WSR APPROACH TO A PRACTICAL IMPLEMENTATION OF COMPUTERIZED AIDS FOR SYSTEM EVALUATION[1]

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Abstract

In this paper, the oriental *Wu-li Shi-li Ren-li* system approach is reviewed at first. Before the WSR system approach was formally proposed by Gu and Zhu at Hull University in 1994, the approach itself underwent a long evolution process in China. The first part of this paper will review the evolution process, followed by brief descriptions of the essentials of WSR approach and its recent developments (various applications) in China. In the second part, the working process of WSR approach to a practical project of developing a computerized decision support tool for evaluation of naval weapon system evaluation is depicted. The concerned task in the project is seemingly a hard problem. However, tremendous effects of human factors, especially the peculiar culture within the clients, variety of disciplines of the project members, and contradiction between the goals and reality changed a hard problem to a messy issue. The key steps for the resolution of the issue are addressed where WSR approach is applied.

Key words: WSR approach, weapon system evaluation

1. Introduction

In this paper, the concerned system for evaluation refers to naval weapon system, more specifically, refers to surface fire. However, the methodology of weapon system evaluation in discussed is a general concept. Every weapon system concept is based on a need to fulfill an anticipated operational requirement during its whole life cycle. The requirement comes from specific missions (goals) set by menace analysis, and leads to a specifically designed prototype through function analysis. The prototype will be under effectiveness analysis for acquirement of a system performance index for those missions. Cost and venture analyses aim to a feasible and successful product at right time and bearable expenditure. Among all tasks about weapon system evaluation, effectiveness analysis plays a dominant role, and worth more endeavors since it helps weapon system developers (decision makers) know directly whether the system can fulfill a specific mission or not. For naval weapon system, the *effectiveness* with which the system fulfills

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this need is the ultimate measure of its tactical utility and its value to the fleet (United States, 1964). There are many methods for effectiveness analysis, ADC (availability, dependability and capacity), SEA (system effectiveness analysis), index method, 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 computing technologies is a great appeal. With popularity of decision support system and its various applications at different fields in China, to develop a DSS for naval weapon system evaluation is a very natural idea for domain people. A project with RMB 50,000 *yuan* was set up by people on evaluation of naval weapon systems (NWS) in mid of 1996 for an exploring research and was undertaken by systems engineering people from Institute of Systems Science (ISS), Chinese Academy of Sciences. The initial goal of the project was to develop a four-base DSS framework for weapon system evaluation. NWS people had already made the initial design whose general idea was to put basic data about various weapon systems in the database (DB), various models for various applications in the model base (MB), relevant methods or algorithms into algorithm base (AB), and experiences and expert knowledge on weapon system evaluation in knowledge base (KB). The main tasks for ISS were to build a DSS framework for NWS people later to add more models and domain knowledge that had not been formulated yet. The planning development length lasted 1 year. As the project was started, ISS people confronted a great deal of difficulty: few background materials, no domain models had been in use, no collection of algorithms, no practical case study materials (data), etc. And the worse thing was that different users in NWS group gave different and even conflicted views about the objectives and functions of the expected DSS. Later, ISS people found the funds were entirely inadequate to meet the real demands of all users. The issue of funds became a big blockage in system development, while NWS users reserved their great desires for a complete DSS framework. Therefore, an intuitively hard problem with clear demands became so hard to be dealt with due to those practical soft constraints and unavoidable conflicts between users' ideal system and little and unorganized resources. As time went by, the human resources changes at both NWS and ISS group led a dilemma of the project. The oriental *Wu-li Shi-li Ren-li* (WSR) system approach was applied to the whole implementation period of the project, which led to satisfactory solutions of various issues, practical computerized aids to the basic tasks in naval weapon system evaluation.

The first part of this paper will briefly review the evolution process, followed by descriptions of the essentials of WSR approach and its recent various applications in China. The second part depicts the whole working process of a latest application of WSR approach to the development of computerized aids for naval weapon system.

2. *Wu-li Shi-li Ren-li* (WSR) System Approach

Difficulties confronted in system practice on complex systems impelled researchers and system practitioners rethought over those analytical methods and explored effective methodologies since 1970s. More considerations were taken into the human and organizational elements that had been eliminated from system design and mathematical modeling by analytic thinking, which was quite inappropriate to unstructured messy problems, rather than synthetic thinking (Tomlinson and Kiss, 1984). Checkland's soft system methodology (SSM) is one of those pioneer explorations in systems thinking. SSM has been developed for use in ill-structured or messy problem contexts where there is no clear view on what constitutes the problem or what action should be taken to overcome the difficult being experienced (Checkland, 1981). The methodology impressed people by its three features: (a) conceptual modeling about the problem situation, instead of mathematical modeling; (b) the resolution of an issue for feasible and desirable changes, instead of optimal solution to a problem; (c) system practice is a learning process by debates and comparisons.

