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Course of Action Visualization (COA VIZ): A Concept for Effective Visualization of COAs for Rapid Decision-Making

by Regina Hartnett

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14. ABSTRACT
Course of Action (COA) development and selection in military planning is a multifaceted and demanding process, characterized by complexity and nuance. This phase is crucial, as commanders and planning staff meticulously evaluate various options to achieve mission objectives effectively, especially in today's dynamic and uncertain operational environment. The complexity of modern warfare presents challenges such as data overload, decision fatigue, and the need for rapid decision-making. Effective communication among team members and stakeholders is also critical to prevent misunderstandings and mission failures. This report introduces the concept of using spider charts as a visualization tool to address these challenges in COA development and selection. Spider charts simplify the evaluation and comparison of COAs by visually representing their attributes on a common scale. This approach not only streamlines the presentation of complex information but also facilitates more efficient decision-making. By addressing the complexities of modern warfare, spider charts have the potential to enhance military planning and contribute to mission success. This report explores the challenges associated with COA development and selection in the military, the benefits of using spider charts as a visualization technique, and how this approach can offer commanders a more effective means of making critical decisions. Ultimately, spider charts represent a promising tool to improve the clarity and efficiency of COA development and selection, making it an invaluable asset in the military planning process.

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19a. NAME OF RESPONSIBLE PERSON	19b. PHONE NUMBER *(Include area code)*
Regina Hartnett	(334) 255-2725

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1. INTRODUCTION

Modern military operations often involve multifaceted and dynamic challenges, including asymmetric threats, nontraditional domains, and interagency and coalition partnerships, and often require swift decision-making to respond to rapidly changing situations. Course of Action (COA) development must address these complexities while considering a wide array of variables and potential contingencies (Joint Chiefs of Staff, 2017). COA development and selection in military planning is a multifaceted and demanding process, fraught with complexity and nuance. It represents a crucial phase where commanders and planning staff meticulously weigh various options to achieve mission objectives effectively. COA is a term commonly used in military, strategic planning, and decision-making processes, but it can also be applied in various other fields such as business, emergency management, and project management. COA refers to the different potential plans or strategies that an individual or organization can consider and evaluate when faced with a specific problem, situation, or objective. The modern battlefield is characterized by a dynamic and uncertain operational environment, rife with diverse threats, rapidly changing conditions, and the need for timely, informed decisions. COA consideration is a complex and critical process that demands a deep understanding of the operational environment, comprehensive analysis of potential strategies, and the ability to make informed decisions under often high-stress conditions. This complexity often poses significant challenges to military planners and commanders, who must navigate a plethora of variables, including enemy capabilities, terrain considerations, logistical constraints, mission timelines and the imperative to minimize risks (Joint Chiefs of Staff, 2017).

One fundamental difficulty in COA development stems from the vast amount of information that military planners must contend with. The sheer volume of data, spanning intelligence reports, logistics assessments, weather forecasts, and more, can overwhelm even the most seasoned professionals. Analyzing this extensive and often heterogeneous data can lead to information overload and decision fatigue, impeding the efficiency and efficacy of the COA development process (U.S. Army, 2020b).

Furthermore, the contemporary military landscape places a premium on rapid decision-making. Delayed or protracted COA development processes may leave little room for commanders to respond swiftly to evolving situations and can have detrimental consequences on mission success. The ability to adapt and make informed decisions in real-time is essential for mission success, underscoring the need for streamlined COA development and selection methods (U.S. Army, 2020a).

Effective communication within the military planning team and between commanders and their staff is another critical consideration. Complex data, lengthy briefings, and

intricate plans can lead to misunderstandings and misinterpretations, potentially resulting in mission failures or unintended consequences. Therefore, there is a growing recognition of the importance of presenting COAs in a clear and concise manner that facilitates a shared understanding among stakeholders (U.S. Department of Defense, 2017). It is imperative for commanders and planning staff to explore innovative approaches to streamline the decision-making process while enhancing the clarity and effectiveness of COA comparisons.

In response to these challenges, there is a burgeoning interest in leveraging visualization tools to enhance COA development and selection. One such tool is the spider chart, also known as a radar chart or spiderweb chart. Spider charts can offer a visual representation of COAs, simplifying the process of evaluating and comparing various COAs. By plotting COA attributes on a common scale and overlaying them on a radar-like chart, planners can quickly grasp the strengths and weaknesses of each option. This visual approach not only streamlines the presentation of complex information but also facilitates more efficient decision-making (Singh & Towari, 2022; Dy et al., 2021).

The following sections will delve deeper into the challenges associated with COA development and selection in the military, explore the benefits of using spider charts as a visualization technique, and consider how this approach can offer commanders a more effective means of making critical decisions in the heat of battle. By addressing the complexities inherent in modern warfare, visual tools like spider charts have the potential to enhance military planning and ultimately contribute to mission success.

2. BACKGROUND

COA development and selection is a critical process in military planning, enabling commanders and staff to make informed decisions and execute operations effectively. The development and selection of COAs involve a systematic approach to evaluate potential strategies and determine the most suitable plan to achieve mission objectives. This section provides background on COA development and selection in the military.

Historical Perspective: COA development and selection have been integral to military planning for centuries. Historical military leaders such as Sun Tzu (*The Art of War*) and Carl von Clausewitz (*On War*) emphasized the importance of strategic thinking and planning, which includes considering multiple COAs.

U.S. Army Doctrine: The U.S. Army has a well-defined process for COA development and selection outlined in its doctrine. Army Doctrine Reference Publication (ADRP) 5-0, *The Operations Process* (U.S. Army, 2020a), and Army Techniques Publication (ATP) 5-0.1, *The Operations Process* (U.S. Army, 2020b), provide detailed guidance on these processes.

