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Evaluating Defense Architecture Frameworks for C4I System Using Analytic Hierarchy Process

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Abstract: Problem statement: The Command, Control, Communications, Computers and Intelligence (C4I) Systems provided situational awareness about operational environment and supported in decision making and directed to operative environment. These systems had been used by various agencies like defense, police, investigation, road, rail, airports, oil and gas related department. However, the increase use of C4I system had made it more important and attractive. Consequently interest in design and development of C4I system had increased among the researchers. Many defense industry frameworks were available but the problem was a suitable selection of a framework in design and development of C4I system. **Approach:** This study described the concepts, tool and methodology being used for evaluation analysis of different frameworks by Analytic Hierarchy Process (AHP). **Results:** We had compared different defense industry frameworks like Department of Defense Architecture Framework (DODAF), Ministry of Defense Architecture Framework (MODAF) and NATO Architecture Framework (NAF) and found that AHP is fairly good tool in terms of analysis. **Conclusion:** Different defense industry frameworks such as DODAF, MODAF and NAF had been evaluated and compared using AHP.

Key words: Architecture framework, view, Analytic Hierarchy Process (AHP), DODAF, MODAF, NAF, C4I system

INTRODUCTION

The Command, Control, Communications, Computers and Intelligence (C4I) systems provide battlefield information for the commanders to make decision and to control the military forces to achieve the mission. The C4I system must provide inclusive information to the commanders in a timely manner and enable the commanders to tell orders actively to the forces on the ground. This will enable the ground forces to execute their tasks effectively [1]. Therefore a careful consideration is required to design a C4I system. One important consideration is the selection of proper modeling tool/framework for C4I system.

This study presents an evaluating approach of different defense industry frameworks like Department of Defense Architecture Framework (DODAF), Ministry of Defense Architecture Framework (MODAF) and NATO Architecture Framework (NAF). These frameworks are mostly used as tools in the design and development process of C4I systems. There are some more frameworks related to defense departments such as Australian Defense Organization Architecture Framework (ADOAF), Department of National Defense Architecture Framework (DNDAF) Canada and French military architecture (AGATE). Some general enterprise architecture may also be used in defense related departments like Model Driven Architecture Framework (MDAF) and Federal Enterprise Architecture (FEA) but they are less important in the design and development process of C4I systems [20-22]. All enterprise architecture frameworks except DODAF, MODAF and NAF are not matured or not formally adopted yet. Therefore our focus of research is on these three frameworks.

The C4I systems are used in various departments such as defense, police, investigation, road, rail, airports, oil and gas where command and control scenarios exist. The main focus of these systems is in defense applications. C4I systems consist of people, procedures, technology, doctrine and authority and play a growing role in information management, data fusion and dissemination[2]. The purpose of a C4I system is to help the commander accomplish his objective in any crucial situation. It consists of four words such as command, control, communications, computers and intelligence. The command is authority that a commander exercises over subordinates by virtue of rank or assignment. The control is also authority which may be less than full command exercised by a commander over part of the activities of subordinate or other organizations.

While computers and communications process and transport information. Intelligence refers to information and knowledge obtained through observation, investigation, analysis, or understanding[3]. An Enterprise Architecture Frameworks (EAF) is a readymade structure that is used to organize enterprise architecture into complementary views. An EA framework is a logical structure for classifying and organizing complex information. The Enterprise Architecture is represented through graphics, models and narratives that describe the enterprise design. To provide consistency across the resulting complex design, the representations are developed according to a unifying architectural framework. A view is a projection of the enterprise architectural model that is meaningful to one or more system stakeholders such as an analysis view is more significant to business and system analyst and less important to system implementers and testers[4,5]. Analytic Hierarchy Process (AHP) is a technique for multiple criteria decision-making. It was developed by Saaty and Shih[17] in the 1970s and has been extensively studied and refined since then[6]. It assists the decision making process by allowing decision-makers to organize and evaluate the significance of the criteria and alternative solutions of a decision. It helps the decision makers find the one that best suits their needs rather than prescribing a correct decision. Some of the decision situations where AHP is applied are choice, ranking, prioritization, resource allocation, benchmarking and quality management[7,8]. The AHP hierarchy is divided into criteria, sub criteria and alternatives. The goal is on top of the hierarchy. Each entity (goal, criteria, sub criteria and alternatives) is enclosed in box known as node. The top node is called parent and others that are originate from parent is called child node. Group of related children are formed comparison groups. The parents of an alternative from different comparison groups are called its covering criteria[9].

