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An Approach to Building Computerized Support for Naval Weapon System Evaluation

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Abstract

In this paper, we discuss the issue about building computerized support for naval weapon system evaluation based on a practical project. The aim of weapon system evaluation is to tell the weapon system developers (decision makers) if the concerned system can fulfill a specific mission within given time and cost. There are specific methodologies in comprehensive evaluation of a weapon system. Domain experts also have their experiences in applying those methodologies to mission analysis. To develop a decision support system (DSS) is a natural idea for domain people in analyzing menace and applying specific models to different tasks among the whole evaluation process. A pioneer project was then initiated. At that project, both the goal and the original design about DSS seemed very clear. However, the implementation became so hard that the biggest problem was not to develop a DSS based on the domain people's design but to make clear what kind of computerized support could really fulfil the tasks proposed by domain people. The paper describes our resolution to this messy problem. Instead of the development of four-base DSS framework by users' original design, a series of integrative platforms or tools were implemented or used for specific evaluation tasks, such as effectiveness analysis, menace analysis, comprehensive evaluation, etc. Our solution is to integrate general knowledge and have the evaluation workflow computerized to help domain people concentrate on analyzing the weapon system effectiveness, which is shown by introduction to effectiveness evaluation tool.

Key words: decision support systems, naval weapon system evaluation.

1 INTRODUCTION

Generally, weapon system evaluation includes menace analysis, function analysis, effectiveness analysis, cost analysis, venture analysis, etc. in consideration of its whole life cycle from planning to a conceptual design, from a prototype to a real product, from deployment to retirement. Effectiveness is a measure of weapon system capacity for the fulfillment of a mission. Menace analysis sets mission (goal) for weapon system design. The result of function analysis is a specifically designed prototype, which will be under effectiveness analysis for acquirement of a system performance index with specific missions. Cost and venture analyses aim at a feasible and successful product at right time and bearable expenditure. Tradeoff exists between effectiveness, cost and venture in weapon system development, and multiple criteria decision analysis methods are helpful for comprehensive evaluation. Among all tasks in weapon system evaluation, effectiveness analysis is more important and worth more endeavors since it tells the weapon system developers if the concerned system can really fulfill a specific mission. There are many methods for effectiveness analysis, ADC (availability, dependability and capacity), SEA (system effectiveness analysis), index method, etc. while ADC method is widely used.

Due to complexities in calculation and model connection in the field of naval weapon system evaluation, application of tremendous achievements of computer technologies is a great appeal. With popularity of decision support system (DSS) and its various applications at different fields in China, to develop a DSS for naval weapon system evaluation is a natural idea for domain people. A pilot project with very limited fund was then set up by some people on evaluation of naval weapon systems (NWS) and was undertaken by systems engineering people from Institute of Systems Science (ISS), Chinese Academy of Sciences since 1996. NWS people had set the goal of the project, to develop a four-base framework of weapon system evaluation DSS. They wished to store basic data on naval weapon systems in a database (DB), and to place various models for various applications in model base (MB) and specific algorithms into algorithm base (AB). Knowledge base (KB) includes the experience and expert knowledge on weapon system evaluation. In NWS people's design, the whole working process of comprehensive evaluation to a naval weapon system was also designed to details even though they had never experienced it in practice. According to initial plan, the main tasks for ISS people were to build a DSS framework where to place models and domain knowledge that had not been of abstraction and aggregation yet. As the project started, ISS people confronted a great deal of difficulty: few background materials, no ready-made computerized domain models for reference and no practical data. Moreover, based on individual experience and understanding, both sides had different and even conflicted individual views about the expected DSS. Fund was another paradoxical problem. Ambitious design and limited fund perplexed cooperative work and led to disputes. Therefore, an intuitively hard problem with clear demands became so hard to be tackled with due to those practical soft constraints and unavoidable conflicts between NWS people's ideal plan and practical situations.

The paper addresses the design and implementation of our resolution to this messy problem. For easy understanding, basic concepts in effectiveness analysis of a weapon system is introduced at first. Then coordination for DSS development is given to exhibit how to change domain people's expected DSS framework into a series of computerized aids to specific tasks. Finally, the design of computerized support to effectiveness analysis of naval weapon system is presented.

