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MULTICRITERIA-BASED PROCEDURE AS DECISION SUPPORT IN THE SELECTION OF GOVERNMENT FINANCED R&D PROJECTS *

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Abstract: A country's innovation policy is supposed to reflect its aspirations and potentials in technology development. The Technology Development Department (TDD) of the Ministry for Science and Technology of the Republic Serbia (MST) is responsible for creating and implementing the governmental innovation policy (GIP). This paper describes the application of a multicriteria-based evaluation and selection procedure of R&D project proposals submitted for financial support within the framework of the GIP. The basic problem encountered in this selection procedure was to define the criteria for evaluating project proposals, while technology development priorities were instrumentalized through these criteria. Results of the project proposal evaluation done for each of the criteria are aggregated in order to get a unique index of their overall quality, using the additive utility concept.

Keywords: Additive utility multicriteria procedure, innovation policy, R&D projects, decision support.

1. INTRODUCTION

The everlasting problem of any innovation, i.e. R&D, policy at the international, national, sectorial, or company level is the selection of R&D projects to be financed within the framework of a specific policy. The problem is technical (the amount of investment for submitted R&D project proposals generally exceeds the available financial resources), political (R&D project selection is by its very nature political, since it includes political influence and criteria), very complex and always very sensitive. Many attempts have been made to introduce objectivity, a wholistic understanding and science-based methods and procedures in solving the problem of R&D project selection.

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Literature on this subject is abundant [10], [15], [16], but there is still room for new approaches and developments [1], [3]. This paper presents a quantitative multicriteria procedure, developed for a very real problem deriving from the adoption and implementation of governmental innovation policy in the Republic of Serbia. However, it seems that the procedure developed for this specific case can be used in similar cases, not only at the national but at the international, sectorial or larger corporation level. Bearing this in mind, the procedure is presented together with a description of the case for which it was been developed and implemented.

2. DESCRIPTION OF THE CASE

The term *"national innovation policy"* is a common denominator for all activities undertaken by governments and other institutions in the area of research and development. In September 1990, the Government of the Republic of Serbia (GRS) adopted the document "Technology Development Policy in the Republic of Serbia" [14] (hereinafter GIP). The framework, intended actions and instruments for implementing the government's innovation policy were defined in this document. The background material used in the process of GIP preparation was mainly supplied by the Science and Technology Policy Research Center, a research unit in the Mihajlo Pupin Institute [2], [5], [11], [12], [13].

