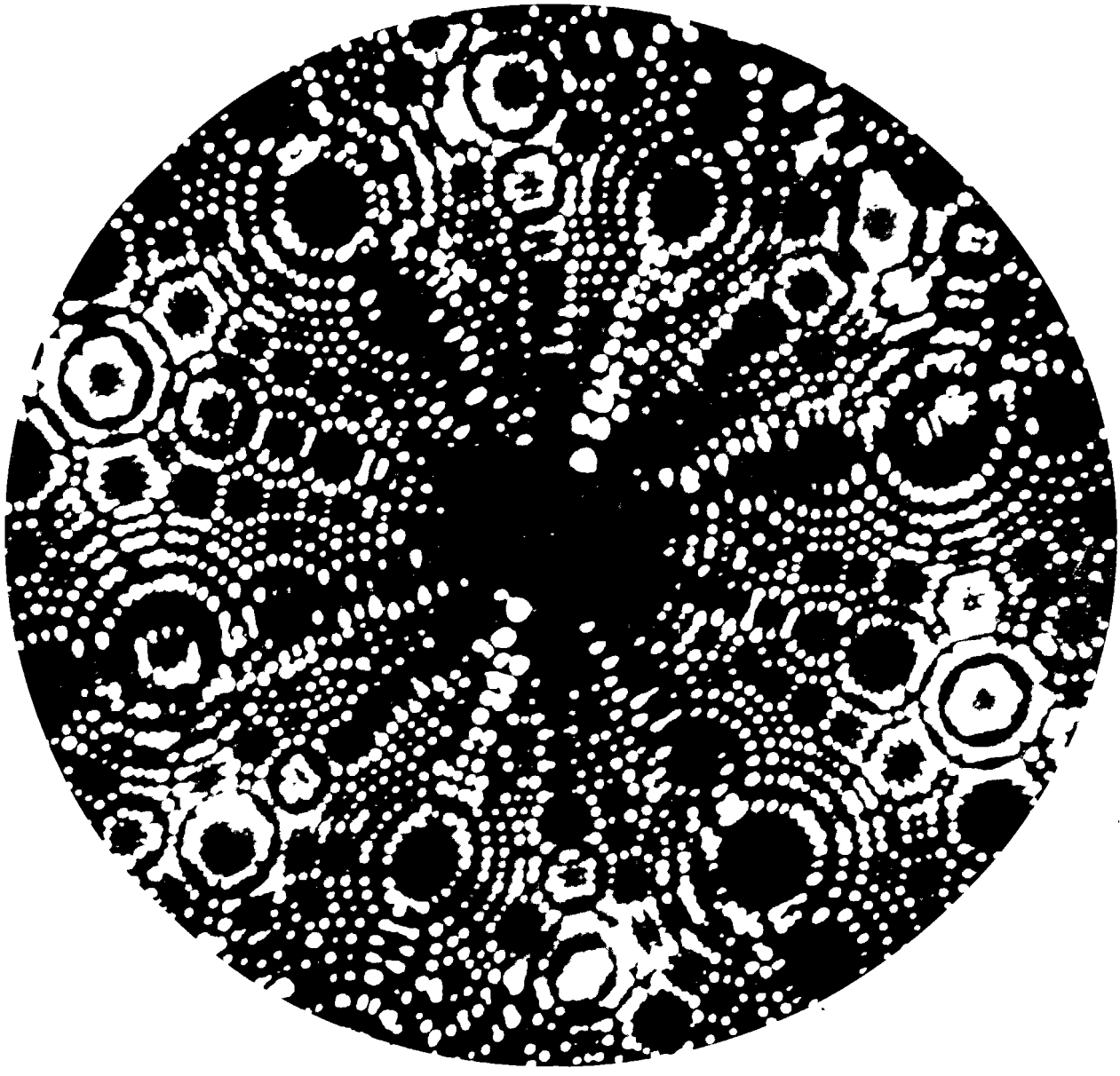
No. 40

Method for priority determination in science and technology

Science policy studies and documents



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Method for priority determination in science and technology

UNESCO/UNACAST surveys
of institutional needs
of developing countries
in the field of science
and technology

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Preface

The Unesco series « Science policy studies and documents» forms part of a programme «to collect, analyse and disseminate information concerning the organization of scientific research in Member States and the policies of Member States in this respect» authorized by resolution 2.1131 (b) adopted by the General Conference of Unesco at its eleventh session in 1960, and confirmed by similar resolutions at each subsequent session.

This series aims at making available to those responsible for scientific research and development throughout the world, factual information concerning the science policies of various Member States of the Organization as well as normative studies of a general character.

The country studies are carried out by the government authorities responsible for policy-making in the field of science in the Member States concerned.

The selection of the countries in which studies on the national scientific policy are undertaken is made in accordance with the following criteria; the originality of the methods used in the planning and execution of the national science policy, the extent of the pratical experience acquired in such fields and the level of economic and social development attained. The geographical coverage of the studies published in the series is also taken into account.

The normative studies cover planning of science policy, organization and administration of scientific and technological research and other questions relating to science policy.

This same series also includes reports of international meetings on science policy convened by Unesco.

As a general rule, the country studies are published in one language only, either English or French, whereas the normative studies and the reports of meetings are published in both languages.

The present volume is devoted to a method for priority determination in science and technology. The method has been developed since 1971 by the Unesco Secretariat assisted by consultants, in response to a request by UNACAST to identify institutional needs in science and technology in developing countries. Early versions of the method have been applied extensively in Africa and Latin America, and later ones experimented with in depth in Indonesia and Colombia.

The method is aimed at disclosing areas of priority for scientific and technological activities, in fields of research, transfer or training, arising according to priorities of development. The disclosure is effected through an assessment of the relevance of scientific and technological disciplines for national development objectives and programmes. The assessment is made by panels of experts drawn from governmental departments and from scientific institutions.

The method is best suited to long-term goals, because of the long lead-times involved in research and training. It can nevertheless be applied to shorter time frames, as is usually the case when dealing with national development plans, provided that the results are interpreted with caution.

The output of the method is a series of priority charts and profiles showing the relative merits of fields of science and technology for the achievement of development objectives, and the relative dependence of the latter on the former. This output can be used by the national science and technology policy-making body to derive the framework for planning and budgeting of scientific and technological programmes by government departments, higher education establishments, research establishments and related institutions involved in the technology transfer process.

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1. Introduction

1.1 Origin

Science left the seclusion of its laboratories and academic institutions forever when, during World War II, it was harnessed for the development of technologies related to military needs. This resulted in the emergence and rapid development of nuclear- and electronics-based weaponry, and subsequently had an overwhelming impact on the world's post-war economic scene through the growing aircraft and computer industries, etc. Research budgets soared to unprecedented levels, as did the number of students enrolling in science and engineering, while increasing proportions of graduates embarked on research careers. By the end of the Fifties, the role of science and technology had become a public issue.

