PALIP : A KNOWLEDGE-BASED KIT FOR PROJECT APPRAISAL AND SYNTHESIS IN LONG-TERM INDUSTRIAL PLANNING

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ABSTRACT

One of the proven techniques used in long-term industrial planning is the so called program approach, where the industrial plan objectives and targets are achieved through a predefined group of distinct programs. With each program constituting a cluster of projects, it is the ultimate goal in the plan preparation stage to determine the number, size, and the extent of the projects grouped to form a given program. Projects appraisal , i.e. the procedure of selecting, filtering and rescheduling of projects under a certain program, represents one of the most important phases and time-consuming tasks in the planning process. This paper describes the structure and utilization of PALIP, a prototype-intelligent system kit that has been developed for the appraisal of industrial projects in early planning stages. The system is based on the program approach within the industrial planning methodology and it accommodates a diversified range of measuring criteria which have been evoluted from the plan objectives. The system output is a quantitative list in which projects are ranked with the above mentioned procedure together with a constrained weighted factor scoring model. PALIP has been developed using Nexpert-object, an expert system shell with open architecture capabilities.

Keywords: Industrial planning, Intelligent technology in planning, Knowledge-based systems, Multi criteria project appraisal, Project management.

1. INTRODUCTION

The problem of project selection and appraisal has been treated in many articles using analytical, qualitative, and quantitative techniques, which vary widely in complexity, the extent of knowledge and information needed. As single decision making models , profitability measures , such as: the internal rate of return, net present value , pay back period, and other profitability ratios represent some of the evaluation criteria adopted by many organizations [1,2,3]. Other models considered the application of multi-criteria decision making techniques to the problem space [4,5]. Systematic approaches have been used for option evaluation analysis of project choices [6]. Decision theory techniques have been applied to select strategic projects considering sequential technological changes [7]. Integer programming was implemented in some reported weighted factor scoring models [8], while goal programming approaches were suggested when extending the problem to include multiple objective functions [9]. Different sorting techniques were proposed to classify groups of projects based on some relative merits [10,11,12].

Considering the previously mentioned approaches, it has been shown that the profitability measures of the project is not the priority issue especially with limited information environment of the project under investigation. The project appraisal process usually suffers from the following difficulties :

- Complexity and diversity of the planning domain.
- Inadequate balance between resources and objectives
- Vast number of variables and parameters.
- Lack of the accumulated expertise.
- Uncertainties in projects data.

As a result, traditional evaluation techniques are insufficient and inadequate, specially at such an early stage of the project life cycle. The previous reasons clearly suggest the knowledge-based systems (KBS's) to be good candidates as tool kits for such planning phase. While there have been numerous application of KBS technology in production, and management applications [13,14] , very few were reported for project selection under multiple criteria in development planning, [for example 15].

This paper has two objectives: first to describe the structure and operation of PALIP, a prototype KBS which depends on a large-scale bundle of criteria to appraise clusters of industrial project in the planning stage, and second to lay-down the frame work of a comprehensive, systematic industrial planning methodology that considers the aforementioned system as a crucial module within its decision making processes.

The proposed KBS is developed using Nexpert-object shell which could be interfaced to other external application environment and data base systems.

2. SYNTHESIS OF THE PROJECT APPRAISAL PROCESS:

As illustrated before, a large portion of the project appraisal process is very much dependent on the experience of the industrial planner. However, developing a reliable knowledge base is also dependent on the planning methodology, strategies, horizon, and the plan priorities. Consequently, as a key factor in developing PALIP, the long-term industrial planning procedure, together with the project appraisal phase was analyzed using the IDEF0 functional decomposition techniques [16]. The planning concept is abstracted with modification from: some UNIDO (United Nations Industrial Development Organization) articles [17,18], several books and references in industrial project planning and assessment including [19,20].

Figure (1) shows a top-down analysis of the industrial planning paradigm at one of its highest functional levels, where the procedure of project appraisal forms a sub-function of node A5. Node A5 itself represents the bottom functional node in the planning process.

Figure (2) illustrates the breakdown of the project appraisal and selection procedure (node A5) into further sub-system functions.

The analysis has indicated that the procedure of project appraisal could be standardized using an integrated knowledge-based system coupled with an analytical procedure for quantifying the reached conclusions. The amount of expertise needed is vast and the KBS model should take into account the following insights :

- Constraints and limitations imposed from the organization's nature (resources).
- External and internal Input factors
- Limited amount of project data
- Multiple-objective evaluation criteria
- Capability to acquire other project data.

3. PALIP DESCRIPTION

As a problem solving system, PALIP constitutes three affiliates, they are: the analytical model , the project selection criteria , and the knowledge base. As a knowledge-based environment, PALIP internal structure incorporates two sub-systems: the articulated knowledge base, and the inference engine. The relationships between the previous elements are exhibited within PALIP system configuration overviewed in Figure (3). PALIP is designed to include three classes of knowledge bases, they are: criteria generation knowledge base, criteria relative weight knowledge base, and the project evaluation knowledge base. The system uses Nexpert Object, an object-oriented expert system shell, under MS windows environment, and it can easily communicate with any external programs environment using a C interface program. PALIP also permits the user to work concurrently and interactively with a project(s) data base media, and previous plan follow-up reports, when attempting to get more information about a specific project before the final analysis is reached.

The basic inputs for PALIP are:

- A list of the industrial projects which constitutes a program,
- Some project data, e.g. size of investment, description, production capacity, location,etc.
- Previous projects types and other operational considerations.