Simultaneously, oriental system thinking, eastern modes of inquiry and oriental ancient philosophies have been also noticed due to their intuitively systemic thinking and emphasis in human relationships. Actually, one of current research focus in SSM is also on cultural analysis (Checkland, 1988). The oriental *Wu-li Shi-li Ren-li* system approach is the product of the synthesis of western and eastern system approaches.

2.1 The Evolution of *Wu-li Shi-li Ren-li* (WSR) System Approach

When western people engaged in system thinking research, they paid attention to oriental traditional systems thoughts. Pressman wrote a paper about the comparison of western and eastern system methodologies (Pressman, 1992). And oriental people also explore their own methodologies to deal with system complexities. In late 1980s, Japanese researcher Professor Sawaragi proposed *Shinayakana* system approach. *Shinayakana* is an adjective in Japanese, means something between hard and soft or both. The main point is how to use methods or tools to manage ill-defined systems and to develop well-defined system. The approach had been applied to develop decision support system for environmental planning at Tokyo bay (Sawaragi, Naito and Nakamori, 1990).

In the late 70s, the Chinese systems engineering expert, Professor Qian, Xuesen began to notice the *Shi-li*, the management and organizing techniques especially for social system practice (Qian, Xu and Wang, 1978). However, right understanding of *Wu-li* (technical design) and *Shi-li* (organizing strategy) could not assure satisfactory resolutions of issues in reality. People began to pay more attentions to human beings. Studies were taken about the roles of human experiences, knowledge and wisdom in system analysis. In the 80s, Qian established meta-synthesis methodology for dealing with open complex giant systems by studying advances in system theory and system engineering practices in China (Qian, Yu and Dai, 1993). Meta-synthesis from qualitative to quantitative approach is to unite organically the expert group, data, all sorts of information, and the computer technology, and to unite scientific theory of various disciplines and human experience and knowledge. Similar interests in oriental system approaches, especially emphasis in human knowledge and wisdom brought both Chinese and Japanese people into cooperative exploration work of oriental systems approach since 1993 (Gu and Tang, 1996).

One the other side, people directly considered more about effects of human factors, or human relationships, as called as *Ren-li*, which was regarded as official desires, motivation in system practice activities at that time. In the mid of 80s, when giving lectures to central governmental officials in Beijing, Professor Gu J.F. talked about considerations of *Ren-li* in decision making process, and suggested to know *Wu-li*, sense *Shi-li* and care *Ren-li* in decision-making. Since then, concerns of *Ren-li* had been taken to many practical projects such as regional planning, provincial decision support systems, etc. But a clear concept of *Ren-li* was not formally proposed until the cooperation in systems approach studies between British, Japanese and Chinese researchers started in 1994.

During a 2-month visit at the Centre of Systems Studies (CSS) at Hull University Professor Gu, together in cooperation with a Ph.D student at CSS, Zhu, Zhichang proposed the oriental *Wu-li Shi-li Ren-li* system approach (Gu and Zhu, 1995). Practical systems engineering experiences in in China and the intensive exchanges with groups of western system researchers facilitated the formulation of WSR system approach with systemic considerations on the Chinese ancient philosophies, inquiry modes and cultures. Therefore, WSR approach can be regarded as the cooperative result of both eastern and western system studies, while the approach itself was originated from system practices in China and the accumulations of continuous exploration in systems approaches by Chinese researchers. Factually, WSR ideas had been applied to a 4-year project in the development of a computerized support system for a local water resources management finished in 1994 (Gu and Tang, 1995).

2.2 *Wu-li Shi-li Ren-li* (WSR) System Approach and its applications

WSR approach represents systemic thinking of interrelations and interactions of *Wu-li*, *Shi-li* and *Ren-li*, the three aspects of holistic activities in system practice. Table 1 lists the ideas of the WSR approach briefly.

Table 1. Ideas of WSR

	Wu-li	*Shi-li*	*Ren-li*
Implication	theory of physical world, laws, rules and regulations	theory of managing, ways of doing	theory of humanity, organizational disciplines, social norms
Objects	objective matter world	organizations, systems	humans, groups, human relations, wisdom
Focus	*What is …*?	*How to …*?	*Shall we …*?
Principles	honest, truth, as correct as possible	harmony, efficiency, as fluent as possible	Humanity, effectiveness, as flexible as possible
Knowledge needed	natural sciences; knowledge on domain fields	management sciences, system sciences	Knowledge on humans and their relations, behavior sciences, etc.

