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Applications of Operation Research in Military

Operations Research – In Defense and Military Operations

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I. INTRODUCTION:

As the ultimate tool for national security, the armed forces are essential. To protect the nation, its critical national interests, and its values against internal and foreign (current or potential) threats of military aggression, defense services are required. In the actual world, a weakly armed nation that is unable to defend itself cannot continue to exist as a sovereign state.

In the present day, the military plays a crucial role in establishing a safe international environment that is conducive to economic progress. Any nation's armed forces are responsible for defending its borders, whether they be on land, in the sea, or even in the air. The army has a sizable contingent of soldiers guarding the frontiers. Any nation's naval force is tasked with fighting on, beneath, or above the water, while the air force engages in air warfare to seize control of the atmosphere. Numerous opportunities exist for various operations falling under these sectors to be optimized in order to increase the effectiveness and power of these forces. Utilizing operations research tools will allow for these optimizations. In reality, the modern profession of operations research emerged during World War 2 in an endeavor to provide diverse armed forces with the best solutions and decision-making tools.

II. LITERATURE REVIEW:

1. Air Force Crew Scheduling: An Integer Optimization Approach
(Matthew J Koch.,2021)

Integer optimization is a natural technique to describe the CRP because the goal is to allocate pilots to flights. The three most important limitations are that there must be an adequate number of qualified pilots, both in terms of quantity and quality, and that no pilot may be assigned to trips that overlap. Integer optimization helps minimise the effects of these limitations.

2. Sortie Optimization and Munitions Planning
(Gerald G. Brown et al, Dennis M. Coulter et al, Alan R. Washburn.,1994)

The problem of incorrect assortment of sorties and loading of weapons can be solved by using large-scale non-linear programming. The single-period objective is to maximise the estimated destroyed target value over the forecast weather states by allocating sorties that use the best delivery techniques for each weather condition with the available aircraft and weapon stocks.

3. Applied Game Theory to Improve Strategic and Tactical Military Decision Making
(Fox, J Def Manag.,2016)

In order to simulate human decision-making in competitive contexts, game theory uses mathematics. By employing game theoretic analysis to forecast how a cunning adversary would behave in a particular scenario, analysts can ascertain which side is most likely to prevail. Military strategists can determine the amount of capability required to get the best results for their side with the help of these kinds of information.

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4. A Review of Operations Research Applications in Workforce Planning and Potential Modelling of Military Training
(Jun Wang.,2005)

It infers us how different kinds of Models can fix the problems of ineffective workforce planning, insufficient people and their unattained potential leading to unaffordable costs of hiring, recruiting, promoting and assigning workforce to respective best suited work. Markov chain model, Simulation Model, Optimising Model and System Dynamics are four major models used for cost-effective strategic planning and decision making.

5. Growth of Military Operational Research in India
(N.K Jaiswal.,1994)

Operation Research tools helps in areas like selecting and acquiring weapons, evaluating tactical plans, system modification and improvement, designing and developing weapon systems, war games etc. The cost effectiveness ratio of Measure of Effectiveness (MOE) and Total System Cost (TSC) is majorly used for selecting, acquiring, evaluating and taking a decision for a particular plan. Mostly used for performance evaluation, Management, Mission Planning, Navigation, Digitization, and most importantly Decision Making.

6. **Large-Scale Optimization Planning Methods for the Distribution-of United States Army Munitions**
(S.J Clark et al, C. Barnhart et al, S.E Kolitz.,2004)

A large Scale Optimization Model based on Dantzig - Wolfe decomposition has been used to facilitate the movement of ammo and other materials through various stages and parts of the ship as quick as possible.

7. Large-Scale Optimization Planning Methods for the Distribution-of United States Army Munitions 2004
(S.J Clark et al, S.E. Kolitz et al, C. Barnhart.,2004)

A Mixed Integer Linear Program (FHAM) has been used by Aviation commanders to balance his operational and training needs against his maintenance efforts through allocation of flight hours, resources and maintenance hours

8. Using Game Theory to Analyse Operations Against Time-Critical Targets
(RAND Corporations Research Briefs.,2004)

Game theory has been used by military leaders to calculate and determine the optimum strategies during Time critical target missions to get their expected results.

9. Two-stage layout–size optimization method for prow stiffeners
(Zhijun Liu et al, Shingo Cho et al, Akihiro Takezawa et al, Xiaopeng Zhang et al Mitsuru Kitamura.,2019)

Layout Optimization Tool was used to reduce expenses while increasing efficiency in work and productivity while constructing military ships systems which have multiple design layers.