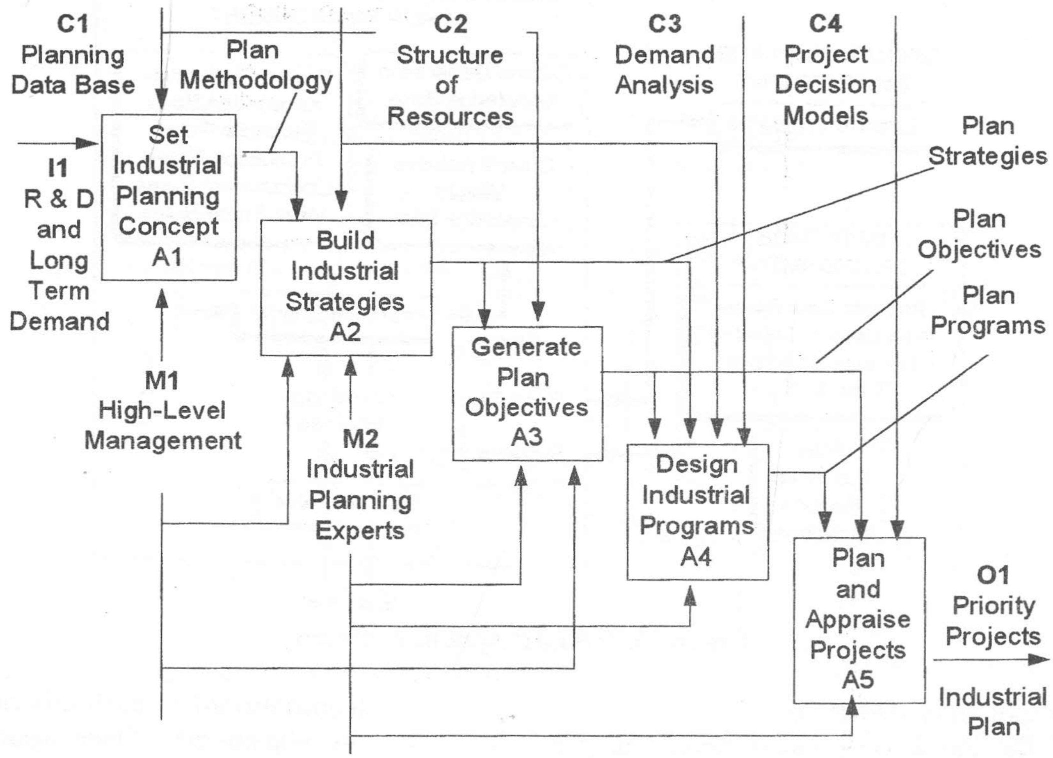

Figure (1). IDEF0 Analysis of the long-term industrial planning procedure: Node A0