Wu-li explains the mechanism of what is concerned, *Shi-li* points out the framework of managerial tasks of making the best use of everything, and *Ren-li* is to make the best possible of human beings and to manage in exploring human's potentials. In reality, dynamic unification of physical world, system organization and human beings is always an aim of system practice activities. All inquires and interventions cover all three aspects and their dynamic interconnection. It is better to connect *Wu-li*, *Shi-li* and *Ren-li* more or less so as to get a comprehensive scenario of the problem, issue or mess, and then to put efforts for a satisfactory and feasible result. When applying WSR approach, we emphasize on knowing *Wu-li*, sensing *Shi-li* and caring *Ren-li*.

Current studies on WSR can be regarded as two directions. One is taken by Dr. Zhu in Britain to explore Chinese traditional systems ideas further in order to explain more about interrelations between *Wu-li*, *Shi-li* and *Ren-li*, and make comparisons of WSR with other western methodologies. Another direction is taken by WSR group in the Institute of Systems Science, Chinese Academy of Sciences by doing a serious practical project, from which to unveil more facets of WSR ideas to new issues. Their continual practice in WSR approach has gradually been recognized in China. Here is a list of some practical WSR applications.

1 *Qinghuangdao water resources decision support system*, taken during 09/91-09/94. This project was for improvement of operations management of an expanding water resources system. The final result was like a decision room for managers' monitoring, analyzing, communicating, and making decisions. WSR approach facilitated the cooperative work between people with multiple disciplines and successful application of computerized system to practical problems by local managers (Gu and Tang, 1995).

2 *Research on diagram of standards system of facilities for commerce in China*, taken during 10/95 - 08/96. This project was to build a framework of standards system of facilities for large and middle scale retailing stores. Because there was no such kind of studies before, different viewpoints of the problem brought the whole project into a dilemma. By WSR approach, new visions were adopted and a satisfactory result was achieved (Gu, et al. 1997).

3 *Synthetic evaluation of commerce automation technology integration and pilot engineering*, taken during 10/96-09/98. This project was one of a key project for promotion of information technology (IT) applications to retailing commerce in China. In order to improve the investment effects, decrease investment repeat and to facilitate IT applications to all retailing units effectively, it was necessary to evaluate IT applications in retailing areas, to examine the effects of pilot projects and e-commerce's affect to the socioeconomic development. WSR approach facilitate the cooperation between multiple institutions, structuring of indicator framework, and implementation of practical evaluation solutions so as to achieve a health development of IT application to the sector (Gu, 1998).

4 *Safety engineering of manned space flight*, which referred to a series of studies in safety analysis research for manned space flight since 1996. WSR approach facilitates to apply quantitative analysis instead of qualitative methods for safety analysis. Among all endeavors, how to collect experiences from various experts, how to integrate those

knowledge and construct quantitative models for practical analysis not only demand right *Wu-li* and *Shi-li* analysis, but also need *Ren-li* analysis to help deal with different domain experts experiences properly.

5 *Evaluation support system for labor market development project in China*, taken in 1997. This project was one of projects in developing labor markets in China sponsored by World Bank. This project was for *monitoring* the process of all developmental projects, *evaluating* their affects and *disseminating* good experiences, also simplified as MED project. WSR approach helped the undertakers of MED project to win the bid, overcame complicated human factors' effects from administrative units, implement feasible strategies and achieve a reasonable result to China government and World bank in time.

The involvement of multiple groups of undertakers is a common feature of those projects. Different disciplines, benefits conflicts between different teams and further between different institutions often made difficulties to the whole working process, especially to the whole system integration if a computerized system was a final result. In such kind of cases, WSR approach can help people to understand what their true problems were and work more effectively and efficiently.

The latest WSR application is on developing weapon system evaluation decision support system, the topic of this paper. The difference between this project and those above-mentioned projects is that there is only one project undertakers group and one users group. The scale of the project was rather small, and the concerned problem seemed more technology-oriented. However, the working process was really out of undertakers' expect as they endeavored to find a right solution to a factually the messy problem. The next part of the paper will describe key steps of the issue resolution process after brief discussion of WSR approach to computerized support development.

2.3 *Wu-li Shi-li Ren-li* System Approach to Intensive Information Support

Regarding unceasing appearance of new term labeled products for decision support with advances in computer technological applications, it is more necessary to give further thinking to provide real requirement-oriented support for DSS users. 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. at first (Doyle, et al. 1993). '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 the uses?' are to be under discussions and debates in order to ascertain how people of the organizations perceive the world. 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 fund, human resources, etc. and lead to a satisfactory resolution which can provide sustainable support for system users. Factually, it is an issue in computerized support design: whether to provide extensive information support which tries to include all possible information into the system regardless of organizational and human constraints, or to select key tasks and build simple but practical aids to users and organizational sustainable development (Tang, 1997). The latter 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 providing even a well-organized information base for decision makers who maybe surf aimlessly in the sea of information, so-called extensive information support.