2. BASIC CONCEPTS IN WEAPON SYSTEM EFFECTIVENESS ANALYSIS

Every weapon system concept is based on a need to fulfill an anticipated operational requirement. The *effectiveness* with which the system fulfills this need is the ultimate measure of its tactical utility and its value to its affiliated system (e.g. the fleet). System effectiveness is a composite of three parameters - performance, reliability, and availability [1].

Definition 1. The *availability* of equipment (system) A is defined as a function of equipment maintainability and mean life. $A = MTBF/(MTBF + MTTR)$, where $MTBF$ is mean-time-between-failures, $MTTR$ is mean-time-to-restore.

Definition 2. Suppose a generalized reliability structure of a naval weapon system (surface fire) can be represented as shown by Figure 1, where single system of each block refers to the corresponding function of equipment, instead to equipment itself. Then equipment may be appeared more than once if it serves multiple functions. For example, radar can be used for both target detect and track, then searching radar and tracking radar can refer to one equipment. In some practical analysis, adjacent system and firing system are regarded as one for simplicity.

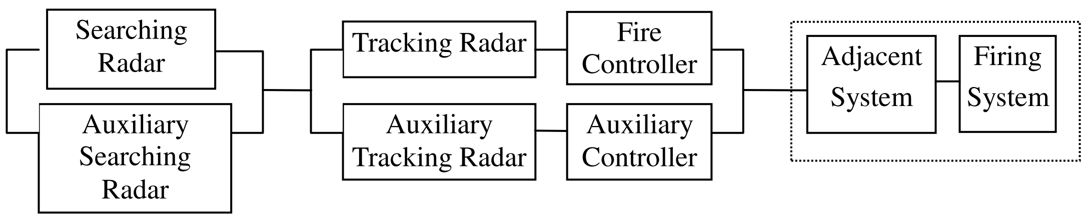

Figure 1. Reliability Block Diagram of a Naval Weapon System (Surface Fire)

Definition 3. An operating state of a weapon system S refers to any recognizable states of a weapon system before or throughout its fulfillment of a mission.

If a weapon system includes M labeled equipment, an operating state S can be represented as a string of 0 or 1: $b_1 b_2 \cdots b_M$, if the ith equipment fails at that point of time, b_i=0; else b_i=1. Theoretically, there are 2^M operating states for a weapon system with M labeled equipment. The weapon system does not work at some states since there is no effective path in Figure 1. All those ineffective states are regarded as only one member in state set. Among 2^M states, the number of effective operating states is small.

Definition 4. Suppose a weapon system has $N+1$ operating states (including N effective working states), $(a_1, a_2, \cdots, a_N, a_{N+1})$ is the availability vector, where a_{N+1}

refers to ineffective state, the other elements refer to effective states. $a_i = \prod_{k=1}^{M} W_k$, $i = 1,2,\ldots N$, $a_{N+1} = 1 - \sum_{i=1}^{N} a_i$; if equipment k works, $W_k = A_k$; else $W_k = 1 - A_k$, $k = 1,2,\ldots M$.

The operational reliability is the probability that the system will maintain a specified level of performance through a given mission - a measure of *how long* it is capable of working without failure. The reliability of a naval weapon system is expressed as a dependability matrix.

Definition 5. $D = \begin{pmatrix} d_{1,1} & d_{1,2} & \cdots & d_{1,n} \\ d_{2,1} & d_{2,2} & \cdots & d_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ d_{n,1} & d_{n,2} & \cdots & d_{n,n} \end{pmatrix}$ is called a dependability matrix, $n = N + 1$. The element $d_{i,j}$ is the probability of the weapon system transits from state *i* to state *j*.

Consider equipment is reparable. The failure rate λ and repair (restoration) rate μ of each equipment are $\lambda = 1/MTBF$ and $\mu = 1/MTTR$. $R(t) = e^{-\lambda t}$ is the reliability function, the failure function is $F(t) = 1 - e^{-\lambda t}$, the reparation function $G(t) = 1 - e^{-\mu t}$, *t* is the system's continuous operating time. Also consider all states of weapon system are independent. If state *i* as $b_1^i b_2^i \cdots b_M^i$, state *j* as $b_1^j b_2^j \cdots b_M^j$, the probability that the system transits from state *i* to state *j* is calculated as follows.