MATERIALS AND METHODS

Related works: The AHP has been used in various areas that are numbered in thousands and produced intensive results in problems involving planning, resource allocation, priority setting and selection among alternative[10]. In recent times, Berrittella *et al*.[11] used AHP in deciding how best to reduce the impact of global climate change. The Microsoft Corporation used it to quantify the overall quality of software systems[12]. Grandzol[13] present an improved method of the faculty selection process in Higher Education at Bloomsburg University of Pennsylvania. Atthirawong *et al*.[14] worked on International location decision-making by using AHP. Dey[15], used AHP in assessing risk in operating cross-country petroleum pipelines. It is used in deciding how best to manage US watersheds at US Department of Agriculture[16]. Abdullah S. Alghamdi[7] presented an approach to evaluate automated web engineering methodology environment using AHP. Saaty and Shih[17] worked in the field of decision making by making hierarchy network structure. They stated that creating a structure is the first step in organizing, representing and solving a problem. Actually, a structure is a mode of a problem. It helps us to visualize and understand the relevant elements within it that we know from the real world and then use our understanding to solve the problem represented in the structure with better confidence.

Therefore a careful consideration is required to build AHP hierarchy network. The analytic hierarchy process is a method of measurement for formulating and analyzing decisions. It is a decision support tool which can be used to solve complex decision problems considering tangible and intangible aspects. Therefore, it supports decision makers to make decisions involving their experience, knowledge and intuition.

Defense architecture frameworks: A brief review of famous defense related architecture frameworks is described below that are landmarks in the development of C4I systems or any other defense related information system.

Department Of Defense Architecture Framework (DODAF): It was developed by Department of Defense, USA in 1990. It defines how to organize the specification of enterprise architectures for US Department Of Defense (DOD) applications. Its first version was released in 1996 and was called as Command, Control, Communication, Computers and Intelligence, Surveillance and Reconnaissance (C4ISR) architectural framework. The second version of C4ISR was released in 1997. In August 2003 the framework of C4ISR v2.0 was reconstructed and DODF v1.0 was released. Recent version 1.5 of DODAF consists of three volumes and was published in April 2007. DODAF 2.0 is released in 2009 but still in refinement phase. DODAF organizes enterprise architectures into four basic view sets such as All View (AV), Operational View (OV), Systems view (SV) and Technical Standards View (TV). Frameworks like MODF, NAF and TOGAF are derived from DODAF. DODAF is more suitable to large system and System-Of-Systems

(SOS). The main focus is on defense applications but it can also be applied to commercial systems[2-4].

Ministry Of Defense Architecture Framework (MODAF): It was developed by Ministry of Defense UK to define a standard way to organize enterprise architectures for defense application. Its first version was released in June 2005. The latest version1.2 of MODAF was released in September 2008. MODAF organizes enterprise architectures into six basic viewpoints which are similar to DODAF views such as All Viewpoint (AV), Operational Viewpoint (OV), Systems Viewpoint (SV) Technical Standards Viewpoint (TV), Standard Viewpoint (StV) and Acquisition Viewpoint (AcV). MODAF provides a means to model, understand, analyze and specify Capabilities, Systems, Systems of Systems and Business Processes. The purpose of MODAF is to provide a rigorous system of systems definition when procuring and integrating defense systems[4,18].

NATO Architecture Framework (NAF): It is an Enterprise Architecture framework by the NATO derived from the DODAF Enterprise architecture. The current NATO C3 System Architecture Framework v2 (NAF v2), issued by NATO in September 2004 provides guidance on describing communication and information systems. Revision 3 of the NATO Architecture Framework (NAF), announced in November 2007, is identical to MODAF at its core, but extends the framework by adding views for bandwidth analysis, SOA and standard configurations. Its views are NATO All View (NAV), NATO Capability View (NCV), NATO Operational View (NOV), NATO Service-Oriented View (NSOV), NATO Systems View (NSV), NATO Technical View (NTV) and NATO Programme View (NPV)[19].

Analytic Hierarchy Process (AHP): An evaluation of three architecture frameworks namely Department of Defense Architecture Framework (DODAF), Ministry of Defense Architecture Framework (MODAF) and NATO Architecture Framework (NAF) using AHP is presented. The AHP process consists of four steps such as selecting a goal, list criteria and sub criteria and finally alternatives are determined (Fig. 1).