Joint Military Planning: In joint military operations involving multiple branches of the armed forces, COA development and selection are coordinated efforts to ensure unity of effort. The joint planning process, as outlined in Joint Publication 5-0, *Joint Planning* (Joint Chiefs of Staff, 2017), guides this approach.

Decision Support Tools: Military planners often use decision support tools, such as war-gaming and simulation, to analyze and compare COAs. These tools help assess the feasibility, acceptability, suitability, and risk associated with each COA. The use of such tools is discussed in various military publications, including the *Joint Operations Planning Process* (U.S. Department of Defense, 2017).

Operational Planning Frameworks: The military employs various operational planning frameworks, such as the Military Decision-Making Process (MDMP), which is detailed in Field Manual (FM) 5-0, *The Operations Process* (U.S. Army, 2019), to facilitate COA development and selection. These frameworks provide a structured approach to planning and decision-making.

Interagency and Coalition Operations: In contemporary military operations, cooperation with interagency partners and coalition forces is common. COA development and selection processes have adapted to incorporate the considerations

and requirements of these partnerships, as discussed in joint publications and allied doctrine.

Contemporary Challenges: Modern military operations often involve complex, asymmetric threats and nontraditional domains, such as cyber warfare and information operations. COA development and selection must address these contemporary challenges and incorporate multi-domain operations concepts.

The development and selection of COAs remain a cornerstone of military planning, and these processes continue to evolve to meet the challenges of contemporary warfare. Military doctrine and publications provide the framework and guidance necessary to execute these crucial aspects of operational planning.

The purpose of identifying and assessing COAs is to determine the most suitable and effective approach to achieve desired goals or address challenges. A breakdown of the concepts follows:

1. **Problem Identification or Goal Setting:** The first step in developing COAs is to clearly define the problem that needs to be solved or the goal that needs to be achieved. This step involves understanding the context, constraints, and objectives involved.
2. **Generation of Alternatives:** Once the problem or goal is well-defined, the next step is to brainstorm and generate a range of possible solutions or strategies. These alternatives should be diverse and creative to ensure that all potential options are considered.
3. **Evaluation and Analysis:** After generating a list of alternatives, each COA must be thoroughly evaluated and analyzed. This involves assessing the advantages, disadvantages, risks, costs, and benefits associated with each option. Criteria for evaluation may vary depending on the specific context but can include factors like feasibility, effectiveness, efficiency, and ethical considerations.
4. **Selection of Preferred COA:** Based on the analysis, one or more COAs may stand out as the preferred options. These are the strategies or plans that are most likely to achieve the desired outcomes with the fewest drawbacks or risks.
5. **Development of Detailed Plans:** Once a preferred COA is chosen, it needs to be developed into a detailed plan. This involves outlining the specific steps, resources, timelines, and responsibilities required to implement the chosen strategy effectively.
6. **Monitoring and Execution:** The selected COA is put into motion, and progress is continuously monitored. This involves tracking key performance indicators,

adjusting the plan as necessary, and addressing any unforeseen challenges that may arise during implementation.

7. **Feedback and Adaptation:** Throughout the execution phase, feedback is collected and analyzed. If the chosen COA is not producing the desired results or if new information becomes available, adjustments may be made to the plan.
8. **Completion and Review:** Once the objectives are met or the problem is resolved, a final review is conducted to assess the overall success of the chosen COA. Lessons learned are documented to inform future decision-making processes.

COAs provide a structured framework for decision-making and planning, helping individuals and organizations make informed choices and adapt to changing circumstances. It is important to remember that the effectiveness of a chosen COA depends on the quality of the analysis, the accuracy of assumptions, and the ability to adapt when necessary.

3. COAs IN THE MILITARY

In a military context, the COA is a fundamental component of the planning process for military operations on the battlefield. These actions are developed and assessed to help military commanders and planners make informed decisions and effectively achieve their objectives in a complex and dynamic environment. An explanation of COA on the battlefield follows:

1. **Mission Analysis**: The process begins with a clear understanding of the mission, which includes the commander's intent, the overall objective, and the operational environment. This stage involves gathering intelligence, assessing the enemy's capabilities and intentions, and considering friendly forces, terrain, weather, and other relevant factors.
2. **COA Development**: Once the mission analysis is complete, military planners generate a range of alternative COAs. These COAs are potential plans or strategies that outline how the mission can be executed. COAs may vary in terms of approach, timing, and resource allocation.
3. **War-gaming**: War-gaming is a crucial step in the COA process. It involves simulating and analyzing each COA to identify potential outcomes, vulnerabilities, and risks. War-gaming helps the planning team understand how different COAs may play out on the battlefield and assess their feasibility and effectiveness.
4. **COA Comparison and Evaluation**: After war-gaming, the various COAs are compared and evaluated against specific criteria and commander's guidance. These criteria typically include factors such as the likelihood of success, risk to friendly forces, potential casualties, resource requirements, and alignment with the commander's intent.
5. **Selection of the Best COA**: Based on the evaluation, the military commander and planning team select the best-suited COA. This is the COA that is most likely to achieve the mission objectives while minimizing risks and maximizing the use of available resources.
6. **Plan Development**: The chosen COA is then developed into a detailed operational plan. This includes specifying the movement of troops, allocation of resources, coordination with supporting units, timing of actions, and the establishment of command-and-control structures.
7. **Execution**: Once the plan is finalized, it is executed on the battlefield. This involves deploying troops, executing operations, and adapting to the dynamic and often unpredictable conditions of combat.
8. **Monitoring and Assessment**: Throughout the execution phase, military leaders continuously monitor the progress of the operation. They assess whether the

plan is achieving its objectives and make adjustments as needed in response to changing circumstances.