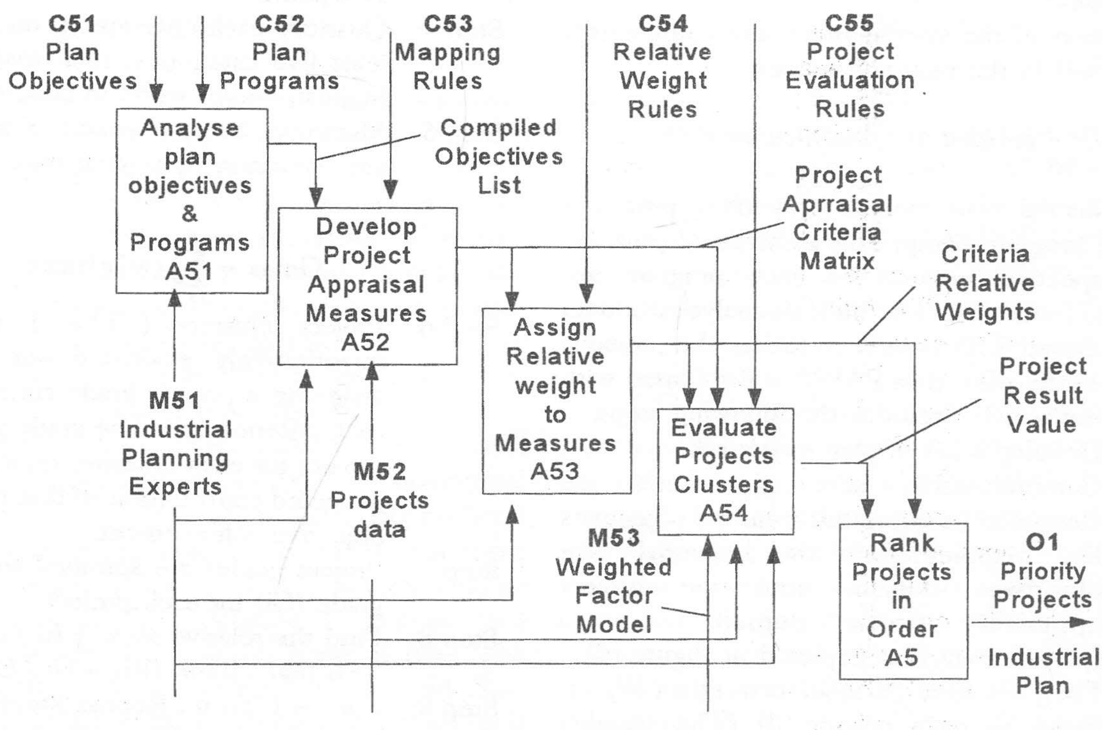

Figure (2). IDEF0 Breakdown analysis of the project appraisal procedure: Node A5

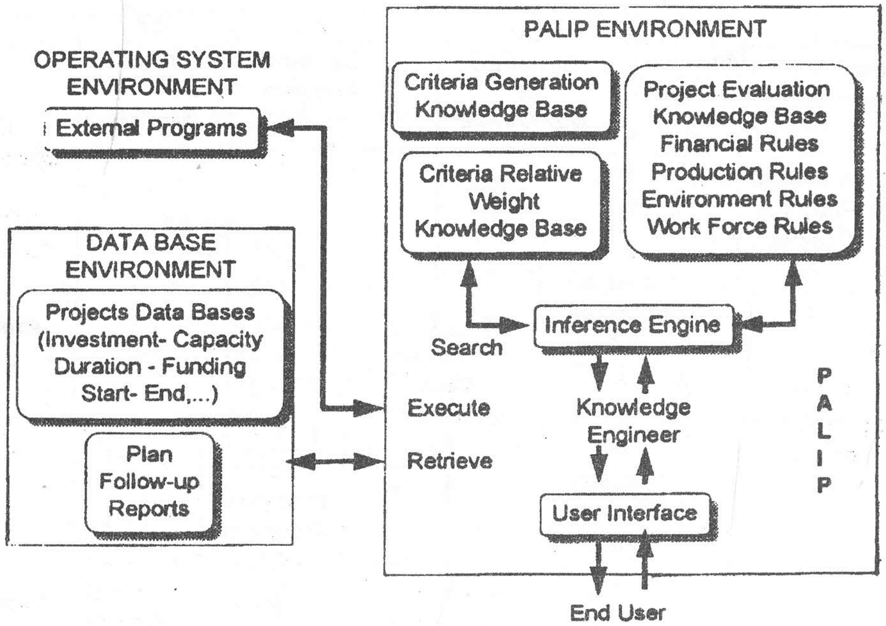

Figure 3. PALIP system overview.

The final output from PALIP are:

- A list of the industrial projects ranked in plan priority descending order.
- A value for each project that quantifies its contribution to the achievement of the plan objectives.

A description of the system items and components are discussed in the next sub-sections.

3.1 *PALIP Algorithm (the analytical model)*:

The industrial plan consists of a set of programs with each program comprising a cluster of projects. The prospective projects of each program are grouped to form a list. The built-in analytical model of the proposed KBS system considers the previous structure of the plan, thus PALIP is developed with a procedure which includes the following steps:

Step 1: Develop a list of plan objectives

Step 2: Comprehensive sets of criteria are Compiled (interpreted) from the objectives list. Mapping from the industrial plan objectives domain onto the project appraisal criteria domain is a (one-to-many), as depicted in Figure (4).

Step 3: For j = 1 to m , a relative weight (Wj) is given to each criteria (j) (The weights reflect the degree of importance (contribution) of each criteria in satisfying the objectives) . Once again, the relative weight is function of many factors such as; the plan period, the plan methodology, Priorities, and the industrial planner viewpoint.

Step 4: Quantify each criterion (j) on a scale of at least five categories, such that: lowest to highest, and/or worst to best, etc.

Step 5: Maximum Score (Gmax) is calculated for each criterion (j). Such that:

$$Gmax = \sum_{j=1}^{m} (wjgj)max$$

Step 6: Project clusters (i = 1 to n) are quantitatively evaluated one by one by assigning a project grade corresponding to each criterion (gj). The grade given to each project for each criterion represents the expected contribution of that project to the objective achievement.

Step 7: Project grades are summed to give a total grade (Gi) for each project.

Step 8: Find the relative rank (Ri) of Project (i) such that : Rank (Ri) = Gi / Gmax

Step 9: For i = 1 To n , Repeat Steps 7, and 8 .

Step 10: List projects in descending order , Stop

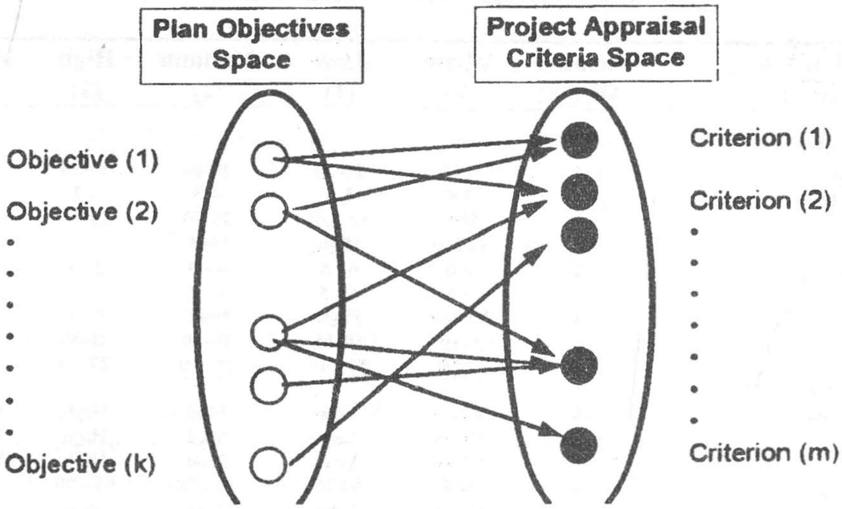

Figure 4. Mappling from the industrial plan objectives space onto project appraisal criter space.

The abstracted analytical technique in the last seven steps within the above procedure is known as the weighted factor scoring model , and it is summarized in Appendix A.

3.2. *Project Appraisal Criteria:*

An interpretation of the industrial plan objectives in the form of a project appraisal measures are listed in the matrix illustrated in Table (1). As stated earlier, there is potentially a large number of criteria that can be used for project evaluation. However, such group of measures should reflect the organization's objective over the planning period. Consequently, it was found in developing PALIP that five major clusters of criteria are sufficient to cover most of the project types and to fully describe the objectives of any organization, as: financial measures, production measures, environmental measures, economic measures, and labor-related measures. The criterion parameter under each of the title measures are self explanatory, and they need no further discussion. The relative weight of each criterion is set on a maximum scale of five. The other next five columns represents the guidelines (datum) for the KBS rule generation procedure as it will be expressed in the following sections.

As an industrial expert, PALIP will try to quantify the contribution of each project in satisfying the plan objectives. This is accomplished by assigning values from (0) to (4) for each project to have for each listed criterion in the matrix of Table (1).
In most of the cases, PALIP asks the user several questions about the project parameters and characteristics. When the user inputs a value for a parameter, the value can be either a continuos or discrete. Continuos quantities will be converted to discrete values by rules in the knowledge base. Discrete values are inferred and will automatically be given a value as part of the inference process by using the project appraisal matrix . For example, when asked, a user would enter a value for the size of investment needed for the project (the third appraisal criterion). Hence the system automatically inferred the entered value and gives a corresponding grade , and a result value. Many of the listed criteria require further investigation to reach a conclusion. For example, a user can not prompt a direct answer on the project contribution to GDP (again refer to the first criterion under the economic measures of Table 1). It is the system role, to extract such an information from the user through a set of relevant questions , as it will be illuminated in the knowledge base section of this paper.