Concurrently, a general worldwide concern emerged to apply science and technology to development. This concern was reflected in United Nations deliberations which culminated in a world conference (UNCSAT-United Nations Conference on the Application of Science and Technology to the Development of Less Developed Countries) held in Geneva in 1963. Thereafter, the United Nations Economic and Social Council's Advisory Committee on the Application of Science and Technology to Development (UNACAST) prepared the World Plan of Action whose major aims were (1, p. 4)*

(a) the building up in developing countries of the necessary structure of scientific and technical institutions to enable them to make the best use of science and technology in their development, and
(b) the mounting of an attack, through the various organizations of the United Nations system, on a number of specific high priority problems, either by obtaining new knowledge or by applying existing knowledge to development.

Within the framework of the world Plan of Action, UNACAST requested Unesco (1, p. 71) to proceed with a country-by-country world survey of institutional needs of developing Member States in the field of science and technology. It indicated the major steps involved in this survey (1, p. 72) :

(a) An analysis to determine the scientific and technological priority requirements of each nation. The survey will be based on the development plans, and/or other statements of national goals of each nation;
(b) A separate analysis of the scientific and technological capabilities of the nation;
(c) The delineation of the science and technology institutions demanding priority consideration by the nation. This list will be based on the above two analyses and will carefully balance the requirements of relevance and excellence. It will follow the agreed plan as described in section H;**
(d) The combination of the national requirements into an over-all regional plan. Efforts will be made to develop inter-institution agreements among neighbouring countries and thus avoid gaps and overlaps in the regional network of institutions; and
(e) The collation of regional plans into a world plan. The world plan for institutional development will be a priority listing of those scientific and technological institutions which demand concerted development action by the world community during the 1970-1980 decade.

If individual national surveys are to be of pratical value to the countries themselves, they must be carried out in some depth and tie in with the countries' own policy-making and development planning procedures. Given the scale of effort involved in such a broad and far-reaching undertaking, one of the first tasks for an international organization such as Unesco, was to work out a standard conceptual and operational framework, within which individual surveys could be organized and performed by the countries themselves. In particular, step (a) above involves the analysis of scientific and technological priority requirements arising from national development goals. This raises the question of «relevant» science and technology, which in turn, requires the development of an appropriate methodology to define the «relevance».

An operations research approach was adopted from the start and was based on the QUEST method (2), which was developed within the U.S. Department of Defense in the Sixties to determine the research and development requirements in planning new weaponry. In essence, the QUEST method linked science to military missions through its contribution to the relevant

* Numbers in parentheses refer to the list of references included in the Bibliography, Annex 1.

** Section H (1, p. 89) referred to in this excerpt is reproduced in Annex 3.4

technologies. Certain features of the present method were drawn also from a method developed in France in 1965 by the "Délégation générale à la recherche scientifique et technique" for the purpose of measuring intersectorial exchanges between research and industry (3).

Methodologically, this type of approach requires that experts rate given features of a set of alternative operations, and that, through simple algorithms, decision-making criteria be constructed such as «merit indices» which make discrimination from among the operations possible from the decision-maker's particular point of view. In this case, the «alternative operations» are the research undertakings (including activities related to technology transfer) which can be carried out in the various fields of science and technology, and the «feature» is the relevance of the particular research undertaking for a given development objective. Alternatively, the «operations» can be the specialized manpower development and training activities, instead of research or technology transfer activities, or a mix of the two, with the «feature» remaining the same. The «merit index» is a number measuring the over-all relevance of the operation in question with respect to the entire set of development objectives. This criterion, combined with assessments of capability, will provide the basic information required by the policy-maker for allocating resources among alternative undertakings in research and transfer or in education and training.

The present method has been developed gradually since 1970 (3, 4, 5, 6) by a team composed of members of the Unesco Secretariat and consultants; the successive versions were modified according to experience gained during applications of earlier methods.

Extensive series of exercises, based on early versions of the method, were carried out in Africa (8) and Latin America (9) during 1971-72, covering some 20 and 15 countries respectively. In-depth applications based on later versions, were made in Egypt and Indonesia (10) in 1973 and in Colombia (11) in 1975.

While the basic rationale of the method remained essentially the same through all these exercises, its conditions of application were greatly improved over time. Organizational, procedural, and human aspects proved to be the major factors affecting its validity and usefulness. These aspects will therefore be developed in the exposé.

1.2 Aim

The world survey of institutional needs in science and technology requested by UNACAST involves five steps (as listed in the preceding section), of which steps (d) and (e) simply consist in aggregating country needs at regional and then at world level, but the present study is not concerned with these two steps.

However, the first three steps constitute self-contained and country-specific operations aimed at «the delineation (on a country-by-country basis) of the science and technology institutions demanding priority consideration» (step c), on the basis of two types of analyses: needs analysis (step a), and capability analysis (step b). This publication is essentially devoted to a description of the conceptual and operational framework for needs analysis, with indications given where necessary on how capability analysis ties in with it. Techniques for capability analysis are more readily available than for needs analysis and the reader is referred to current literature on the subject (for instance, the Unesco Manual for surveying the national scientific and technological potential, Ref. 12).

The aim of the present priority determination method is to provide an appropriate analytical tool for the first step of a national survey by i.e. disclosing the scientific and technological priority actions arising from the national development priorities. To some extent, this is the more important and difficult step from both the conceptual and operational standpoints because it requires detailed statements on development priorities, which often turn out to be highly subjective and raise politically sensitive issues. In contrast to this, capability analysis proves less delicate because it can at least be tangibly grounded on objective and quantifiable «snapshots» of what exists in terms of numbers of specialists, fields of specialization, information, equipment and facilities available, and financial appropriations.

The priority determination process is part of a political process. Hence, any analysis used in determining priorities will be meaninful and usable only so far as it is legitimatized, i.e. either achieved by the nationals themselves or, when achieved or helped by outsiders, at least politically controlled by nationals. Therefore, the present method is intended for use, first and foremost, by national authorities concerned with policy-making in science and technology.

Furthermore, the method has been designed to interlock with local development planning and budgeting procedures and has been made flexible enough to accommodate the wide variety of such procedures.

Finally, since the method is meant to be used at policy-making levels, it aspires to bring major issues to the fore and to clarify the debate among those in the concerned scientific community on the one hand, and the socio-economic development planners who represent the political community at large on the other.

1.3 Approach

1.3.1 Conceptual framework

«Relevant» science and technology refers to knowledge that can be identified as having a likely impact on predetermined (developmental) objectives. The conceptual approach adopted here is a normative and deductive one.

The logical sequence, therefore, starts with a statement (which has often to be generated ab initio, for all practical purposes) of national goals and development objectives. This statement constitutes the working hypothesis of the exercise. It must be detailed enough and couched in terms that allow a meaningful identification of the causal relationship between these goals and objectives on the one hand, and the science and technology inputs on the other.

Not all developmental objectives or national goals are pursued at the same time with the same intensity. There is always an explicit or implicit priority rating of goals and objectives which reflect the political will

devoted to, and the resources available for, their achievement. Furthermore they are not logically independent; the objectives are hierarchically structured. The relative importance and the interdependence of national goals or development objectives are two outstanding features which have been considered in the method.