9. **Feedback and Adaptation**: Feedback from the battlefield, intelligence updates, and changes in the enemy's actions may necessitate adaptations to the plan. Flexibility and the ability to make rapid decisions are crucial in responding to unforeseen challenges.
10. **Mission Accomplishment and After-Action Review**: Once the mission is accomplished or the operation is completed, a thorough after-action review (AAR) is conducted. This review assesses the overall success of the COA, identifies lessons learned, and provides valuable insights for future planning and operations.

COAs on the battlefield are a structured and systematic way for military commanders and their planning teams to make critical decisions under high-stress, dynamic, and often life-threatening conditions. The process allows for flexibility and adaptability while ensuring that military operations are conducted with the best chance of success and the safety of personnel in mind. Previously and currently, commanders and their staff conduct planning and COA consideration using the MDMP.

The MDMP is a systematic and standardized approach used by military commanders and staff to plan and execute operations effectively. MDMP is designed to facilitate informed decision-making, enhance situational understanding, and ensure that military missions are accomplished with precision. It is a structured process that consists of several steps:

1. **Receipt of Mission**: The MDMP begins with the receipt of a mission from higher headquarters. This mission statement outlines the commander’s intent, the mission’s purpose, the operational environment, the concept of operations, and any other relevant guidance.
2. **Mission Analysis**: In this phase, the staff conducts a thorough analysis of the mission. This includes understanding the operational environment (terrain, weather, enemy forces, and friendly forces), identifying constraints and limitations, and conducting a comprehensive intelligence assessment. The goal is to gain a deep understanding of the situation.
3. **COA Development**: Based on the mission analysis, the staff generates a range of potential COAs. These are detailed plans and strategies that outline how the mission can be accomplished. Typically, three or more COAs are developed to ensure a thorough examination of options.
4. **COA Analysis**: Each COA is subjected to a detailed analysis, including war-gaming. Wargaming involves simulating and evaluating each COA to identify

potential strengths, weaknesses, risks, and opportunities. During this phase, the staff considers factors such as force requirements, logistics, intelligence, and anticipated enemy reactions.

5. **COA Comparison**: The staff compares the various COAs to determine which one best aligns with the commander's intent, accomplishes the mission, and minimizes risks. This phase involves a detailed evaluation using specific evaluation criteria and factors, such as feasibility, acceptability, suitability, and the likelihood of success.
6. **COA Approval**: The commander reviews the analyzed COAs and approves one as the COA to be executed. This selected COA becomes the basis for the subsequent planning and execution phases.
7. **Orders Production**: Once the COA is approved, the staff develops detailed orders that provide instructions for the execution of the chosen COA. These orders include task organization, timing, sequencing of actions, control measures, and essential information for subordinate units.
8. **Movement and Maneuver**: The plan is executed on the battlefield, with troops and resources deployed according to the orders. This phase involves the movement and maneuver of forces to achieve the mission's objectives.
9. **Sustainment**: Sustainment involves providing necessary logistics support, including supplies, ammunition, medical care, and transportation, to maintain the operational effectiveness of the forces throughout the operation.
10. **Battle Tracking and Assessment**: The staff continuously monitors and tracks the progress of the operation as it unfolds. This includes assessing the success of individual actions, evaluating the situation, and making adjustments as needed.
11. **Decision Point Review**: Decision points are specific points in the operation where the commander reevaluates the situation and makes key decisions based on the progress of the mission. This may involve adjusting the plan, issuing new orders, or making critical decisions about the operation.
12. **AAR**: After the mission is completed, a thorough AAR is conducted to assess the overall success of the operation. Lessons learned, best practices, and areas for improvement are documented to inform future planning and operations.

The following steps detail the Army Mission Analysis and COA development process using an example of a reconnaissance patrol:

Step 1: Receipt of Mission

- Receive the mission from higher headquarters.
- Understand the commander’s intent and guidance.

- Review the mission statement, which includes the who, what, when, where, and why of the operation.

Example: “Your unit has received a mission to conduct a reconnaissance patrol in Sector Alpha to gather intelligence on enemy activities and report back within 48 hours.”

Step 2: Mission Analysis

- Gather information about the operational environment, including terrain, weather, and enemy capabilities and intentions.
- Identify constraints, limitations, and critical factors that may affect the mission’s success.
- Determine the purpose of the mission and the desired end state.
- Develop the commander's critical information requirements to guide intelligence collection efforts.

Example: “Terrain in Sector Alpha consists of dense forests and rugged hills, which may limit visibility. Weather forecasts indicate heavy rain in the next 24 hours. Enemy forces in the area are known to be well-armed and likely to conduct ambushes. The purpose of the mission is to gather information on enemy strength and positions.”

Step 3: COA Development

- Generate a range of potential COAs that could accomplish the mission. Typically, three or more COAs are developed.
- Each COA should offer a different approach, taking into account the analysis of the mission and operational environment.
- Assign names or designators to each COA for easy reference.

Example:

1. COA Alpha: Conduct a direct approach through Sector Alpha to gather intelligence.
2. COA Bravo: Conduct a flanking maneuver to avoid enemy positions and reach the objective.
3. COA Charlie: Insert a reconnaissance team via helicopter to gather information covertly.

Step 4: COA Analysis

- Evaluate each COA by considering its feasibility, acceptability, suitability, and risk.

- Use war-gaming techniques to simulate how each COA may unfold and identify potential challenges or opportunities.
- Consider factors such as the likelihood of enemy contact, terrain suitability, resource requirements, and potential outcomes.

Example: During war-gaming, it is discovered that COA Alpha is the riskiest due to the likelihood of direct enemy engagement. COA Bravo appears to be the safest but may take longer to reach the objective. COA Charlie offers a chance to gather intelligence covertly but depends on helicopter availability.

