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A knowledge-based intelligent decision support system for national defense budget planning

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Abstract

In this paper, we present a new framework for knowledge-based intelligent decision support systems for developing a national defense budget planning. The planning procedure for and architecture of the national defense budget in Taiwan are discussed in detail. In particular, the theories and techniques of intelligent decision support are used in the yearly practical budget planning process. Based on data in the financial database and knowledge in the knowledge base, we easily adjust the beforehand budget proposal. Furthermore, a knowledge-based intelligent decision support system has been implemented and it collects a series of rules extracted from national defense experts for successful reasoning. By using forward reasoning and knowledge rules, the system can automatically change and regenerate the national defense budget plan immediately. Finally, the empirical functions of the KIDSS system are also addressed.

Keywords: National defense budget planning; Intelligent decision support systems; Knowledge bases; Model bases; Forward reasoning

1. Introduction

National defense budget planning is a complicated and tedious process. However, it plays a key role in achieving the military's objectives. The objective of the ROC national defense expenditures is mainly to make the best use of military financial resources so as to fulfill defense missions and implement policies correctly in terms of time, quality, and quantity while effectively utilizing limited financial resources to ensure readiness and strengthen combat capabilities through an efficient management system. However, owing to increasing budget demands related to the development of a diversified society, social welfare and overall national economic development, the proportion of the total government budget assigned to the ROC national defense budget has dropped annually from 25.32% in 1993 to 16.53% in 2002. The total government budget was NT$ 1070.71 billion in FY 1993 and NT$ 1518.72 billion in 2002, an increase of NT$ 448 billion. The growth rate was 41.84%. On the other hand, the national defense budget was NT$ 271.09 billion in FY 1993 and NT$ 261.04 billion in 2002, a decrease of NT$ 10.04 billion or 3.70%. In addition, the Legislative Yuan recently approved the central government's annual budget. The value of the national defense budget for FY2004 is 265 billion NT dollars. Its proportion of the total government budget, 16.5%, is still decreasing.

Furthermore, when the central government sometimes internally adjusts the total government budget or when it is cut by the Legislative Yuan, the MND has to change its budget proposal. This takes time and is a complicated process. Every year, when the budget for national defense expenditures is cut, this causes many arguments among organizations. Each unit hopes to get as much money as possible. Therefore, how to balance the budget demand for every organization is a big challenge. Thus, for the above reasons, we have developed a Knowledge-based Intelligent Decision Support System (KIDSS) for defense budget planning to provide and refresh real-time information which decision-making officers can use to keep abreast of the implementation status of relevant policies so as to achieve the goals prescribed by the budgetary plan. The intelligent decision support system for national defense budget

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planning aims to effectively make decisions on the processes involved in budget planning. By using sensible analysis and planning, managers are able to precisely and quickly complete the financial budget plan.

Government budgeting is a process that matches resources and needs in an organized and repetitive way so that collective choices are properly resourced. Budgeting systems have been studied by many researchers in the past (Caiden, 1982; Schich, 1978; Tyran, 1992; Welsch, 1976; Wildavsky, 1974, 1992). Considering the past decade of radical reform of planning and budgeting in the Ministry of National Defense (MND), it is perhaps not surprising that some concerns have been expressed about alignment and coordination of the planning and budgeting processes across the military's organizations. Alignment and coordination pose many challenges. One challenge foreseen by us is related to the proliferation of incompatible system, which can seriously hamper alignment and coordination even after other problems of an institutional or legislative nature have been taken care off. Based on the routine operations of each subordinate organization across the MND, we find that the greatest benefit for alignment and coordination would be achieved by establishing an impartial critical standard for budgeting and workflow automation among the core processes of each organization. This would do the following: strengthen the elusive link between planning, budgeting, and priority across organizations; achieve maximum effectiveness of the annual budget as a coordination tool, which is important because it may be the only time when all approved project actions are planned and reviewed; bridge the gap between top-level organizations and subordinate organizations, which often only speak to each other through summarized reporting in formal documents.

The widespread use of the Internet and computer technology provides an opportunity to enhance the techniques of expert systems (ES) and decision support systems (DSS), which help managers deal with and manage this fast changing environment (Chan, Jiang, & Tang, 2000; Eriksson, 1996; Huang, Huang, & Mak, 2000; Li, 2000; Liang & Huang, 2000; Matsatsinis & Siskos, 1999; Ozbayrak & Bell, 2003; Pal & Palmer, 2000; Wong et al., 2003). Additionally, researchers have attempted to develop effective intelligent systems to assist managers in making decisions about how to solve financial problems. Lawrence and Sim (1999) developed a financial DSS to improve decision-making for currency and interest forecasting. His study found that while decision-making was improved in comparison with a control, most of the potential value of the DSS was lost. Khorshid (1995) proposed a framework for a computer-based DSS to support the development planning process. The economic planning support system was designed to generate a medium-term economic plan for national economies.

Rapid advances in information technology have also opened up an enormous number of business opportunities (Bigus & Bigus, 1998; Bui, 2000; Choi, 1998; Choi, Park, Kim, Joo, & Sohn, 2000; Eriksson, 1996; Hamper & Baugh, 1998; Jackson, 1995; Koutsoukis, Mitra, & Lucas, 1999; Liang & Huang, 2000; Luger & Sandhusen, 1998; Sandhusen, 2000; Yang, 1997). Liang and Huang (2000) applied intelligent agents to support electronic trading. A three-layer framework for the EC environment was built. In the architecture, knowledge was built to help the market maker, an agent, to determine which type of trading should be chosen. The paper also gave some examples of rule expression, which adopted Knowledge Query and Manipulation. Li (2000) established a hybrid intelligent system to prove the usefulness of a logic process for strategic analysis of marketing strategies. It aids doing group assessment of strategic marketing factors through managerial intuition and judgment, and helps managers deal with uncertainty and fuzziness. Additionally, it generates intelligent advice that is useful for planning marketing strategies.