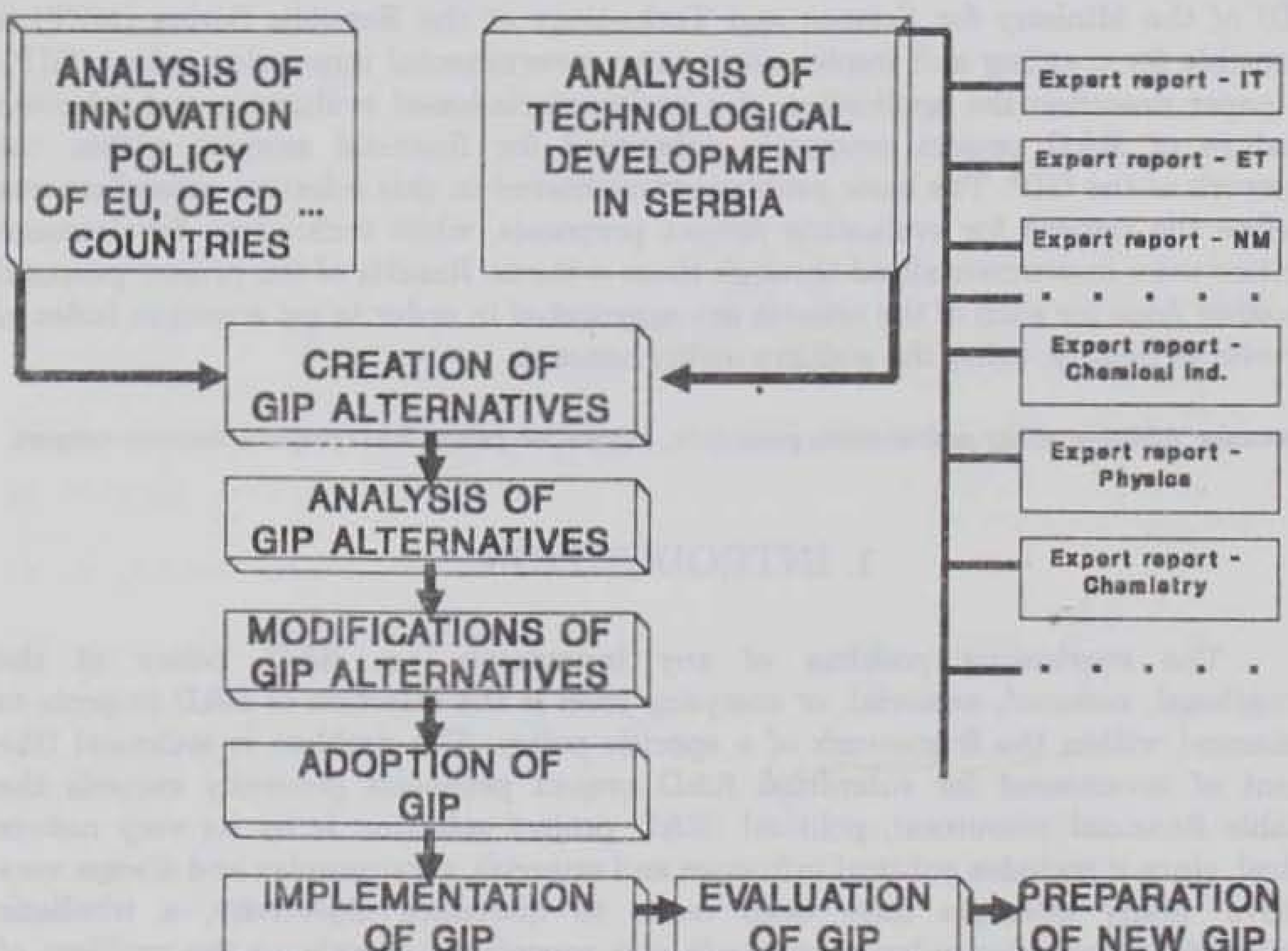


Figure 1: Pha f the Government Innovation Policy's Lifespan

The lifespan of GIP consists of several phases (Fig. 1). The first phase encompasses an analysis of experience gathered abroad, accompanied by the work of experts in particular fields of science and technology. The main output of the work done in this phase is a report on the state of the art and prospects for each investigated R&D field. An important element of this report is a survey of financial and other resources required for performing the intended R&D activities in the respective fields of science and technology. Most experts naturally place the greatest emphasis on the field they deal with; as a result, the desired resources for R&D projects enormously exceed even the most optimistic projections of available resources. This is why the next phase in the GIP lifespan concentrates on the creation of a set of measures, instruments and activities to be undertaken by the government with the aim of designing and implementing a national innovation policy suited to the achieved level of domestic science and technology development, and defines the government's aspirations and available resources. After the GIP document had been adopted, the government takes steps towards the third phase in the GIP lifespan: its implementation and continuous evaluation of the experience gained. The evaluation is intended to identify shortcomings and introduce modifications which would allow a redefinition of GIP.

The main part of GIP is devoted to measures with market sector benefits, with the goals:

- To enhance the overall innovative capability of the economy;
- To help the establishment of new companies based on new technologies, and
- To develop the behavior of the public sector so that it will contribute significantly to the technological development of the market sector and to the development of a national innovation infrastructure [14].

To achieve the above goals, the government decided to take general and specific measures. The general measures include the taxation policy (tax exemptions) and the financing of innovation projects. Specific measures include support for precompetitive research projects, stimulation of the diffusion of new technologies, quality assurance promotion, assistance to enterprises based on new technologies and coordination of the technological development of the public sector (public procurements etc.).

Immediately after the adoption of GIP the TDD of the MST announced a call for the submission of project proposals to be cofinanced from the governmental budget [6],. This call strictly stated:

- how to prepare and write a proposal;
- types of R&D programs;
- prioritized technology fields / programs;
- conditions for cofinancing;
- project evaluation criteria, and
- project selection procedure [6].

We shall shortly describe each of these elements.

R&D Programs

Projects to be cofinanced are classified according to objective, contents and scope of R&D activities, into the following three programs:

(I) Strategic Technological Research Projects (STRP),
(II) Precompetitive R&D Projects (PRDP),
(III) Innovation Projects (IP).

Strategic Technological Research Projects are those R&D projects which are "intended to produce essential R&D prerequisites for Serbia's long-term technology development ... and to link applied research with basic research" [2]. *Precompetitive R&D Projects*, involving several enterprises and R&D organizations, are those intended to raise the level of the technological capability of the involved organizations, whose results should provide a basis for the development of new products and processes. The *IP* program consists of those R&D activities which are very close to commercial application and thus it also includes activities on finalizing some previously started development up to the phase of product or process commercialization (e.g. design, construction and fabrication of a prototype or pilot plant, testing, completion of technical documentation, etc.).

Prioritized Technology Fields

The following fields have been taken as priorities in this case of GIP:

- Information Technologies (IT);
- Energy Technologies (ET);
- BioTechnologies (BT);
- New Materials (NM);
- Healthy Food (HF);
- Revitalization of existing technologies and Quality improvement (RQ).

Priority subfields were also determined for each of the above-stated fields.

Conditions for cofinancing

The R&D organizations registered for conducting R&D activities were invited to submit project proposals for all three programs. Industrial organizations were invited to propose projects for PRDP and IP programs, on condition that at least one registered R&D organization participated in each proposal. Project proposals for IP program could also be submitted by individuals "with adequate innovative results" [2].

The maximum duration of project cofinancing is up to 3 years for STRP, up to 2 years for PRDP, and up to 1 year for IP program. The TDD's share in financing STRP has been set at up to 70%, and in PRDP and IP up to 50% of total project cost.

Considering that the requested resources would significantly exceed those available, and that all the submitted proposals would in general satisfy the requirements, it was essential to define a methodology for the evaluation and selection of the submitted R&D projects as well as a procedure for its implementation. The methodology should enable the decision makers to create priority lists of R&D projects for financing purposes, based on a reliable evaluation and the overall quality of the submitted R&D projects.

For the moment, we shall leave the description of the specific case and concentrate on the essence of this paper: the methodology / procedure for R&D project proposal evaluation and the generation of a priority list, i.e. the selection procedure.

3. THE METHODOLOGY FOR R&D PROJECT EVALUATION AND SELECTION

This methodology defines:

(a) the evaluation and selection procedure;
(b) technical support instruments [9].

The project evaluation and selection procedure consists of the following activities (Fig. 2):

(1) Announcement of the invitation;
(2) Registration, classification and formal checking of project proposals;
(3) Compliance test of project proposals with the adopted GIP (Test I);
(4) Accuracy and integrity validation (Test II);
(5) Peer review of project proposals (Test III);
(6) Aggregation of the results of project proposal evaluations and creation of priority lists;
(7) Selection of proposals for cofinancing;
(8) Corrections and, if necessary, repetition of some activities as requested by the decision maker;
(9) Action on complaints and preparation for final decisions on cofinancing.