$$\begin{cases} d_{i,j} = \prod_{k=1}^{M} d_k(t), \\ d_{i,N+1} = 1 - \sum_{j=1}^{N} d_{i,j}, \quad \text{where} \\ d_{N+1,i} = 0. \end{cases}$$

where if $b_k^i = 1$ and $b_k^j = 1$, $d_k(t) = R_k(t)$; if $b_k^i = 1$ and $b_k^j = 0$, $d_k(t) = F_k(t) = 1 - R_k(t)$; if $b_k^i = 0$ and $b_k^j = 1$, $d_k(t) = G_k(t)$; if $b_k^i = 0$ and $b_k^j = 0$, $d_k(t) = 1 - G_k(t)$; $i, j = 1,2,\ldots N$.

The performance capacity of a weapon system is the probability that the system will satisfy mission performance requirement with specified design limits, a measure of 'how well' it does its job when working properly.

Definition 6. $C = (c_1, c_2, \cdots, c_n)^T$ is the capacity vector of a weapon system, $n = N + 1$. The element c_i is weapon system's capacity at state *i*.

The calculation of capacity vector is relevant to specified missions.

Definition 7. The operational effectiveness is the product of the three characteristics, availability, dependability, and capacity, i.e.

$$E = A \cdot D \cdot C = (a_1, a_2, \cdots, a_n) \begin{pmatrix} d_{11} & d_{12} & \cdots & d_{1n} \\ d_{21} & d_{22} & \cdots & d_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1} & d_{n2} & \cdots & d_{nn} \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{pmatrix} = \sum_{i=1}^{n} \sum_{j=1}^{n} a_i d_{ij} c_j, n = N + 1 .$$

Such effectiveness analysis method is also called ADC method and widely used in various weapon systems' evaluation. For a period of time, computer applications of ADC method for weapon system in China stayed at calculation of availability vector, dependability matrix, capacity vector and their final product. Most programming work was done for specific weapon system with fixed state set. Thus those programs lack generality. And those programs were usually abandoned or could not be shared as the evaluation project was finished or the original programmers left. The computer application level at system effectiveness evaluation was very low. The dependence in manual work of searching the states of the systems was a big blockage.

So there are continual needs to enhance level in applying computer technologies, especially to weapon system evaluation. That is the initial drive for such a pilot project. Next we address our resolutions of those issues in project.

3. APPROACH TO THE DEVELOPMENT OF COMPUTERIZED SUPPORT FOR WEAPON SYSTEM EVALUATION

The core dispute in the pilot project was about what kind of DSS should be developed. Actually, NWS people insisted a 4-base framework, which was beyond ISS people's capacity with given funds. Excluding funds issue, both sides still had different views towards the final products. Here, system thinking to DSS, its trend and its implementation approach is referred for better understanding.

3.1 System Thinking to Decision Support and its Development

With advances in computer technological applications, the making of new term labeled decision support products is unceasing. Then it is more necessary to give further thinking to DSS and its development so as to avoid confusions and to produce real requirement-oriented support products for DSS users. 'What is nature of the computer-based support system?', 'of what larger system is a DSS a part?' or 'what is the pertinent aid for decision making?' are to be under discussions and debates in order to ascertain how people perceive the organizational world. DSS development is a socio-technical issue. Such kind of debates aim to achieve a proper recognition of *right* activities and to legitimize them as being meaningful to whom is concerned so as to make efficient use of limited resources and obtain a satisfactory resolution which can provide sustainable support for decision makers.

The computerized decision support products are problem-oriented so to achieve effective aid to problem-solving process. The integration in business intelligence tools, such as on-line analytical processing (OLAP) with data warehousing technology exhibits the current decision support framework in practice. Focus on key issues resolution in consideration of limited resources and organizational sustainable development is of more concerns during DSS development. This view is called intensive information support, which emphasizes to provide right information support for decision-makers at right time with right quality and quantity, instead of pursuing comprehensive information support while decision makers may surf aimlessly in the sea of data, a possible result of so-called extensive information support [2]. However, each information support mode is not opposite to the other, but reflects different approaches to different information systems. Along with tremendous advances in networking technologies, especially in the Internet, enterprise information portal (EIP) and enterprise knowledge portal (EKP) becomes the next big investment opportunity in the IT sector [3]. That also reflects the extensive and intensive information support for decision making. Gradually, DSS evolves into a kind of concept of providing pertinent support to any kind of decision-making activities.

