 | | | | | | 0.95 | 9.74 |
| 0 | 33 | | | | | | 3.08 | 7.59 |
| 0 | 26 | | | | | | 0.2 | 5.05 |
| 0 | 45 | | | | | | 0.11 | 0.32 |
| 0 | 30 | | | | | | 1.14 | 1.17 |
| 0 | 27 | | | | | | 0.72 | 0.84 |
| 0 | 25 | | | | | | 1.02 | 2.87 |
| 0 | 25 | | | | | | 0.08 | 0.94 |
| 0 | 26 | | | | | | 6.05 | 5.65 |
| 0 | 30 | | | | | | 1.41 | 2.13 |
| 0 | 32 | | | | | | 3.2 | 4.58 |
| 1 | 28 | | | | | | 1.34 | 2.77 |
| 0 | 45 | 1 | 23 | 5 | 50 | 4.2 | 0.56 | 1.54 |
| 0 | 23 | 1 | 7 | 2 | 31 | 6.6 | 0.34 | 1.71 |
| 0 | 34 | 1 | 17 | 3 | 59 | 8 | 1.81 | 2.91 |
| 0 | 42 | 2 | 7 | 23 | 41 | 4.6 | 0.94 | 0.94 |
| 0 | 39 | 1 | 19 | 5 | 48 | 13.1 | 1.93 | 4.36 |
| 1 | 26 | 1 | 1 | 1 | 14 | 7.5 | 0.3 | 0.75 |



Distribution Fitting Result

| Distribution | Test Stati... | P-Value | Rank |
|---|---|---|---|
| Erlang | 0.02 | 96.12 % | 1 |
| Beta 4 | 0.03 | 80.43 % | 2 |
| PERT | 0.03 | 78.43 % | 3 |
| Gamma | 0.03 | 58.60 % | 4 |
| Lognormal | 0.04 | 40.63 % | 5 |
| Gumbel Maximum | 0.04 | 35.63 % | 6 |
| Lognormal 3 | 0.05 | 10.99 % | 7 |
| Pearson VI | 0.08 | 0.36 % | 8 |
| Normal | 0.08 | 0.15 % | 9 |
| Rayleigh | 0.09 | 0.12 % | 10 |
| Laplace | 0.09 | 0.10 % | 11 |
| Parabolic | 0.09 | 0.03 % | 12 |
| Cauchy | 0.11 | 0.00 % | 13 |
| Gumbel Minimum | 0.11 | 0.00 % | 14 |
| Exponential | 0.11 | 0.00 % | 15 |
| Arcsine | 0.12 | 0.00 % | 16 |
| Pearson V | 0.13 | 0.00 % | 17 |
| Logistic | 0.14 | 0.00 % | 18 |

Statistical Summary



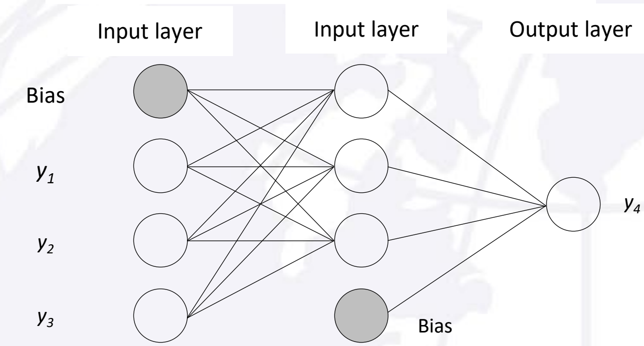
Erlang
Alpha = 2.62
Beta = 5.17

Kolmogorov-Smirnov Test Statistic
Test Statistic: 0.02
P-Value: 96.12 %

| | Actual | Theoretical |
|---|---|---|
| Mean | 10.22 | 13.55 |
| Stdev | 6.83 | 8.37 |
| Skewness | 1.02 | 1.24 |
| Kurtosis | 1.00 | -0.71 |