Simultaneously with the project evaluation and selection procedure, the TDD's authorized bodies (TDD Council and Boards established for project monitoring by technology fields) carry out the procedure for resource allocation by technology fields (IT, ET, BT, NM, HF, RQ) and programs (STRP, PRDP, IP).

To perform the stated activities, the methodology prescribes the following support instruments [9]:

- sandardized forms for project proposal submission, project proposal reviews and reports by proposers on project proposal status;
- software support for creating databases on project proposals and reviews, required surveys, statistics and reports on project selection;
- a specifically designed method for multicriteria analysis and evaluation of project proposals.

The core element of this methodology is the evaluation of R&D project proposals (criteria and aggregation). It has a feedback influence on project proposal preparation and submission and thus it is of primary importance to project selection. This is the reason for its detailed description.

Multicriteria evaluation of project proposals

Multicriteria evaluation of project proposals is the basis of R&D project selection. Thus, the definition of criteria is one of the most delicate and important parts of evaluation [7], [8]. These criteria have been defined in accordance with:

(a) the general objectives stated in the GIP, and
(b) the specificities of STDP, PRDP and IP programs.

The selection of criteria to be applied was made on condition (a) of non-colinearity among criteria and (b) that the number of criteria corresponds to a balance between the tendency for project evaluation completeness and the decision makers inclination to deal with few criteria.

The full set of criteria consists of two subsets: basic and control criteria. The *basic subset* contains criteria for direct evaluation of the hard components of R&D proposals while the *control subset* contains criteria for evaluation of the soft components and associated risk of R&D proposals, and in some hidden way represents the evaluation of evaluators - intended to increase the objectivity of the evaluation procedure. We stress that evaluations by criteria from the control subset serve only to "control" the evaluations by criteria from the basic subset. These control evaluations have no direct bearing on the creation of the aggregate index.

The basic subset criteria are grouped according to the subject matter which is being evaluated with their use. Accordingly, there are four groups (G):

G1 - The relevance of R&D results

Criteria from this group are used to evaluate the objectives and contents of expected results with respect to: (a) the state of foreign and domestic research in the respective field, and (b) technological up-to-dateness of expected project results, i.e. the scientific contribution (for STDP and PRDP) and technological justifiability (for STDP, PRDP, IP).

G2 - The adequacy of planned inputs

The aim of this group of criteria is to evaluate the adequacy of the planned material, financial and human resources for project accomplishment.

G3 - The availability of expected R&D results

Criteria from this group are used to compare expected R&D results from the proposed project with those already existing worldwide, considering their up-to-dateness (the level of originality), availability, relevance, access to existing knowledge and technologies, etc.