In terms of policy-making in science and technology a country's institutional infrastructure should be able to cope with the whole spectrum of innovative activities through which scientific and technological knowledge is produced, disseminated, practically applied, and propagated throughout the productive sectors of the economy. Broadly speaking, the following types of activities must be performed: research and experimental development (R&D), activities related to the transfer of science and technology and the provision of scientific and technological services (STS). To be comprehensive, a survey of institutional needs should include all the institutions performing these basic activites, as well as the institutions responsible for the education and training of the specialists who practice them. While the bulk of the specialized manpower produced by the latter institutions is intended for the production system, the method theoretically lends itself - by extended coverage - to scientific and engineering manpower development planning for the entire economy. However routine scientific and technological activities directly linked with producing goods and services, as defined in economic theory, do not fall within the scope of activities normally dealt with under science and technology policy.

Essentially the present approach derives institutional needs in science and technology from the performance requirements of the above-mentioned activities. The categories to be scanned in the survey should, therefore, be closely associated with those describing specialization areas in the institutions performing these activities. A breakdown by scientific and technological discipline is the most convenient classification for the practical purposes of identifying institutions, describing substantive areas of higher education and R&D, making international comparisons, and computing aggregate figures at regional or world levels. In sum, the contribution of science and technology to national goals and development objectives is disclosed in terms of fields of knowledge, with the relevance of each field assessed in relation to the others.

The use of a classification by fields of knowledge to characterize inputs requires that one further specifies the type of activity involved. There are essentially two: research or transfer (in the given area of specialization), on the one hand, and education and training on the other. The first type relates to the creation of new, or the importation of existing, knowledge, while the second type relates to the transmission of knowledge through higher education systems, both being considered as independent means for the achievement of development objectives.

If «science and technology» are described in terms of fields of knowledge, the basic disciplines are likely to be relegated to the background in terms of relevance because they are, by their very nature, more remote from practical objectives, at least in those analyses which are made in short or medium time frames. This is corrected by considering the interdependence of sciences and technologies.

Finally, the method is designed to ensure the comprehensive and self-consistent charting of the development objectives to which the science and technology inputs relate and, conversely, of the inputs required by each development objective.

The disclosure of such relationships, along with a determination of over-all relevance of science and technology inputs to development objectives on the one hand, and the over-all dependence of objectives on those inputs on the other, will provide the basic elements for the determination of a country's scientific and technological priority requirements.

1.3.2 Operational framework

Determining priorities is sometimes a political act, sometimes a technical one. The priority setting of national goals or development objectives pertains rather to a political act and is therefore essentially subjective.

But priority setting, even when seen as a technical act, often remains highly subjective, because, in analyzing very complex situations, qualitative attributes which cannot be objectively defined let alone measured are included. For instance, the cause-effect relationship, which is the base of relevance assessment, can, at least in principle, be made objective if not measurable, if all the variables involved, and the laws governing their interaction are known. Since this is never the case, one has to resort to the synthetic judgement of an «expert» with the best knowledge of the case at hand.

In so far as the method faithfully models the decison-making processes, it will, by structuring a more consistent and coherent dialogue between experts, provide a neutral vehicle for subjective judgements while disclosing their underlying implications. But the substantive contents of its results will only be as valid and credible as the original assessments made by the experts. This most important feature points to the necessity of ensuring a proper level of expertise and authority among the panelists called on to participate in an «exercise» i.e. the actual application of the method in a national context. The reliability of the results is ensured by controlled utilization of expert opinions through properly designed application procedures of the method, and by a number of built-in sensitivity tests.

Since the method is meant to aid in a complex decision-making process, its applications should - to the greatest extent possible and as a matter of credibility - involve all those who will be affected by the potential decisions. Two groups of persons are involved: the scientists and engineers who will do the work once orientations are set, and who have to be motivated accordingly; and government planning authorities and officials from the various ministries who will be responsible for setting development objectives and for planning and budgeting the related programmes - they are the potential «clients» of science and technology, and as such will have a say in the appropriation of government funds to scientific and technological activities.

1.4 Scope and limitations

1.4.1 Development objectives

The more detailed and concrete a development objective the easier it is to identify the impact which the importation of a technology, the undertaking of a given piece of research work, or the training of a given brand of specialists might have on the programme. Conversely, broad policy goals or wide-sweeping development objectives cannot be handled meaningfully by the present method: they must first be disaggregated until the connexion with science and technology inputs becomes close enough to be visible.

In principle, the list of development objectives used should be comprehensive. However, the more concrete objectives such as those found in agricultural development, industrial development, transport development, etc, and which usually relate to the production of goods or the establishment of material infrastructures, are more easily dealt with by the present method than those objectives which relate to social or cultural development.

1.4.2 Science and technology

As was mentioned in section 1.3.1, science and technology inputs are represented by fields of knowledge and by types of activities envisaged within each field.

The scope of fields of knowledge which will be subsumed under the general heading «science and technology» must then be defined. Once again, for the sake of comprehensiveness, nomenclatures covering all fields, from mathematics through pure and applied natural science to social and human sciences can be used as a starting point. It should be made clear however that the «harder» the science, the better it is handled by the method. For the «softer» brands of science, the relevance assessments are less meaningful and much more difficult to interpret, except perhaps for certain types of the more mathematically grounded social sciences, e.g. econometrics, demography, linguistics, statistics, etc. Therefore it is advisable to reduce the range of the fields covered to mathematics, pure and applied natural sciences, and engineering sciences and technology during trial applications. When experience in handling the method has been acquired, it can be applied to other fields.

Because the nomenclature of inputs is discipline-based, the method will not disclose inputs which are not readily characterized as specialized fields. Such is the case with scientific and technological services (See Appendix 3.4), for instance geological surveys, information and documentation services, instrumentation and standards services, extension and transfer services and so on. These must be disclosed by other means, as must institutions whose main functions are policy-making and/or co-ordination.

Finally, another limitation of the method is the exclusion of non-oriented fundamental research for obvious reasons since the method aims at discriminating among research/transfer or training undertakings related to extra-scientific objectives. Even if a specific objective with the sole purpose of promoting the advancement of science is included, the method is not the right instrument to rate non-oriented against oriented research.

1.4.3 Time-frames

Specialists' training and research projects usually span periods of the order of five years or more. Therefore the method is best suited to long time-frames, i.e. for the handling of long-term objectives. On the other hand, development objectives are usually set in a short to medium time-frame, which presents an apparent contradiction. However, as a result of the inertia built into development processes, priorities very seldom undergo violent changes over periods of 10 years and even more. Development problems are not resolved overnight, so that although the political commitments to certain courses of action may be limited to short periods, the complex of development objectives is expected to remain, on the whole, approximately the same over one or more subsequent plan periods (extending the perspective from 5 to 10 or 15 years), and the relevance analysis remains valid.

1.5 Requirements and constraints

1.5.1 National prerequisites

There are two major prerequisites to the successful application of the method.