Some research based on DSSs or ESs has focused on solving military problems by using the above skills (Choi & Ahn, 1997; Choi, Ahn, Han, Kim, & Kim, 1998; Wen & Wang, 2001; Worm, Jenvald, & Morin, 1998; Zhuge, 1998). Choi, Ahn, Han, Kim, and Kim (1998) proposed a knowledge-based decision system for goal directed military resource planning that uses sequential linear goal programming. Liao (2000) used the DSS with case-based reasoning to simulate and train military officers. This approach aids the implementation of military SOP of command and control, and the development of a war game training system. Liao (2000) also proposed a knowledge-based military geographical intelligent system that supports the combat needs of different military organizations.

This paper is organized as follows. Section 2 describes the Planning, Programming and Budgeting System and the process of budget planning. In Section 3, the architecture of the knowledge-based intelligent decision support system for national defense budget planning is illustrated. Section 3.1 gives the structure of the database, rule base, and model base. In Section 3.2, the process of rule reasoning is explained. To help the readers understand how it works, the knowledge-based intelligent decision support system for national defense budget planning is implemented and its functions explained in Section 4. Finally, some important conclusions are drawn and future works discussed in Section 5.

2. The planning, programming and budgeting system and the process of budget planning

The Planning, Programming and Budgeting System (PPBS) is the core of the national defense resource allocation process in the Republic of China (ROC). It establishes the framework and provides the mechanisms for making decisions about national defense and provides ways to reexamine prior decisions in light of the current environment (i.e. evolving threats, changing economic conditions, etc.). It is an iterative process composed of three distinct but interrelated and overlapping phases: Planning, Programming and Budgeting. Each of these phases contributes to the overall objective of PPBS and each phase overlaps the next.

In the first step in the process, the Planning Phase, the objective is to identify threats to national security, assess present capabilities to meet those threats, and recommend the forces required to defeat them. This phase ends with Defense Planning Guidance (DPG). In the second step, the Programming Phase, the mission is to transform the guidance, information and decisions of the Planning Phase into a 5-year resource proposal. The challenge of this phase for the Services' is to effectively apply fiscal constraints to the largely non-fiscally constrained guidance supplied by the Planning Phase and to generate an acceptable proposal for how to assign the available dollars to programs. The Budgeting Phase, the last step, takes the 5-year resource proposal developed in the Programming Phase and reviews the first years based on fact-of-life execution issues. The purpose of this step is to develop an executable proposal that will best accomplish the services' approved programs. After several budgetary reviews are conducted, the MND submits a budget estimate to the central government. This is a request for the Legislative Yuan, the ROC 'Congress', to appropriate the required resources to carry out the plan (see Whitepaper).

There are four important factors involved in the formation of national defense funding policies: overall national economic development, governmental financial capability, national security, and the budgetary system of the ROC Armed Forces. The objectives of the policies are to effectively support combat readiness and achieve the defined national defense goals, as shown in Fig. 1.

The guidelines for the policies can be divided into three categories: budget acquisition and planning, budget distribution and allotment, and budget management and assessment.

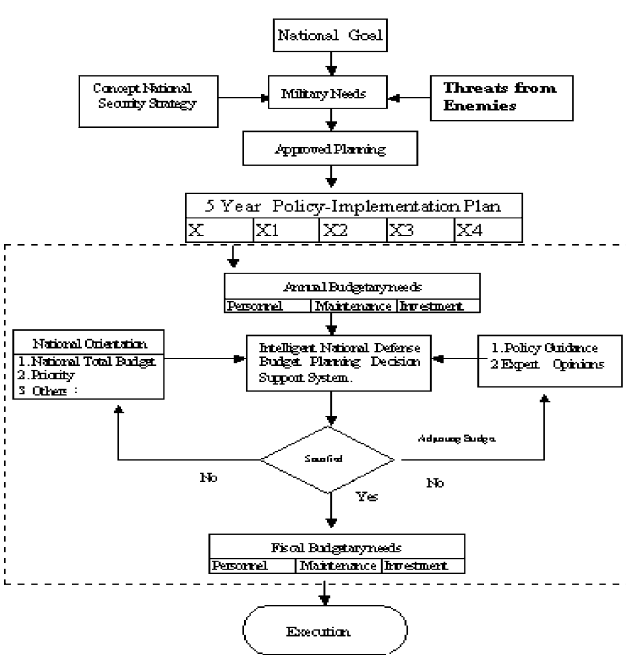


Fig. 1. The process of formulating a national defense budget plan.

1. *Budget acquisition and planning*. Based on the mid- and long-term Planning, Programming and Budgeting System (PPBS), the mid-term budget-line appropriated by the Executive Yuan, the priorities of military buildup and preparedness, and the principle of 'planning after the acquiring budget,' the MND completes a mid-term budgetary administration plan, which is then submitted to the Executive Yuan for auditing, so as to refine the mid-term plan for national defense funding.
2. *Budget application and allotment*. In line with the PPBS of the ROC Armed Forces and the defense budget-line appropriated by the Executive Yuan, the MND satisfies budgetary demands for obligatory expenditures, continuously meets the basic budgetary needs for living, operating, exercising and training in the military, and strives to increase the budget in order to maintain combat readiness of the ROC Armed Forces. Furthermore, the MND annually completes budgetary plans for military investment in R&D, and for producing and procuring advanced weaponry and equipment so as to support future military operations.
3. *Budget management and assessment*. Based on the concept of the military buildup and restructuring program of the ROC Armed Forces, the MND follows the procedures incorporated into the 5-year policy-implementation plan to fine-tune its annual budgetary planning activities. Once the budgetary plan is completed, the MND supervises implementation of the budgetary plan on a monthly basis. In addition, a special mechanism of fund management is established to supplement the defense budgetary activities.

In general, the budget planning process is operated in two main phases: budget formulation and budget execution as described in the following (see Statistics Accounting). Budgeting and financial management in the ROC government is strictly controlled by the various levels of government and the Executive Yuan. Fig. 2 shows the whole process of national defense budget planning.

Basically, in the budget formulation phase, the general budget for the central government and the budgets for subordinate government agencies are prepared in five primary stages as follows.