Table 1. Project Appraisal Criteria Matrix

CRITERIA (Measures)	Relative Weight	VLow (0)	Low (1)	Medium (2)	High (3)	VHigh (4)	Result Value
(1) FINANCIAL MEASURES:							
Net Present Value ($M)	4	< 10	20-30	30-40	40-50	> 50	
Time Until Breakeven (yrs)	4	5 <	5-4	4-3	3-2	< 2	
Size of Investment ($M)	3	50 <	50 - 30	30-20	20-10	< 10	
Risk Level	4	VHigh	High	Med.	Low	VLow	
Project Duration (yrs)	2	> 6	6 - 5	4 - 3	2 - 1	< 1	
Pay-back Period (yrs)	3	> 6	6 - 5	4 - 3	2 - 1	< 1	
Impact of inflation	4	VHigh	High	Med.	Low	VLow	
(%) of funding	2	< 10	10-15	16-20	21-30	< 30	
(%) of self financing	3	> 50	50 - 40	39 -30	29-20	< 20	
(2) PRODUCTION MEASURES:							
Technology level involved	3	VLow	Low	Med	High	VHigh	
Production flexibility	4	VLow	Low	Med	High	VHigh	
Productivity enhancement	3	VLow	Low	Med	High	VHigh	
Local Raw material (%)	4	< 5	5 - 20	21 - 50	51 - 70	> 70	
Availability of raw material	5	VLow	Low	Med	High	VHigh	
Comparative advantage	2	VLow	Low	Med	High	VHigh	
Quality of products	2	VLow	Low	Med	High	VHigh	
Maintainability	3	VLow	Low	Med	High	VHigh	
Maintenance Cost	4	VHigh	High	Med	Low	VLow	
Production Costs	2	VHigh	High	Med	Low	VLow	
Tooling Complexity	1	VHigh	High	Med	Low	Vlow	
Energy consumption	2	VHigh	High	Med	Low	Vlow	
(3) ENVIRONMENTAL MEASURES:							
Liquid and Gaseous effluents	4	High	Med	--	--	Nil	
Ground water Pollutants	5	High	Med	--	--	Nil	
Air Pollutants	5	High	Med	--	--	Nil	
Solid wastes	5	High	Med	--	--	Nil	
Noise levels	5	High	Med	--	--	Nil	
Resources consumption	3	VHigh	High	Med	Low	Vlow	
Plant Industrial Safety	5	VLow	Low	Med	High	VHigh	
Level of Health care procedures	5	VLow	Low	Med	High	VHigh	
Impacts on the near industries	4	VHigh	High	Med	Low	Vlow	
Plant monitoring and control	1	Poor	Fair	Good	VGood	Excell.	
Material Storage Systems	2	Poor	Fair	Good	VGood	Excell.	
Waste minimization system	3	Poor	Fair	Good	VGood	Excell.	
(4) ECONOMIC MEASURES							
Contribution to GDP	5	VLow	Low	Med	High	VHigh	
Import substitution	4	VLow	Low	Med	High	VHigh	
Export promotion	3	VLow	Low	Med	High	VHigh	
Product demand	4	VLow	Low	Med	High	VHigh	
Level of Competition	3	VHigh	High	Med	Low	Vlow	
Backward & Forward linkages	2	VLow	Low	Med	High	VHigh	
Regional development	1	VLow	Low	Med	High	VHigh	
Local manufacturing content (%)	4	< 10	10 - 30	31 - 50	51 - 70	> 70	
(5) LABOR-RELATED MEASURES:							
Labor intensive technology	4	VLow	Low	Med	High	VHigh	
Training requirements	2	VHigh	High	Med	Low	Vlow	
New organization Structure required	1	VHigh	High	Med	Low	Vlow	
Labor skill level	3	VHigh	High	Med	Low	Vlow	
Work force safety	5	VLow	Low	Med	High	VHigh	

3.3. *System Knowledge Base:*

An essential stage in the development of PALIP knowledge base is the establishment of the domain and scope of knowledge. Such domain and scope have been illustrated within PALIP's algorithm and its appraisal criteria. As mentioned earlier, the knowledge base itself is composed of an articulated knowledge base, and an inference engine.

3.3.1. *The Articulated Knowledge Base :*

The articulated knowledge base has been carried out through the knowledge engineering task. In this task the related and available chunks of knowledge were acquired and articulated. An example of one of PALIP's knowledge articulation process is shown in Figure (5). Hence, a knowledge base manual was collated and the project evaluation knowledge base is represented in the form of rules.

Presently the system incorporates the core project evaluation knowledge base with its different types of rules including : Financial rules, production-related rules, environment rules, economic rules, and work force rules. The other two knowledge-bases, namely: the criteria generation knowledge base and the criteria relative weight knowledge base are under development.

Based on the nature of the appraisal process, and the characteristics of the evaluation criteria, PALIP rules are categorized into: Direct rules , In-direct (uncertainty) rules. Direct rules incorporates discrete, quantitative (numerical) values a user would provide to the system to reach definite conclusions, whilst an indirect rule requires additional knowledge manipulation by the system through stimulating the user to answer a series of questions. In both cases, the system will interpret the final conclusion into a criterion grade scale ranging from : very low (a value of 0) to very high (a value of 4), as shown in Table (1).