The selection of criteria and sub criteria is based on the works as practiced by Roger in Microsoft, Antony et.al in DSTO and Lean et.al in architecting C4I systems[1, 23, 24]. The main criteria include performance, tool support, completeness, adoptability and guidance. The criteria performance is divided into sub criteria namely interoperability, scalability. In the same way, the criteria completeness is divided into sub criteria taxonomy, process and maturity. Similarly, the criteria guidance is divided into practice, governance and partitioning as sub criteria. The performance of an Enterprise Architecture Framework (EAF) is measured by interoperability and scalability. Interoperability refers the ability of an architecture framework or a product to work with other architecture frameworks or products. Scalability refers to ability of growth in the architecture framework in a graceful manner[23,24]. The second criteria tool support state that which architecture framework is more flexible to designing tool usage. Thirdly, completeness of EAF is measured by taxonomy, process and maturity. Taxonomy refers a methodology for organizing and categorizing architectural artifacts (a specific document, report, analysis and model that contributes to an architecture description). The process refers a step by step process for creating enterprise architecture. So maturity guides in assessing effectiveness of architecture framework in C4I systems. The adoptability refers which architecture framework is more adopted as compared to others in the field of C4I system. The practice guidance refers to how much the methodology helps you understand the mindset of enterprise architecture into your organization and develop a culture in which it is valued and used. Governance guidance refers to how much help the methodology will be in understanding and creating an effective governance model for enterprise architecture. Partitioning guidance refers to how well the methodology will guide you into effective autonomous partitions of the enterprise, which is an important approach to managing complexity.

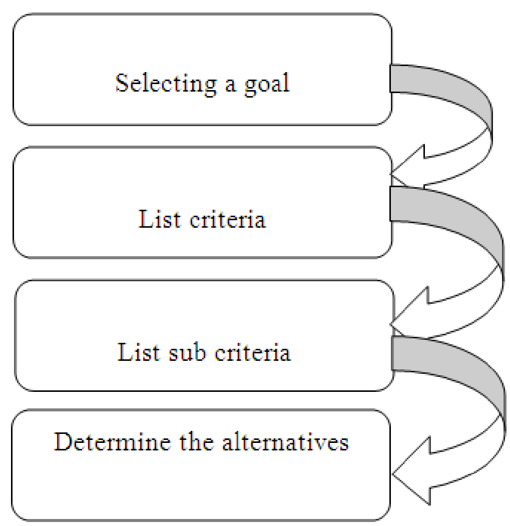

Fig. 1: AHP steps

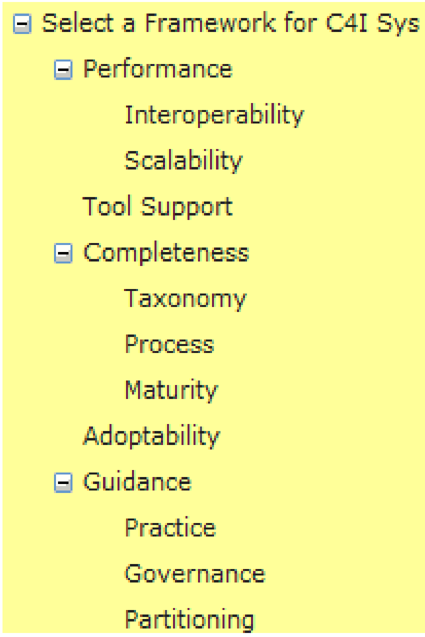

Fig. 2: Detail criterion

The AHP detail criterion generated by AHP project is shown in Fig. 2.

The Analytic Hierarchy Process (AHP) hierarchy can be visualized as shown in the following diagram, with the goal (select a framework for C4I System) at the top, the alternatives (DODAF, MODAF and NAF) at the bottom (not shown due to complexity) and the criteria (performance, tool support, completeness, adoptability and guidance) and sub criteria (interoperability, scalability, taxonomy, process, maturity, practice, governance and partitioning) in the middle. After AHP hierarchy has constructed then the next phase is to assign priorities to its nodes. Priorities are numbers associated with the nodes of an AHP hierarchy. The assignment of priorities is based on the information obtained from various websites and previous study[1,23,24]. The scale used for pair wise comparison is shown in the Table 1.

The priorities are assigned to criteria and sub criteria and its associated weights are calculated by AHP Project software. The consistency ratio is also calculated by the AHP project. If the consistency ration is smaller or equal 10%, the inconsistency is acceptable. If the consistency ratio is greater than 10%, we need to revise the subjective judgment. In this work the consistency ratio is less 0.1 so there is no any inconsistency.

Table 1: Priorities assignments

Intensity	Definition
1	Equal importance
2	Weak importance
3	Moderate importance
4	Moderate importance plus
5	Strong importance
6	Strong importance plus
7	Very strong importance
8	Very strong importance plus
9	Extreme importance

The final decision is based on the results obtained by the AHP hierarchy.