Automatically Generate Assumption

OK Cancel


$$\hat{x}_t = \phi_0\left(w_{co} + \sum_h w_{ho}\phi_h\left(w_{ch} + \sum_h w_{ih}x_{t-j_i}\right)\right)$$

$$MLE = \frac{n}{2}ln(2\pi) - \frac{n}{2}ln\frac{SSE}{2} - SSE\left[\frac{n}{2SSE}\right] \quad AIC = \frac{-2MLL}{n} + \frac{2k}{n}$$

$$HC = \frac{-2MLE}{n} + \frac{2kln(ln(n))}{n} \qquad PT = \frac{p(xf) - p'}{\sqrt{v - w}}$$

$$LPOM(x) = (S|(x)| + 1) \times (n + 1) \div (n| | + 1 - U(x))$$

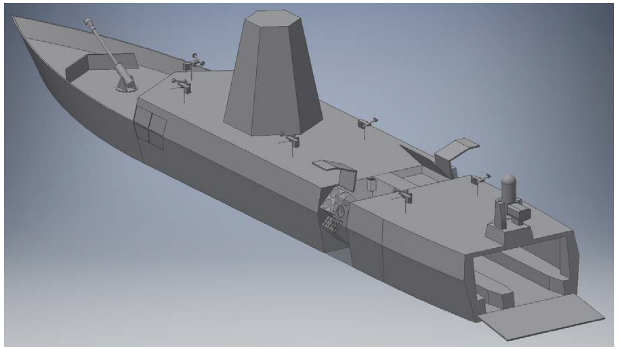
$$p_y^{<} = |O(x)\ U(y)|, p_y^{>} = |F(x)\ U(y)|, \text{and } y\ U(x)$$

# Potential Operational Metrics in DOR

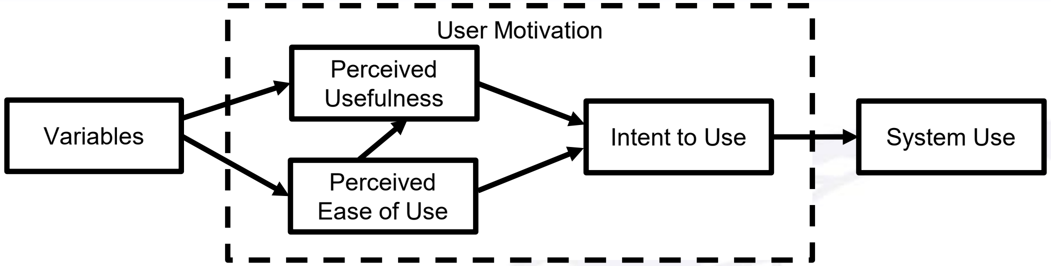
- **Inherent Availability** (IA). Measures operational percentage in an ideal support environment per design specifications. $IA = \frac{MTBF}{MTBF+MTTR}$
- **Effective Availability** (EA). Probability a ship's system is available at any instant during the maximum operational period, accounting for all critical failures, reparable and nonrepairable at sea, and preventive maintenance. $EA = 1 - \frac{MTTR}{MTBF+MTTR} - \frac{MDT}{MT} - 0.5\frac{MT}{MTTF}$
- **Mission Reliability** (MR). Operational Ready Rate (ORR) compared to its Inherent Reliability (IR). $MR = ORR * IR$
- **Operational Dependability** (OD). Probability a system can be used to perform a specified mission when desired. $OD = \frac{MTTF}{MTBF}$
- **Mean Down Time** (MDT), **Mean Maintenance Time** (MMT), **Logistics Delay Time** (LDT). and their combinations.
- **Achieved Availability** (AA), **Operational Availability** (OA), **Mission Availability** (MA)
- **Cost Deterrence and Avoidance**. Soft or shadow-revenue (cost savings) over the economic and operational life of the program or system.
- Traditional Financial Metrics. **Net Present Value** (NPV), **Internal Rate of Return** (IRR), **Return on Investment** (ROI), and other metrics, as long as there are financial and monetary values.
- **Budget Constraint**. FY Budget limitations and probabilities of budgetary overruns.
- **Total Ownership Cost** (TOC) and **Total Lifecycle Cost** (TLC). Accounting for the cost of developing, producing, deploying, maintaining, operating, and disposing of a system over its entire lifespan. Uses **Work Breakout Structures** (WBS), **Cost Estimating Categories** (CEC), and **Cost Element Structures** (CES).
- Multiple value metrics can be determined from **Subject Matter Experts** (SME): **Expected Military Value, Strategic Value, Future Weapon Strategy**
- **Capability Measures** (CM). Difficult to quantify and needs SME judgment:
  - Innovation Index, Conversion Capability, Ability to Meet Future Threats
  - Force Structure (size/units), Modernization (technical sophistication), Combat Readiness, Sustainability
  - Future Readiness (ability to meet evolving threats, ability to integrate future weapons systems)
- **Domain Capabilities** (DC)
  - Portfolios are divided into different domains, and each domain is optimized separately, and then combined into the enterprise level and re-optimized; for example, Coastal Defense, Anti-Air Surface Warfare, Anti-Surface Warfare, Anti-Submarine Warfare, Naval Strike, Multi-Mission Air Control, Sea Control, Deep Strike, Missile Defense, etc.
  - We can add constraints whereby each domain needs to have a minimum amount of capability or systems, and within each domain, we can utilize different "value" parameters.