Step 5: COA Comparison

- Compare the analyzed COAs to determine which one best aligns with the commander's intent, accomplishes the mission, and minimizes risks.
- Use evaluation criteria and factors established during the mission analysis phase.

Example: After comparing the COAs, the commander decides that COA Bravo aligns best with the intent, as it provides a balance between safety and accomplishing the mission.

Step 6: COA Approval

- The commander reviews the staff's analysis and approves one COA to be executed.
- The approved COA becomes the basis for subsequent planning and execution phases.

Example: The commander approves COA Bravo and issues orders accordingly.

The Mission Analysis and COA development process sets the stage for detailed planning and execution. It ensures that the chosen COA is well-informed and aligned with the mission's objectives while considering the complexities of the operational environment.

Factors assessed during an Army Mission Analysis and COA development process can vary depending on the specific mission and operational context. However, there are several common factors and considerations that military planners typically assess. These factors help in evaluating the feasibility, suitability, and effectiveness of each COA. Here are some key factors that might be assessed:

1. **Enemy Capabilities and Intentions:**

    a. Strength and disposition of enemy forces.
    b. Likely COAs by the enemy.
    c. Threat level and capabilities (e.g., weapons, tactics, intelligence).
2. **Terrain and Weather:**
    a. Terrain analysis, including obstacles and chokepoints.
    b. Weather conditions and their impact on visibility, mobility, and operations.
3. **Friendly Forces:**
    a. Availability and readiness of friendly forces.
    b. Capabilities and limitations of supporting units.
    c. Coordination with adjacent units.
4. **Time and Space:**
    a. Time available for mission execution.
    b. Distance to the objective and required movement rates.
5. **Logistics and Sustainment:**
    a. Availability of supplies, ammunition, and fuel.
    b. Resupply and casualty evacuation plans.
    c. Logistic support requirements.
6. **Command and Control:**
    a. Communication capabilities and limitations.
    b. Command and control structures and procedures.
7. **Risk and Mitigation:**
    a. Assessment of risks associated with each COA.
    b. Risk mitigation measures and contingency plans.
8. **Feasibility and Resources:**
    a. Feasibility of executing the COA with available resources.
    b. Resource allocation and allocation of combat power.
9. **Commander's Intent and Guidance:**
    a. Alignment of each COA with the commander's intent and guidance.
    b. Adherence to the overall mission's purpose and end state.
10. **Legal and Ethical Considerations:**
    a. Compliance with international law and rules of engagement.
    b. Ethical considerations, including civilian protection and cultural sensitivity.

Comparing the factors of different COAs involves a systematic analysis of each COA against these considerations. Here is an example of how this might look:

Example Factors Comparison for COA Selection:

Suppose there are three potential COAs for a reconnaissance mission:

1. **COA Alpha**: A direct approach through dense forested terrain with a high likelihood of enemy contact.
2. **COA Bravo**: A flanking maneuver through open terrain, avoiding known enemy positions but taking a longer route.
3. **COA Charlie**: A covert insertion by helicopter behind enemy lines to gather intelligence.

Assess each COA against the factors mentioned above:

- **Enemy**: COA Alpha has the highest risk of enemy contact, while COA Charlie minimizes it.
- **Terrain and Weather**: COA Bravo offers the easiest terrain, while COA Alpha has challenging forested terrain.
- **Friendly Forces**: All COAs need to consider coordination with friendly units.
- **Time and Space**: COA Charlie may be the fastest due to helicopter insertion.
- **Logistics**: COA Charlie requires air support for insertion.
- **Command and Control**: COA Charlie may require sophisticated command and control for air assets.
- **Risk**: COA Alpha poses the highest risk, while COA Bravo is the safest.
- **Feasibility**: All COAs are feasible but have different resource requirements.
- **Commander's Intent**: COA Charlie aligns with the intent of gathering intelligence with minimal risk.

Based on this comparison, the commander might select COA Charlie as the preferred COA, as it aligns best with the commander's intent and mission requirements while effectively managing risk. However, the final decision would consider all factors and be based on the specific context and commander's guidance.

Normalizing data is a process used to bring different attributes or factors onto the same scale, typically between 0 and 1, making it easier to compare and analyze them. There are various methods to normalize data, but one common approach is min-max scaling. The following steps are used to normalize the factors mentioned in the previous example using min-max scaling:

Step 1: Identify the Range of Each Factor

For each factor, determine the minimum and maximum values within the dataset. Let us assume that the factors have the following ranges:

- **Enemy**: Range from 1 (low) to 5 (high).
- **Terrain and Weather**: Range from 1 (favorable) to 5 (unfavorable).

- **Friendly Forces**: Range from 1 (well-coordinated) to 5 (poorly coordinated).
- **Time and Space**: Range from 1 (ample time and space) to 5 (limited time and space).
- **Logistics**: Range from 1 (abundant resources) to 5 (scarce resources).
- **Command and Control**: Range from 1 (strong control) to 5 (weak control).
- **Risk**: Range from 1 (low risk) to 5 (high risk).
- **Feasibility**: Range from 1 (highly feasible) to 5 (not feasible).
- **Commander's Intent**: Range from 1 (strong alignment) to 5 (weak alignment).

