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Review

Decision support system for optimum decision making process in threat evaluation and weapon assignment: Current status, challenges and future directions

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ABSTRACT

While advancement trends in 'Decision Support System' have frequently been reported in air defense literature, a gap still exists to present a holistic viewpoint for management of threat evaluation and weapon assignment (TEWA). This study reviewed 156 papers from peer reviewed journals and conference proceedings published during 1975 to 2016. The current status of TEWA indicates several challenges associated with decision support system, most notably, application of technological advancement for the better human control in critical time constraint situations. For better decision making and overcoming human limitations, the technological advancements in decision support system are promising. This paper proposes a new approach and presents a combination of decision support system and threat perception, with simultaneous evaluation, neutralization, weapon supply, inventory and assignment. In this study, we have reviewed the evolution in development of threat neutralization systems which have been attempted or developed to date. From practical perspective, the study provides a design overview of the existing methods, highlights features/merits of the approaches used in decision support system development. We have also discussed the current challenges regarding such applications and proposed a new approach for efficient and effective TEWA. The proposed approach elucidates the significance of the inclusion of new parameters identified in literature review. Some of the important features of proposed TEWA-DSS are: (1) GIS mapping of vulnerable assets/points (VA/VPs), (2) Weapon Deployment (WD) based on criticality of VA/VPs and using forecasting techniques, (3) Threat Perception (TP), and evaluation, (4) operating tactics, (5) Weapons Selection (WS) based on its supply chain and inventory management using forecasting methods and (6) optimum and cost-effective Weapon Assignment (WA). The SWOT analysis of the proposed model shows the significance of this model. Moreover, the model implementation using Simon and Turban phases of decision making processes showed that the proposed TEWA strategy is an effective and efficient tool for the identified problem of optimum decision making. This study will catch the attention of researchers working on DSS and open new horizons to bring remarkable improvement in existing system by incorporating the missing parameters.

1. Introduction

Fast changing national strategic interests, depleting value systems, terrorism and high pace of technological development have increased the lethality of threat to an unimaginable level. Information Technology (IT) enabled processes enhanced the accuracy of threat forecast and mitigation. Deployment of weapons and engagement of targets in contemporary arms have gained strategic status. The institutionalization of evaluating strategic national security challenges has revolutionized the decision system and made the task much harder (Azimirad & Haddadnia, 2015; Gandee, 1986).

In real time environment, Air Defense (AD) has been intriguingly linked with Strategic Cognitive Decision-Making (SCDM) process (Liebhaber & Feher, 2002; Naseem et al., 2014) requiring multiple parameters like threat potency, resource constraints (Bell et al., 2011; Roux & Vuuren, 2008) and seeking optimal solution

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based on accurate Threat Evaluation and Weapon Assignment (TEWA) (Azimirad & Haddadnia, 2015; Dahlbom & Helldin, 2013; Schwenn et al., 2015). TEWA is considered core component of Air Defense system (ADS). In a military domain, threat identification (Riveiro et al., 2014) and weapon assignment (WA) is the responsibility of humans (Daniel, 1979; Kangaspunta et al., 2012; Metler & Preston, 1990). Most of the time, there are critical instances where prompt decisions (Azak & Bayrak, 2008; Bloom & Chung, 2001) are required for effective neutralization of threats (Bayrak & Polat, 2013) and protection of vulnerable areas (Bell et al., 2011; Kharal, 2010).

Analysis of threat evaluation (TE) process reveals that intruder's approach to identify and hit targets is crucial in creating defense response and therefore summons a careful impact analysis. The defender must keep contingent options and solutions (Dahlbom & Helldin, 2013; Jorgensen & Strub, 1979; Nasaruddin & Latif, 2013; Riveiro et al., 2014). Although computer aids are available to the operators yet threat analysis entails high risk (Nasaruddin & Latif, 2013; Riveiro et al., 2014; Roux & Vuuren, 2008). The wrong perception, estimation and calculation in TEWA can result in worst-case scenarios (Azak & Bayrak, 2008; Azimirad & Haddadnia, 2015; Naseem et al., 2014). In real-time environment, TE process is considered challenging under normal conditions and possibly worse under extreme situations due to limited time, stress and multi-tasking demands. Ultimately, it is the responsibility of human operators (Berthelemy et al., 2002; Daniel, 1979) to perform data analysis and propose recommendations on basis of data provided for TE thus entailing high risk and complexity (Deng et al., 2010; Erlandsson & Niklasson, 2014; Naseem et al., 2014; Riveiro et al., 2014). It may propagate uncertainty and risk making it imperative to reduce the cognitive load on operators while enhancing threat assessment and decision making (Azimirad & Haddadnia, 2015; Riveiro et al., 2014).