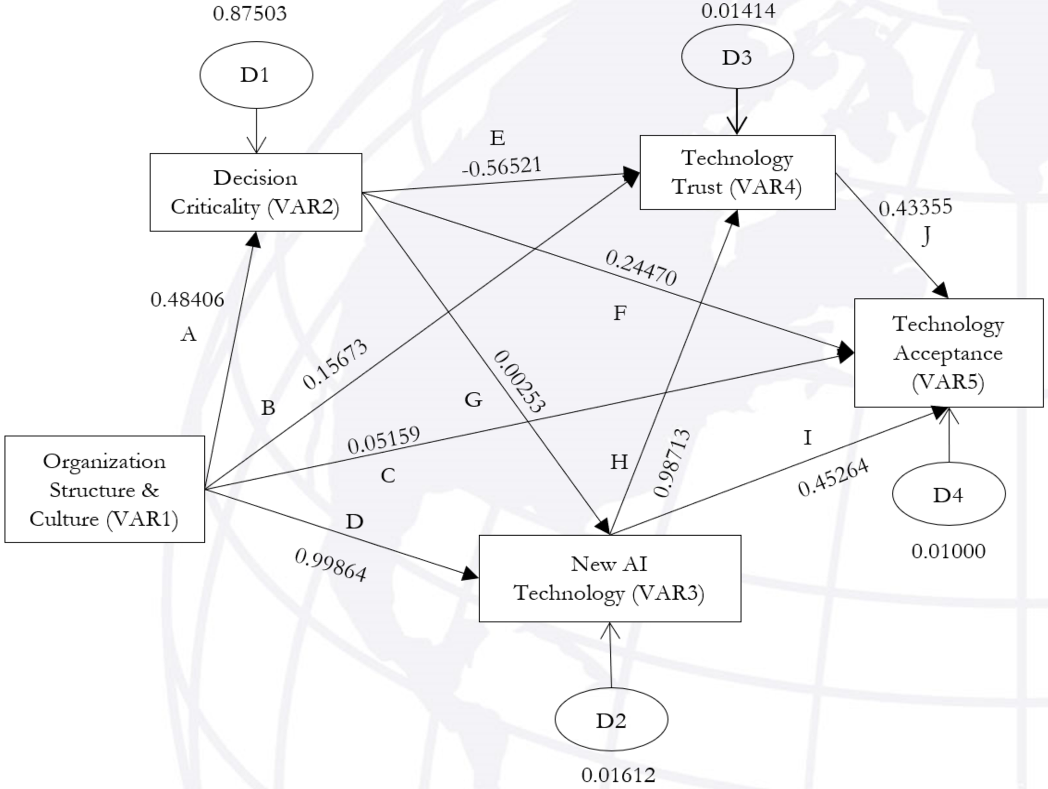
# Technology Trust & Use

Sea Ox & Sea Otter (EOD)



LMACC Lightly Manned Autonomous Combat Capability (Sea Hunter/Sea Strike)



# BACKUP

# AI/ML: MDA, SVM, LIMDEP

AI Machine Learning: Multivariate Discriminant Analysis (Linear) (Supervised)

| Group | 1 | 2 | 3 |
|---|---|---|---|
| Count | **85** | **93** | **66** |
| Prior | **0.3484** | **0.3811** | **0.2705** |

| Classification Results | | True Group | |
|---|---|---|---|
| Put Into Group | 1 | 2 | 3 |
| 1 | **68** | 16 | 3 |
| 2 | **13** | 67 | 13 |
| 3 | **4** | 10 | 50 |
| Total N | **85** | 93 | 66 |
| N Correct | **68** | 67 | 50 |
| Proportion | **0.8000** | 0.7204 | 0.7576 |

N: **244**
N Correct: **185**
Proportion Correct: **0.758197**

| VAR | 1 | 2 | 3 |
|---|---|---|---|
| Global Mean Vector | 15.6393 | 20.6762 | 10.5902 |
| Means of Features in Groups | | | |
| 1 | 12.5176 | 24.2235 | 9.0235 |
| 2 | 18.5376 | 21.1398 | 10.1398 |
| 3 | 15.5758 | 15.4545 | 13.2424 |