First, the country concerned must be prepared to tell the scientists and engineers called upon to do work «relevant» to national development exactly what it wants, and what the plans and policies are. Without any guidance from political leaders and planning agencies, the scientific community can hardly be indicted as irrelevant. Therefore a formal national development plan, or any other detailed political commitments equivalent to a plan, constitute a first prerequisite. An adequate level of capability and experience in the planning and budgeting of government development programmes will ensure that the results of an exercise are properly accounted for in the later planning phases, and that the exercise has played a role in shaping things to come.

Secondly, the scientific community must be large, varied and experienced enough to afford a relatively comprehensive and expert coverage of the fields of specialization involved. Gaps in the profile of nationally available expertise may be filled in by calling on outside specialists. However, too great a proportion of foreign personnel in the relative composition of panels would dampen the political impact of the exercise.

The method provides for the establishment of a dialogue between the scientists and engineers on the one hand and various government officials responsible for development programmes on the other. It is desirable for the latter to have scientific or engineering backgrounds because their abilities to assess the implications of development programmes in terms of science and technology inputs will be enhanced thereby.

1.5.2 Procedural constraints

The method involves the participation of many specialists and government planners and technical advisers; in fact, as many as are necessary to ensure a comprehensive

coverage of all the objectives and all the fields of knowledge. It further requires confrontations among them, which means that they must meet en masse (discarding the futuristic possibility of board meetings at a distance through communications gadgetry).

Formal methods of group interaction - such as, to some extent, the priority determination method described in this publication - are still seldom used by, let alone known among, decision-makers. On their first recourse to such methods, they are as much going through a learning process as they are going through a decision-making process.

The limited time available to participants with heavy job commitments, and participants' needs to become acquainted with formalized decision-making processes, point to the necessity of simplifying the procedures and making the various steps in the underlying rationale as visible as possible.

For instance, the use of over-sophisticated algorithms and complicated computer programmes for processing the results of the exercise would be counter-productive, because the participants would remain foreign to the whole process, and their confidence in the results would decrease proportionately.

Bearing in mind that the exercise is meant to form the basis for planning and budgeting the scientific and technological effort of the country, its holding must be timed properly to fit the national planning and budgeting cycles. Also, the information generated by the exercise must be presented in formats which are compatible with those used by planning authorities.

2. Description of the method

In this section the method is presented from a formal point of view, with a detailed discussion of its three major areas of analysis: national development objectives (hereafter referred to as development objectives or simply objectives), science and technology (S&T) inputs, and the relevance of the latter to the former. A concrete, if fictitious, example is thoroughly worked out to illustrate the various steps involved. Practical considerations of the conditions of application and the utilization of the results are taken up in the next section.

2.1 General considerations

2.1.1 General framework

The method basically consists in making explicit the complex of logical relationships between development objectives and potential undertakings in science and technology fields.*

The first major step consists in *identifying* the development *objectives* of the country and in designing appropriate formal descriptions of these objectives as well as of the variety of science and technology inputs, among which logical relationships will subsequently be disclosed.

The second major step is the *disclosure of such relationships* through the scoring of each individual item (i.e., a development objective, or a field of science and technology) on the basis of its relevance to the other items, resulting in a double-entry table, or matrix. There are three types of scoring operations, depending on whether one scores an objective against other objectives, a science** against objectives, or a science against other sciences. The results are displayed in three corresponding matrices, conventionally referred to as the D/D (D for « development ») cross-support matrix, the S/D (S for « science ») relevance matrix, and the S/S cross-support matrix. Three model matrices are shown in Annex 2.

The third major step is the *construction of priority charts* for fields of science and technology. This involves the computation, according to appropriate algorithms, of over-all scores of relevance for each S&T field and of over-all scores of S&T dependence for each objective. This computation in turn requires the rank-ordering of objectives according to their priority and the calculation of corresponding weight numbers. The rank-ordering and weighting procedure for objectives is achieved in two steps. First, panels of experts rank-order the objectives directly with the weight numbers derived from the results according to a simple algorithm. This result is then corrected on the basis of the objectives cross-support for each other.

The fourth major step is an *assessment of the cross-support* of the S&T fields for one another. Its aim is to disclose those fields of knowledge, usually associated with science taken in the restricted sense (as opposed to technology) which are more basic and more remote from the objectives, but nonetheless essential to the development of the relevant technologies.

2.1.2 Nomenclatures

Nomenclatures play a significant role in the method. They are the basic tools which delimit the conceptual and operational areas that must be broken down to make the problem tractable, i. e. structuring the dialogue and forming a consensus of opinion among experts with various institutional affiliations and with equally varied backgrounds, on a subject covering no less than science and technology on the one hand, and the entire development scene on the other. Nomenclatures play the role of a formal language for communication among the participants and help reduce ambiguities in their respective subjective assessments to a minimum.

Two types of nomenclatures are used in an exercice: notional and institutional. The nomenclatures for fields of science and technology, development objectives and broad policy goals are among the former. The domains of government responsibility and the scientific and technical institutions are among the latter. Some such nomenclatures are shown in Annex 3.

* In a fully self-consistent framework, the exploration of such undertakings would disclose unsuspected potentialities which in turn would lead to a reformulation of objectives, thus closing the loop in the analysis of objectives/means relationships, only after which step would the objectives be set. This type of approach is more sophisticated and more intellectually satisfying, but it requires more complicated planning procedures. It can be used once one is fully acquainted with the present method, which is believed to constitute a valid first approximation to the other approach.

** Short for: field of science and technology.

2.2 Ends: development objectives

2.2.1 Identification and formulation

As mentioned earlier, the statement of development objectives constitutes the starting point of the exercise and its basic working hypothesis. In many respects, it is also the most difficult part.

There are four outstanding features of the development objectives which must be examined here: policy status, time-frame, specificity, and finality (teleological character).

The statement of objectives should reflect official policy, to ensure the political validity of the exercise. The statement can be derived from official declarations or documents on broad policies, and on current and future development plans.

Because of the long lead-times involved in either training scientists and engineers or carrying out research projects, the objectives must be set in the long-term. However, politically endorsed statements on objectives are usually set in shorter time-frames. A judgement must then be made on whether extending the objective beyond the time-frame of the political commitment made to its pursuit makes (1) political sense and (2) operational sense. If the problem to be solved is likely to be effectively solved within much less than 10 years, it does not make much sense, operationally, to investigate how science and technology, in its research or training aspects, can help achieve the objective. The transfer of a technology might be a more meaningful proposition within short time-frames, although experience shows that its adaptation to local conditions demands the availability of highly qualified technical personnel and some measure of research and development work, all of which then lengthen the period extending from its inception to its intended impact on the local situation.

The statement must be specific. The objectives should be described in terms that allow a direct perception of the instrumental character of potential research/transfer or training undertakings. They should be as concrete as possible and, wherever applicable, quantified, if relevance is to be assessed meaningfully and with a reasonable degree of confidence. For instance, «agricultural development» is obviously too general an objective to allow meaningful relevance assessment. «Crop production increase» is still too general. But «to increase the production of a given crop variety by x per cent over n years» would be suitable.