(1) From December of each year to January of the following year, annual programs are drawn up, the budget is planned, and receipt and expenditure policies are set for the next fiscal year. Major tasks include formulating Executive Yuan administrative policies, drawing up a general summary of the administration programs and budgeting guidelines for the central and local governments, and drafting rules for preparing both

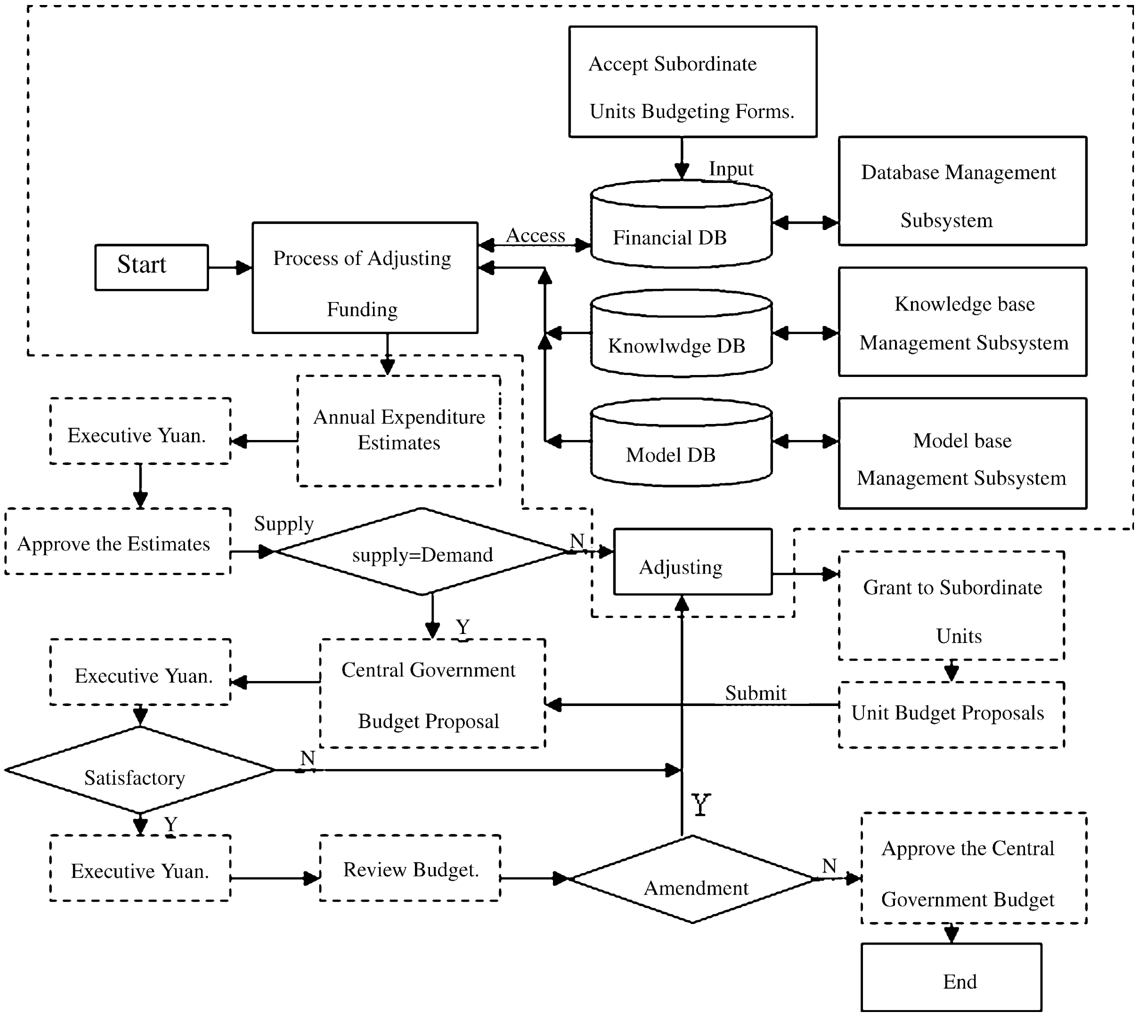


Fig. 2. The approval process for the central government budget and the national defense budget.

the general budget for the central government and the budgets for subordinate government agencies.

(2) From February to March, the scale of the central government general budget is verified, and budget expenditure estimates for each supervisory agency as well as appropriation plans for each operating agency are approved. Each operating agency shall prepare operation programs during this period. Major tasks include the preparation of administration programs by each government agency, setting expenditure budget lines for each central government agency, granting budget lines for provincial (municipal) governments, and preparing operation programs and budgets for all subordinate agencies.

(3) From April to June, each government agency prepares its annual expenditure estimates, and the Executive Yuan considers approval of these estimates. Major tasks include preparing budgets based on annual expenditure estimates and annual revenues reported by each government agency, re-screening such estimates, screening annual expenditure estimates for subordinate agencies, submitting annual operation programs, and calling meetings of the Budget Review Committee.

(4) From July to August, the Executive Yuan compiles and prepares the general budget proposal, the budgets for subordinate agencies, and the consolidated budget tables. According to the provisions of the Budget Law, all government agencies must submit their agency budget proposals via their superior to the Executive Yuan prior to a deadline. The Directorate General of Budget Accounting and Statistics (DGBAS) combines these agency budget proposals into a central government budget proposal. After the budget proposal is approved in a cabinet meeting, the Executive Yuan submits the central government budget proposal to the Legislative Yuan prior to a deadline for legislation.

(5) From September to November of the next year, the Legislative Yuan (LY) reviews the central government budget proposal. The LY invites the Premier, the DGBAS Director-General, and the Finance Minister to give reports on administrative programs and on the process of preparing the annual revenue and annual

expenditure budgets to the LY. Relevant committees review different parts of the proposal first, and the results of these reviews are reported at a joint conference session of the entire LY for the purpose of review. Then the budget proposal is submitted to the floor of the LY for the second and third readings. After its passage by the LY, the President promulgates it.