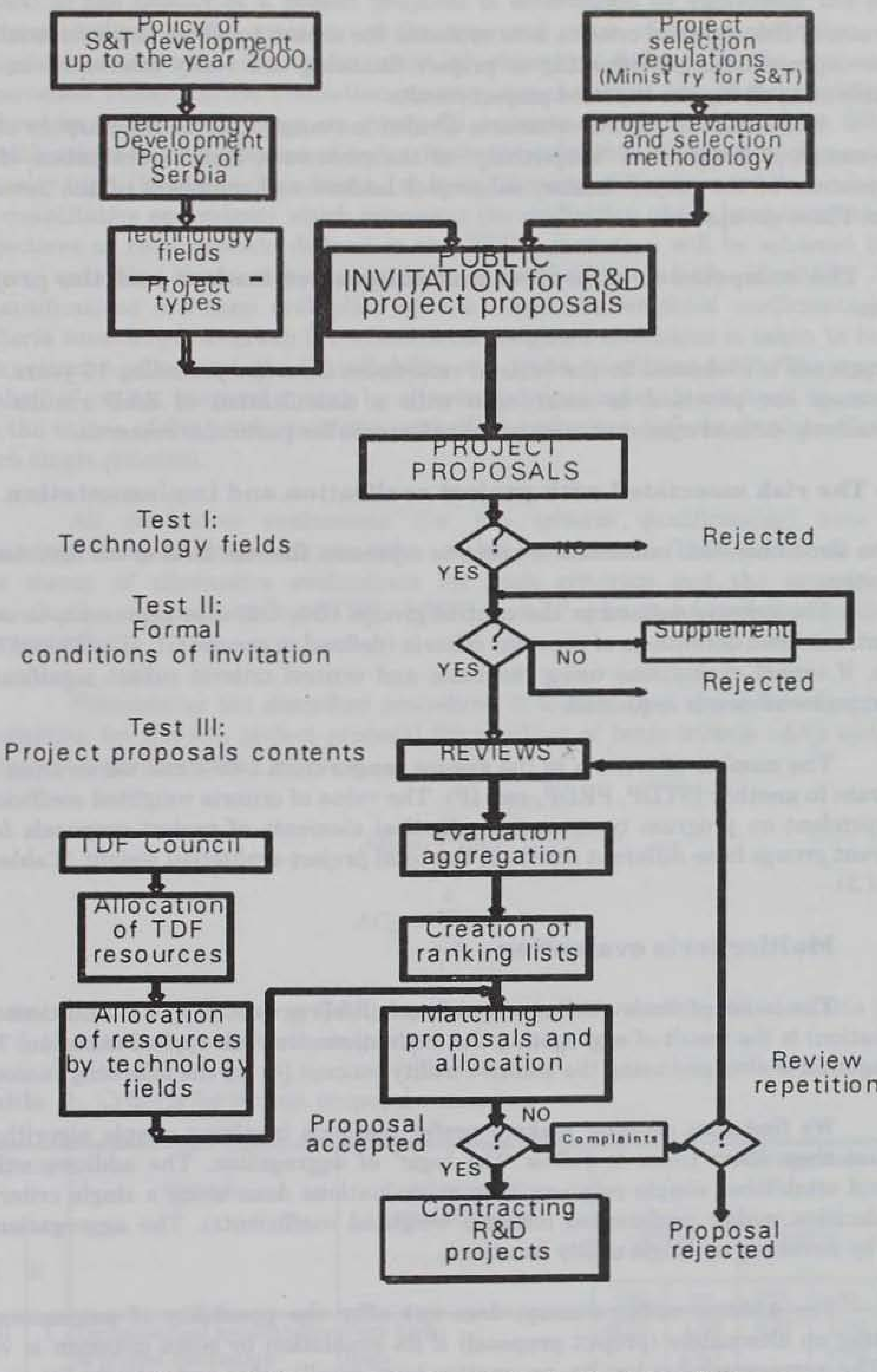


Figure 2: Project evaluation and selection procedure

G4 - Demand for expected R&D results

The aim of this group of criteria is to evaluate the extent to which the industrial and other organizations participating in project financing are really interested in, and capable of, applying the expected project results.

The subset of control criteria is divided in two groups, for the purpose of: (a) assessment of the level of "subjectivity" of the reviewers, and (b) evaluation of the competence of the project leader, subproject leaders and members of the research team. These groups are:

G5 - The competence of project and subproject leaders and the project team.

Competence is evaluated on the basis of references from the preceding 10 years. The references are provided in accordance with a classification of R&D results and normatively defined minimum number of references for particular research.

G6 - The risk associated with project realisation and implementation.

At the same time, this evaluation is taken to represent the risk level of the investment allocation.

The criteria defined in the control groups (G5, G6) also represent, to some extent, modified definitions of previous criteria (defined in groups G1, G2, G3 and G4). Thus, if expert evaluations using the basic and control criteria subset significantly differ, a new review is requested.

The number of criteria in the groups ranges from 1 to 3 and varies from one program to another (STDP, PRDP, and IP). The value of criteria weighted coefficients is dependent on program type, so that identical elements of project proposals from different groups have different shares in the total project evaluation weight (Tables 1, 2 and 3).

Multicriteria evaluation

The index of the overall quality of each R&D project proposal (multicriteria evaluation) is the result of aggregating the evaluations for each applied criterion. This aggregation is obtained using the additive utility concept [4] for the following reasons:

1. We find that decision makers prefer methods involving simple algorithms, because they allow them to follow "the logic" of aggregation. The additive utility method establishes simple relations among evaluations done using a single criterion and decision maker preferences (criteria weighted coefficients). The aggregation is done by summing up single utility functions.

2. The additive utility concept does not offer the possibility of automatically rejecting an alternative (project proposal) if its evaluation by some criterion is very low. The aggregate index has its no matter how small) value and priority list, made according to the aggregate index for all project proposals. It is a complete ranking of the quality of all proposed projects.

When the additive utility concept is used, the aggregate "value" (i.e. total index) of the quality of a project proposal is determined by expressing the project proposal utility as the measure of the expected value of the contribution of the proposed research to the achievement of objectives defined in the Government Innovation Policy. In the evaluation process, experts select one of the qualifications offered by each criterion (e.g., in group G1, experts can choose one of the following qualifications for the criterion of technological justifiability of project implementation: (a) very high, (b) high, (c) moderate, (d) low). These qualifications are then associated to quantitative equivalents which represent the evaluation of the level at which some objectives or requirements defined in the TDD's invitation will be achieved (in the above example, these values are: (a)=1; (b)=0.67; (c)=0.42; (d)=0.08). These quantifications are then multiplied by the respective weighted coefficients of the criteria considered (in group G1 whose total weighted coefficient is taken to be 0.45, the criterion of technological justifiability was given coefficient 0.27). The aggregate "value" of project proposal quality by all criteria (total index) is obtained by summing up the values of the products of the quantified evaluation and weighted coefficient of each single criterion.

All qualitative evaluations (i.e. the criteria qualifications) have their quantitative equivalent which can take a value from **0** to **1**. Table 1 lists all criteria, the states of alternative evaluations for each criterion and the corresponding quantitative equivalents for STRP, PRDP and IP groups of projects (programs), respectively.

Formalizing the described procedure, it follows that the index of aggregate evaluation for the i-th project proposal for a subset of basic criteria (AB_i) and for a subset of control criteria (AC_i) are:

$$AB_i = \sum_{j=1}^{4} ab_{ij} \tag{1}$$

$$AC_{ij} = \sum_{j=5}^{6} ac_{ij} \tag{2}$$

where: $i = 1,...,n$ - denotes project proposal; $j = 1,...,4$ - denotes basic criteria group; $j = 5, 6$ - denotes control criteria group.