RESULTS

A comparative analysis between main criteria of the AHP hierarchy is described here. The weights calculated by AHP project and associated with criteria and sub criteria are shown in the Fig. 3. According to AHP hierarchy the sum of local weights and global weights should be equal to one. The criteria is ranked first as performance (LW = 0.32, GW = 0.32), completeness (LW = 0.25, GW = 0.25) as second, guidance (LW = 0.20, GW = 0.20) as third, tool support (LW = 0.13, GW = 0.13) as fourth and adoptability (LW = 0.09, GW = 0.09) as the last.

The graphs are represented with different colors as shown in Fig. 4.

The result of each criterion in each architecture framework is shown in the graph with different colors in Fig. 5.

The two graphs in the Fig. 6 and Fig. 7 illustrate comparative analyses between MODAF and DODAF. In the first radar graph Fig. 6, a comparison is shown between main criteria into two different colors. The radar graph in Fig. 7 shows a comparison between sub criteria.

The subsequent two graphs in the Fig. 7 and Fig. 8 show comparative analyses between MODAF and NAF. The radar graph in Fig. 8 displays a comparison between sub criteria.

The results proved that MODAF is leading to DODAF in case of interoperability, governance, practice and adoptability wise. While DODAF is leading to MODAF in case of scalability, tool support, taxonomy, process completeness, maturity and partitioning wise. In case of NAF to MODAF and DODAF, the NAF has secondary position.

After comparative analysis of results it has been found that MODAF is ranked as first, DODAF as second and NAF as third in our assessment methodology.