Typical sample rules of PALIP are exhibited in the following forms:

Direct Rules

```
RULE :  Rule _10
IF      Net_Present.Value is greater than 50
THEN    Net_Present.Value is Confirmed
        AND 4 is assigned to NPV.Grade
        AND NPV.Grade* NPV.Weight is assigned to NPV.Criteria
RULE   : Rule_11
IF      Net_Present.Value is less than 50
        AND Net_Present.Value is greater than 40
THEN    Net_Present.Value is confirmed
        AND 3 is assigned to NPV.GRADE
        AND NPV.Grade* NPV.Weight is assigned to NPV.Criteria
```

Indirect Rules:

```
RULE   : Rule_27
IF     Industry.category is "Assembly"
       AND Industry_type.Engineering is FALSE
       AND Technology.advanced is FALSE
       AND Manuf_content.percent is less than 20
THEN Contribution_to_GDP is confirmed.
       AND 1 is assigned to Cont_GDP.grade
       AND Cont_GDP.grade*Cont_GDP.wieght is assigned to
Cont_GDP.criteria
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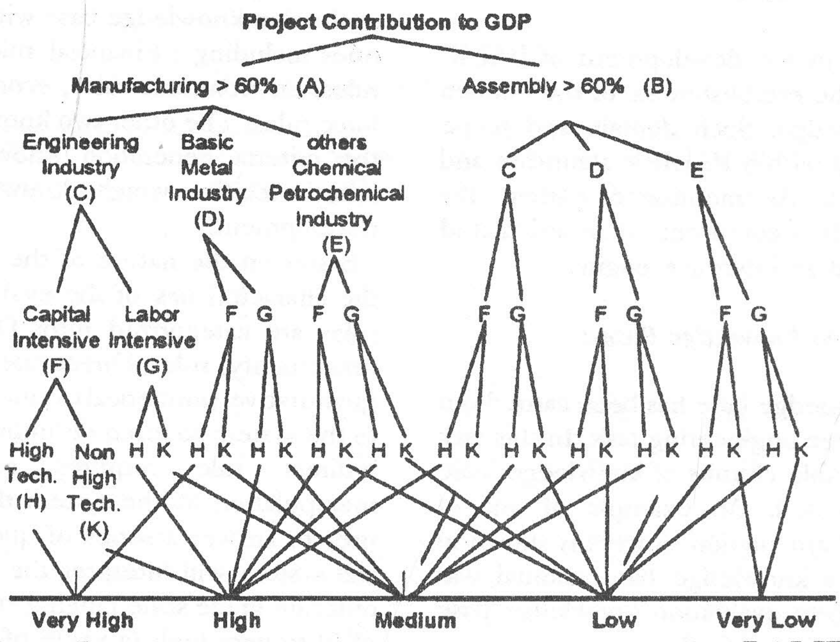

Figure 5. A sample of the knowledge articulation process in PALIP presented in the form of a decision tree.

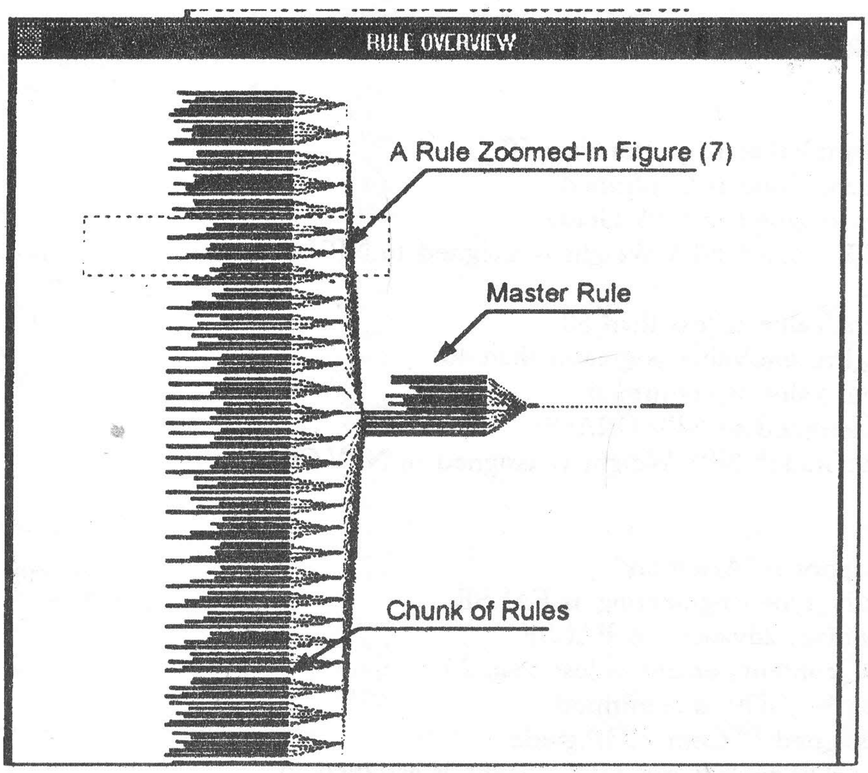

Figure 6. Rules relationship as it appears in PALIP development environment.

An overview of the system's global network structure of rules is depicted in figure (6), with a focus on one of the rules.

3.3.2. *The Inference Engine:*

One of the most important features of PALIP is its development environment which is highly graphic allowing rapid incremental development with direct access to the reasoning mechanism. Full control is achieved on the shell reasoning mechanism through the four methods of inferencing on rules namely: backward chaining, forward chaining, semantic gates, and context links.

Figure (7) shows a screen print out of a rule during the knowledge processing session. The first two conditions indicate a rule which has been fired and investigated . The third condition shows a rule which is being investigated, while the last condition is waiting for investigation.

The inference engine in PALIP is the basic control mechanism that directs the backward and forward chaining search through the knowledge base to satisfy the procedure. The inference engine will continue to attempt all the rules until a project grade is obtained. A portion of PALIP source code is exhibited in Appendix (B).

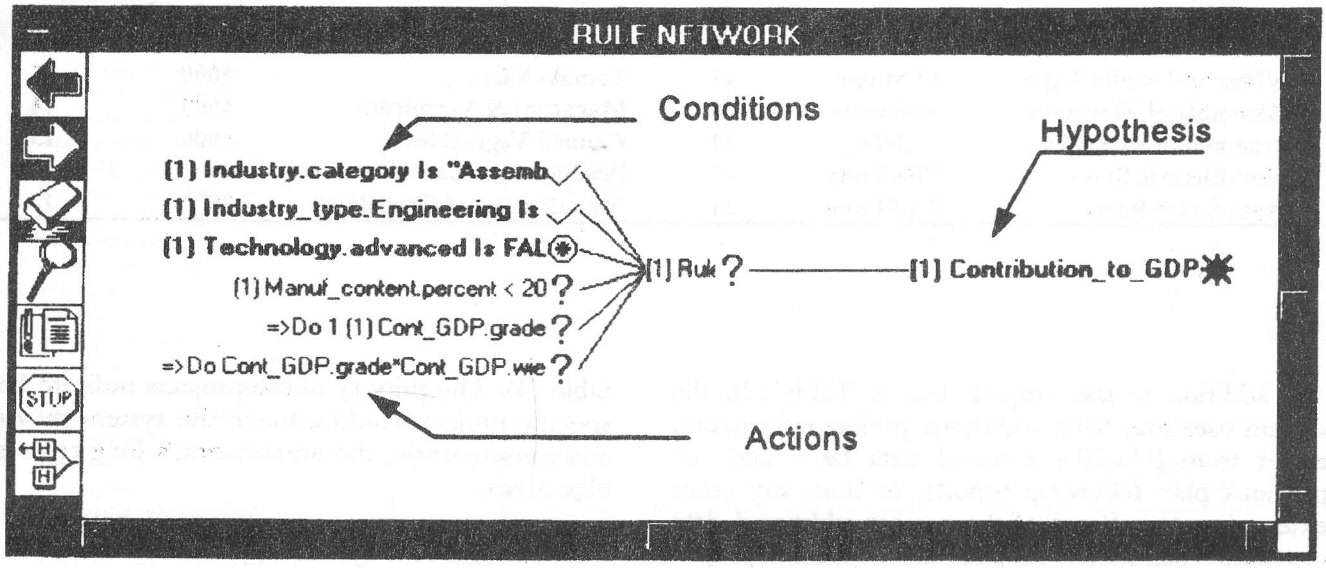

Figure 7. One of PALIP's rules during the reasoning process.

4. EXAMPLE CONSULTATION:

A hypothetical example of a long-term planning session is given in this section to illustrate how PALIP can be applied to tackle the problem of project appraisal within the planning domain.

The example problem is one that might be encountered at a large organization that anticipate to develop its industrial capabilities through executing a comprehensive program which contains a group of industrial investment opportunities , i.e. a number of prospective projects.

The input to the system is the list of projects shown in Table (2), where it can be noticed that the list contains a wide spectrum of industrial projects which covers many industry types, e.g. chemical, petrochemical, engineering, food, basic, intermediate , and end-product industries. Production capacity, and size of investment also differ significantly between projects. Such variability were intended so as to demonstrate a real-life problem, where an organization has to pick-up projects to execute from a large pool.

Table (2). A group of industrial projects which forms a program

Project Title	Capacity (T/Year)	Investment ($M)	Project Title	Capacity (T/Year)	Investment ($M)
Recovery of Lead	2000	4	Refrigerators	12000 unit	52
Manufacture of Polyyol	20000	5	Agricultural Tractors	2000 unit	35
Pressed Wood	4000	11	Washing Machines	30000 unit	31
Manufacture of Toiletry	2000	8	Quality Furniture	5000	23
Synthetic rubber	10000	50	Storage Batteries	330000 unit	60
Adhesives	6000	13	Mechanical Complex	23000 unit	80
Synthetic Flowers	1200	5	Hand Tools Manufacture	1000 unit	20
Floor Covers	7000	13	Elect.-Mechanical Shop	152000 unit	80
Photographic Films	800	16	Air, Fuel, and Oil Filters	--	--
Synthetic Fabrics	9000	90	Computer Systems	2000 unit	30
Synthetic Fibers	10000	40	Manufacture of Toys	5000	8
Clothes Industry	15000	50	Blankets	3000 unit	25
Polyethylene Preforms	1000	5	Rugs & Carpets	20000	12
Metal Welding Electrodes	1500	9.5	Porcelain Insulators	300000 unit	--
Ceramic Sanitryware	15000	20	Sanitary Taps & Fittings	250	25
Video and Audio Tapes	37 M units	11	Tomato Sauce	5000	15