AI Machine Learning: Classification with Gaussian SVM (Supervised)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Accuracy | 85% | 85% | 85% | 100% | 100% | 100% | 100% | 100% |
| Omega | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 |

| Forecast | Group | Forecast (Test Vars) | Group (Test Vars) |
|---|---|---|---|
| 1.013598 | 1.00 | 1.013598 | 1.00 |
| 1.013860 | 1.00 | 1.013860 | 1.00 |
| 0.922405 | 1.00 | 0.922405 | 1.00 |
| 0.709851 | 2.00 | 0.709851 | 2.00 |
| 1.016426 | 1.00 | 1.016426 | 1.00 |
| . . . | . . | . . . | . . |
| 0.670190 | 2.00 | 0.670190 | 2.00 |

Generalized Linear Model (Probit with Binary Outcomes)

| | Coefficient | Std. Error | Wald Test | P-value |
|---|---|---|---|---|
| Intercept | **-1.218323** | 0.170237 | 51.2172 | 0.000000 |
| VAR1 | **-0.113973** | 0.016800 | 46.0252 | 0.000000 |
| VAR2 | **-0.033448** | 0.012279 | 7.419795 | 0.006451 |
| VAR3 | **0.013898** | 0.003350 | 17.2135 | 0.000033 |
| VAR4 | **0.092666** | 0.010965 | 71.4226 | 0.000000 |

| | |
|---|---|
| Log-Likelihood | -214.3784 |
| Restricted Log-Likelihood | -285.4773 |
| McFadden R-squared | 0.249053 |
| Cox and Snell R-squared | 0.247531 |
| Nagelkerke R-squared | 0.363593 |
| Raw Akaike Info. Criterion | 438.7567 |
| Raw Bayes Criterion | 459.8298 |
| Chi-Square | 142.1979 |
| Degrees of Freedom | 4 |
| P-value | 0.000000 |

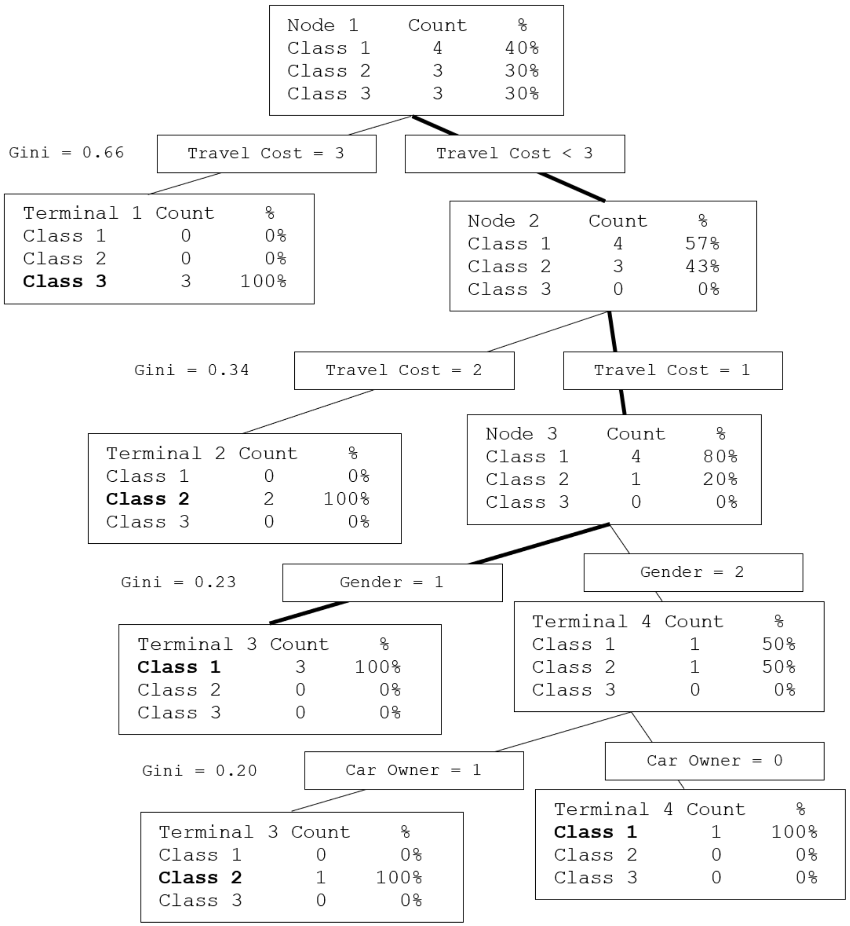
**Confusion Matrix**

| | Predicted Response | |
|---|---|---|
| True Response | y = 1 | y = 0 |
| y = 1 | True Positive TP | False Negative FN |
| y = 0 | False Positive FP | True Negative TN |

| | Predicted Response | |
|---|---|---|
| True Response | y = 1 | y = 0 |
| y = 1 | 70 | 59 |
| y = 0 | 39 | 332 |

| | Predicted Response | |
|---|---|---|
| True Response | y = 1 | y = 0 |
| y = 1 | 64.22% | 15.09% |
| y = 0 | 35.78% | 84.91% |