Table 1: Criteria for project proposal evaluation

Group		Criteria	Alternative qualifications	Programs:					
				STDP		PRDP		IP	
Gj	k			wcv	qa	wcv	qa	wcv	qa
G1	1	Technological justifiability of project realization	Very high	0.27	1.00	0.32	1.00	0.50	1.00
			High		0.67		0.69		0.70
			Moderate		0.42		0.38		0.40
			Low		0.08		0.07		0.10

Group		Criteria	Alternative qualifications	Programs:					
				STDP		PRDP		IP	
Gj	k			wcv	qa	wcv	qa	wcv	qa
G1	2	Scientific basis	Very high	0.18	1.00	0.17	1.00	-	-
			High		0.75		0.71		
			Significant		0.38		0.43		
			Low		0.13		0.14		
G2	1	Research cost	Unrealistically high	0.13	0.66	0.15	0.66	0.25	0.80
			Realistic		1.00		1.00		1.00
			Unrealistically low		0.66		0.66		0.80
G3	1	Availability of planned project result	High	0.20	1.00	0.18	1.00	0.15	1.00
			Significant		0.60		0.60		0.66
			Low		0.20		0.20		0.16
G4	1	Demand for planned project result	High	0.22	1.00	0.18	1.00	0.10	1.00
			Significant		0.60		0.60		0.62
			Low		0.20		0.20		0.25
G5	1	Competence of project team for the respective field of project proposal	High	0.15	1.00	0.10	1.00	0.17	1.00
			Significant		0.60		0.60		0.60
			Low		0.20		0.20		0.20
G5	2	Competence of project leader	Competent	0.22	1.00	0.17	1.00	0.17	1.00
			Not competent enough		0.25		0.20		0.20
G5	3	Competence of subproject leaders	Competent - max value=	0.11	1.00	0.08	1.00	-	-
			Not competent enough - max value=		0.25		0.20		
G6	1	Material and equipment availability for project realization	Completely	-	-	0.05	1.00	-	-
			Mainly				0.66		
			Significantly				0.33		
			Minimally				0.03		
G6	2	Risk of research investment (project realisation)	Very high	0.22	0.07	0.26	0.07	0.25	0.07
			High		0.27		0.27		0.33
			Significant		0.47		0.47		0.66
			Low		1.00		1.00		1.00
G6	3	Risk associated with project result implementation	Very high	0.30	1.00	0.34	1.00	0.41	1.00
			High		0.70		0.70		0.68
			Significant		0.40		0.40		0.40
			Low		0.10		0.10		0.12

Legend: *wcv* - *weighted coefficient value (w);*
qa - *quantitative equivalence (r).*
k - *index for the number of criteria in group Gj.*

The partial aggregates a_{ij} are formed as the sums of the products of single evaluations, r_{ijk}, and the weighted coefficients of criteria, w_{jk}, within the criteria group considered:

$$ab_{ij} = \sum_{k=1}^{m_j} r_{ijk} \bullet w_{jk} \quad ; \; j = 1, \ldots, 4 \tag{3}$$

$$ac_{ij} = \sum_{k=1}^{m_j} r_{ijk} \bullet w_{jk} \quad ; \; j = 5, 6 \tag{4}$$

where m_j is the number of criteria in the j-th group of criteria, on condition that:

$$\sum_{j=1}^{4}\sum_{k=1}^{m_j} w_{jk} = 1 \ ; \ \sum_{j=5}^{6}\sum_{k=1}^{m_j} w_{jk} = 1 \tag{5}$$

Priority or Ranking lists

Evaluations by a single criterion and aggregate evaluations are inputs for creating three sets of priority (ranking) lists (S) for each group of projects i.e. programs (STRP, PRDP, IP):

S1: priority lists of project proposals by each single criterion (created using single evaluation index, r_{ijk}), for each program (S11 for STRP, S12 for PRDP, S13 for IP);

S2: priority lists of project proposals by criteria group (they are created using partial aggregate index, a_{ij}), for each program (S21 for STRP, S22 for PRDP, S23 for IP);

S3: priority list (one) of project proposals formed according to aggregate evaluation index, A_i, for each program (S31 for STRP, S32 for PRDP, S33 for IP).

Decision makers consider priority list S3. In cases when additional information is needed, priority lists by partial aggregates (S2) and single criterion (S1) are used for detailed identification of evaluations. This usually happens in cases where two or more project proposals differ slightly in aggregate criteria values (apart from the position in the priority list, decision makers also receive aggregate criteria values, i.e. partial aggregate values and evaluations according to single criterion, in the case of priority lists S2 and S3). The decision makers then consider partial aggregates, or even single criterion evaluations, in order to understand more clearly the quality of individual project proposals.

Peer evaluation of project proposals

Project proposals are evaluated by the peer review technique. Each proposal is evaluated by two independent (unknown to each other), anonymous experts (their identity is only known to authorized administrators in TDD). The evaluation index value of project proposal, r_{ijk}, is determined by averaging the evaluation indexes of both reviews, i.e.

$$r_{ijk} = \frac{r_{ijk}(e_1) + r_{ijk}(e_2)}{2} \tag{6}$$

where e_1 and e_2 denote the first and second expert, respectively.