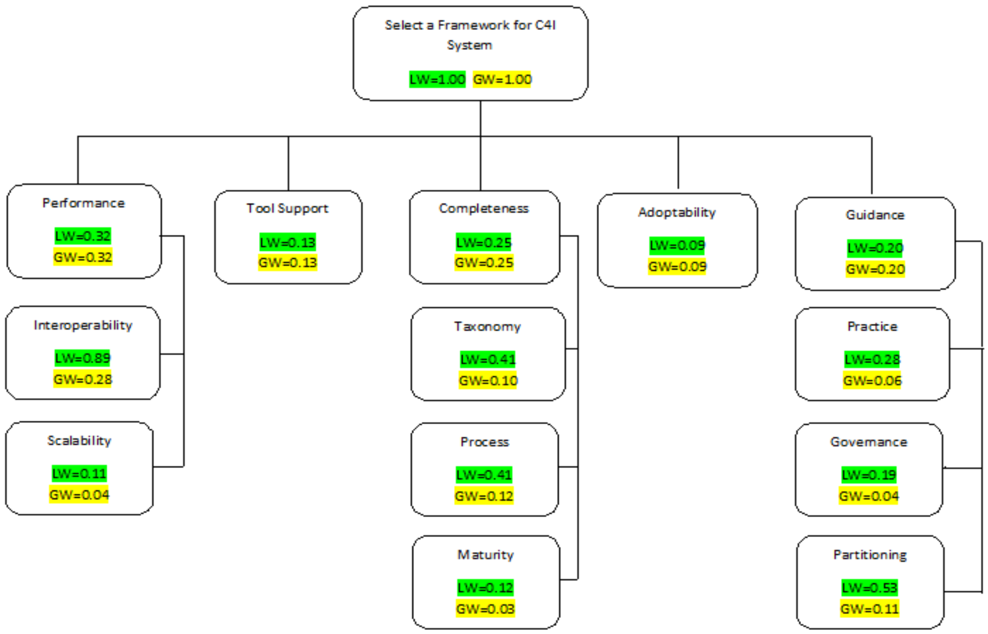

Fig. 3: AHP tree

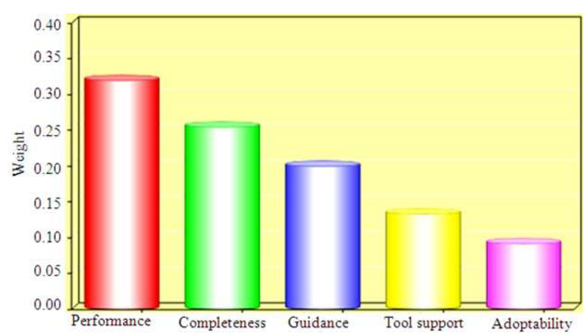

Fig. 4: Criteria ranking

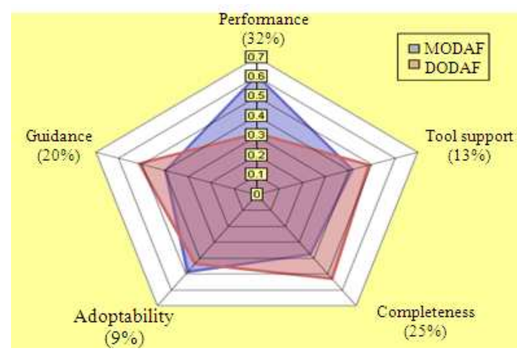

Fig. 6: MODAF-DODAF-alternatives comparison

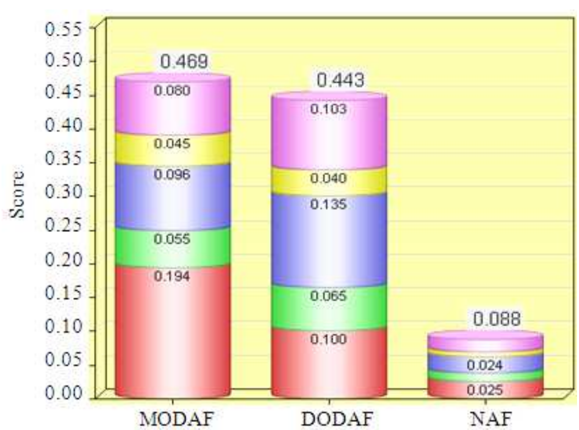

Fig. 5: Alternatives ranking

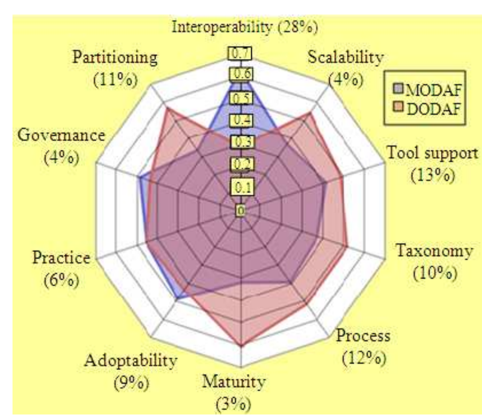

Fig. 7: MODAF-DODAF-alternatives comparison

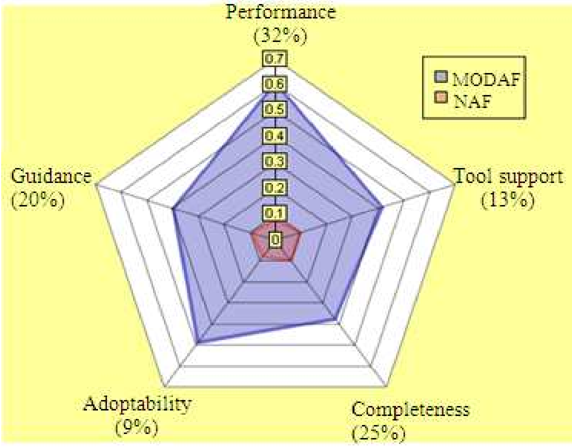

Fig. 8: MODAF-NAF-alternatives comparison

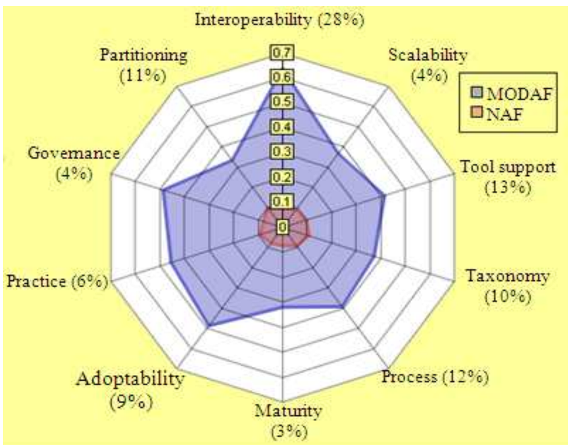

Fig. 9: MODAF-NAF-alternatives comparison

DISCUSSION

This study compared and analyzed three architecture frameworks. After observing different criteria and alternatives in the graph analysis, it had concluded that in some cases DODAF was preferable as compared to MODAF and vice versa. The NAF had secondary ranking in this applied approach. The AHP project software is used as tool for experiment and analysis. Moreover, a brief review had provided about different defense architecture frameworks, C4I system and Analytic Hierarchy Process (AHP).

CONCLUSION

C4I systems are imperative in defense environment and their applications are also increasing in civil departments such as police, investigation and airports. At future step, various tools that support for modeling and development of C4I system are the main emphases of the research.

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