The statement must be teleological, or give precise indications of achievements aimed at, not just the general nature of the activity; in the example mentioned above, «crop production» would be insufficient.

In Unesco's experiments, nomenclatures of objectives proper were seldom used, probably because they have not yet become part of planning practices in governments, and hence the corresponding information was not available. There is no ready-made international standard nomenclature of development objectives, although some work has been done on nomenclatures of objectives of R&D, in particular by Unesco, the European Economic Community, and the Organization for Economic Cooperation and Development (13). The three nomenclatures used by these organizations are shown in Annex 3.1.

In the absence of politically-endorsed, detailed statements couched in terms of the items of a nomenclature of objectives, recourse must be made to nomenclatures of types of activities, such as the International Standard Industrial Classification (ISIC), shown in Annex 3.2, provided additional information is given on what the implicit government objectives are within each area of activity represented by the nomenclature item.

Experience has shown that nomenclatures with a number of items ranging from 50 to 100, will generally describe the total development picture with sufficient accuracy for the purpose of the exercise. A hypothetical list of development objectives, comprising 52 items, is shown in Table 1. This list is adapted from a list used in an actual exercise.

The specificity of the items requires that they be generated by more than one panel, i. e. by individual teams from different ministries, each covering an area of activities. In the example shown in Table 1, there would be eight teams, from eight ministries, who would independently generate their own group of «objectives».

At this stage, a set of items (objectives) is broken down into sub-sets according to ministerial responsibility over related activities, i. e. objectives relating to agricultural programmes regrouped under the heading "Agriculture" and so on.

2.2.2 Priority ranking

Development objectives differ in the scale of resources devoted to their achievement, in the timing of the related efforts, in the political determination which sustains their pursuit or the political consensus about them, and so on. The over-all relevance of a given area of scientific and/or technological endeavour has to take this basic fact into account. Hence, objectives must be rank-ordered according to some general operational criterion, which we choose as the priority, thus defined: the development effort will be arranged (in time and in magnitude) to secure the achievement of first-order priority objectives first, then, resources remaining, for the achievement of second-order priority objectives, and so on. In practice, the number of categories of priority is small, i.e. less than 10. For our purpose, four will suffice; this even number is adopted to avoid the middle-of-the-road effect in ascribing an item to a category.

Sorting out objectives among priority categories must be done in two steps.

(1) First step

First, each individual panel (ministerial group) sorts out its own objectives into four categories by decreasing order of priority, priority being understood from the point of view of the ministry to which the panel belongs, i. e. with respect to the over-all goals or missions of the ministry. For instance the objectives listed in Table 1 might, after such a sorting process, be rank-ordered as shown in Table 2. Note that in some cases (e. g. Mining, Manpower), the last priority category may be void of items, because there are too few items to be sorted out among the four categories of priority.

The significance of the rank-order is clear: all objectives within the same priority category are perceived as deserving equal priority, i. e. it is impossible to decide or determine in any significant way which one is «more»

Table 1: Hypothetical list of development objectives

AGRICULTURE
Rice
Secondary food crops
Rubber
Sugar
Other plantation crops
Livestock
Fisheries
Forestry
MINING
Oil and gas
Tin
Bauxite, etc.
Sulphur, coal
INDUSTRY
Food, beverages and tobacco
Textile, footwear and leatherware
Wood and related products
Chemicals and related products
Non-metallic mineral products
Basic metal industries
Machinery and equipment
PUBLIC WORKS
Rehabilitation of irrigation
Extension of irrigation
Other water resources
Roads and bridges
Engineering services
Housing
Water supply
Waste disposal and recycling
Electricity

COMMUNICATIONS
Land transportation
Sea transportation
Air transportation
Telecommunications and post
Tourism
EDUCATION
Primary education
Secondary education
Teachers training
Higher education (Social sciences)
Higher education (Science and technology)
Non-formal education
Culture and sports
HEALTH
Family planning
Community disease control
Environmental sanitation
Health services
Nutrition
Health education
Infants health
Food and drug control
MANPOWER
Employment creation
Vocational training
Income distribution
Industrial relations

Table 2: Hypothetical rank-ordering of objectives (independent frames of reference)

	Order of priority			
	1	2	3	4
AGRICULTURE	Rice Secondary food crops	Other plantation crops Livestock	Forestry	Rubber Sugar Fisheries
MINING	Oil and gas	Tin Bauxite	Sulphur	
INDUSTRY	Food, beverages and tobacco Textile, footwear and leather	Chemicals and related products	Basic metal industries Machinery and equipment	Wood and relat. products Non-metallic mineral products
PUBLIC WORKS	Extension of irrigation	Electricity Roads and bridges	Other water resources Rehabilitation irrigation Water supply Engineering services	Housing Waste disposal and recycling
COMMUNICATIONS	Sea transportation Land transportation	Air transportation	Telecommunications and post	Tourism
EDUCATION	Primary education	Secondary education Higher education (S&T)	Non-formal education	Teachers training Higher education (Soc. Sc.) Culture and sports
HEALTH	Family planning	Community disease control Health education Health services	Environmental sanitat. Nutrition Infants health	Food and drug control
MANPOWER	Employment creation	Vocational training Income distribution	Industrial relations	

urgent or important than the others. If some programmes have to be slowed down or abandoned, achievement of first-priority objectives naturally over-rides the achievement of second-priority objectives and so on. As also seen from Table 2, the objectives are not necessarily evenly distributed (in number) among the four priority categories. Both front-loading and back-loading occur in practice, although the latter case is somewhat more frequent, because one tends to be selective in granting a first priority status. The priority 4 category is actually a residual group, and sometimes its elements do not have equal priority: that is, some differences in importance are still perceived, which could be accommodated only by adding further priority, categories, 5, 6, etc.. For *our own purposes* four categories will generally suffice, and otherwise the inhomogeneity in the last category will not raise any difficulties in the subsequent procedure. Therefore, category 4 in the most general way, would be interpreted as a residual group containing all objectives which were estimated to be of less importance than category-3 objectives, irrespective of their relative importance among themselves.

What has been said above applies to each ministerial sub-set of objectives independently. The individual rank-ordering says nothing about the comparative merit or priority of objectives belonging to different ministerial sub-sets.

(2) Second step

The second step therefore will consist in combining the independent rank-orders of the sub-sets in Table 2 into a common rank-order of the total set of objectives.

To do this, a common frame of reference must be defined, i. e. a common set of criteria applied to all ordered subsets. A separate panel would have to be constituted, with some members coming from the ministerial panels to argue the case among themselves and other members with arbitration powers.