In the first step of the budget execution phase, the budget is promulgated by the President and all organizations then pay expenses based on the budget plan. The DGBAS of the Executive Yuan and the DGBAS of the MND must control and monitor execution by all organizations' budget plans according to the Budget Law. Next, The Ministry of Audit, ROC, audits all units at the end of the fiscal year to check whether their expenditures were legal or not. Therefore, the entire process is very strict and organized to make sure that all the funds are spent at the correct time and used efficiently according to government regulations.

3. The architecture of the knowledge-based intelligent decision support system for National Defense Budget Planning

The KIDSS system is composed of four main components, as shown in Fig. 3: the database management subsystem, the model base subsystem, the knowledge acquisition subsystem, and the dialogue subsystem. The database management subsystem mainly contains a relational database which is managed by a software program called the database management system, and which provides speed data retrieval, updating, and appending. A DSS database is a collection of current or historical data from a number of applications or units. The data in a DSS database are usually extracts or copies of operational databases, so using a DSS does not interfere with critical operation systems. The model base subsystem includes many statistical, management scientific models, or other quantitative models that offer the system's analytical or forecasting capability to solve future outcomes. There are many types of models. Statistical models generally contain the full range of expected statistical functions including means, medians, deviations and scatter plots. Optimization models, such as linear programming and dynamic programming, are often adopted to determine the optimal resource allocation to maximize or minimize an objective function. Forecasting models are used to predict sales, production, or expenditures. Modeling languages for building adequate models are also included and together are called the model base management system. This paper focuses on the use of forecasting models to predict operation maintenance, personnel maintenance, and military investment.

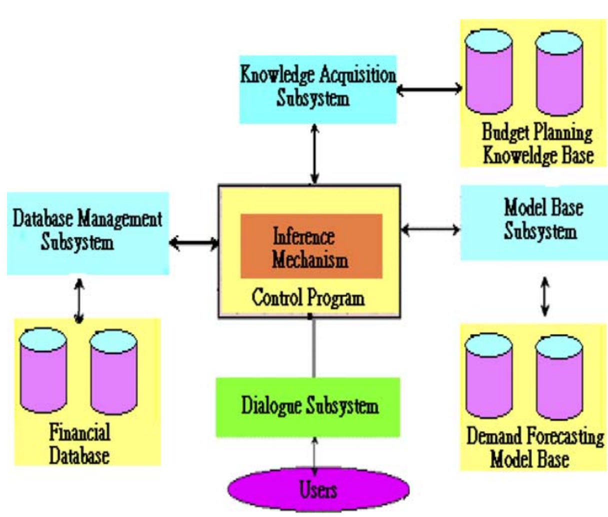


Fig. 3. The architecture of the knowledge-based intelligent national defense budget planning decision support system.

As for the knowledge-based acquisition subsystem, it can support any of the other subsystems or play as an independent role. It suggests alternatives or actions to decision makers. Additionally, it can be inter-connected with the company's knowledge base. Finally, the dialogue subsystem supports a friendly environment for communicating with and giving commands to the DSS through this subsystem.

The above four subsystems form the DSS application system, which is connected to the Internet. The control program first gets input data through the friendly interface (i.e. the dialogue subsystem). Next, it searches for rules to select a suitable model and to execute the model to get analytical financial results. Additionally, all the parameters values needed by the models are retrieved from the financial database. After finishing model analysis, the inference engine uses the results of the model analysis to perform a suggested action. Of course, sometimes, the inference engine may independently infer knowledge rules without using any model. Fig. 3 only shows the general structure of the KIDSS system. In the next section, we will examine in detail each component of the KIDSS system and illustrate practical operations.

3.1. The structure of the database, rule base, and model base

Owing to the superior integration, distribution, and easy-of-use, relational databases management systems are the most popular development tools for building business information systems. In addition, the characteristics of data warehouses are subject-oriented, integrated, time-variant, and non-volatile. Hence, based on the technology and concept of relational databases and data warehouses, a financial database was developed to efficiently determine a 5-year national defense budget.

The database consists of six tables, including Password, BudgetSubject, UnitsMapping, UseforMapping, Budget-Estimates, and BudgetPlan. The main function of the Password table is to verify users' identification. Thus, the Password table is composed of four attributes: *id*, *password*, *unit*, and *management_level*. The BudgetSubject table provides diverse descriptions and functions for budget planning. The attributes of BudgetSubject are *year*, *expenditure-type*, *maintenanceorcapital*, *function*, etc. UnitsMapping and UseforMapping provide the mapping function between units and subjects for reference. The attributes of the UnitMapping table consist of *unit-no*, *unitname*, *services*, *supervising-unit*, *budgetcode*, *unitlevel*, *formulationlevel*, and *priority*. The attributes of the UserforMapping table are mainly *year*, *purpose*, *purpose-name*, *budget-class*, and *use-level*. BudgetEstimates is used to create budget proposals and contains the attributes such as *code*, *year*, *expenditure-type*, *maintenanceorcapital*, *account*, *formulation-no*, *demand*, *adjust*, and so on. Finally, the BudgetPlan table contains the key items needed to edit the budget plan. The attributes of the table include *code*, *year*, *expenditure-type*, *maintenanceorcapital*, *account*, *number*, *demand*, *approved*, etc.

After the above tables are referenced, the annual national defense budget is created in accordance with the following equation:

Annual National Defense Budget = Personnel Maintenance Fees + Operation Maintenance Fees + Military Investment Fees.

In Fig. 4, the following five components are extracted and stored in the financial database during extraction:

1. Guidelines for building up the armed forces;
2. the plan for force restructuring of the armed forces;
3. the plan for force restructuring of services;
4. historical budget data;
5. current budget data.

Through the database management subsystem, the KIDSS system allows uses to conduct online real-time analysis to edit budgeting-related operations. Moreover, for the purpose of forecasting the annual national defense budget, many management sciences and statistical analysis techniques are considered for use in prejudging whether the annual national defense, personnel maintenance, operation maintenance, or military investment fees are adequate or not. In this paper, we adopt Autoregressive Integrated Moving Average Models (ARIMA) in the model base to predict various fees according to historical data.