# AI/ML: CART & GUASSIAN MIX

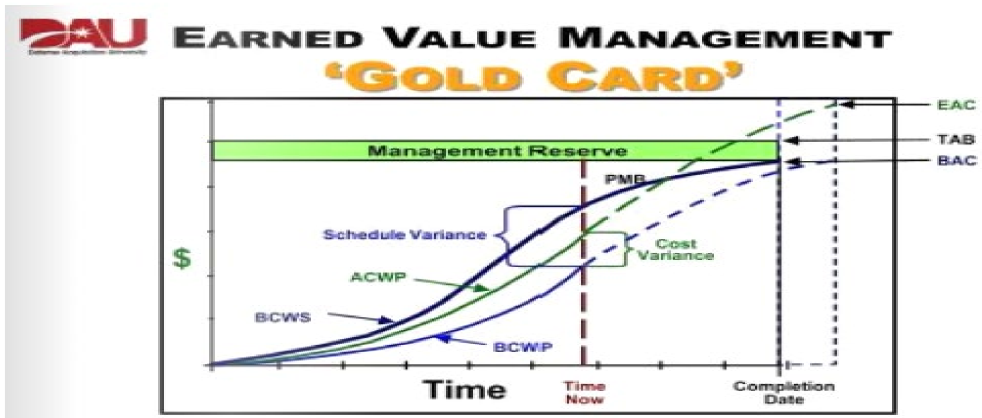


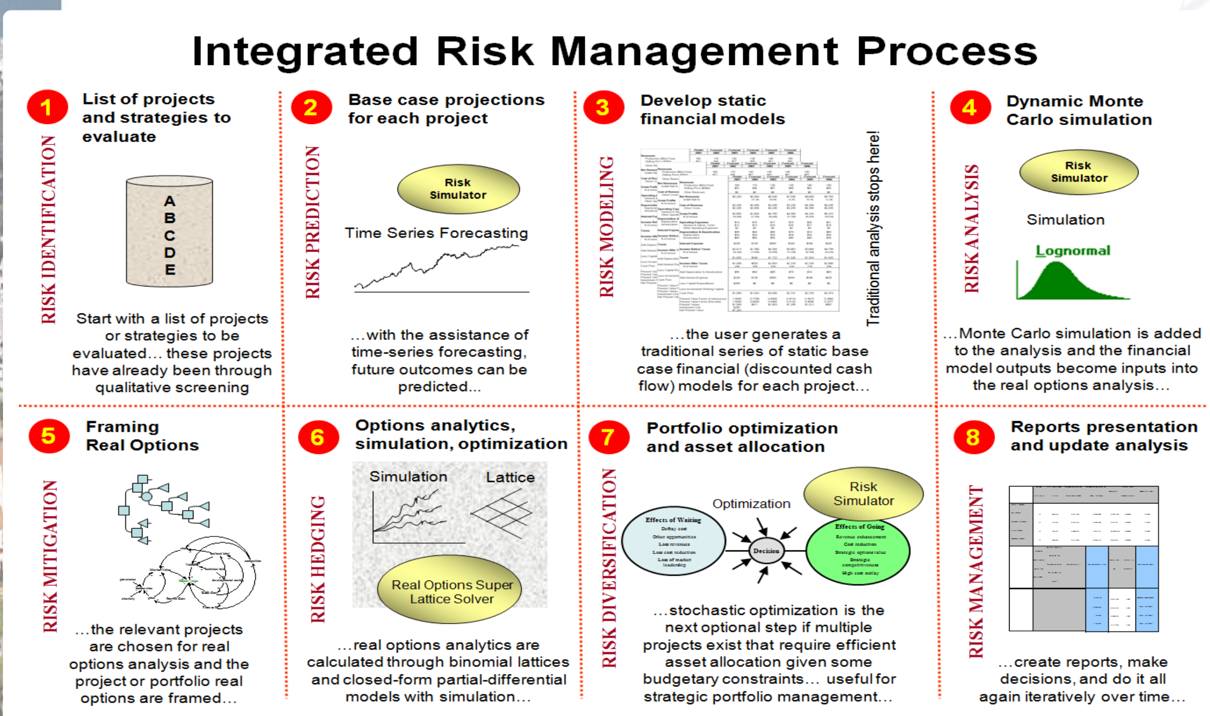

| | Actual Category is X | Actual Category is Not X |
|---|---|---|
| Predicted Category is X | True Positive (TP) | False Positive (FP) |
| Predicted Category is Not X | False Negative (FN) | True Negative (TN) |
| | Positive Sensitivity Recall = TP/(TP+FN) | Negative Specificity = TN/(TN+FP) |