Step 2: Apply Min-Max Scaling

To normalize the data for each factor, use the following formula:

Normalized Value=Actual Value−Min ValueMax Value−Min ValueNormalized Value=Ma × Value−Min ValueActual Value−Min Value

A normalization example for the Enemy factor is as follows:

- For the **Enemy** factor with an actual value of 3 (in the range 1–5):

Normalized Enemy=3−15−1=24=0.5 Normalized Enemy=5−13−1=42=0.5

Here is an example of how to normalize the factors for COA comparison using min-max scaling:

Suppose the following factors apply for three potential COAs:

1. **Enemy Contact Risk** (Scale: High, Medium, Low)
    a. COA Alpha: High (3)
    b. COA Bravo: Medium (2)
    c. COA Charlie: Low (1)
2. **Terrain Difficulty** (Scale: Difficult, Moderate, Easy)
    a. COA Alpha: Difficult (3)
    b. COA Bravo: Moderate (2)
    c. COA Charlie: Easy (1)
3. **Time Required** (Scale: Hours)
    a. COA Alpha: 12 h
    b. COA Bravo: 8 h
    c. COA Charlie: 6 h

To normalize these factors using min-max scaling:

Step 1: Normalize Enemy Contact Risk and Terrain Difficulty:

For both factors, assume that "High" or "Difficult" gets a value of 1, "Medium" or "Moderate" gets a value of 0.5, and "Low" or "Easy" gets a value of 0.

- **Enemy Contact Risk:**
  - COA Alpha: 3 (High) -> 1 (normalized value)
  - COA Bravo: 2 (Medium) -> 0.5 (normalized value)
  - COA Charlie: 1 (Low) -> 0 (normalized value)
- **Terrain Difficulty:**
  - COA Alpha: 3 (Difficult) -> 1 (normalized value)
  - COA Bravo: 2 (Moderate) -> 0.5 (normalized value)
  - COA Charlie: 1 (Easy) -> 0 (normalized value)

Step 2: Normalize Time Required:

For this continuous variable (hours), min-max scaling is used to normalize it between 0 and 1 based on the minimum and maximum values in the dataset.

- Calculate the minimum and maximum values for "Time Required":
  - Min = 6 h
  - Max = 12 h
- Normalize "Time Required" for each COA using min-max scaling formula:
  - COA Alpha: (12 h - 6 h) / (12 h - 6 h) = 1 (normalized value)
  - COA Bravo: (8 h - 6 h) / (12 h - 6 h) = 0.5 (normalized value)
- COA Charlie: (6 h - 6 h) / (12 h - 6 h) = 0 (normalized value)

Now, all three factors are normalized to a common scale between 0 and 1, making it easier to compare them directly. In this example, lower values for normalized factors generally indicate more favorable attributes (e.g., lower risk, easier terrain, shorter time required). However, the specific weight or importance of each factor in the decision-making process would depend on the mission and the commander's guidance.

Spider Chart for COA Comparison

In this spider chart, each factor is plotted on a scale from 0 at the center to 1 at the outer ring for each COA. The factors include Enemy Contact Risk, Terrain Difficulty, and Time Required.

- Enemy Contact Risk:
  - COA Alpha: 1 (High) -> Represented as a point on the outer ring.

    - COA Bravo: 0.5 (Medium) -> Represented as a point at half the distance from the center to the outer ring.
    - COA Charlie: 0 (Low) -> Represented as a point at the center.
- Terrain Difficulty:
    - COA Alpha: 1 (Difficult) -> Represented as a point on the outer ring.
    - COA Bravo: 0.5 (Moderate) -> Represented as a point at half the distance from the center to the outer ring.
    - COA Charlie: 0 (Easy) -> Represented as a point at the center.
- Time Required:
    - COA Alpha: 1 (12 h) -> Represented as a point on the outer ring.
    - COA Bravo: 0.5 (8 h) -> Represented as a point at half the distance from the center to the outer ring.
    - COA Charlie: 0 (6 h) -> Represented as a point at the center.

This spider chart visually compares the factors for each COA, displaying how they differ in terms of Enemy Contact Risk, Terrain Difficulty, and Time Required. It is evident that COA Charlie has the lowest risk, easiest terrain, and shortest time required, while COA Alpha has the highest risk, most difficult terrain, and longest time required. COA Bravo falls in between these two extremes for each factor.

Table 1 shows an example of a unit's Maneuver COAs factors with the original raw data (minutes or numbers) for each factor, while Table 2 presents the normalized values for maneuver COAs for each factor.

Table 1. Maneuver COAs spreadsheet

Factors (minutes, people)	COA A	COA B	COA C	COA D	Min	Max	Range (max-min)	Variable - min COA A	Variable –min COA B	Variable –min COA C
Time before detection	580	569	540	596	540	596	56	40	29	0
Time to mission goals	359	353	361	345	345	361	16	14	8	16
Time to detect enemy	451	449	455	445	445	455	10	6	4	10
Sensor to shooter time	11	7.7	6	10	6	11	5	5	1.7	0
Number of assets used	238	233	235	240	233	240	7	5	0	2
Number of friendly losses	112	106	111	109	106	112	6	6	0	5
Number of enemies killed	250	250	255	235	235	255	20	15	15	20

Table 2. Normalized values for maneuver COAs A–D (variable–min/range)

Key factors	COA A	COA B	COA C	COA D
Time before detection (min)	0.714285714	0.517857143	0	1
Time to mission goals (min)	0.875	0.5	1	0
Time to detect enemy (min)	0.6	0.4	1	0
Sensor to shooter time (min)	1	0.34	0	0.8
Number of assets used	0.714285714	0	0.285714286	1
Number of friendly losses	1	0	0.833333333	0.5
Number of enemies killed	0.75	0.75	1	0
Number of enemies killed[a]	0.25	0.25	0	1

[a] Flipped for consistency of scale direction.

Once these factors have their values normalized, they can easily be plotted on a spider chart. Figure 1 demonstrates an example of the four COAs (A–D) with seven factors identified for comparison for a unit maneuver.