In the rule base, the specialized domain knowledge is presented in the form of *if* ⟨*antecedent clauses*⟩ *then* ⟨*consequent clauses*⟩ statements. If the antecedent clauses are true, then the consequent clauses are true. The rules in the rule bases are triggered if their antecedents match. Here, knowledge engineers must elicit knowledge rules based on annual defense budget formulating regulations, professional national defense experiences, and judgments. All rules must be coded in IF–THEN–ELSE statements for execution on computers and stored in the knowledge base. Fig. 5 presents the architecture and dataflow of the rule base. The inference engine needs to select a suitable model from the model base. Next, the engine uses the model to analyze and then gets results by making use of historical data retrieved from the database. Upon receiving the final results, the engine needs to infer and explain, the situation and trigger actions or alternatives for decision makers. Fig. 6 presents that the knowledge acquisition subsystem accesses rules that contain in the knowledge base and used to reason via the inference engine. Furthermore, in order to enable users to easily manage the rule base, model base, and knowledge management, we have designed a user transparency approach that can be used to modify all vital information,

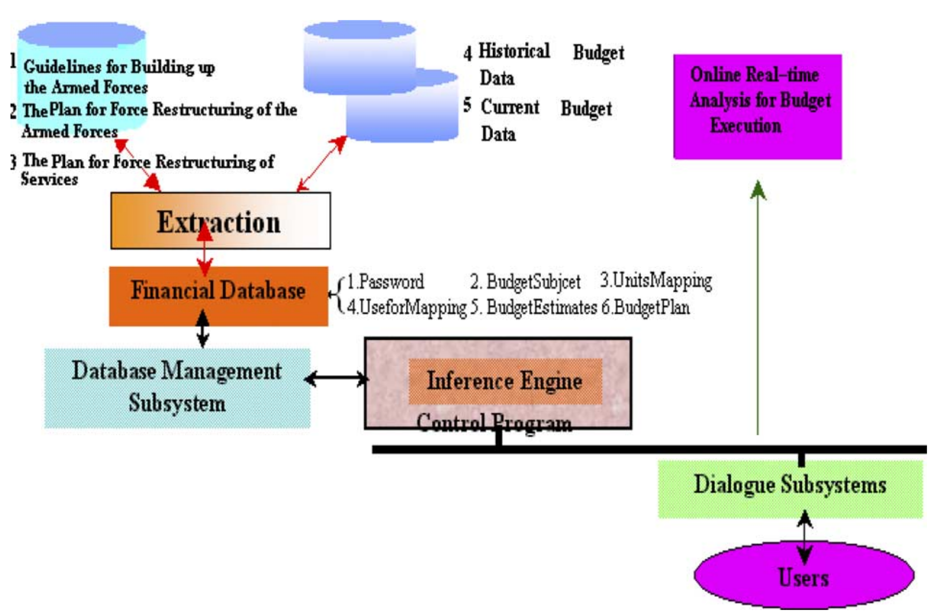


Fig. 4. The architecture and dataflow of the database.

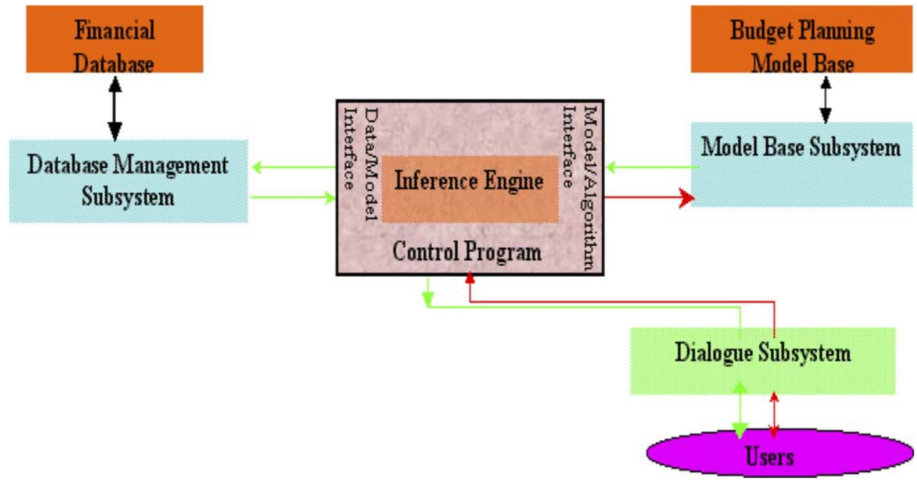


Fig. 5. The architecture and dataflow of the rule base.

if necessary, without revising the program source codes. Users can modify, add or drop into the system their latest rules, models, or knowledge. Once the new knowledge has been input, the system is able to automatically diagnose budget planning related problems and suggest appropriate alternatives for developing the national defense budget plan.

3.2. Rule-based reasoning

Knowledge presentation plays an important role in knowledge reasoning. A well-designed knowledge presentation will affect the performance of an information system. Knowledge-based expert (or decision support) systems must have the following characteristics:

1. *Representational adequacy*. This is the ability to professionally describe all knowledge and to compact with all knowledge in a knowledge base.
2. *Inferential adequacy*. It can inference new rules from some given rules and easily build a new structure.
3. *Inferential efficiency*. This is the ability to efficiently reason, quickly execute and get conclusions.
4. *Acquisitioned efficiency*. Knowledge should effecttively be accessed.

In the past decades, different schemes of knowledge-based expert systems have been developed. Production rules are usually used in knowledge presentation. However, predicate logic, semantic networks, frames, scripts, and decision trees are also adopted.