When single criterion evaluations by two experts $(r_{ijk}(e_1), r_{ijk}(e_2))$ greatly differ (tend to extremes), the project proposal is subjected to a third, also anonymous, expert evaluation (the third expert is unknown to the previous two).[1]

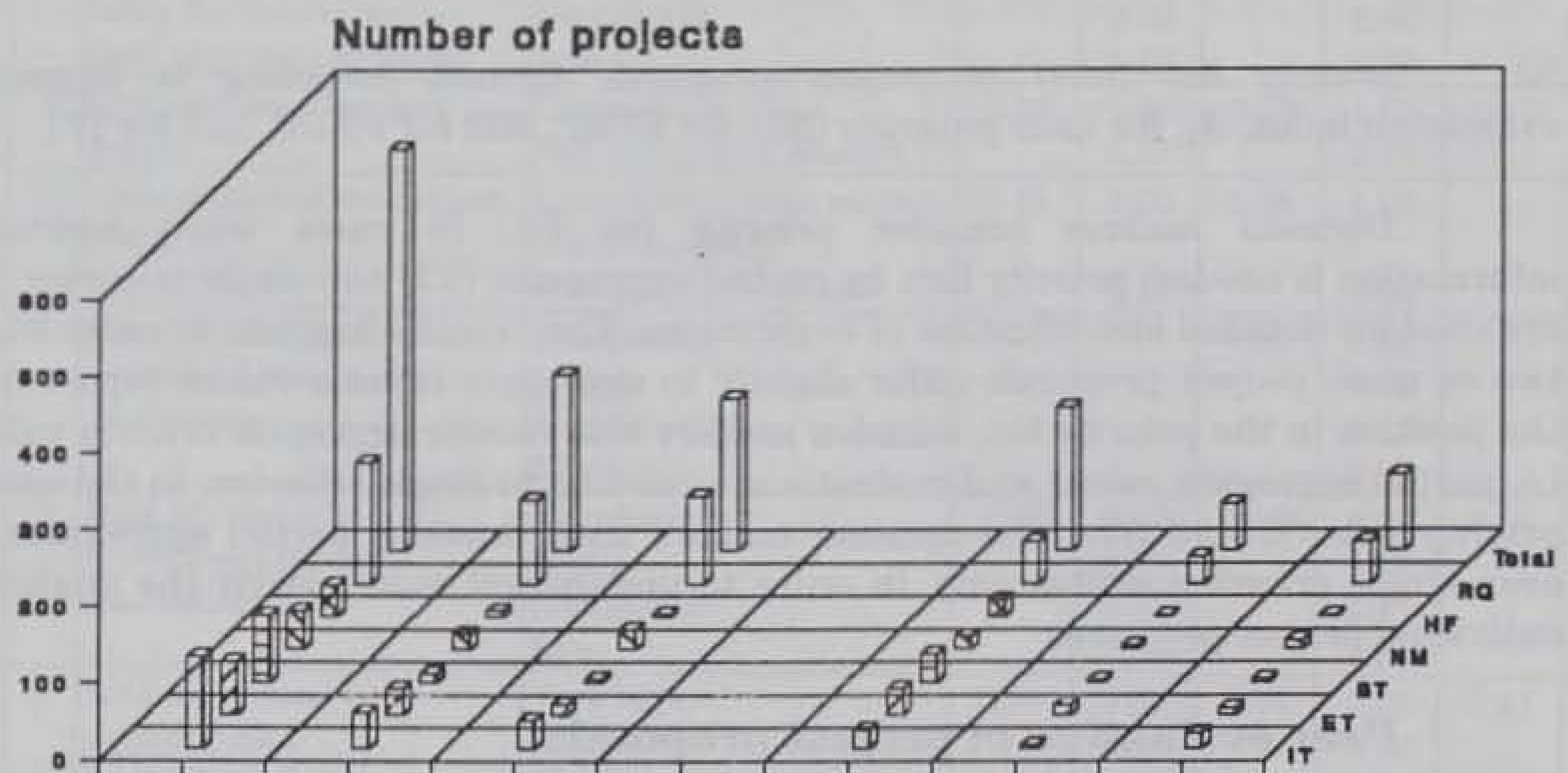
4. BACK TO THE CASE

The methodology described in Chapter 3 was used in selecting projects which were financed by the Ministry for Science and Technology of the Republic of Serbia for the period 1991-1993. Figures 3, 4 and 5 show some results of the described methodology for this concrete case. Results are grouped according to the following indicators:

(a) the number of projects by programs (STRP, PRDP, IP) and technology fields (IT, ET, BT, NM, HF, RQ);

(b) the duration of projects by programs (STRP, PRDP, IP) and technology fields (IT, ET, BT, NM, HF, RQ);

(c) proposal submitting organizations (university departments, institutes, R&D units, industrial enterprises, individuals) by programs (STRP,PRDP,IP) and technology fields (IT,ET,BT,NM,HF,RQ).



	STRP	PRDPL	IP		STRP	PRDP	IP
Total	525	230	188		107	91	88
RQ	168	110	114		65	88	64
HF	41	8	6		21	1	1
NM	50	21	26		17	5	12
BT	57	11	5		37	3	4
ET	70	54	16		24	16	8
IT	116	48	88		22	4	15