For those organizations lacking infrastructures to develop extensive information support tools, intensive support aids can achieve both efficiency and effectiveness in system development and fit for organizational activities. The idea is more practical in China where many organizational activities are not fully well-organized, and organizational cultures and human factors play dominant roles in making use of information, which WSR system approach tries to take into synthetic considerations. By empirical investigation and analysis, eight constructs for DSS theory are identified, environment, task, implementation strategy, DSS capability, DSS configuration, user, user behavior, and performance (Eierman, et al. 1995). Table 2 lists some points of WSR approach to intensive information support development by 8 DSS constructs.

Table 2. WSR approach to the development of intensive information support

	Wu-li	*Shi-li*	*Ren-li*
System 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, manpower	Data flow, information intensification, manpower planning	Organizational culture

Now we concern about computerized support for naval weapon system evaluation. It had been referred that ADC method was the most popular methods in weapon system evaluation. ADC method considers that system effectiveness is a composite of three parameters - performance, reliability, and availability. The history of computer applications of ADC method for naval weapon system in China was not short. But all programming work was limited to simple tasks which was done independently for specific missions, such as calculation of availability vector of a weapon system, its dependability matrix (reliability), capacity vector (performance) and their final product (effectiveness of the weapon system). Before programming work, the analyst should manually fix the operable state set of the weapon system[3]. Therefore those programs based on specific system structure lack of generality, and were usually abandoned after the system evaluation or the original programmers left. As new missions come,

[3] An operating (operable) state of a weapon system refers to any recognizable states of a weapon system before or throughout its fulfillment of a mission.

programming should be done again. Clearly, the computer application level at system effectiveness evaluation was very low. Searching the operable states of a weapon system manually was one of important reasons. So there are continual needs to improve the computer application levels, especially to the weapon system evaluation methods.

3. WSR Approach to the Development of Computerized Aids for Weapon System Evaluation

In order to build practical effective information support for naval weapon system evaluation, the first important task for ISS people was to find what was the *right* thing worth efforts in this project. It was a hard searching and learning process with clients' changing requirements and inadequate funds.

3.1 What is the *right* thing worth endeavors?

By the contract and original design by NWS people, ISS side firstly organized a group including 6 persons and engaged into learning background knowledge (extensive information about weapon system evaluation). After documents investigation and domain experts' guidance, a detailed design about computer implementation of integration framework of weapon system evaluation DSS was formulated, which included interface designs, database and model base systems management. The necessity of validation of the design proposed further requirements about NWS existing models and weapon system parameters for the constructions of database, model base and knowledge base by ISS people. However, NWS group (3 persons, including 1 senior expert in weapon system evaluation research, 1 young expert and 1 new comer for technical support) could hardly provide their so-called existing specific models for integration design. And their endeavors in the project were sharply decreased at the first half year due to their other projects. Moreover, one young experts left and ISS people visits were unwelcome! Factually, ISS people tried in vain to depict a clear and fluent data flow diagram from the original evaluation requirement to the final comprehensive evaluation results for the definition of parameters between models and interfaces due to lack of necessary information and cooperation by domain people. The three-base DSS framework was not the right thing in this project.

Timely adjustments of human resources were made in ISS side. One person was engaged in database work since there were definitive requirements and accessible domain expert supports. Another two persons with operations research theory background only engaged in effectiveness analysis methods with no further efforts to other problems. Through communications, 2 tasks were seemed the desires of NWS people: (1) computer implementation of a graphical display of reliability diagram for any given weapon systems; (2) model base management so as to have a well organization of various models in weapon system effectiveness calculations. Even though there were few computer implementations of those specific models for specific missions, NWS people were willing to accept any interfaces in links to models implemented in future. They even had more ambitions, to reprogram all those past programs by popular programming languages so as to put them into the model base. Those two tasks maybe the right thing.

Meanwhile, ISS side gradually understood a peculiar culture of NWS group, whose original goal of this project was in a competition with another similar group in their institute. DSS application in their field was rather a new concept and probably a good excuse for applying large research funds, so a preliminary research project was accepted with tight budget. That was why NWS side could provide a sketch of work flow in weapon system evaluation and emphasized on three-base DSS structure even though they had few necessary collections and refinements about data, models and so-called knowledge for their designed DSS development. And ISS people were not welcome to on-the-spot investigations due to complicated human relationships. Even harmony did not exist in NWS group. Controversial reality and evasive attitudes hampered ISS people in effectiveness analysis work for another half a year. Finally both quitted from the project with no computer implementations.

Negotiations on project timetable and feasible goals of this project were taken after one year. Another young expert entered into NWS group and communications became easier. However, each NWS person still impressed ISS people with their different viewpoints about a same issue. After one year exploration, the right thing worth practical efforts was to find a appropriate way to achieve computerized decision support to effectiveness analysis with few requirement of background information, since NWS side could not provide a case to help ISS people fix a start position for computer implementation. However, the right thing was too general for start of programming work in weapon system evaluation.