As we mentioned in Section 3, rules are presented as a set of *if* ⟨*antecedent clauses*⟩ *then* ⟨*consequent clauses*⟩ rules. Basically, there are two types of reasoning: backward chaining and forward chaining. Forward chaining, which is a data-driven approach, starts from a basic idea and then tries to draw conclusions. It checks the IF part of IF–THEN rules to find out whether the antecedent clauses of the rule is matched. As each rule is tested, the program can inference one or more conclusions. Conversely, backward chaining is a goal-driven method. It starts with a goal to be verified as

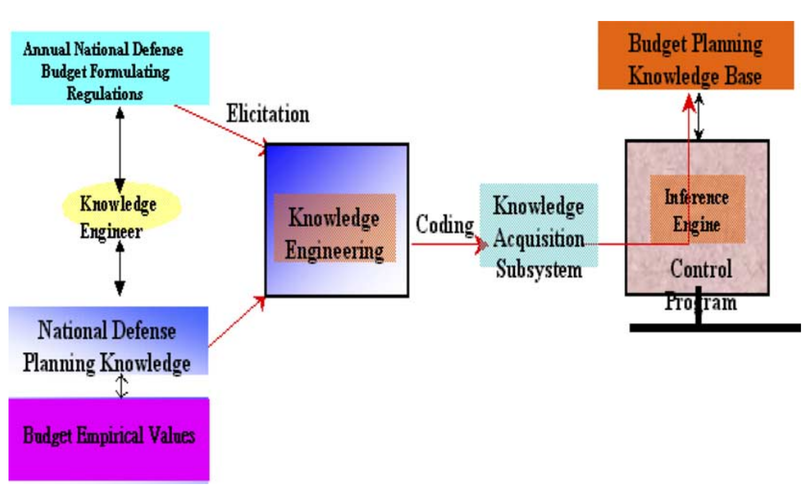


Fig. 6. The architecture and dataflow of the knowledge base.

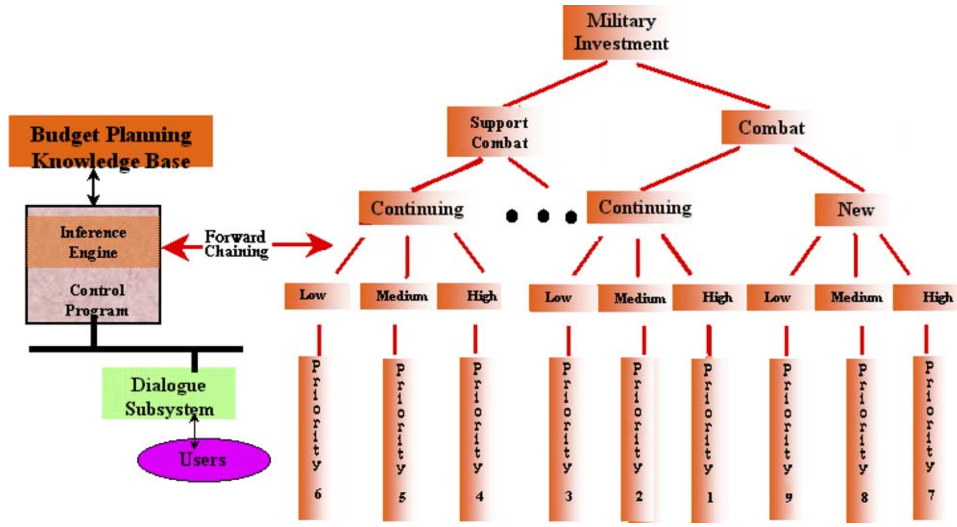


Fig. 7. The forward chaining reasoning process.

either true or false. It then examines all the THEN parts of IF–THEN rules. A rule that contains this goal in its consequent clause will be checked to know whether its antecedent clause is true. If fails, the program searches for another rule whose conclusion is the same as that of the first one. This process continues until all possibilities have been tested. Our approach makes use of forward chaining.

Fig. 7 shows an example of reasoning about military investment. Generally, equipment for military investment can be divided into two categories: combat and combat support equipment. Combat equipment is equipment (e.g. various weapons) can be used to directly destroy buildings, apparatus, or men. Combat support equipment is equipment that indirectly aids the military effort in battles and includes transportation tools, devices for education and training, etc. The effectiveness of this equipment is classified as low, medium, or high. Priority for equipment is assigned based on scores ranging from 1 to 9. Priority 1 means that the item will be chosen first, and priority 9 means that it will be chosen last. While a national defense budget proposal is formulated, the forward chaining method is used to choose adequate rules or generate new rules.

According to the chosen rules, the inference engine can guide each organization in creating its budget proposal. To clarify the forward chaining procedure, several example rules in the knowledge base for budget planning are shown below:

Rule: 1 if Condition = “combat” and Situation = “con-continuing investment” and effectiveness = “high” then Priority = “1”
Rule: 2 if Condition = “combat” and Situation = “new investment” and effectiveness = “high” then Priority = “7”
Rule: 3 if Condition = “support combat” and Situation = “continuing investment” and effectiveness = “high” then Priority = “4”
Rule: 4 if Condition = “support combat” and Situation = “continuing investment” and effectiveness = “medium” then Priority = “5”
Rule: 5 if Target value ≧ Amount and 7 ≦ Priority ≦ 12 then add this item and its value to Chosen and Amount
Rule: 6 if Priority ≦ 6 then add this item and its value to Warning and Amount
Rule: 7 if Chosen ≠ Empty and Amount = Target value then print Chosen and Amount
Rule: 8 if Warning ≠ Empty and Amount = Target value then print Warning and Amount

Assume that the target value of the cutting budget is 10 billion NT dollars and let the Chosen, Warning, and Amount arrays be ∅, 0, and ∅ respectively. Now we can use the above rules to introduce the forward chaining procedures as follows:

Start: In forward chaining, we start with known facts and acquire new facts using rules that have known facts on their IF sides.
Step 1: According to Rules 1–4, the inference engine can determine every item’s priority in the budget planning table, BudgetPlan.
Step 2: Now, if Rule 2 fires and the value of Amount is less than or equal to the cutting budget target value, then the record in BudgetPlan will be added to Chosen and Amount based on Rule 5.
Step 3: Using Rule 7, all records in the array Chosen are printed. Hence, all items which need to be cut will be printed for inspection and discussion.