Military commands heavily rely on automated and semi-automated defense tools to match with the pace of global technology challenges (Kosiakoff et al., 1975) assuring infallible homeland security and territorial sovereignty (Brown et al., 2001; Nilsen, 2012). Existing semi-automated mode of TEWA can prove too risky due to the limitations of human mind and effect of external variables of stress, time and memory retrieval. It is rational to support decision making process with full automation and least human interference with a view to avoid fatal errors that may jeopardize the whole AD.

The study audits existing decision process and suggests a better strategy for optimal decision support system. The proposed approach encompasses the significant parameters of supply chain and inventory management in TEWA-DSS. These are the parameters that play an imperative role in making decisions among various alternatives in time critical situations. Many authors studied the importance of these parameters in defense sector separately, but no specific study could be found that integrates both of these parameters with TEWA-DSS. This research addresses the situation, analyzes the research gap and proposes a strategy that is likely to outperform the previous techniques and opens the new horizons for the researchers.

This paper is divided into five sections. Section 1 comprises of introduction. Section 2 explains the materials and methods for this study. Section 3 describes the review of DSS based TEWA developments in defense applications. Section 4 presents the challenges in current decision support systems and presents the proposed strategy. Finally, the conclusion and future directions are presented.

2. Materials and methods

No specific review study has been found in the context of DSS for TEWA. It was difficult to find the appropriate time period from which articles would be collected to review in this paper. A systematic search strategy was used to find the maximum studies have been done in last many years. During search, it is observed that the most of theories proposed were in 1980s onwards. Therefore, the TEWA-DSS literature search has been conducted from 1975 to 2016. The multiple bibliographic databases were searched including JSTOR, ProQuest, ISI and Scopus. The bibliographies were scanned for existing reviews and eligible studies. The publisher journal websites used for the collection of studies are Elsevier, Science Direct, Springer Link, Wiley Online Library and Oxford Journals. The conference proceedings were also scanned to get maximum related studies. There were few studies which were most relevant and the citations in those studies assisted in getting more relevant literature. The specific keywords for TEWA-DSS search included "threat evaluation", "weapon assignment", "decision support system", "threat perception", "weapon deployment", "optimum", "strategic management", "critical decision making", "air defense system", "resource allocation in defense", "operational performance", "intelligent systems", "logistics", "military studies", and "command and control" . The Boolean operator "AND" has been used to narrow the scope of the literature search. In this way, the only related studies were found in search process. The only articles included were published in English, in peer reviewed journals and conferences. None of the review paper based on TEWA-DSS could be found to include in this study. No conference abstracts, even if published, were included in this study.

Primarily, a total of 164 articles were collected during search process. Then, a total of 139 articles were identified as potentially relevant based on TEWA-DSS and included in this study. The other 25 articles were not more relevant to the specific study. Therefore, these articles were excluded from the review. All relevant articles were acquired in full length. Initially, the papers with more citations were studied. Furthermore, the other articles were analyzed. While reviewing these articles, approximately 17 additional references were discovered by checking the reference sections of more cited articles. These additional references have been missed in primary search. A total of 156 articles were reviewed in this review paper. It is attempted to include all articles matching the stated criteria. All new articles published up to the point of the final draft of this manuscript were reviewed. Articles were categorized into four sections: Strategic Management, Air Defense, Critical Decision Making and Decision Support System. Within each category, authors read each paper, summarize the relevant points for the evidence tables, find the relation with TEWA-DSS and made comparison study as shown in Tables 1–3.

3. Review of DSS based TEWA

3.1. Concept map

TEWA-DSS is a critical system that keeps the interaction of a dynamic and non-deterministic environment. It contains intelligent threat detection, identification and assessment with weapons allocation/scheduling. There are different concepts related to TEWA-DSS as follows:

3.1.1. Air Defense System

Air Defense System (ADS) on land comprises of two major components; mobile pieces in air and composite installations on ground. This research paper focuses on the land based composite system as a part of Battle Emergency Management Control System (BEMCS). The focal concern of any ADS is to create effective denial to any invader (air craft, missile, drones etcetera) with remote detection and allocation of weapons for engagement. Such systems primarily turn to maximize air threats neutralization with effective

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