3.2 How to fulfill the *right* tasks?

Peculiar background of the project and strange attitudes of clients impressed the author when she was fully involved into the project for effectiveness analysis one year later. For a clear understanding of the project so as to find a practical solution to the project implementation. Checkland’s CATWOE analysis was applied. CATWOE is a mnemonic word of six elements during conceptual modeling about what is concerned, where

***C**ustomers* - Victims and beneficiaries of what the system does. In this project, NWS people were the direct beneficiaries. And the field of the naval weapon system would be also benefited from a successful results of above-mentioned two tasks are also for the relevant field.

***A**ctors* - Those who carry out the system activities. Both ISS and NWS members in this project were actors, but played different active and not harmonious activities. For example, NWS technical support person kept on modifying their original diagram of weapon system evaluation work flow, and concerned models about system capacity calculation but could not provide case materials. Two ISS persons on effectiveness analysis emphasized on ADC calculation while ignoring a practical computer

implementation. So one went too further away from model integration, while the other was over academically oriented;
T*ransformation* - The purposeful activity which transforms an input into an output. The input was NWS design and diagram of their current evaluation workflow. The output was an effective decision support tool for evaluation;

W*eltanschauung* - The world view which makes it meaningful to consider the system. In this project it referred to the goal of both sides, to improve level of naval weapon system evaluation by advanced computer technologies, to acquire an advantage for more funds (for NWS people), and to expand WSR applications (for ISS people), etc.

O*wners* - Those who can stop the activity. Both sides were owners. Even though one year passed, weapon system database had been implemented while fund had been almost exhausted, NWS group became more active in the project but ignoring expenditure issue;

E*nvironmental constraints* - The things in its environment which this system takes as given. Peculiar background of the project, different views from all NWS group members, ambitions in achieving a complete DSS product vs. few accumulations of weapon system evaluation models and case studies, bias in exploring computer implementation of effectiveness analysis by ISS group, inadequate fund, inactive attitudes in ISS group, etc.

Object-oriented analysis was adopted to avoid an impractical pursuit of a general DSS framework with lack of necessary materials after CATWOE analysis. More computer-oriented endeavors were taken, i.e. visualization of reliability block diagram of a weapon system and automatic generation of operating state set of a weapon system. The latter had never been implemented in naval weapon system in China. Only by automation operating states generation, a visualizing analysis of weapon system reliability diagram would be meaningful in practical system functional analysis against a specific menace. The right thing was founded.

According to principle of intensive information support, a series of Visual Basic 4.0 applications were implemented, including menace analysis (MENACE), effectiveness analysis (EFFECT), cost analysis (COST) and comprehensive analysis (AHP). An on-line help and weapon system database by VFP 5.0 were also linked under the same workgroup titled Naval Weapon System Evaluation Aids (NWSEA). Such kind of results was too far away from the original DSS structures by NWS people. There was an issue for negotiation.

3.3 Shall we demand clients to accept the results?

The concept of DSS spread widely and have already had many applications in China (Gu, Tang and Dong, 1994). However, the real users of DSS often had to accept such a labeled system in relevant projects since all their knowledge about DSS usually came from developers. Moreover, users had not proposed their real demands at quick development. In this project, the situation was totally different. The users had already designed a three-base structure DSS with a diagram of workflow in weapon system evaluation before the project started; while developers provided a series of tools instead of an integrative system finally. Confined to the three-base framework, NWS people thought system effectiveness evaluation tool was their expected model base management system, then they still demanded a knowledge base shell. Pull and push strategies were applied to changing their views and finish of the project.

Pull strategy meant systemic ideas about DSS and its advances were taught. Since DSS emphasized support, so to provide effective support for weapon system evaluation was the goal, which could be implemented by small and easily operated applications. The important was not the framework itself, but the functions. Knowledge on right purposeful activities in weapon system evaluation had been reflected by those interfaces of each application. Object-oriented techniques were effective means to reflect domain knowledge into system implementation. More advanced ideas were introduced so as to help NWS people improve their knowledge on decision support.

Push strategy meant NWS people had been persuaded to accept the ideas of the developer about computerized decision support and gave up impractical illusions, since they could not provide necessary knowledge and enough fund for three-base DSS framework. When each application could be regarded a kind of model management tool, meta-knowledge about weapon system evaluations work had been embedded into the task-oriented series applications by object-oriented mechanism.

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)

Implemented by Visual Basic 4.0, EFFECT is one of four computerized support tools for naval weapon system evaluation (Tang, 1998). The design of EFFECT reflects a feasible coordinated representation of the *Wu-li* in weapon system analysis (weapon system concept and its evaluation mechanism), *Shi-li* in integrative implementation considering further expand, and *Ren-li* in considering more human factors in implementation. *Ren-li* considerations especially referred to the subjective goals of this project for NWS people, the differences in knowledge of weapon system evaluation among NWS people, their world views in this projects, etc.