When the Executive Yuan makes some adjustments to or reduces national defense expenditures, the MND can use the KIDSS system, which adopts the forward chaining method and the algorithm shown below to automatically list proposed budget cuts for all subordinate units' items. After the MND informs all the subordinate units of the proposed items to be cut, if no appeals are received from subordinate units within 14 days, the items are deleted. Therefore, the mechanism is able to easily and quickly adjust the national defense budget proposal. The following algorithm first checks the table *military* and finds out all the items which have priority equal to 12. When the amount of values of these items is less than the target value, the algorithm chooses the items which have priority equal to 11 as items to be cut. The process continues until the target value is achieved. However, items which have priority less then or equal to 6 are not allowed to be cut because they are for continuing military investment. Cutting them may cause serious problems as contracts may be violated or construction projects may be interrupted. The algorithm for listing all the items to be cut is as follows:

```
for(i=12;i≧7;i..)
{
if(The value of cutting amount !=target value)
   {
   select A, B, C, D from military
   where D=i;
   printf(%c %c %d %d);
   }
   endif;
   exit(0);
}
```

(A: Budget Item, B: Budget Name, C: Amount D: Priority)

4. System implementation

National Defense Management College (NDMC), Taiwan, ROC, is responsible for education in MND budget acquisition and planning, application and allotment, and management and assessment. Three NDMC students in the Master's degree program participated in the 2-year research project. The students collected financial data from the current DGBA databases. Moreover, regulations and policies were also gathered and stored in a financial database. Then, the researchers simulated the processes involved in national defense budget planning, starting with budget planning and ending with completion of the MND budget plan. When KIDSS was implemented, 46 officers from different organizations of the Directorate General of Budget Accounting and Statistics, the MND, ROC, were invited to evaluate the architecture discussed in Section 2 of this paper. During the period of evaluation, the officers offered many professional suggestions regarding practical difficulties involved in budget planning and their own important experiences with rules. After the processes of the KIDSS were simulated step-by-step, 86.96% of the officers were satisfied the results and felt the system was very friendly as well as easy to use. Six out of the 46 officers, 13.04%, felt that the system would be valuable and useful if some small adjustments were made in the setting of rules for fairness. In particular, if a few experts involved in national defense affairs were to participate in evaluating the rules in the rule base, the accuracy of the system would be much better. Furthermore, if the Analytic Hierarchy Process (AHP) approach was used to select key factors, the rules in the rule base would be more precise.

Fig. 8 displays the login menu of KIDSS. To ensure the security of KIDSS, the fields UserId and Password must be filled in and the information verified. Fig. 9 shows an entry form for planning the national budget proposal. Note that the fields Year, Account, Unit, Program, and Class can be retrieved from the tables BudgetClass, UnitsMapping, UseforMapping, and BudgetPlan. Only the fields Description and Demand need to be filled in during planning.

However, the central government sometimes needs to reallocate or adjust the budget in light of various considerations. Upon receiving the amount of the budget cut, the MND must immediately make adjustments to its budget. Thus, according to the knowledge rules described previously, the MND lists all the proposed items to be cut whose priority is less or equal to 12. This online real time process is repeated until the amount of the budget cut is achieved. The MND then informs all of its subordinate

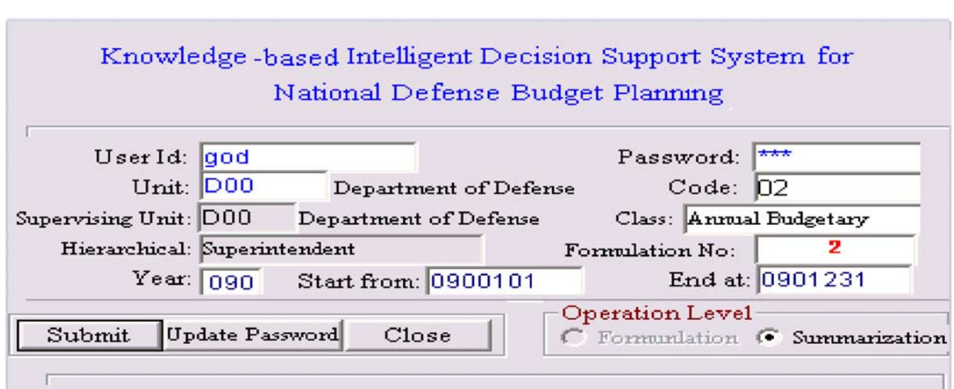
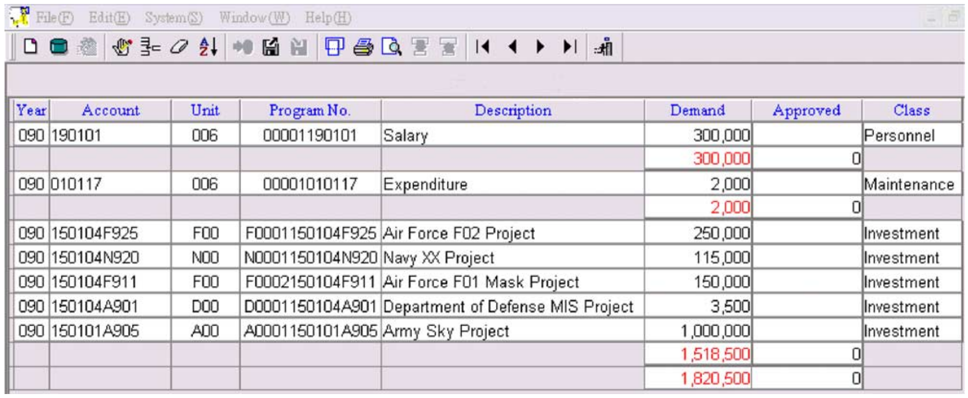
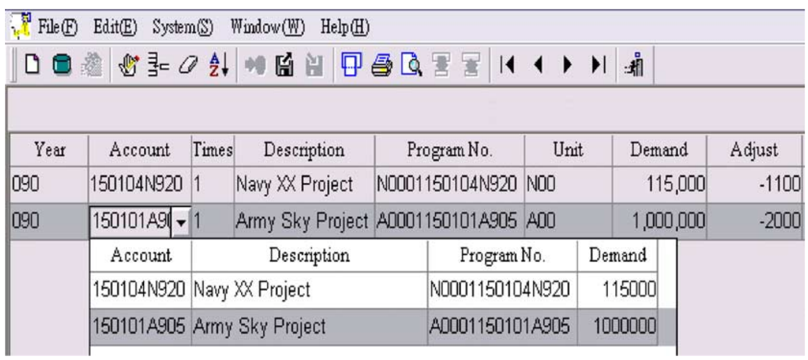


Fig. 8. The login menu of the knowledge-based intelligent decision support system for national defense budget planning.