Table 1 lists some points of *Wu-li Shi-li Ren-li* (WSR) approach to DSS development, where 8 DSS system constructs for DSS theory come from empirical investigation and analysis [4]. WSR approach is an oriental system approach, where holistic thinking of *Wu-li* (conceptual model), *Shi-li* (organizing strategy) and *Ren-li* (theory of human relationships), and their interrelations and interactions is emphasized to get a comprehensive scenario of the concerned issue in system practice activities [5].

Table 1. WSR Approach to DSS Development

	Wu-li	*Shi-li*	*Ren-li*
DSS construct	system configuration, task, capability, user	implementation strategy, environment, performance	User behavior, performance
Operation	technical implementation, functional analysis	system management, logical analysis	Human intervention, cultural analysis
Objects	extensive information, human resources	data flow, information intensification, manpower planning	Organizational culture, office politics, data ownership
Task	*What is …*?	*How to …*?	*Shall we …*?
Principles	honest, truth, as correct as possible	harmony, efficiency, as feasible as possible	humanity, effectiveness, as reasonable and flexible as possible

In China, due to the effects of *Ren-li*, organizational politics and cultures, a fluent information flow is often blocked. For information system designers, right *Wu-li* (all information objects relevant to the concerned workflow) and *Shi-li* (the strategies to fulfill fluent information flow) can only be practically implemented by proper considerations of *Ren-li* factors. Data ownership is a critical issue in developing decision analytical tools, especially for those people between parallel functional departments. Without effective collaboration and clear regulations, data processing work cannot be fulfilled in practice. Group benefits, ever-lasting competitive and cooperative relations affect applications of many decision analysis methods. That is why *Ren-li* considerations become highlight in practice.

3.2 Building Effective Aid to Weapon System Evaluation in View of Coordination

In the pilot project, the important thing for both NWS and ISS people was to get a common understanding about the final product before taking further endeavors in computerized work. Three kinds of coordination work, negotiation coordination (NC), technical coordination (TC) and practice coordination (PC) had been taken for requirement analysis, selection of technical paths to system implementation, and effective DSS applications during the whole process of the project.

3.2.1 Coordination during DSS development -NC

The objective of NC is to make clear practical goals of a project [6]. Investigations and requirement analysis had been taken to understand what the real problems were. A number of specific computational and descriptive models about various weapon systems, the elements and the operational process had been developing for specific system evaluation tasks by domain people during the past years. Therefore NWS people wished to integrate all of them into MB and AB, as depicted in their 4-base DSS framework design. However, ISS people did not think 4-base framework DSS was necessary. A learning process was implied here towards a clear conceptual scenario of the expected DSS, the basis for system design and implementation. By communications, both sides quickly realized that the model integration was an important issue and should be solved effectively for a successful end of the project.

Even though computerized work was always expected in the project, many endeavors were relevant to coordination between both ISS and NWS people and different group members during the project undertaking.

- Coordination among NWS group members

All members expressed their aspirations by their experiences and duties at their positions. Then their introductions to domain knowledge were quite different. Some experts gave clear outlines, some only talked details of some specific and complicated models whose relevant materials could not be provided. Meanwhile, NWS people were also improving or even developing those models. Since the pilot project was also a competitive means for NWS people to compete with their rival departments of a same organization, it was unavoidable that almost all NWS experts proposed high standards for the relevant functions in the DSS. Moreover, requirements seemed so extensive, from specific model improvement to model integration, from DB construction to data input, etc. NWS people pursued optimal problem solving at every facet in their work, which was really beyond initial requirements for ISS people. Some respective requirements were in conflicts. Organizational culture, inconsistent objectives and changing and extensive requirements brought negative effects to project.