Assembly of Elevators	400 units	40	Macaroni & Vermicelli	4500	14
Iron and Steel Ropes	3000	12	Canned Vegetables	5000	13
Non-Electric Stoves	50000 unit	27	Production of Snacks	500	4
Auto Spare Parts	7.4 M unit	21	Manufacture of Chocolates	2500	17

In addition to the project data in Table (2), the system user may have additional project information either from PALIP's external data base, and the previous plan follow-up reports, or from any other external source. Some of the project additional data provided includes: project description, project location, product types, expected customers, product imports, future demand.

A sample consultation using PALIP is depicted in Appendix (C), which shows selected portions of the questioning dialog as inferred and detailed for the 'manufacture of Polyyole' , one of the nominee projects in the previous list, the user input is represented in under-lined bold text.

The system output appraisal matrix for the same project, i.e. the manufacture of polyyole, and the project final grade as calculated and extracted using PALIP, is listed in Table (3).

Similar forms have been elaborated for every project in the original input group . Finally, the output ranking of the projects was obtained based on PALIP's internal grading system , as illustrated in table (4). The priority of the projects indicate how a specific project would achieve the system measures and consequently, the organization's long term plan objectives.

Comments on the system outputs:

The resulting order in table (4) shows a range between a maximum score of (77.9%) for the project of mechanical complex, and (39.2%) for the project of manufacture of chocolates. The highest grades were granted to projects which can be classified as: engineering industries of high production volumes, high value-added, semi-heavy industries, high technology, and of strong backward/forward linkages with other industries. Petrochemicals, and chemical projects came in the second order , e.g. the production of synthetic rubber. Light industries (metallic and non-metallic) projects occupied intermediate positions , specially those producing industrial products, e.g. the manufacture of hand tools, steel ropes and cords, and welding electrodes.

In general, the projects of food , assembly , and consumer products came at the end of the previous order in PALIP consultation. Although they can be categorized among the top priority group, environmentally sensitive projects were classified of less priority, e.g. the production of refrigerators. Having the projects filtered and ranked as in table (4), the organization will execute those projects having a certain grade limit, or the first group of projects that matches the resources upper bound (mainly financial resources).

Table (3). Project Appraisal Output Matrix - Project Title : 'Manufacture of Poly-yole'

CRITERIA (Measures)	Relative Weight	VLow (0)	Low (1)	Medium (2)	High (3)	VHigh (4)	Result Value
(1) FINANCIAL MEASURES:							
Net Present Value ($M)	4		1				4
Time Until Breakeven (yrs)	4			2			8
Size of Investment ($M)	3					4	12
Risk Level	4			2			8
Project Duration (yrs)	2				3		6
Pay-back Period (yrs)	3		1				3
Impact of inflation	4				3		12
(%) of funding	2		1				2
(%) of self financing	3		1				3
(2) PRODUCTION MEASURES:							0
Technology level involved	3			2			6
Production flexibility	4		1				4
Productivity enhancement	3		1				3
Local Raw material (%)	4			2			8
Availability of raw material	5				3		15
Comparative advantage	2	0					0
Quality of products	2					4	8
Maintainability	3				3		9
Maintenance Cost	4				3		12
Production Costs	2					4	8
Tooling Complexity	1				3		3
Energy consumption	2						0
(3) ENVIRONMENTAL MEASURES:							
Liquid and Gaseous effluents	4		1				4
Ground water Pollutants	5		1				5
Air Pollutants	5		1				5
Solid wastes	5					4	20
Noise levels	5					4	20
Resources consumption	3					4	12
Plant Industrial Safety	5			2			10
Level of Health care procedures	5			2			10
Impacts on the near industries	4		1				4
Plant monitoring and control	1			2			2
Material Storage Systems	2			2			4
Waste minimization system	3		1				3
(4) ECONOMIC MEASURES							0
Contribution to GDP	5		1				5
Import substitution	4					4	16
Export promotion	3		1				3
Product demand	4			2			8
Level of Competition	3					4	12
Backward & Forward linkages	2			2			4
Regional development	1		1				1
Local manufacturing content (%)	4			2			8
(5) LABOR-RELATED MEASURES:							
Labor intensive technology	4		1				4
Training requirements	2			2			4
New organization Structure required	1			2			2
Labor skill level	3			2			6