A simple procedure consists in iterative segmentation. The panel first considers the set of objectives which were granted first priority by each individual panel, and breacks down the set into two groups, a first group (the first priority category of the full rank-ordered set) containing all those objectives of the original set believed to deserve top priority, on the basis of the common set of criteria mentioned above (those criteria will generally be related to over-all policy goals such as GNP growth, income distribution, full employment, national defense, foreign exchange reserves, etc...), and a residual group. Referring to Table 2, this would mean considering the objectives listed under colum 1. Assume that the panel has selected the following objectives as being of over-riding importance, and deserving of top-priority:

Rice
Secondary food crops
Oil and gas
Food, beverages and tobacco
Textile, footwear and leatherware

The residual set is then amalgamated with the set of objectives appearing under column 2 in Table 2, and the process is repeated. At the end, items will be left over from the set under column 3. These will be amalgamated with the set under column 4, and they together will constitute the (residual) set of objectives of Priority 4. A hypothetical rank-ordered set of objectives is shown in Table 3.

At this stage, one has a set of objectives (partially) rank-ordered according to priority. Generally, it is expected that the number of objectives will increase with decreasing order of priority. In some cases, the residual category (priority-4) might contain considerably more items than any of the preceding ones.

The significance of this rank-ordering of objectives is the following: in case of an unexpected budget cut, the programmes under the last rank-ordered objectives would be the first to suffer reduced funding, short of outright elimination, the penultimately ranked would be next and so on. The priority attribute of a development objective should not be confused with the financial or physical magnitude of the effort needed for its achievement. Some objectives will by nature require heavy investments in capital or in manpower, although they may be pursued with less determination, i. e. more likely to be scaled down or even abandoned in case of crisis, while others with smaller requirements will remain untouched. This distinction should be carefully emphasized when the procedure is explained to panelists because of the natural tendency to associate priority with budget magnitude.

2.2.3 Interdependence of development objectives

Development objectives constitute a complex of interdependent entities, and this characteristic must be taken into account in the ranking procedure, prior to weighting.

The method for disclosing interdependence relationships proceeds in a similar way to the generation of the relevance matrix S/D (see section 2.4.4 below), except that the discipline nomenclature is replaced by the nomenclature of objectives.

In the present case, the relevance of each objective to each of the other objectives is estimated. The reader is referred to Annex 2, where a model D/D matrix is shown. The scores in the figure are represented by the following symbols: ■, ●, ○ depending on whether the contribution of an objective (listed in the left-hand column) to the achievement of an objective (listed in the top row) is estimated to be critical (■), important (●), or simply of interest (○). A blank space indicates irrelevance. For instance, reading row-wise, one sees that the "Rice" objective (first row) is estimated to be *critical* (■) for the achievement of the following objectives: «Food, beverage and tobacco» «Nutrition» «Employment creation» and «Income distribution»; it is further estimated to be *important* (●) for the «Infants health» objective and finally *of interest* (○) for the «Livestock» and «Tourism» objectives. Conversely, in reading column-wise, those objectives which are required in various degrees for the attainment of a given objective are immediately discernible. For example to fulfill the «Rice» objective (first column), the following objectives are shown to be:

critical (■): Rehabilitation of irrigation
Extension of irrigation
Income distribution

Table 3:
Hypothetical rank-ordering of objectives
(common frame of reference)

Order of priority
1
Rice Secondary food crops Oil and gas Food, etc. Textile, etc.
2
Other plantation crops Livestock Forestry Tin Bauxite Chemicals and related prod. Extention of irrigation Roads and bridges Electricity Primary education Secondary education Higher education (S&T) Family planning Employment creation
3
Rubber Sugar Fisheries Sulphur, coal Basic metals Other water resources Machinery and equipment Land transportation Sea transportation Non-formal education Community disease control Infants health Health education Vocational training Income distribution
4
Wood and paper products Non-metallic mineral products Rehabilitation of irrigation Engineering services Housing Water supply Waste disposal/recycling Air transportation Telecommunications and post Tourism Teacher training Higher education (Soc. Sc.) Culture and sports Environmental sanitation Health services Nutrition Food and drug control Industrial relations

Table 4: Upgrading the priority order of objectives

	Priority group 1	2	3	4
Rice	●			
Secondary food crops	●			
Oil and gas	●			
Food, etc.	●			
Textile, etc.	●			
Other plantation crops		●		
Livestock	●←○			
Forestry		●		
Tin		●		
Bauxite		●		
Chemicals and related prod.	●←○			
Extension of irrigation	●←○			
Roads and bridges		●		
Electricity		●		
Primary education		●		
Secondary education		●		
Higher education (S&T)		●		
Family planning		●		
Employment creation		●		
Rubber			●	
Sugar	●←○			
Fisheries			●	
Sulphur, coal			●	
Basic metals	●←○			
Other water resources	●←○			
Machinery and equipment		●←○		
Land transportation			●	
Sea transportation			●	
Non-formal education		●←○		
Community disease control			●	
Infants health			●	
Health education			●	
Vocational training		●←○		
Income distribution	●←○			
Wood and paper products				●
Non-metallic mineral products				●
Rehabilitation of irrigation	●←○			
Engineering services		●←○		
Housing		●←○		
Water supply			●←○	
Waste disposal recycling			●←○	
Air transportation				●
Telecommunication and post				●
Tourism				●
Teacher training		●←○		
Higher education (Soc. Sc.)		●←○		
Culture and sports				●
Environmental sanitation			●←○	
Health services			●←○	
Nutrition			●←○	
Food and drug control	●←○			
Industrial relations				●
Number of objectives N	14	18	13	7
Weight of group W	8	4	2	1
Relative unit weight = $\frac{W}{N}$	4.00	1.53	1.08	1

Table 5:
Final rank-ordering of objectives

Order of priority
1
Rice Secondary food crops Sugar Livestock Oil and gas Food, etc. Textile, etc. Chemicals and related prod. Basic metals Rehabilitation of irrigation Extension of irrigation Other water resources Food and drug control Income distribution
2
Other plantation crops Forestry Tin Bauxite Machinery and equipment Roads and bridges Engineering services Housing Electricity Primary education Secondary education Teacher training Higher education (Soc. Sc.) Higher education (S&T) Non-formal education Family planning Employment creation Vocational training
3
Rubber Fisheries Sulphur, coal Water supply Waste disposal/recycling Land transportation Sea transportation Community disease control Environmental sanitation Health services Nutrition Health education Infants health
4
Wood and paper products Non-metallic mineral products Air transportation Telecommunications and post Tourism Culture and sports Industrial relations

important (●): Chemicals and related products
Other water resources
Land transportation
Higher education (Social sciences)
Higher education (Science and technology)
Non formal education
Community disease control
Food and drug control
Employment creation

of interest (○): Machinery and equipment
Roads and bridges
Vocational training.

In the figure, all diagonal elements are marked critical, that is, an objective is by definition considered essential to itself. Furthermore, there are instances where two objectives are mutually essential to each other, such as «Rice» and «Income distribution».

A diagram such as the one shown in the D/D matrix brings out the logical relationships linking the various objectives, and ensures self-consistency. The major use of the diagram is to modify the rank-ordering of the objectives (Table 3) so that it is self-consistent. For instance, the «Rice» objective, according to Table 3, has been ascribed first priority, and the «Extension of irrigation» objective only second priority. On the other hand the Matrix D/D reveals that the latter objective is of critical importance for the former, and actually deserves at least the same first priority. The priority order of the objective «Extension of irrigation» should therefore be upgraded from 2 to 1. In like fashion, «Income distribution» will be upgraded from 3 to 1 «Rehabilitation of irrigation» from 4 to 1. One proceeds thus for all first priority objectives, then for second priority objectives, and so on. The result of this operation is shown in Table 4. At the end, one is led to a new rank-ordering (Table 5), with each priority group comprising the objectives of the initial group accompanied by their direct auxiliaries.