- Coordination among ISS group members

From communications with NWS people, ISS people had got a rough scenario of comprehensive evaluation of naval weapon system, and different tasks were assigned by participants' experiences. Since NWS people could not cooperate with ISS people at all relevant work in 4-base development and models for weapon system evaluation were so diverse, most of ISS people engaged in model integration considering fund and time constraints. Different members proposed different solutions to model integration. Those approaches reflected different views towards what kinds of support appropriate for domain people (not only for NWS people) and individual adaptability for model integration. Model dictionary was a quick reply for NWS people. Petri net was an advanced approach but beyond both capabilities. Computerized workflow of evaluation process was a practical alternative where existed some hard problems which had not been solved by domain people for long. Those three alternatives were all very difficult for ISS people. The selection was regarded as a multiple criteria decision making process whose objectives were fulfillment of DSS functions with high cost-effectiveness ratio and user's satisfaction. Manpower' capabilities, technology trend, time constraints, tradeoff between academic pursuits and engineering requirements, all those factors had troubled ISS people. As a key and hard problem was successfully solved, the third approach became the only alternative in project while the other two were abandoned. Adaptability of individual's knowledge structure for practical problems was a factor for manpower planning. Obviously, ISS people could not and would not meet all requirements from NWS people. Successful solution of some key and hard problems was an alternative to end such a time-consuming project with so limited fund.

- Coordination among NWS and ISS people

Most of NWS members overestimated ISS people's capacity to solve all problems and asked ISS people to provide various helps for them during the project. Because of a pilot project, NWS people expected a perfect result so as to apply larger project later. NWS people continual eager of including all analytical models into their ambitious DSS was beyond their own capacity and misled ISS people, who was very dissatisfied with so limited funds and customers' wrong assumptions and increasing excessive requirements. The effectiveness of cooperation work was highly affected by preferences, beliefs, and morals of both sides. The totally different organizational culture led to unharmonious and inefficient communications and delayed the project for one year. For example, NWS people regarded the pilot project as a means to compete with their rivals, then ISS people's investigation on the spot was unwelcome, which had puzzled ISS people in understanding the real requirement for over one year. How to stimulate developer's endeavors and to balance the aspiration level of users and developers meant NC lasting the whole process of project undertaking,

Even though the goal of this project could be simply understood. Different viewpoints towards the final products were not easily integrated especially with different organizational environments. NC worked to integrate different ideas into a synthetic one for further actions. Soft system approaches are useful to fulfill NC. Instead of *doing the thing right* along the traditional development process, soft system approaches endeavors to *do the right thing*, i.e. to make clear the issues such as requirements, human resources, funds, etc. before any further steps [7]. NC is the practices of soft system approach. The successful solution to the key problem was a right thing to mollify the conflicts between both sides and bring strength to NWS people in competition with their rivals.

NC went on with TC's cooperation. If no successful technical path in model integration was reached, there was no end of NC.

3.2.2 Coordination within a Concrete DSS - TC

TC denotes the coordination between functional components of DSS, representing an appropriate strategy of system management and control, which integrates the respective components organically into a complete system.

In this project, NWS people had already drawn a 4-base DSS framework. However, there lacked model dynamic linking and constructing, and descriptions of communications between DB, MB, AB, KB and interface were quite obscure. That indicated that TC was not comprehensively considered. ISS people had to design and implement exact control strategy and every functional component.

However, it was very difficult for ISS people to undertake those jobs before having a good understanding of them. It was unnecessary to understand details of those models or algorithms, while a basic knowledge about functions of models or algorithms was indispensable for design of a feasible and effective framework. But this time NWS people themselves could not meet ISS people's requirements. ISS people proposed three approaches to model integration based on document survey, model dictionary, Petri net, and computerized workflow of analysis. Lack of compete introduction to domain models meant the implementation of model dictionary was vain efforts. Petri net was an approach for model management in effectiveness analysis process [8]. However, discussions only stayed at paper work, which was not fit for such a practical project. In the last approach, the biggest problem was how to link all models into a fluent working process. By insistent communications and further thinking, ISS people realized that it was necessary to implement automatic generation of effective state set of a weapon system for method integration, which had also been expected for long by domain people. A general tool allows the weapon system reliability structure be changed according to user's definition, while adoption of flexible weapon system structure increases complexity of implementing specific algorithm for such a hard problem.

As the kernel problem was solved, the third approach became feasible and finally a computerized platform for effective analysis was developed. As a matter of fact, the unfeasibility of the other approaches was also due to the concerned ISS people did not realize what was key and hard tasks to be finished at first.