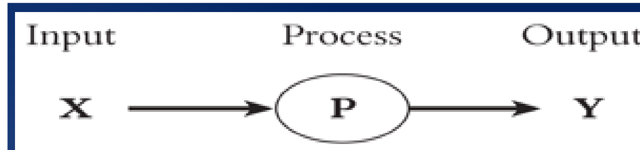
```
AI Machine Learning: Classification with Gaussian Mix & K-Means (Unsupervised)
Log-Likelihood:       -532.6046

K-Means
        Cluster 1     Cluster 2     Cluster 3     Cluster 4     Cluster 5
           10            10            13             7            10

Gaussian Mix Probabilities for Each Row :
        Cluster 1     Cluster 2     Cluster 3     Cluster 4     Cluster 5
         0.9981        0.0000        0.0019        0.0000        0.0000
         1.0000        0.0000        0.0000        0.0000        0.0000
         0.0032        0.0000        0.0000        0.9968        0.0000
         0.0000        0.0000        1.0000        0.0000        0.0000
         0.0235        0.0000        0.0000        0.9765        0.0000
         0.0013        0.0000        0.9850        0.0136        0.0000
          . . .         . . .         . . .         . . .         . . .
         0.0000        1.0000        0.0000        0.0000        0.0000
         0.0000        1.0000        0.0000        0.0000        0.0000
         0.0000        0.0000        1.0000        0.0000        0.0000

K-Means Assignments for Each Row
               1
               1
               4
               3
               4
               3
               .
               2
               2
               3
```

```
AI Machine Learning: Classification Regression Tree (Supervised)


Category      Actual     Predicted     Accuracy
   1            4            4          100.00%
   2            3            3          100.00%
   3            3            3          100.00%

  Training Dataset
 Actual      Forecast          Testing Dataset Forecast
  1.00         1.00              1.00
  1.00         1.00              1.00
  2.00         2.00              2.00
  1.00         1.00              1.00
  1.00         1.00              1.00
  2.00         2.00               . .
  2.00         2.00
  3.00         3.00
  3.00         3.00
  3.00         3.00
```

# EVM to IRM




$P(X) = Y$

Fundamental assumptions:

1. If X = Y no value has been added.
2. "value" ∝ "change"
3. "change" can be measured by the amount of knowledge required to make the change.

So "value" ∝ "change" ∝ "amount of knowledge required to make the change"

| Steps | Learning Time | Process Description | Binary Query Method |
|---|---|---|---|
| One | Identify core process and its subprocesses. | | |
| Two | Establish common units and level of complexity to measure learning time. | Describe the products in terms of the instructions required to reproduce them and select unit of process description. | Create a set of binary yes or no questions such that all possible outputs are represented as a sequence of yes or no answers. |
| Three | Calculate learning time to execute each subprocess. | Calculate number of process description words, pages in manual, and lines of computer code pertaining to each subprocess. | Calculate length of sequence of yes or no answers for each subprocess. |
| Four | Designate sampling time period long enough to capture a representative sample of the core processes final product or service output. | | |
| Five | Multiply the learning time for each subprocess by the number of times the subprocess executes during the sample period. | Multiply the number of process words used to describe each sub process by the number of times the subprocess executes during sample period. | Multiply the length of the yes or no string for each sub process by the number of times the subprocess executes during sample period. |
| Six | Calculate cost to execute knowledge (learning time and process instructions) to determine process costs. | | |
| Seven | Calculate ROK and ROP and interpret the results. | | |