4.1 System Evaluation Workflow

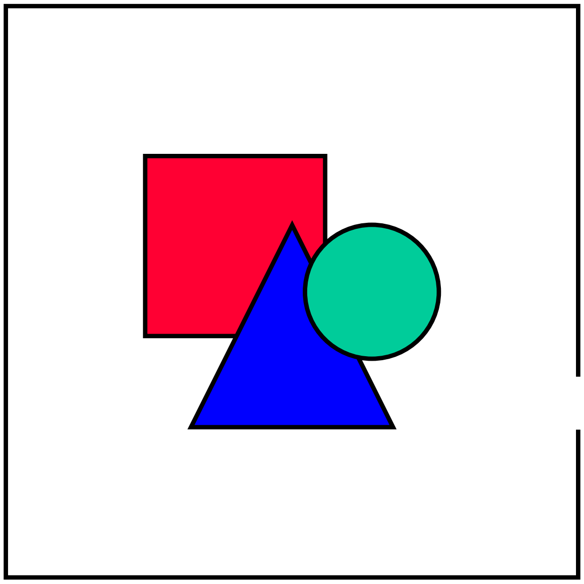

Figure 1. EFFECT Main Window

The main frame of EFFECT is as shown in Figure 1. 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*. The structure diagram shown in the main window is a general reliability block diagram of a naval weapon system (surface fire, where single system of each block refers to the corresponding function which equipment has, instead denotes to the equipment itself. So equipment may be appeared more than once if it serves multiple functions, such as both target detect and track function for radar. In some practical analysis, adjacent system and firing system are regarded as one for simplicity.

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 for the number of equipment as shown in Figure 2. Since one equipment can serve multiple functions, necessary examination should be taken to assure a right number of equipment in a weapon system. After the inputted weapon system passes the 'Test', the number of equipment is calculated, 'Confirm and return' button will become valid. The reliability diagram at main window is refreshed with current system structure in analysis. Only one system is analyzed at one time.

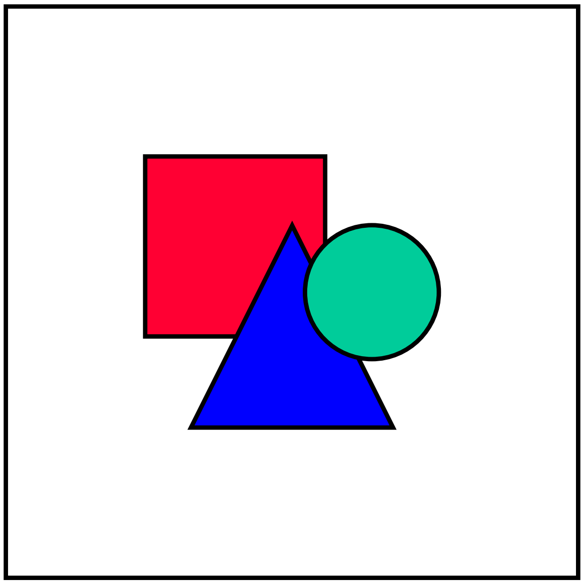

Figure 2

The right input of a practical system is a critical step in defining a new weapon system. Some rules should be followed strictly, such as one fire controller must be inputted when track radar exist. Those rules are formulated based on the general reliability diagram as shown in main window.

Here comes an issue. Can such kind of rules assure the right reliability diagram of the real system? Or can the weapon system operating state not be changed? That is a *Wu-li* problem in weapon system analysis. Connecting subsystem (search radar), support subsystem (target track and fire controller) and adjacent subsystem (magazine and launcher) are serial connected in a naval weapon system (surface fire). The number of equipment or their pairs in each subsystem could be changed, the serial relation cannot be changed. Then those transformation rules will not lead to changes of the reliability diagram of a practical system, which is also guaranteed by right algorithm of system state generation.

The diagram in Figure 1 is the default of weapon system reliability diagram. Advances in naval weapon systems development may bring new possible prototypes, then selection of reliability diagram prototypes will be done before the definition of system structure. At present, we have only one prototype (default).

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 3.