Then a series of frameworks for different analytical tasks in weapon system evaluation were constructed or applied to support whole process by similar ideas. Instead of stored in a KB, some basic rules and criteria in evaluation process were embedded into those independent applications. Various models were integrated into the platform as system elements' attributes. Interactive interfaces were provided to input values of the attributes. Some input came from relevant files with unified formats. The idea of our solution is to integrate general knowledge of weapon system evaluation into a tool, instead of implementation of MB. That also escaped the messy situation of model collection and development. Obviously, the final products did not follow NWS people's original design and then could not meet their extensive requirements. However, those aids would provide appropriate support for domain people to concentrate on analysis. The implementation of different applications brought flexibility to users in task fulfillment. Such kind of solutions is problem-oriented, instead of structure-oriented. Whatever the final structure for DSS it is, it is problem decides the structure, not vice versa. TC emphasizes logical feasibility.

3.2.3 Coordination between DSS, users and the environment - PC

The coordination between DSS, users and the environment refers to the coordination during DSS utilization. After the implementation of DSS, original developers leave except some maintenance tasks. The focus changes to how to utilize DSS effectively and reasonably. DSS development is a process to break the equilibrium within past workflow, while new equilibrium would be reached by coordination between DSS, users and the environment, the work of practice coordination. DSS users have the duty to utilize DSS to contribute for problem solving. PC aims to build a bridge between DSS, problems and related environment, and to keep the products of TC active. NC affects PC's effectiveness.

As ADC method was successfully implemented, NWS people were so satisfied and thought MB was finished. They began to demand a KB. On the other hand, since the algorithm of automatic state generation was based on a general framework of naval weapon system, users had to learn how to transfer a practical weapon system into the general framework for correct input. NWS people faced new challenges. However they were reluctant to apply new tools in their daily work in spite of their original eager and ambition in the project. Some just asked the developer to improve the tool so as to make operations easier. For example, one NWS person asked to add one conditional state to differentiate reparable system and irreparable system. Factually it was unnecessary. A rather larger value to MTTR for that functional element was a feasible alternative to denote an irreparable system. That was not a defect of the computerized aid, but implied need to enhance individual's analytical levels. Here pull and push strategies were applied.

Pull strategy meant systemic ideas about DSS and its trend were taught. Since DSS emphasized support, to provide effective support for weapon system evaluation was the ultimate goal, which could be implemented by simple and flexible applications. The important was not the framework itself, but the functions. Knowledge on right purposeful activities in weapon system evaluation had been reflected through the framework of each application. Object-oriented techniques were effective means to represent domain knowledge. More advanced ideas were introduced to help NWS people improve their knowledge on DSS.

Push strategy meant NWS people had been persuaded to accept better analytical tools and gave up impractical illusions, since they could not provide necessary knowledge and enough fund for 4-base DSS framework. When each application could be regarded as a kind of model management tool, meta-knowledge about weapon system evaluation work had been embedded into the task-oriented series applications.

Better TC leads to flexible products and can help users to improve workflow and explore potentials in their daily work. Table 2 summarizes three kinds of coordination in this project from WSR approach.

Table 2. Coordination and WSR approach during weapon system evaluation DSS development

	Wu-li	*Shi-li*	*Ren-li*
NC	Investigation and requirement analysis,	Task assignment, manpower planning	Harmony within DSS development group,

	manpower		facilitation between actors and customers
TC	Domain knowledge (weapon system), DSS knowledge	Computerized evaluation workflow, model integration	Considerations in DSS trend, users' preference and actors' capabilities
PC	Implemented computer aids, practical problems, environment constraints	DSS ⟷ Problem ⇘ ⇗ Environments	Flexible practice, effective support, improvement of workflow in practice

Next a brief introduction to EFFECT (computer aid to ADC effectiveness analysis) is presented to exhibit object-oriented implementation of providing appropriate support at appropriate time and place.

4 SYSTEM EFFECTIVENESS ANALYSIS AID (EFFECT) [9]

4.1 System Evaluation Workflow

Implemented by Visual Basic 4.0, EFFECT is one of computerized support tools for naval weapon system evaluation. Figure 2 is the main frame of EFFECT. The sequence of menu items reflects the workflow in effectiveness analysis: firstly define a *system* structure, then generate operating *state* set, finally, calculate system *effectiveness*.