Year	Account	Unit	Program No.	Description	Demand	Approved	Class
090	190101	006	00001190101	Salary	300,000		Personnel
					300,000	0	
090	010117	006	00001010117	Expenditure	2,000		Maintenance
					2,000	0	
090	150104F925	F00	F0001150104F925	Air Force F02 Project	250,000		Investment
090	150104N920	N00	N0001150104N920	Navy XX Project	115,000		Investment
090	150104F911	F00	F0002150104F911	Air Force F01 Mask Project	150,000		Investment
090	150104A901	D00	D0001150104A901	Department of Defense MIS Project	3,500		Investment
090	150101A905	A00	A0001150101A905	Army Sky Project	1,000,000		Investment
					1,518,500	0	
					1,820,500	0	

Fig. 9. The national defense budget planning form of the KIDSS system.



Year	Account	Times	Description	Program No.	Unit	Demand	Adjust
090	150104N920	1	Navy XX Project	N0001150104N920	N00	115,000	-1100
090	150101A9(	1	Army Sky Project	A0001150101A905	A00	1,000,000	-2000

Account	Description	Program No.	Demand
150104N920	Navy XX Project	N0001150104N920	115000
150101A905	Army Sky Project	A0001150101A905	1000000

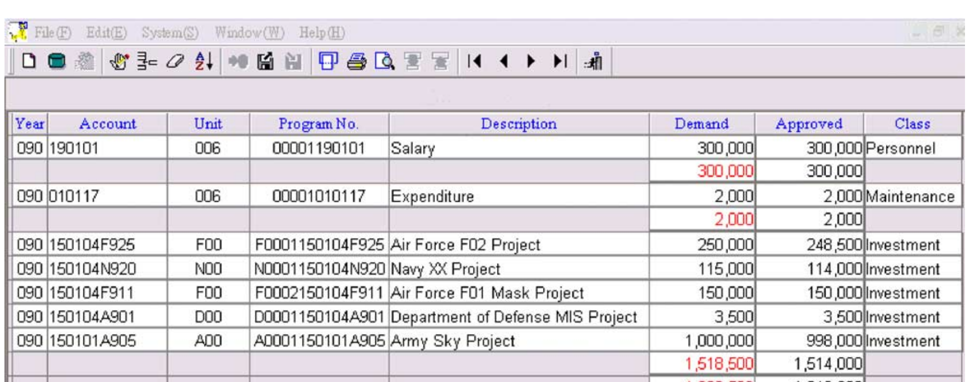
Fig. 10. The form used to adjust the national defense budget proposal.

organizations of the adjustments. If no appeals received from any organization within 14 days, the items will automatically be deleted. Fig. 9 shows the operations involved making adjustments.

After several iterative inspections, the MND completes the annual national defense budget proposal, as shown in Fig. 10. Then, the MND submits the proposal to the central government. Next, the central government combines the budget proposals received from all departments and hands the combined budget over to the Legislative Yuan. Once the budget proposal of the central government is approved, the annual national defense budget is granted, as shown in Fig. 11.

5. Conclusions and future work

With advances in knowledge engineering, knowledge-based expert systems and decision support systems are certain to become essential decision-making tools. Most



Year	Account	Unit	Program No.	Description	Demand	Approved	Class
090	190101	006	00001190101	Salary	300,000	300,000	Personnel
					300,000	300,000	
090	010117	006	00001010117	Expenditure	2,000	2,000	Maintenance
					2,000	2,000	
090	150104F925	F00	F0001150104F925	Air Force F02 Project	250,000	248,500	Investment
090	150104N920	N00	N0001150104N920	Navy XX Project	115,000	114,000	Investment
090	150104F911	F00	F0002150104F911	Air Force F01 Mask Project	150,000	150,000	Investment
090	150104A901	D00	D0001150104A901	Department of Defense MIS Project	3,500	3,500	Investment
090	150101A905	A00	A0001150101A905	Army Sky Project	1,000,000	998,000	Investment
					1,518,500	1,514,000	
					1,820,500	1,816,000	

Fig. 11. The final annual national defense budget plan of the MND.

managers need to make decisions in today's complicated societal and global business environments. Thus, it is vital to provide a well-designed decision support system to help managers improve the quality of decision-making.

In order to clarify the knowledge-based DSS system, this paper has presented the architecture of the KIDSS system and developed a knowledge-based intelligent decision support system that can help managers and users quickly edit or update the national defense budget plan. In the system, forward reasoning is used to infer new facts in light of old facts in IF–THEN statements. For model selection, the inference engine plays an essential role in determining which model is most suitable. In Particular, the model base employs the ARIMA forecast model to estimate the amount of future demand.

Furthermore, to help users easily manage the rule base, model base, and knowledge base, we have designed a user transparency approach that users can employ to modify all vital information, if necessary, without revising the program source codes. Users can modify, add or drop their latest rules, models, or knowledge into the system. When new knowledge is input, the system is able to automatically diagnose budget planning related to problems and suggest appropriate alternatives for developing the national defense budget plan.

Although the KIDSS system has been carefully designed, there are still several ways in which we can further improve its functions in the future. In particular, we may adopt models of artificial neural networks to enhance the quality of financial forecasting analysis. In addition, fuzzy logic reasoning can be incorporated to assist the decision-making process. Therefore, an artificial neural network combined with a fuzzy logic model may provide a better way to deal with the problem of budget planning. Finally, some Internet-based fuzzy logic expert systems are not stand-alone systems but hybrid systems. In the knowledge base of a DSS system, a hybrid system may include not only a rule base but also a case base that can be used to solve financial problems. Thus building a fast and efficient hybrid DSS will be a major focus of our research in the future.

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