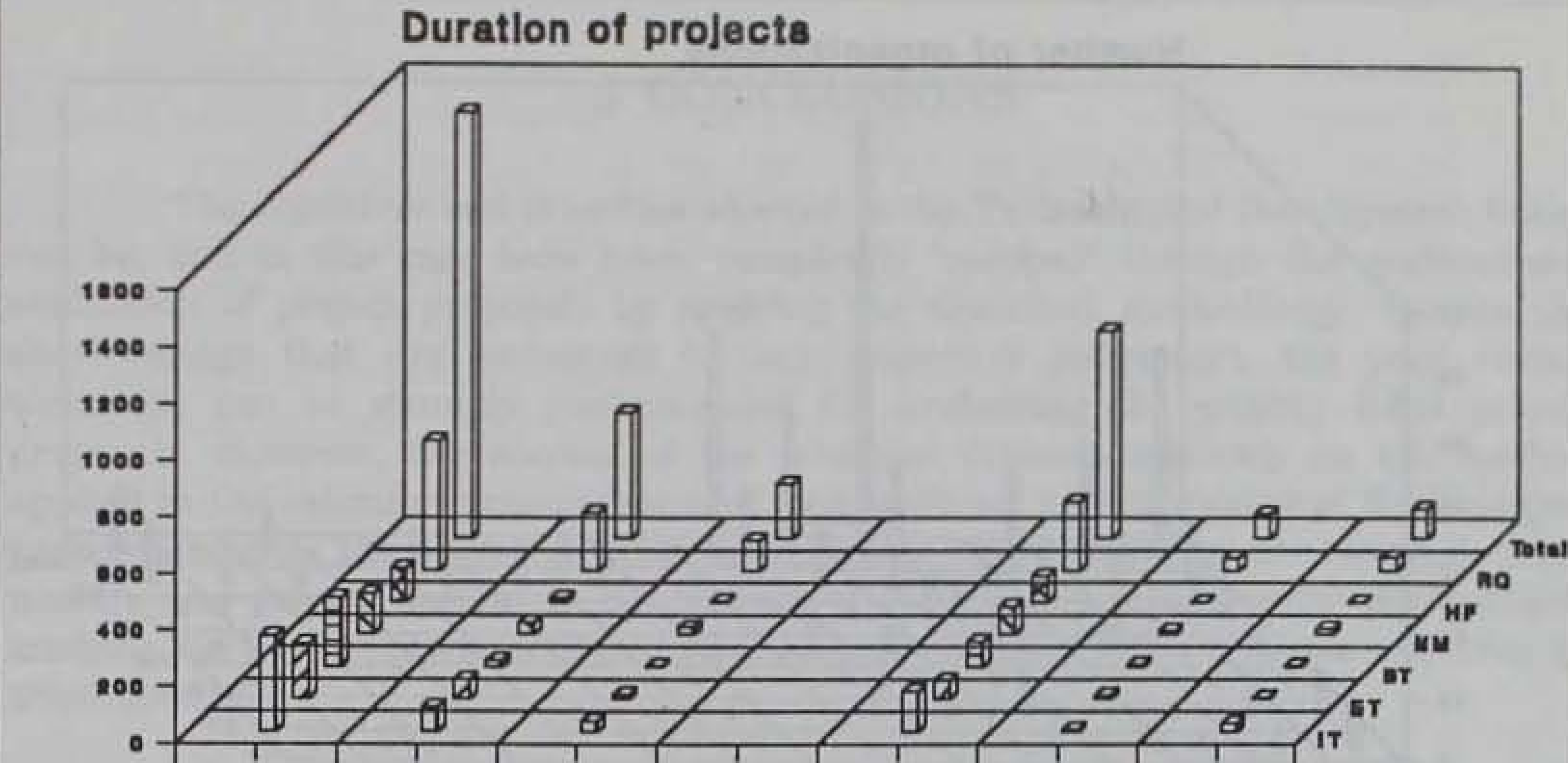
Project proposals Projects accepted for financing

Programs and Technology fields

Source:STI Data Base,M.Pupin Inst. & MST

Figure 3: Number of projects - survey by programs and technology fields

[1] Requests for an anonymous and independent reviews were obeyed in the case described in this paper. A third review is requested in less than 1% of the total number of project proposals. This low percentage can be ascribed, to some extent, to the high quality and the high level of objectivity of expert evaluations.



	STRP	PRDPL	IP		STRP	PRDP	IP
Total	1502.8	444.8	183.1		734.1	87.2	109.4
RQ	466.5	207.77	106.1		242.04	46.86	48.46
HF	120	16	2.66		56.76	1	0.6
NM	145.6	42.33	26.86		100.88	13.21	19.83
BT	246.6	22.3	4.82		81.6	7.6	4
ET	166.5	66.6	14.74		66.5	16.07	4.86
IT	558	56.7	34.86		142.86	6.75	81

Project proposals — Projects accepted for financing

Programs and Technology fields

Source:STI Data Base,M.Pupin Inst. & MST

Figure 4: Duration of projects - survey by programs and technology fields

The following are a few remarks which may be of wider interest:

1. The number of submitted project proposals was extremely large (nearly 1000). One of the reasons is that TDD is practically the only public source of R&D financing in the Republic of Serbia;
2. The share of proposals coming from enterprises and individuals of the total number of submitted proposals is considerably smaller than that from R&D organizations (3.65% and 96.35%, respectively). Apart from the fact that R&D organizations are more adequately organized for such invitations, the reason also lies in a certain amount of reluctance by individuals and entrepreneurs to deal with the bureaucratic system of government financial support. This should be taken into account in future governmental actions in financing R&D projects for attitude small and medium-scale companies and private entrepreneurs;
3. Requests for resource allocation, expressed in man-years, indicate an unrealistic attitude by project proposers regarding the source of financing (TDD). TDD's available resources amounted to 30 million DEM per year. The amount requested was nearly 2.5 times larger than the available funds. The largest number of expert reports indicated that requests for financing were exaggerated;
4. Nearly two-thirds of the proposals were rejected (347 out of 954 were proposed for the acceptance). This was a departure from the previous practice of allocating "a bit to everyone".