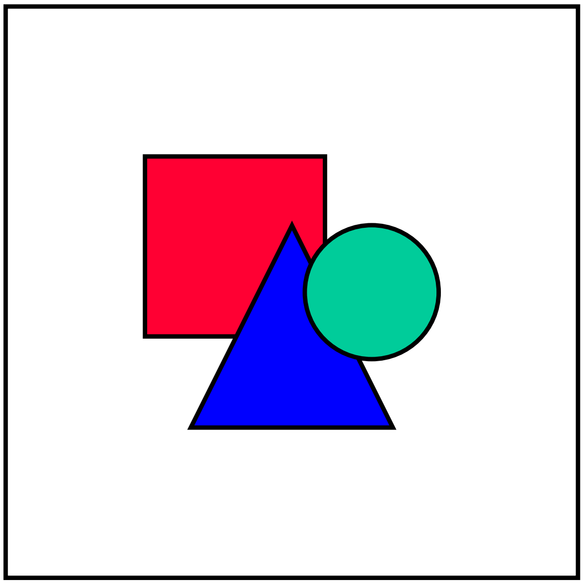

Figure 3. Effective operating states and visualization in reliability diagram.

The states represented by strings of 0 and 1. Click one state, the index of the state at the state list appears in right item, and front color of the name of operating equipment in system structure diagram at the main window will change to green, 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 3, the 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 activates the property window about the equipment (Figure 4). This window simultaneously serves as client interface to visit remote weapon system databases implemented by ODBC mechanism. Click on the button of 'remote link' will activate searching engine by which to find proper equipment from weapon databases fit for current weapon system design. Here, two parameters of equipment are concerned, MTBF (mean-time-between-failure) and MTTR (mean-time-to-restore). Database should be closed before confirm and return. Interactive input of the data is also allowed.

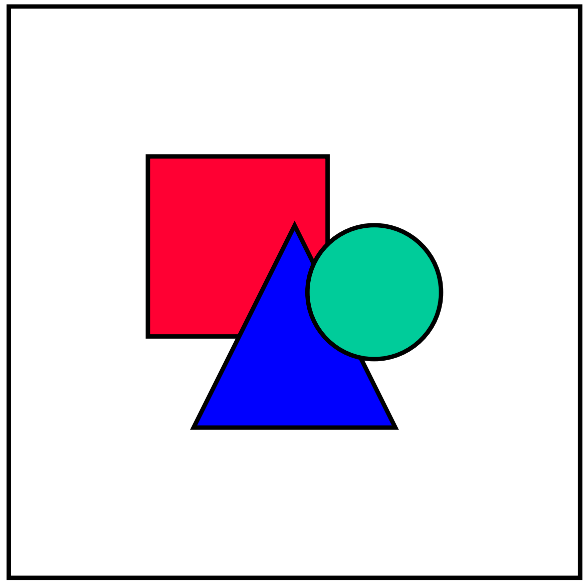

Figure 4. Client Interface of Visit Weapon Systems Database

As EFFECT was finished and for test, one NWS person indicated one weakness, it did not consider the irreparable system. She suggested a new window for selection between irreparable and reparable equipment, since irreparable equipment did not have a parameter as MTTR. In reality, NWS peoples' incremental desires and over interruption in EFFECT design not only greatly affect ISS people's system thinking about whole computerized work, but also hamper the further cooperation. After a second thought, the problem was easily solved since as MTTR close to infinity, the equipment is regarded as irreparable. In practice, MTTR can be set more than 10,000 hours. Here effects from human factors were easily overcome by the *Wu-li* -the method itself. Right *Wu-li* and *Shi-li* are essential to dealt with *Ren-li*.

4.4 System Effectiveness Calculation

In 'effectiveness' menu item, there are four items, 'availability vector', 'dependability matrix', 'capacity vector', and 'system effectiveness'. Before generating states, availability and capacity cannot be calculated. All results can be printed out. After calculating availability vector, the item 'dependability' becomes valid. Click dependability, a prompt message will be bounced to demand input continuous working unit (default value: 0.25 hours).

Since the calculation of the capacity vector is relevant to specific conditions, so EFFECT accepts file and interactive input to avoid of vain efforts to make clear all possible models of system capacity for specific missions. Actually, waiting for NWS people provide system capacity models during the first year of the project still followed the traditional step, *do the thing right*.

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 result of system effectiveness is shown from a prompt message window.

The essence of EFFECT was 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, there were no differences in three-base DSS framework issue. The project was finished after two years work. More-than-one-year vain exploration in the project showed the effects in system practice without a harmony in *Ren-li.*

EFFECT can also be served as a training tool for people to learn how to do weapon system evaluation using ADC method. The learning process is the process to solve the evaluation problem.

5. Conclusion

In this paper, the process of WSR approach to practically developing computerized support tool for naval weapon system evaluation in China is presented. The huge effects of human factors by both users and developers, and the conflicts in benefits between them changed a hard problem to a messy issue. Even for a very hard problem with no human factors (weapon system evaluation), human factors still greatly affect the practical implementation of computerized support tools. The application of WSR approach is for finding a feasible resolution of the man-made messy issues.