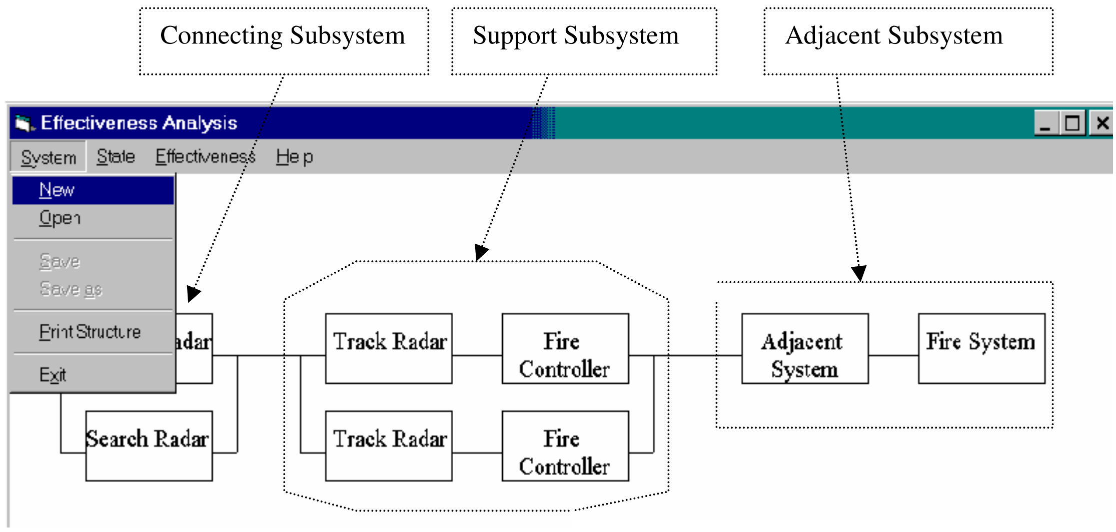

Figure 2. EFFECT Main Window

Under 'System' menu, there are 6 items for selection, 'New', 'Open'; 'Save', 'Save As', 'Print Structure', 'Exit'. To start a new system analysis, or analyze an old weapon system, the system reliability structure window is the interactive tool to define system structure and check the number of equipment as shown in Figure 3. Since one equipment can serve multiple functions, necessary examination should be taken to assure a right number of equipment of a weapon system. As the inputted system passes 'Test', the number of equipment is known and 'Confirm and return' button becomes valid. The reliability diagram at main window is refreshed to display current system in analysis. Only one system can be analyzed at one time.

Figure 3. Definition of a weapon system

Right input of a practical system is a critical step in defining a new system. Some rules should be followed strictly. Connecting subsystem (search radar), support subsystem (target track and fire controller) and adjacent subsystem (magazine and launcher) are of serial relations in a naval weapon system (surface fire) based on the general reliability diagram. The numbers of equipment or their pairs in each subsystem may be changed, the serial relation cannot be changed. So one fire controller must be inputted as one track radar exists. Figure 1 is the default of weapon system reliability diagram. Development of naval weapon systems may bring new possible prototypes, then selection of reliability diagram prototypes will be done before system structure definition. Currently, only one case (default) is considered.

4.2 Automatic generation of system effective states

After the definition of system structure, menu item 'effective state' under 'State' becomes valid. A window of effective operating states appears after single click the item as shown by Figure 4.

Figure 4. Effective operating states and visualization in reliability diagram.

The states are displayed as defined in Definition 3. Click one state, the index of the state at the state list appears in upper right box, and front color of name of the working equipment in the system structure diagram at the main window will change to green. That is the visualization analysis of system states. Such a mechanism provides effective aid for decision-makers in system capacity analysis. The total number of system states is the number of strings plus 1(ineffective state). There are 7 states in Figure 4, then total number of operating states is 8; the dimensions of availability and capacity vector are 8, the dependability matrix are 8×8 matrix.

4.3 Searching Data from Remote Weapon System Database through LAN

Double click any blocks of equipment at the reliability diagram in the main window pops up the property window about the concerned equipment as shown in Figure 5. This window simultaneously serves as client interface for remote visit to weapon system databases implemented by ODBC mechanism. Click on 'DB Link' button activates searching engine by which to find proper equipment in the weapon database fit for current analysis. Three parameters are in need, MTBF, MTTR and the type of the equipment. Database should be closed before 'Confirm and Return'. A large value to MTTR (>1000 hours) means the equipment is irreparable. Interactive input of the data is also allowed.