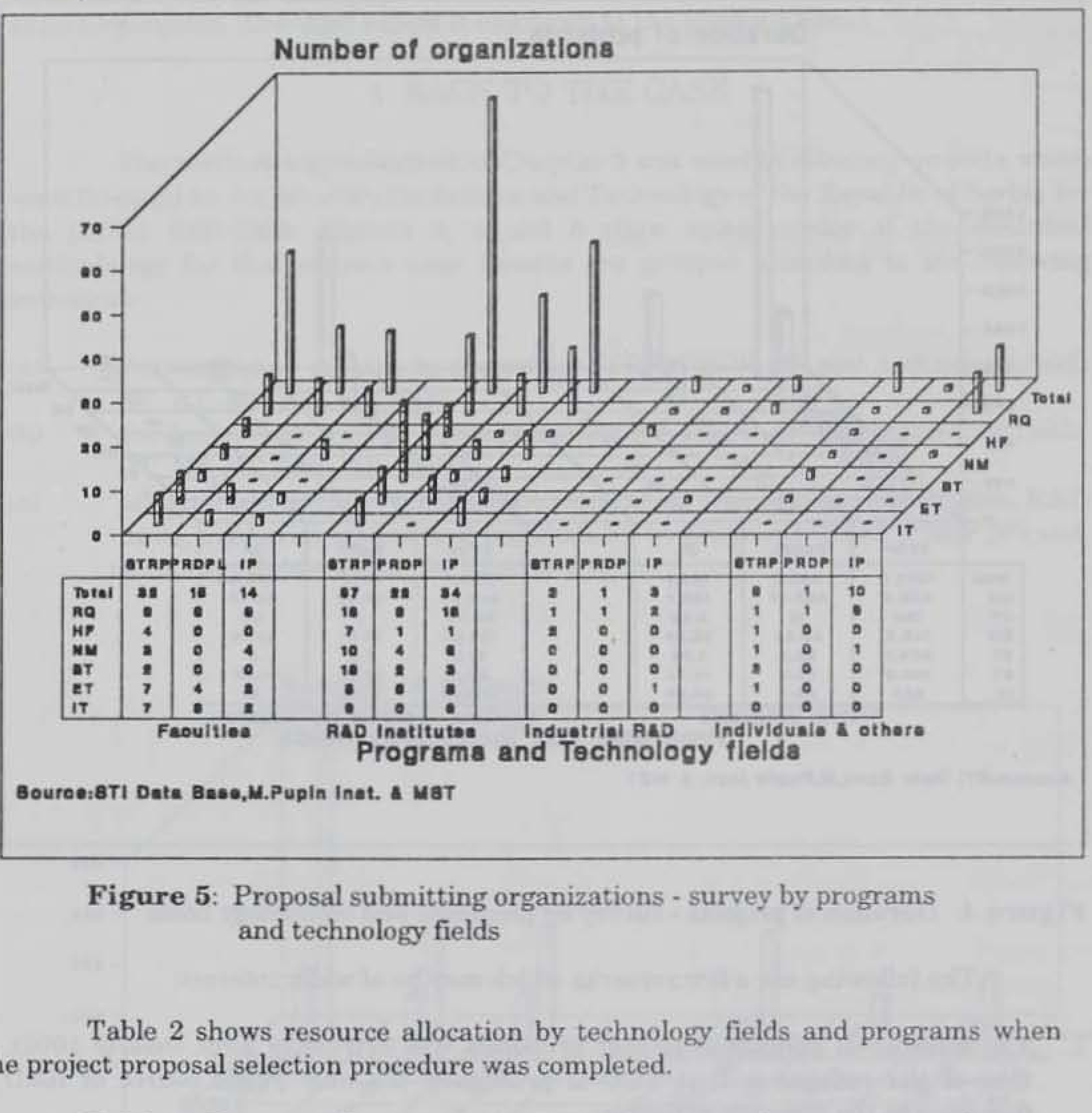


Figure 5: Proposal submitting organizations - survey by programs and technology fields

Table 2 shows resource allocation by technology fields and programs when the project proposal selection procedure was completed.

Table 2: Resource allocation under TDD's invitation, by programs and technology fields

TECHNOLOGY FIELDS	RESOURCE ALLOCATION (%)			
	STRP	PRDP	IP	Total
Information Technologies (IT)	17.10	0.60	3.50	21.20
Energy Technologies (ET)	7.50	0.60	0.54	8.64
BioTechnologies (BT)	10.10	0.60	2.98	13.68
New Materials (NM)	10.80	1.20	0.24	12.24
Healthy Food (HF)	9.60	0.10	0.06	9.76
Revitalization of existing technologies and Quality improvement (RQ)	25.20	4.30	4.98	34.48
Total:	80.30	7.40	12.30	100.00

5. CONCLUSIONS

The objectives and priorities adopted in the Technological Development Policy can be, and in this case have been, completely "mapped" through the multicriteria evaluation of project proposals by applying the described methodology. Despite the shortcomings that are immanent in any subjective judgement, the peer review technique can be strongly recommended for evaluating the validity R&D project proposals. However, the success of the selection depends not only on the method applied in the selection process but also, and more so, on the quality of R&D project proposals and on the degree of Cooperativeness of all participants: reviewers, decision makers and project proposers. So, instead of including how successful multicriteria analysis has been in the selection of R&D projects in this specific case, we will focus on the following:

(1) Complete methodological support has been provided for the evaluation and selection of R&D projects for TDD. This was of crucial importance for decision making and thus very acceptable to decision makers;

(2) The criteria and procedures used for project proposal evaluation ensured full instrumentalization of the governmental innovation policy;

(3) However, the selected projects represent the actualization of the governmental innovation policy only at the level of competence expressed by R&D institutions and individuals through R&D project proposals.

The described support to decision makers is under further development:

(1) The development of a decision support system (DSS) to automate the decision making procedure and provide decision makers with easier access to all the required information;

(2) The development of information support to certain procedures within the evaluation (development of database on experts in in particular science and technology fields, which are the main source of information on potential reviewers; databases on completed R&D projects, R&D projects in progress, etc.).

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