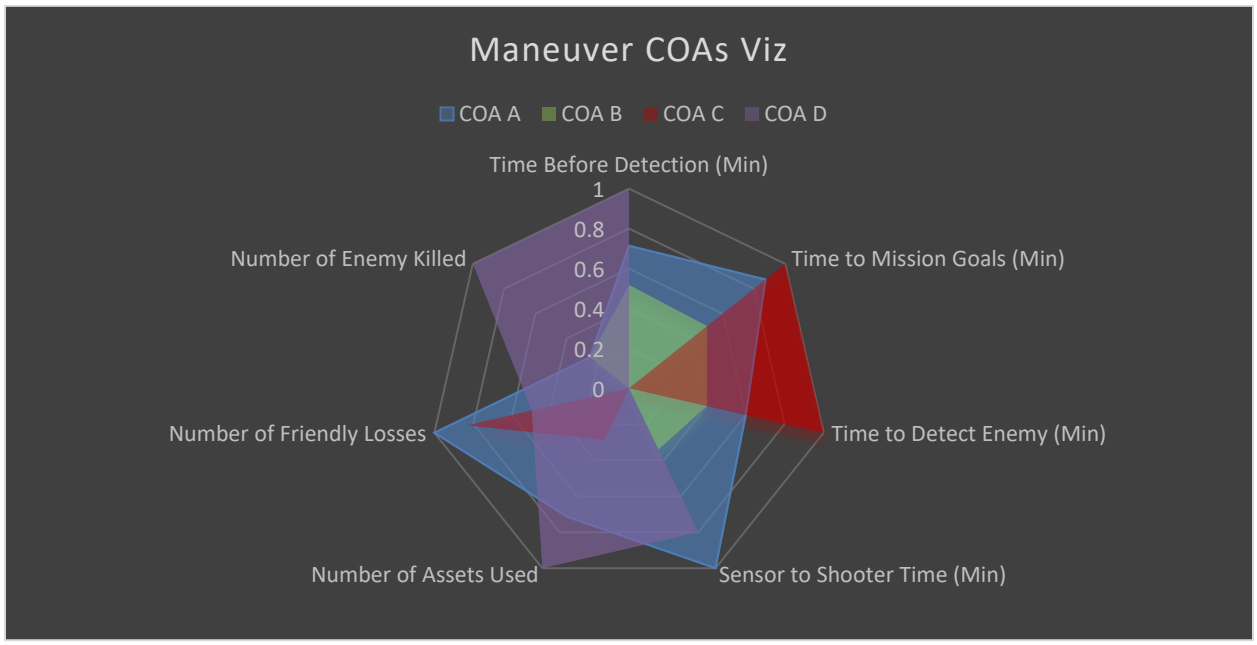

Figure 1. Maneuver COA spider chart

The center of the spider chart is labeled 0 and indicates the lowest risk. The outer ring is labeled 1 and indicates the most risk. Each factor within the COA lies somewhere between 0 and 1 and indicates that factor's risk level. Using this novel technique, a commander can visualize the risks and/or benefits of each factor within each COA. Additionally, commanders can assess the COA as a whole by observing the size of the COA. The way in which these COA visualization (COA VIZ) spider charts are constructed and visualized is such that the size and shape or footprint of each COA on the spider chart is instantly clear and obvious. The smaller the overall COA shape, due

to the individual factors being closer to 0, the lower the risk associated with a particular COA. In this maneuver COA spider chart visualization, COA B has the smallest footprint. The commander can quickly and easily determine that the COA with the smallest risks is COA B. The ability to see the totality of the factors using this visualization technique can reduce workload, increase situation awareness, and decrease decision-making time.

The commander can also dive deeper into each COA and each factor of each COA by showing the actual numbers for each factor and comparing each COA against one another to determine the best COA based on the mission. Figure 2 displays a comparison of COA A and COA B with raw data for easy comparison and understanding.