Work force safety	5				3		15
Project Score							321
Maximum Possible score							608
Project Grade (%)							52.80%

Table 4. The projects cluster as ranked in priority descending order by PALIP.

Rank	Project Title	(%) Grade	Rank	Project Title	(%) Grade
1	Mechanical complex	77.9	21	Synthetic Flowers	55.8
2	Electro-Mechanical Shop	75.8	22	Recovery of Lead	54.8
3	Washing Machines	75.4	23	Sanitary Taps and Fittings	53.3
4	Agricultural Tractors	74.2	24	Manufacture of Polyyol	52.8
5	Storage Batteries	73.3	25	Assembly of Elevators	51.7
6	Synthetic Rubber	70.8	26	Manufacture of Toys	51.7
7	Non-Electric Stoves	68.8	27	Floor Covers	50.4
8	Video and Audio Tapes	66.8	28	Pressed Woods	50.4
9	Hand tools Manufacturing	65.4	29	Quality Furniture	50.0
10	Adhesives	65.0	30	Computer Systems	50.0
11	Polyethylene Preforms	65.0	31	Macaroni and Vermicelli	49.6
12	Auto Spare Parts	64.6	32	Synthetic Fibers	49.2
13	Porcelain Insulators	63.8	33	Tomato Sauce	48.8
14	Iron and steel Ropes	62.1	34	Canned Vegetables	47.9
15	Ceramic Sanitary ware	60.4	35	Photographic Films	47.1
16	Air, Fuel, and Oil Filters	60.0	36	Production of Snacks	45.8
17	Metal Welding Electrodes	60.0	37	Manufacture of Toiletry	45.0
18	Clothes Industry	57.5	38	Synthetic Fabrics	40.8
19	Rugs and Carpets	57.1	39	Manufacture of Blankets	40.4
20	Refrigerators	56.2	40	Manufacture of Chocolates	39.2

5. CONCLUSIONS

The Planning System

As a project appraisal tool, PALIP uses a wide spectrum of criteria which were primarily generated from the industrial plan objectives of a specific organization. The extent of the project appraisal measures and the relative weight of each criterion reflects the status of such an organization. This limitation should not affect the validity and generalization of PALIP in selecting project for similar applications . For example, variations in assigning relative weights to the different criteria will not significantly differ among organizations, since every organization is sincerely considers, for instance, the environmental impacts of its projects (see the project appraisal matrix).

The articulated knowledge

As in many similar systems, the process of knowledge articulation is the most important phase in PALIP. Such a procedure is based on the project appraisal technique as proposed by one person. Another system developed using another expert's rules might produce a different set of results. Yet this situation is common when developing a knowledge expert system applications. Such situation is also justified, since it is virtually impossible to derive optimum solutions to the problem which PALIP is handling .

The knowledge base

As mentioned earlier, PALIP is originally designed to incorporates three distinct knowledge bases. Currently, the system utilizes only the knowledge base of the project appraisal criteria and its rules. A very important knowledge base is the one which generates the criteria from the long term plan objectives. Another knowledge base is the one which assigns relative weights to the criteria. Both knowledge bases should be considered in any modification of PALIP.

The expert system shell

PALIP has been built using a rule-based platform, more enhancement could be obtained if the object-oriented capabilities of PALIP's development shell (Nexper-object) is used. Features like : definition of objects, classes ,methods ,multiple inheritance, etc. are some powerful system building strategies ,which could be adopted in PALIP future versions, if any.

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Appendix (A)

Constrained Weighted Factor Scoring Model

The following model have been adopted with modifications from reference [8]
Let (**n**) be the total number of projects, and (**m**) be the total number of criteria and the criterion relative weight is (**w**), and the project total grade is (**G**) such that for project (**i**) **i = 1,2, ..., n** and criterion (**j**) **j = 1,2,..., m**
A project Grade (G_i) would be defined as:

$$G_i = \sum_{j=1}^{m} g_{ij} w_j$$

Where,
g_{ij} = The grade of project (i) on the criterion (j)

w_j = The relative weight of the criterion (j)
The following relative weight scaling constraints may be used (but not necessary):

$$0 \leq w_j \leq 1$$

and,

$$\sum_{j=1}^{m} w_j = 1$$

Additional constraints may be added , and again the project grade (Gi) could be amended as:

$$G_i = \sum_{j=1}^{m} g_{ij} w_j \prod_{k=1}^{l} C_{ik}$$

Where,
C_{ik} = 1 if the project (i) satisfies the Constraint (k), and
C_{ik} = 0 if the project (i) dose not

Appendix (B)

A portion of PALIP's Source Code