2.2.4 Weighting

The basic aim of the method is to provide a global indicator that will allow discriminating among fields of knowledge according to their overall importance for achieving the total set of objectives. This indicator is the overall relevance, a particular combination (yet to be determined) of the relevance of the discipline to each individual objective. The latter relevance is assessed subjectively, and a relevance mark R_{ij} is ascribed to each pair (discipline i, objective j). For ease of handling, the relevance marks are displayed in a double-entry table or matrix, and are hence referred to as matrix elements (Table 6).

In order to derive an overall relevance mark R_i for discipline i from a set of individual relevance marks R_{ij}, one needs to take into account the fact that objectives generally differ in importance. Mathematically, this is tantamount to ascribing to each objective a weight coefficient W. It is shown in the Appendix following this section that when objectives are rank-ordered according to priority, this coefficient W is given by:

$$W = \frac{2^{4-k}}{N_k}$$

where k is the priority order of the objective and N_k is the total number of objectives having the same priority order. For instance, referring to Table 5, which gives the final rank-ordering of the objectives, one sees that

$$N_1 = 14 \qquad N_2 = 18 \qquad N_3 = 13 \qquad N_4 = 7$$

and hence the unit weights of all objectives with first order priority are:

first order priority: $W = \frac{2^{4-1}}{N_1} = \frac{8}{14}$

and so on:

second order of priority: $W = \frac{2^{4-2}}{N_2} = \frac{4}{18}$

third order of priority: $W = \frac{2^{4-3}}{N_3} = \frac{2}{13}$

fourth order of priority: $W = \frac{2^{4-4}}{N_4} = \frac{1}{7}$

In most calculations, only the relative magnitude of these weights has a significance, and hence any set of numbers proportional to the above set might be used to suit any purpose, for instance, to facilitate computational operations. In the S/D matrix of Annex 2, the following numbers were used for calculating the priority profile:

$$W_1 = 7 \times \frac{8}{14} = 4.00 \qquad W_2 = 7 \times \frac{4}{18} = 1.53$$

$$W_3 = 7 \times \frac{2}{13} = 1.08 \qquad W_4 = 7 \times \frac{1}{7} = 1.00$$

Appendix – Weight coefficients for priority-ordered objectives

Assessing the relative merit of two or more alternatives against a combined set of criteria is a problem of common occurrence in the decision-making process. In our case, the alternatives are the various fields of science and technology in which either innovation activities (through research or technology transfer) or training activities can be undertaken, and the problem of choice arises because efforts cannot be sustained in all fields concurrently. The global merit we take as the relevance, and the combined set of criteria are the development objectives against which each S&T field will be scored for its relevance.

These objectives are rank-ordered according to priority. This has direct implications on the numerical weights which can be ascribed to each individual objective.

Table 6: Relevance matrix

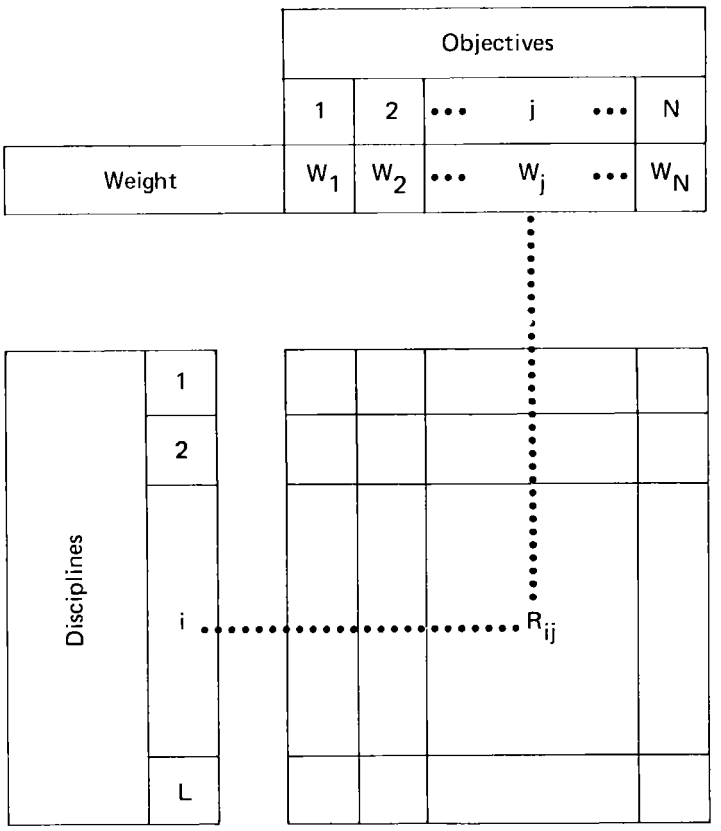


Table 7: Relevance in a simple priority-ordered world (2 disciplines/4 objectives)

	Order or priority				
	1	2	3	4	
Objectives	Rice	Electric power	Land transportation	Housing	
Weight	W_1	W_2	W_3	W_4	
Agronomy	1	0	0	0	$R_{Ag} = W_1$
Civil eng.	0	1	1	1	$R_{Civ} = W_2 + W_3 + W_4$

To show this, four cases (or models of the decision-making process) are treated in order of increasing complexity. In the following, R_{ij} denotes the relevance of discipline i to objective j, and R_i its overall relevance.

CASE 1

The simplest problem is the fictitious situation in which all objectives (N in number) are considered equally desirable or in the same order of priority (that is, there are no priorities !), and in which a discipline can only be relevant or irrelevant (R_{ij} = 0 or 1). In this case the global importance or merit of a given discipline is accurately described by the number of objectives to which it is relevant, that is, the overall relevance number R_i is the sum of individual relevance numbers R_{ij}:

$$R_i = \sum_{j=1}^{N} R_{ij}$$

CASE 2

The next simplest problem is one in which each objective has a different order of priority (the set of objectives is totally ordered). In the most general way, the overall relevance should be a weighted sum, the weight coefficient W_j reflecting the order of priority of objective j:

$$R_i = \sum_{j=1}^{N} R_{ij} W_j$$

Assume now a hypothetical world where only four objectives would exist: food production, energy production, transport and construction, and where the development priorities would be, in that order:

Rice
Electric power
Land transportation
Housing

and where scientific knowledge would be confined to two disciplines: agronomy and civil engineering. Assume further that the relationship between the two disciplines and the four types of objectives would be as shown in Table 7, and finally that the objectives are independent, that is, the fulfillment of any one of them is independent of the fulfillment of the others.