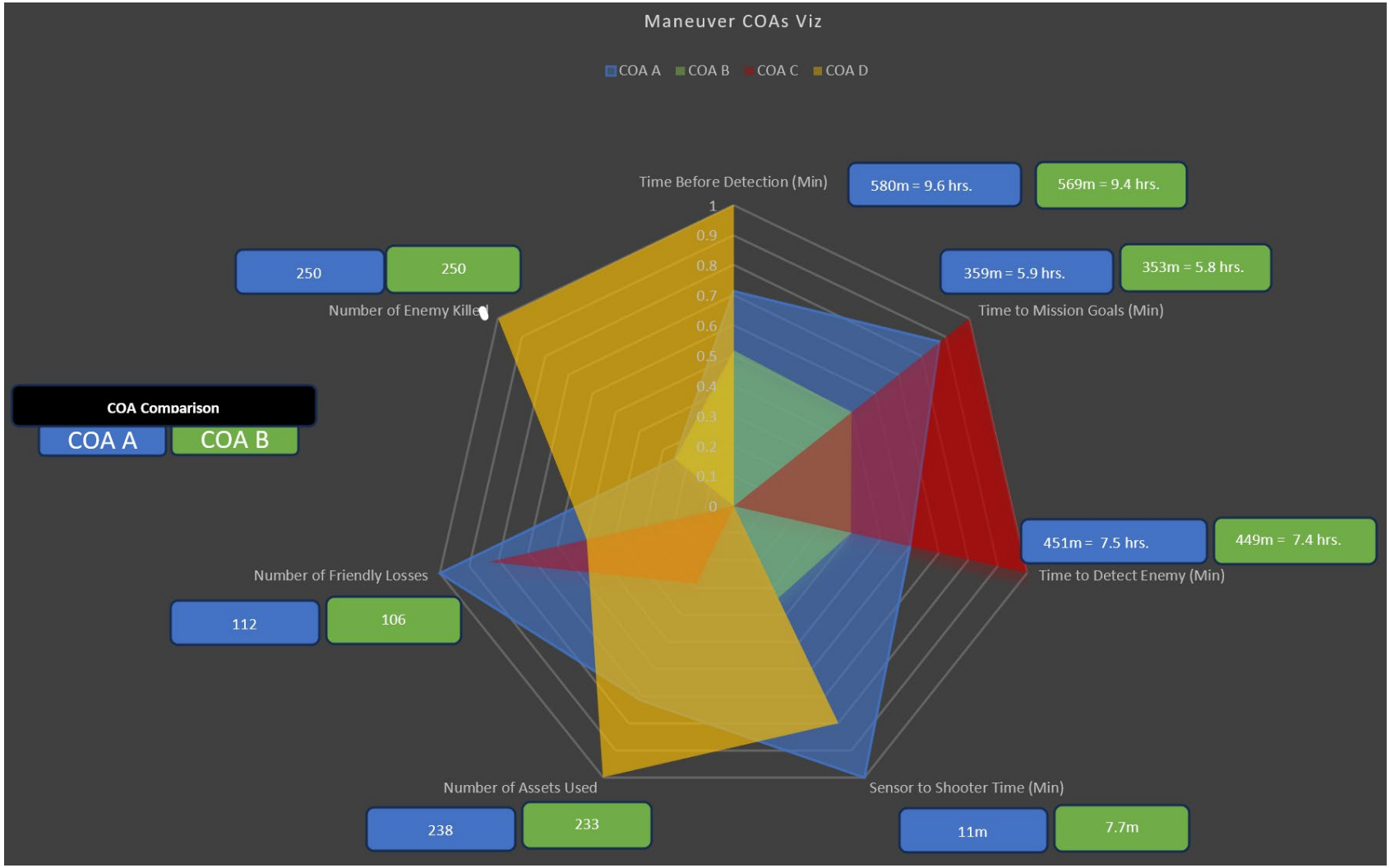

Figure 2. COA VIZ with raw metadata

4. FUTURE RESEARCH

Future research in COA development and selection in military planning offers several promising avenues for investigation:

- **Integration of Artificial Intelligence (AI)**: Research can explore how AI and machine learning algorithms can assist in the analysis of vast amounts of data during COA development. Developing AI-driven decision support systems that can generate and evaluate COAs based on real-time information and historical data could be a significant advancement.
- **Human Factors and Decision-Making**: Understanding the cognitive processes involved in COA selection is crucial. Research could delve into decision-making under stress, individual and group dynamics, and cognitive biases that affect COA development and selection. Strategies for mitigating these factors could be developed.
- **Enhancing Communication Tools**: Investigate advanced communication tools and technologies that can improve the sharing of COAs among military planning teams and between commanders and staff. This includes exploring virtual reality (VR), augmented reality, or immersive decision-making environments.
- **Quantitative Metrics for COA Evaluation**: Develop standardized quantitative metrics and frameworks for evaluating COAs. Research can focus on defining key performance indicators and metrics that can objectively measure the effectiveness of different COAs, allowing for more data-driven decision-making.
- **Cross-Domain Integration**: Examine how COA development can be integrated with other military domains such as logistics, cyber warfare, and diplomacy. This holistic approach may provide more comprehensive solutions.
- **Cross-National Comparative Studies**: Compare COA development and selection processes across different nations and military organizations. This could yield insights into best practices, cultural influences, and variations in approaches.
- **Training and Simulation**: Develop and test training programs and simulation exercises that replicate the complexities of modern warfare and COA development. These programs can help prepare military personnel for real-world situations.
- **Ethical Considerations**: Investigate the ethical implications of using AI and advanced technologies in COA development and selection. This includes addressing issues related to transparency, accountability, and the potential for autonomous decision-making systems.
- **Long-term Effects of COA Selection**: Study the long-term consequences of COA selection, including the impact on civilian populations, infrastructure, and

post-conflict stabilization efforts. Understanding these effects can inform more responsible and ethical decision-making.

- **Human–AI Collaboration**: Explore the dynamics of human-AI collaboration in COA development. Research can focus on how AI systems can complement human decision-making and how trust in AI recommendations can be established.

These future research directions have the potential to advance the field of COA development and selection, making it more effective, efficient, and ethically responsible in the face of evolving military challenges.

Future research on the use of spider charts to evaluate COAs presents the following possibilities:

- **Comparative Analysis of Visualization Methods**: Research can compare the effectiveness of spider charts with other visualization techniques in COA evaluation. This could include methods like decision matrices, flowcharts, or heatmaps. Understanding the strengths and weaknesses of each method can help tailor visualization to specific military planning scenarios.
- **Dynamic Spider Charts**: Develop interactive spider charts that can adapt in real time to changing data and scenarios. This dynamic approach could allow military planners to receive instant feedback on how adjustments to COAs affect their overall effectiveness.
- **User Interface Design**: Investigate the design principles for creating user-friendly interfaces for spider charts and other COA visualization tools. Usability studies can help optimize these tools for military planners.
- **Integration with Geographic Information Systems (GISs)**: Explore how spider charts can be integrated with GIS technology to provide spatial context to COAs. This can help planners better understand the geographical implications of their strategies.
- **Machine Learning for COA Evaluation**: Research can examine the use of machine learning algorithms to automatically generate spider charts based on historical data and real-time information. This could streamline the COA evaluation process.
- **Human-Centered Visualization**: Investigate how to design spider charts and other visualizations that align with the cognitive processes of military planners. This may involve studying how humans naturally process complex information and tailoring visualization accordingly.