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 computerized system effectiveness evaluation. Visualized analysis of weapon system operating states greatly improves human-machine interaction. Visit to the remote weapon data base through LAN implemented by using ODBC is helpful to explore the potentials of expanding weapon databases. Those technical solutions facilitate to validate what kind of practical goals in computerization of weapon system evaluation, a trend of integration of diverse models, tools for synthetic support work for improving the weapon system evaluation work in China.

WSR system approach has been applied to a variety of practical projects in China. Further considerations of *Ren-li* and keeping a harmony among the project teams are imperative to achieve feasible resolution of the concerned issues, and also for sustainable practice from the resolution. However, overemphasis in *Ren-li* and harmony will not always achieve a satisfactory solution, just like this project. Factually ISS people gave the clients a very good solution to their concerned issue with cost of manpower, time and funds just for meeting the clients incremental requirements so as to achieve good remarks from NWS people. Further thinking about *Ren-li* is a long and continual goal for WSR system studies in practice.

6. References

Checkland, B. 1981. *Systems Thinking, Systems Practice*, John Wiley & Sons.

Checkland, B. 1988. "Researching Systems Methodology: some Future Prospects", in *Systems Prospects*: *the Next Ten Year of Systems Research* (R.L. Flood, et al. eds.), Plenum Press, pp9-15.

Doyle, K.G., et al. 1993. "Soft Systems and Systems Engineering: on the Use of Conceptual Models in Information System Development", *Information Systems Journal*, Vol.3, No.3, 187-198.

Eierman, M.A.et al. 1995. "DSS Theory: A Model of Constructs and Relationships", *Decision Support Systems*, Vol.14, No.1, 1-26.

Gu, J. F. and Tang, X. J.1995. "WSR System Approach to a Water Resources Management Decision Support System", in *Systems Methodology I: Possibilities for Cross-Cultural Learning and Integration* (Midgley, G. and J. Wilby eds.), The University of Hull Press, pp41-48.

Gu, J. F. and Tang, X.J.1996. "Soft Systems Engineering Methodology and Soft Operations Research", in *Systems Studies* (G.Z. Xu ed.), Zhejiang Education Publishers, Hangzhou, pp170-178. (in Chinese)

Gu, J. F. and Zhu, Z.1995. "The *Wu-li Shi-li Ren-li* Approach (WSR): an Oriental Systems Methodology", in *Systems Methodology I: Possibilities for Cross-Cultural Learning and Integration* (Midgley, G. and J. Wilby eds.), The University of Hull Press, pp31-40.

Gu, J. F. Tang, X. J. and Dong, Y. K.1994. "The Development of Decision Support Systems in China", *Computers and Industrial Engineering*, Vol. 27, Nos. 1-4, 177-180.

Gu, J.F. et al. 1997. "*Wu-li Shi-li Ren-li* Approach to Preparing the Diagram of Standard System for Commercial Accommodations and Facilities in China", in *Systems Methodology III: Possibilities for Cross-cultural Learning and Integration*, proceedings of the 3rd UK-China-Japan Workshop (Z. Zhu and J. Wilby ed.), The University of Hull Press, Hull, UK.

Gu, J.F. et al. 1998. "WSR System Approach to the Study of Synthetic Evaluation of Commercial Information Systems in China", in *Systems Science and Systems Engineering* (ICSSSE'98, Gu J.F. et al. eds.), Scientific and Technical Documents Publishing House, pp.252-256.

Pressman, T.E. 1992. A synthesis of systems inquiry and the eastern mode of inquiry, *Systems Research*, Vol.9, No.3, 47-63.

Qian, X. S., Xu, G.Z. and Wang, S.Y. 1978. "A New Technology in Management - Systems Engineering", *Wenhuibao*, p1.(in Chinese)

Qian, X. S., Yu, J.Y. and Dai, R.W. 1993. "A New Discipline of Science - The Study of Open Complex Giant System and its Methodology", *Chinese Journal of Systems Engineering and Electronics*, Vol.4, No.2, 2-12.

Sawaragi, Y., Naito, M. and Nakamori, Y. 1990. "*Shinayakana* Systems Approach in Environment Management", Proceedings of the 11th World Congress on Automatic Control, IFAC, Pergamon Press, Vol.V, pp511-516.

Tang, X.J. 1997. "Soft System Approach to Intensive Information Support", in *Management Practice and Chinese Culture* (Yau, H.M. ed.), Research Center for Chinese Management, City University of Hong Kong. (in Chinese)

Tang, X.J. 1998. "Effectiveness Analysis (ADC Method)", Technical Report, Institute of Systems Sciences, Chinese Academy of Sciences, Beijing. (in Chinese)

Tomlinson, T. and Kiss, I. 1984. *Rethinking the Process of Operational Research and Systems Analysis*, Pergamon Press, England.

United States, Bureau of Naval Weapons. 1964. *Reliability Engineering Handbook*, NAVMEPS OO-65-502, 1964.