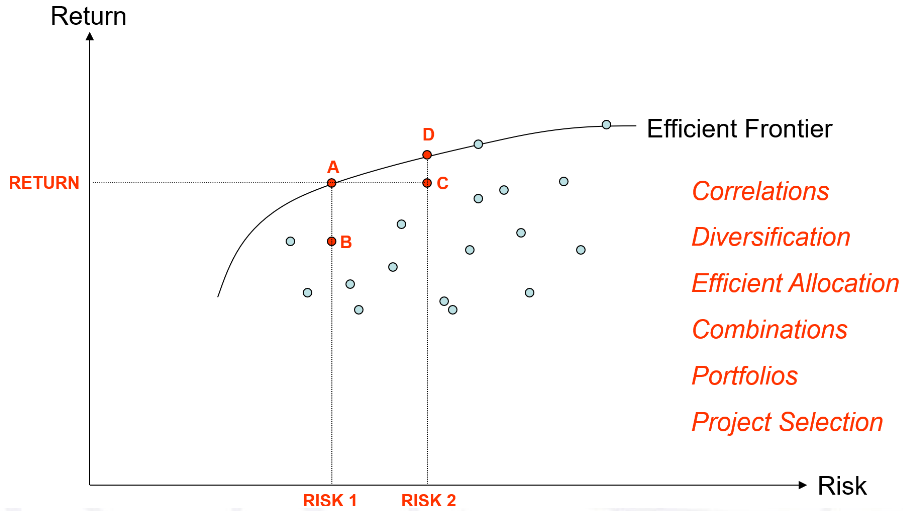
# Stochastic Portfolio Optimization

| Index | 1 | 2 | 3 | 4 | 5 | Count | |
|---|---|---|---|---|---|---|---|
| Model | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | | |
| Objective Function | 1,408,735.7351 | 51.1642 | 53.5600 | 48.1000 | 53.5600 | | |
| Optimized Constraint 1 | 6.0000 | 7.0000 | 7.0000 | 6.0000 | 7.0000 | | |
| Optimized Constraint 2 | 3,800,000.0000 | 4,000,000.0000 | 4,000,000.0000 | 3,750,000.0000 | 4,000,000.0000 | | |
| Option 1 | 1 | 1 | 1 | 0 | 1 | 4 | MH60R |
| Option 2 | 0 | 0 | 0 | 0 | 0 | 0 | CCOPS |
| Option 3 | 1 | 1 | 1 | 1 | 1 | 5 | WEATHER |
| Option 4 | 0 | 1 | 1 | 0 | 1 | 3 | SSDS |
| Option 5 | 1 | 1 | 1 | 1 | 1 | 5 | BMD |
| Option 6 | 0 | 1 | 1 | 1 | 1 | 4 | NIFC-CA |
| Option 7 | 1 | 0 | 0 | 0 | 0 | 1 | SPQ-9B |
| Option 8 | 0 | 1 | 1 | 1 | 1 | 4 | CIWS-CEC |
| Option 9 | 1 | 0 | 0 | 1 | 0 | 2 | RDDL |
| Option 10 | 1 | 1 | 1 | 1 | 1 | 5 | SM-2 BLK |
| | NPV | OPNAV | W/AVG | COMMAND | KVA | | |

Stochastic optimization with Markowitz efficient frontier and efficient allocation of resources with optimal program selection.

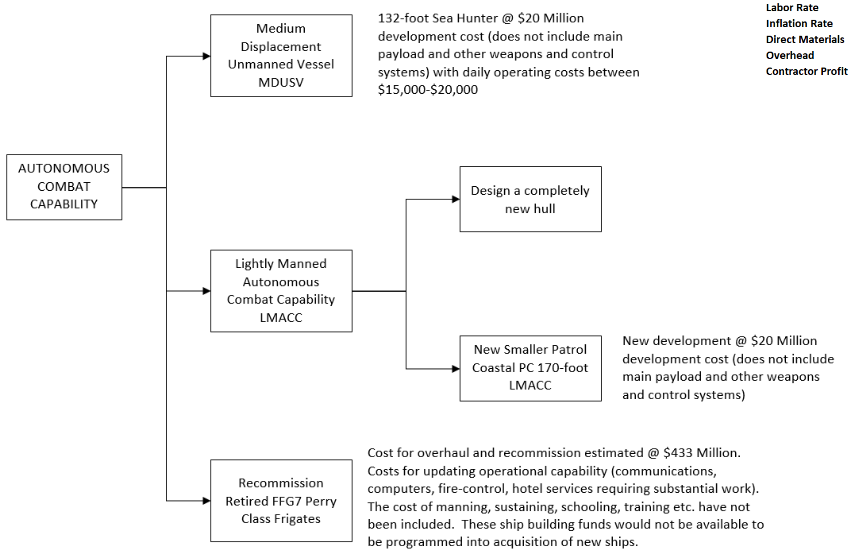
Preference Ranking Organization Methods for Enrichment Evaluations [PROMETHEE], Elimination and Choice Expressing the Reality [ELECTRE] Methods, Multi-Criteria Analysis [MCA], Portfolio Optimization, Hierarchical Scoring-Ranking, etc.