- **3D and VR Visualizations**: Experiment with 3D and VR-based visualizations to immerse military planners in virtual environments where they can interact with and evaluate COAs more intuitively.
- **Visualization for Multi-Domain Operations**: Develop visualization techniques that can represent COAs across multiple domains (land, sea, air, cyber, space) simultaneously. This can help planners address complex, multi-domain threats effectively.
- **Collaborative Visualization Tools**: Create collaborative COA visualization tools that allow multiple stakeholders to work together in real time, regardless of their physical location. This is especially relevant for joint military operations involving different branches and agencies.
- **Ethical and Security Considerations**: Research the ethical implications of using advanced visualization tools in military planning, including issues related to data security, privacy, and transparency.
- **Visualization for Education and Training**: Explore how COA visualization can be used in military training programs to teach aspiring officers and planners the art of strategy development and evaluation.
- **Human–AI Collaboration in COA Visualization**: Investigate how AI can assist in generating and analyzing COA visualizations and how human–AI collaboration can enhance decision-making.

These research opportunities can enhance the utility of spider charts and other visualization techniques in COA evaluation, making military planning more efficient, effective, and adaptable in a rapidly changing world.

Based on the complexity and plethora of various missions the military faces, the spider chart may not be the most effective way of visualizing COA evaluation. Often, the commander and his staff want to assess how the mission is progressing and change things on the fly. The ability to assess missions over time may require other visualization techniques to complement the COA VIZ spider chart. The following list outlines alternative visualization techniques for COA evaluation, along with how they compare or complement the use of spider charts as an effective way to visualize and compare COAs:

1. **Decision Matrices:**

   Description: Decision matrices, also known as decision grids, allow military planners to evaluate COAs by assigning numerical values to various attributes and criteria. These values are then used to calculate a total score for each COA.

Comparison to Spider Charts: Decision matrices are more quantitative in nature, providing a clear numerical basis for COA evaluation. However, they may not capture the nuances and relationships between attributes as effectively as spider charts.

2. **Flowcharts:**

   Description: Flowcharts use graphical representations of processes, decisions, and outcomes. They can be adapted to depict the sequential steps and dependencies of COAs, making it easier to understand the logical flow of operations.

   Comparison to Spider Charts: Flowcharts excel in illustrating the sequence and hierarchy of actions within a COA, which spider charts do not emphasize. However, they may not be as effective in capturing the comparative strengths and weaknesses of different COAs.

3. **Heatmaps:**

   Description: Heatmaps use color gradients to represent the relative intensity of attributes or criteria within COAs. They provide a visual summary of where COAs excel or underperform.

   Comparison to Spider Charts: Heatmaps are useful for quickly identifying the most favorable and unfavorable aspects of different COAs. They are less structured than spider charts and may not offer as granular insights into individual attributes.

4. **Network Diagrams:**

   Description: Network diagrams, such as influence diagrams or causal loop diagrams, illustrate the relationships between various factors and their impact on COAs. They are helpful for understanding cause-and-effect dynamics.

   Comparison to Spider Charts: Network diagrams are particularly effective for depicting complex interdependencies between variables, which spider charts do not convey as explicitly. However, they may be more abstract and less intuitive.

5. **Scenario Trees:**

Description: Scenario trees outline the possible outcomes and decision points within each COA, helping planners visualize the consequences of different choices at critical junctures.

Comparison to Spider Charts: Scenario trees are excellent for exploring the potential consequences and contingencies within COAs. They are complementary to spider charts, which focus on attribute comparisons.

6. **Time-Lapse Simulations:**

Description: Time-lapse simulations provide a dynamic visual representation of COAs over time. They show how events unfold, allowing for a better understanding of the evolving nature of military operations.

Comparison to Spider Charts: Time-lapse simulations offer a holistic view of COAs in action, showcasing their temporal aspects. Spider charts, on the other hand, are static and do not capture temporal dynamics.

The choice of visualization technique for COA evaluation should align with the specific needs of the military planning context. Spider charts are valuable for assessing the relative strengths and weaknesses of COAs across multiple attributes in a concise manner. However, they may not be suitable for all aspects of COA evaluation, such as depicting sequential processes or complex causal relationships, whereas other techniques like flowcharts, network diagrams, or time-lapse simulations may be more appropriate. The selection of the right visualization tool should consider the nature of the data, the complexity of the COAs, and the preferences of the military planning team (Dy et al., 2021).

5. CONCLUSION

COA development and selection in military planning are intricate and vital processes that demand careful consideration and adaptation in the face of evolving challenges on the modern battlefield. The dynamic and complex operational environment, coupled with the need for rapid decision-making, has underscored the necessity for innovative approaches to streamline COA development. Moreover, the overwhelming volume of data and the imperative for clear communication further highlight the need for improved methodologies.

The introduction of visualization tools, such as spider charts, represents a promising step forward in addressing these challenges. Spider charts offer a visually intuitive way to present and compare COAs, simplifying the decision-making process and enhancing the understanding of complex information. By providing a concise and comprehensible representation of COA attributes, commanders and planning staff can make more informed decisions under high-stress conditions.

In an era where adaptability and efficiency are paramount, leveraging visualization tools like spider charts holds great potential for enhancing military planning. This report explores the intricacies of COA development, the advantages of spider charts as a visualization technique, and how this innovative approach can empower commanders to make effective decisions in the heat of battle. Ultimately, by embracing these tools and methodologies, we can better navigate the multifaceted landscape of modern warfare and contribute to the success of military missions.

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LIST OF ACRONYMS

AAR	after-action review
ADRP	Army Doctrine Reference Publication
ATP	Army Techniques Publication
COA	Course of Action
COA VIZ	Course of Action Visualization
DAC	DEVCOM Analysis Center
DEVCOM	U.S. Army Combat Capabilities Development Command
FM	Field Manual
GIS	Geographic Information System
MDMP	Military Decision-Making Process
VR	virtual reality

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