Remote data access can help EFFECT users to select any possible weapon equipment for analysis and comparison of different sets of parameters. By use of multimedia weapon databases, on-line analytical evaluation of system effectiveness is possible if users have authority of database access.

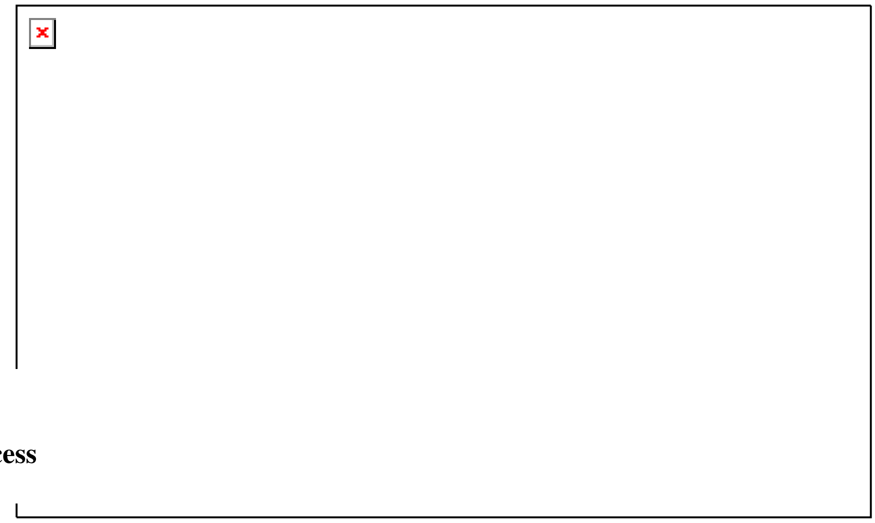

Figure 5. Client Interface of Weapon Systems Database Access

4.4 System Effectiveness Calculation

In 'effectiveness' menu item, there are four items, 'availability vector', 'dependability matrix', 'capacity vector', and 'system effectiveness'. Before weapon system states are generated, both availability and capacity items are invalid. After the calculation of availability vector, the item 'dependability' becomes valid. Click dependability, a prompt message will be bounced for user's inputting continuous working unit (default value: 0.25 hours).

Since the calculation of the capacity vector is relevant to specific missions, so EFFECT accepts file and interactive input in avoid of vain efforts in dynamic link to all possible models of system capacity for specific missions. Actually, wait for NWS people provide system capacity models during the first year of the project brought much waste in time and cost.

It is important that elements in capacity vector should match their system working state. Visualization analysis of system operating states will decrease the unmatched errors. The final calculating result of system effectiveness is shown at a prompt message window.

The essence of EFFECT is the automatic generation of system effective operating states, the most desirable thing for NWS people who admit it was a breakthrough in their fields. With such a satisfactory result at a preliminary research project, 4-base DSS framework issue was not talked again. The project was finally ended after two years work. More than one-year vain exploration showed the effects in system practice without a harmony in *Ren-li*.

5. CONCLUSION

In this paper, coordination-oriented approach to practical development of computerized support tool for naval weapon system evaluation in China is presented. The huge effects of human factors and conflicts in benefits between customers and developers changed a hard problem to a messy issue. Effective coordination is key to project implementation, especially to make clear what is *Wu-li* and how to take *Shi-li* in hard problem solving.

Instead of 4-base DSS framework according to customers' original design, a series of integrative platforms or tools were implemented as feasible computerized aids to the basic tasks in naval weapon system evaluation. The idea of our solution is to integrate general knowledge and have the evaluation workflow computerized which helps domain people concentrate on analysis work and improve analytical workflow.

The transition from the pursuit of a complete DSS framework to intensive information support is a critical successful factor to the satisfactory finish of this project. Automatic generating the operable weapon system state makes it possible to real integrative computerized system effectiveness evaluation. Visualized analysis of weapon system operating states greatly improves human-machine interaction. Remote weapon database access through LAN implemented by ODBC is helpful to explore the potentials of weapon databases utilization. Those technical solutions facilitate the validation of what kind of practical goals in computerization of weapon system evaluation, a trend of integration of diverse models and tools for synthetic support to improve weapon system evaluation work in China.

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