10. Topology optimization of an oil tanker bulkhead subjected to hydrostatic loads
(Md. Shahidul Islam.,2021)

A Topology Optimization Tool was used by the Naval architects to reduce the price while boosting cargo capacities and space constraints.

11. Optimization of Naval Ship Compartment Layout design
(Adam J. Thomas.,2008)

Naval architects used Layout Optimization Tools to create objectively constructed layouts to mee the requirements of a modern warship while also reducing the expenses.

III. FINDINGS AND ANALYSIS:

Following are our tool wise findings and analysis from our research and their applicability –

1. Game Theory: In war situations the outcome of a participant's action is based on the actions of other participants. It helps in comparing all the alternatives available and the effectiveness of those alternatives on both the parties. It is called 'Two-person Zero sum' where the net effect remains zero and the outcomes are favourable for the one who thought about the counterpart's reaction and made a decision in time accordingly.

Military strategists may utilize game theory to integrate these concepts into TCT (Time Critical Targets) operations. In order to discover the best strategy and aid in decision-making, game theory comprises analyzing tactical choices, giving opponents numerical values, and calculating potential plans. This may be used by analysts to identify which side has the best chance of winning and to forecast how a cunning adversary would behave in a certain situation. If both parties appropriately appraise the situation, the losing side may choose to withdraw from the engagement. If

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the chances of handing the attacker major losses in a basic SEAD (Suppression of Enemy Air Defenses) battle are slim, the defense may determine that safeguarding his SAMs (Surface-to-Air Missiles) is more important than attempting to shoot down strike aircraft. These kinds of information help military strategists decide what degree of capability is required to achieve the best outcomes for their side. Military strategists can determine the amount of capability required to get the best results for their side with the help of these kinds of information.

2. The Game of Chicken: We know that everyone makes strategies to take decisions. Here also, each participant has their own set of strategies – best case, worst case, compromise etc. The final outcome would depend on what choices do the participants make and at what time. The outcome would be different if the decisions are made simultaneously and would vary if the decisions are made one after the other acting.

3. The Prisoner's Dilemma: In a particular war situation, both parties can have a dilemma of taking a particular action or not, because there would be repercussions of their own actions too, and these consequences could last for a long time too. So, the decisions depend on what results are expected and with what time constraints.

4. Markov Chain Model: It gives us the probability of which state a Markov process will be in at the next moment is determined by current state which are independent of time and their being. It helps in promotion and recruitment procedures to maintain given class proportion structure.

5. Simulation Model: It is a "What if" answering model, which uses situations and different inputs to find what kind of outcomes they would produce. These are mostly used in training and pre training period. Types like Dynamic or Static, Stochastic or Deterministic, Discrete or Continuous depending on the nature of the problem and the type of solution it would need.

6. Optimizing Model: Four types of programming models such as – Linear programming, Integer programming, Goal programming and Dynamic programming. In these models, the main goal is to optimize the solution to its full potential and find the best possible outcome, keeping given constraints in mind.

The linear mixed-integer programme the number of hours till maintenance, the minimum number of hours for a firm, and the minimum and maximum number of flight hours flown throughout the planning cycle are among the data that FHAM employs. FHAM starts the following month with the same conditions as the previous one. FHAM offers a continuous state flow into maintenance, eliminates the problem of phase maintenance backlogs, and improves battalion deploy ability. The maximum monthly flying hours for each aircraft are set by FHAM to be the lesser of 30 or the number of remaining flight hours before phase. The minimum number of flight hours for an aircraft is set by FHAM to be either 3 or the number of flight hours left before phase. As a mechanism for allocating flying hours, FHAM has the adaptability and skills required.

7. System Dynamics: These help in supply chain modelling and management which has non-linear complexities. It considers dynamic behaviors which affect our analysis of demand and changing ordering and production. Large problems were created because of these gaps and thereafter diagrams like Cause Loop Diagram (qualitative) and Stock and Flow Diagram (quantitative) were used to solve them.

8. Non-Linear Programming: The technique of addressing an optimization issue where part of the constraints or the objective function are nonlinear is known as nonlinear programming (NLP). The calculation of an objective function's extrema (maxima, minima, or stationary points) across a collection of unknowable real variables while requiring the fulfilment of a set of constraints is known as an optimization problem.

The single-period objective is to maximize the estimated destroyed target value over the forecast weather states by allocating sorties that utilize the best delivery techniques in each weather condition with the available aircraft and weapon stocks.