## Diversifying Risk



# Stochastic Predictions

The figures illustrates the analysis of alternatives or strategic options. Based on the pricing policy on PC 14 at the Bollinger Machine Shop and Yard, we were able to extrapolate the data for 1990 to current dollar values (2020) for patrol coastal (PC) boats. The Monte Carlo simulated cost shows a range of $16.4 million to $32 million, with a 90% confidence interval. The range depends on the number of ships, where there is a learning curve (i.e., cost reduces over the course of multiple ships). The figures also show the simulated expected value of PC boats at $23.6 million.




**170 foot Patrol Coastal (PC) by Bollinger Shipyards**

| | 1990 | $11.42 | | | |
|---|---|---|---|---|---|
| | Direct Labor | | Direct Materials & Overhead | | Total |
| **ITEMIZATION** | Hours | Dollar | Materials | Overhead | |
| Hull Structure | 41,734 | $476,602 | $122,800 | $738,733 | $1,338,135 |
| Propulsion Plant | 1,897 | $21,664 | $3,254,200 | $33,578 | $3,309,442 |
| Electric Plant | 6,640 | $75,829 | $307,000 | $117,534 | $500,363 |
| Command and Surveillance | 1,897 | $21,664 | $798,200 | $33,578 | $853,442 |
| Auxiliary Systems | 11,382 | $129,982 | $798,200 | $201,472 | $1,129,654 |
| Outfit and Furnishings | 15,176 | $173,310 | $614,000 | $268,630 | $1,055,940 |
| Armament | 949 | $10,838 | $122,800 | $16,798 | $150,436 |
| Integration and Engineering | 949 | $10,838 | $61,400 | $16,798 | $89,036 |
| Ship Assembly and Support Services | 14,227 | $162,472 | $61,400 | $251,832 | $475,704 |
| **SUBTOTAL** | 94,851 | $1,083,198 | $6,140,000 | $1,678,953 | $8,902,151 |
| **CONTRACTOR PROFIT @ 10%** | | | | | $890,215 |
| **GRAND TOTAL UNIT PRICE** | | | | | **$9,792,367** |

| | 2020 | $23.06 | Inflation | 2.37% | |
|---|---|---|---|---|---|
| | Direct Labor | | Direct Materials & Overhead | | Total |
| **ITEMIZATION** | Hours | Dollar | Materials | Overhead | |
| Hull Structure | 41,734 | $962,359 | $247,959 | $1,491,656 | $2,701,974 |
| Propulsion Plant | 1,897 | $43,744 | $6,570,907 | $67,801 | $6,682,452 |
| Electric Plant | 6,640 | $153,114 | $619,897 | $237,326 | $1,010,337 |
| Command and Surveillance | 1,897 | $43,744 | $1,611,732 | $67,801 | $1,723,277 |
| Auxiliary Systems | 11,382 | $262,462 | $1,611,732 | $406,814 | $2,281,007 |
| Outfit and Furnishings | 15,176 | $349,949 | $1,239,794 | $542,420 | $2,132,163 |
| Armament | 949 | $21,883 | $247,959 | $33,919 | $303,761 |
| Integration and Engineering | 949 | $21,883 | $123,979 | $33,919 | $179,781 |
| Ship Assembly and Support Services | 14,227 | $328,065 | $123,979 | $508,501 | $960,546 |
| **SUBTOTAL** | 94,851 | $2,187,203 | $12,397,938 | $3,390,156 | $17,975,297 |
| **CONTRACTOR PROFIT @ 10%** | | | | | $1,797,530 |
| **GRAND TOTAL UNIT PRICE** | | | | | **$19,772,827** |

| | Min | Likely | Max | Simulation |
|---|---|---|---|---|
| **Manhours** | 65,000 | 94,851 | 125,000 | 94,851 |
| **Labor Rate** | $13.11 | $23.06 | $47.97 | $23.06 |
| **Inflation Rate** | 0.46% | 2.37% | 4.90% | 2.37% |
| **Direct Materials** | $6,140,000 | $12,397,938 | $25,788,912 | $12,397,938 |
| **Overhead** | $1,678,953 | $3,390,156 | $7,051,852 | $3,390,156 |
| **Contractor Profit** | 9.00% | 10.00% | 11.00% | 10.00% |
| | **Total Unit Cost for Ship Only (2020 Dollars)** | | | **$19,772,827** |

**As a basis of comparison, we use the 32 foot Sea Hunter**
**Cost of Sea Hunter in 2020 is approximately $20 Million**