```
(@RULE=        R10
      (@LHS=
               (Name  (project.name)    (project.name))
               (Is    (industry.type)   ("petrochemicals")))
      (@HYPO=         Start_appraisal)
      (@RHS=
               (Do    (3)      (Tech_level.wieght))
               (Do    (4)      (prod_flex.wieght))
               (Do    (3)      (prod_enhancement.wieght))
               (Do    (4)      (local_material.wieght))
               (Do    (5)      (raw_mat_available.wieght))
               (Do    (2)      (comparative.wieght))
               (Do    (Tech_level_involved)      (Tech_level_involved))
               (Do    (Production_flexibility)   (Production_flexibility))
               (Do    (Productivity_enhancement)         (Productivity_enhancement))
               (Do    (Local_raw_material)       (Local_raw_material))
               (Do    (Availability_of_raw_material)     (Availability_of_raw_material))
               (Do    (Comparative_advantage) (Comparative_advantage))))
(@RULE=        R140
      (@LHS=
               (Is    (Prod_lab_perc)  ("high"))
               (Is    (Nprod_oprod_perc)         ("low"))
               (Is    (Rmat_prod_perc)           ("high")))
      (@HYPO=         Productivity_enhancement)
      (@RHS=
               (Do    (2)      (Prod_measure.prod_enha))
               (Do    (Prod_measure.prod_enha*prod_enhancement.wieght)
      (prod_enhancement.criteria))))
(@RULE=        R141
      (@LHS=
               (Is    (Prod_lab_perc)  ("high"))
               (Is    (Nprod_oprod_perc)         ("high"))
               (Is    (Rmat_prod_perc)           ("low")))
      (@HYPO=         Productivity_enhancement)
      (@RHS=
               (Do    (3)      (Prod_measure.prod_enha))
               (Do    (Prod_measure.prod_enha*prod_enhancement.wieght)
      (prod_enhancement.criteria)))
(@RULE=        R142
      (@LHS=
               (Is    (Prod_lab_perc)  ("high"))
               (Is    (Nprod_oprod_perc)         ("high"))
               (Is    (Rmat_prod_perc)           ("high")))
      (@HYPO=         Productivity_enhancement)
      (@RHS=
               (Do    (4)      (Prod_measure.prod_enha)))
```

Appendix (C)

A PALIP typical consultation sample (only a small portion is shown)

C:\> Nexpert
> Load PALIP.TKB
Loading Knowledge base .... PALIP
Project Title ? **Manufacture of Poly-Yole**
*
Financial Chunk of Rules ....
> What is the estimated project duration (in years) from start to finish ? 2
> What is the total amount of investment required for the project ($ Millions)? 5
*
> What is the last recorded Inflation level (in %) you would quote in the project area ? 9
> How the project would be affected from such inflation Rate
  Options = [Very high, High, Medium, Low, Very Low]? **Low**
* *Energy consumption* ....
> Does the project include the construction of any furnaces
    Options = [Yes, No] ? **Yes**
> what is the estimated capacity/size of the furnace
    Options = [Large, Medium, Low] ? **Low**
> Is There any other heat dependent processes
    Options = [Yes , No] ? **Yes**
> What Is the number of the heat dependent process
    Options = [Large, Medium, Small] ? **Medium**
* *Production Flexibility* ....
> How would you classify the type of the project equipment ?
    Options = [General , Specialized] ? **Specialized**
> How would you estimate the product-mix which the project will be capable to produce
    Options = [Large , Small] ? **Small**
> What labor category the project will need
    Options = [Skilled , Non-skilled] ? **Non-Skilled**
> What type of Plant layout the project will need ?
    Options = [Product, Process, Combination] ? **Product**
* *Gaseous effluents* ....
> How would you estimate the level of (NOX) in the project
    Options =[High, Medium, Nil]? **Medium**
> How would you estimate the level of (SOX) in the project
    Options =[High, Medium, Nil]? **Medium**
> How would you estimate the level of (CO2) in the project
    Options =[High, Medium, Nil]? **Medium**
> How would you estimate the level of (CO) in the project
    Options =[High, Medium, Nil]? **Medium**
> Is there any gaseous effluents treatment system in the project?
    Options =[Yes, No] ? **Yes**
* *Ground Water Pollutants* ....
> Possibility of any chemical leakage to the ground from the project
    Options = [Yes, No] ? **NO**
> Is the ground water level near
    Options [Yes, No] ? **Yes**
> Is there any waste minimization system
    Options [Yes, No] ? **Yes**
*