9. Topology Optimization: Engineers use topology optimization tool to break away from classic design and manufacturing methods. It helps to create an innovative design which will cost less, work better, and/or save time. The benefits of topology optimization; better fuel efficiency as there is less energy required to

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put parts in motion because of lower friction, lower packaging and transportation costs, less heavy machinery necessary for assembly lines.

10. Layout Optimization: It is a well-known and challenging operations research problem that arises in various applications. An efficient layout can facilitate an increased flow of work, information and material around the site. If the layout is not designed with efficiency in mind, it can limit production, slow processes and impact overall profitability.

11. Dantzig-Wolfe Model: They employ a massively scalable formulation via Dantzig-Wolfe decomposition-based planning technique. Each commodity type used in ammunition has its own specific planning issue. Using optimization approaches, paths through the time-space network are built for each. After these routes have been created, the master problem, another optimization model, is solved to determine the best possible collection of paths. The time-space network's ammunition is traversedby each ammo item using a heuristic planning technique. Additionally, it arranges for ships to transport the flow of munitions along the directed arcs planned for in the time-space network's architecture. Obtaining "good" workable answers that may be utilized to start the optimization planner is the goal of the heuristic approach. The optimal schedule segment is then selected by the optimization planner starting at the POE (point of embarkation) and continuing through the storage to the POD (point of debarkation). The heuristic determines the maximum loading and unloading time for each shipload based on the throughput capacity of the ports and the amount of munitions in each shipload. These planning algorithms are crucial for organizing a regulated strategy for the best and fastest deployment of emergency munitions.

12. The Linear Mixed-Integer Programme: The number of hours till maintenance, the minimum number of hours for a firm, and the minimum and maximum number of flight hours flown throughout the planning cycle are among the data that FHAM employs. FHAM starts the following month with the same conditions as the previous one. FHAM offers a continuous state flow into maintenance, eliminates the problem of phase maintenance backlogs, and improves battalion deployability. The maximum monthly flying hours for each aircraft are set by FHAM to be the lesser of 30 or the number of remaining flight hours before phase. The minimum number of flight hours for an aircraft is set by FHAM to be either 3 or the number of flight hours left before phase. As a mechanism for allocating flying hours, FHAM has the adaptability and skills required.

IV. CONCLUSION:

Government, business, and industry all make extensive use of the principles and methods of operations research.Every military in the world continues to use operations research to enhance its operations management across a variety of deployed strategies.

The Defense Science Board Study completed an extensive technical review of the full spectrum of national capabilities needed to manage escalation and deter adversary aggression. The Study findings emphasized creative ways and means using operations management beyond traditional weapons systems to achieve National Defense Strategy objectives.The four technical domains covered by these conclusions are cyber capabilities, new military multi-domain capabilities, information capabilities, and economic/commercial capabilities.The report provides key recommendations that align with the establishment of strategic engagement campaign leadership and harmonization of these capabilities at the whole-of-government level.

Military OR has been carried out to many critical troubles together with the complicated trouble of scheduling the airlift of 3,50,000 troops and loads of lots of tonnes of shipment in more, than 11,500 missions earlier than and throughout the Gulf War, army balance in a multi-polar world, impact of command, manipulate and verbal exchange on fight dynamics, etc. There have now no longer been any extreme compulsions in our context however with growing competition, constraints, uncertainties and international dependencies to have an effect on choice making, there may be an extra want to contain an interdisciplinary crew of analysts such as Military OR specialists and pc scientists. The want for bringing in cost-effectiveness in our choice making, quantification in region of qualitative appreciation, and higher interplay among analysts and control via the increase of computer technology era is being appreciated.

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V. LIMITATIONS/RECCOMENDATIONS:

Following are the limitations of operation research in defense are following –

1) Higher cost: It has a high upfront cost for everything, including research and analysis, professional assessment, and other fees. Due to detailed study of the application in defense, many a times organisations have to appoint official consultants and professionals for it.
2) Technological dependence: Every analysis requires technological attention, and if technology fails or if there is a loss of records, the confidential data of the military would be affected and become a threat for the country.
3) Reccomeded use of application of measures which help to measure the effectiveness of the supply of important repair items for an aircraft or weapon system. It can be measured in the terms of expected number of aircraft grounded because of supply shortages.
4) Increasing the capabilities of the analysis so as to enable comparisions to be made with other organizations or institutes for know-how and methodology.
5) Introduction of war games and developing them would be a great milestone for the institutes because the games are based on applied operation research in defense.

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