In the event of a crisis (natural disaster, war, etc.) where available resources would be reduced by a considerable factor, two courses of action are possible: scale down the effort either equally for all objectives, or selectively, abandoning one objective after the other until enough savings are made to account for the missing resources. Priority-ranking implies the latter course of action.

For the method to be self-consistent, at least the same order of priority should be granted to the means (disciplines) as is granted to the ends (development objectives) which it serves; otherwise, in the event of a crisis, a given end might still be pursued (say the first priority objective) while the means to it would have been abandoned (because the related discipline came out to be of lesser priority). The weights W_i should therefore be such as to «transfer» the priority content of objectives to disciplines. Referring to the example in Table 7, it is seen that we should have:

$$R_{Ag} > R_{Civ}$$

i. e.

$$W_1 > W_2 + W_3 + W_4$$

and more generally, the W's must satisfy the condition:

$$W_i > W_{i+1} + W_{i+2} + \ldots + W_N .$$

This system of inequalities defines a whole family of possible solutions for the W_i's. Now the ratio W_{i+1}/W_i is a constant, i.e. it is independent of the order of priority i, and it can be proved that the minimum value of this constant is 2. If one then sets this constant equal to 2, and sets the quantity W_N, which is otherwise arbitrary, equal to 1, one obtains a unique solution:

$$W_i = 2^{N-i}$$

In the example of Table 7, we would have:

Order of priority	1	2	3	4
Weight factor	8	4	2	1

In other words, no matter the number of objectives to which a discipline is relevant, it will automatically be outranked by any discipline which is relevant to at least one objective with greater priority, even though the latter may be irrelevant to all objectives of lesser priority.

CASE 3

Next in line of complexity is the case in which the set of objectives is only partially ordered, that is there are N_1 objectives of first order priority, N_2 of second order, and so on. By definition, objectives with the same order of priority have the same weight, which we denote w. The overall relevance of a discipline takes the form

$$R = \sum_{j=1}^{J} n_j \cdot w_j$$

where n_j is the number of objectives with j th priority to which the discipline is relevant, w_j is their unit weight and J is the total number of priority groups.

Applying the same argument used in CASE 2, we see that the coefficients w_j must now satisfy the conditions

$$w_j > N_{j+1} w_{j+1} + N_{j+2} w_{j+2} + \ldots + N_J w_J$$

These conditions would ensure maximum logical consistency. They are however too stringent, since w_j decreases rapidly with increasing j and hence, to any practical extent, only first order priority objectives would be playing any significant role in discriminating among disciplines.

We will therefore require that the coefficients w_j satisfy rather the following limited conditions:

$$N_j w_j > N_{j+1} w_{j+1} + N_{j+2} w_{j+2} + \ldots + N_J w_J.$$

The quantity $W_j = N_j w_j$ can be considered as the weight of group j. Therefore the limited conditions amount to applying the argument of CASE 2 to the priority groups of objectives instead of the objectives individually. The solution of the above system of inequalities is, adapting from CASE 2,

$$W_j = 2^{J-j}, \text{ and the unit weight } w_j = \frac{W_j}{N_j} = \frac{2^{J-j}}{N_j}$$

Consider now two disciplines with overall relevance

$$R = \sum_{j=1}^{J} n_j w_j \quad \text{and} \quad R' = \sum_{j=1}^{J} n_j' w_j$$

respectively.

The logical consistency requirement, in the most general way, now takes the form:

If $n_i = n'_i$ for all $i < j$, and if $n_j > n'_j$,
then one must have $R > R'$, whatever the values of n_i and n'_i for all $i > j$.

The expression derived above for w_j will not ensure that this result is obtained in all cases. It can be shown however that the condition $R > R'$ could theorically be violated in a number of cases which is at most only 1/6 of the total number of all possible cases. This is a relatively negligible effect, and it is thus considered legitimate to use the limited conditions for determining w_j.

CASE 4

The relevance of a particular field of science and technology to a development objective is a qualitative attribute of the logical connection between the two. This connection depends on a host of factors which are collectively perceived when we describe the relevance as «high» «weak» and so on, but its complexity should be properly taken into account. Therefore the last refinement introduced in the coarse model developed above will be to allow for degrees in relevance, which until now has been assumed to be a discrete property, i. e. either present or absent (R = 0 or 1). An ordinal scale with four possibilities (high, medium, low, nil) will usually suffice.

*
* *

This last feature completes the last step made in building up the model. This model is the simplest form possible that will sufficiently realistically represent the relationship between science and technology on the one hand, and development on the other, so as to warrant its use in the decision-making process of priority determination. The model brings out the internal structure of the relationship and thus makes possible the quick identification of critical «nodes» in the network of the relationship.

2.3 Means: science and technology inputs

As was mentioned in the Introduction, the basic descriptors used for representing the domain of science and technology are the fields of knowledge. This particular approach to the Science/Development relationship is a «subject matter approach» whereby the requirements of development objectives are analyzed in terms of the relevance of different subject matters relating to the generation (research) or transmission (training or technology transfer) of information. This approach can be contrasted for instance with an institutional approach, where science and technology are described in terms of institutions, or with a programme approach, where disciplines are replaced by programmes of research, technology transfer, and training.

These two other approaches are in a certain sense more operational, because one would be assessing the relevance of more concrete things, i. e. existing institutions or programmes in a country, which are competing for funds and staff. But they would also be much less helpful in identifying needs and gaps, which by their very nature must be described in terms of things which do not yet exist, a feature which a subject matter (or discipline) nomenclature has, to some extent, since the entire spectrum of specialized knowledge existing the world over is being scanned, not just the one implanted in a given country.

2.3.1 Nomenclature of disciplines

Whereas nomenclatures of development objectives are intimately tied to the particular ideological, political, cultural, economic, or social setting of a country, thus making the use of international nomenclatures difficult (and sometimes unacceptable), nomenclatures of fields of scientific and technological knowledge are, at least in principle, independent of such national settings (that is, for those who believe in the objectivity of science, a question currently debated among the philosophers of science). Except perhaps for the social sciences, which are more dependent on the ideological and cultural determinants of a society, any standard international nomenclature can be used with confidence.

From a logical standpoint, no thoroughly satisfactory nomenclature exists. For this study, the nomenclature used should have entries with approximately the same weights in terms of information content. For instance, physics, physical chemistry, and chemical kinetics cannot be treated on the same footing, the last item being subsumed under the penultimate one which is in turn subsumed under the first one. The items should be more or less mutually exclusive, in order to avoid double-counting, when attributes are cumulated over all items.

2.3.2 Level of disaggregation

The more disaggregated the nomenclature, the greater its discriminating power, and the more meaningful the results of its use.

For practical reasons, two levels will suffice. Two-level nomenclatures generally contain some 100-150 items, if only natural sciences and technology are

covered. The number of items is approximately doubled if social and human sciences are added.

A three-level nomenclature must therefore be used, because the third level serves to nominally define the content of each second-level item. The «proposed international standard nomenclature for fields of science and technology» (14) currently worked out by Unesco, and which precisely contains three levels, is shown in Annex 3.3.

The particular grouping of second-level items under first-level aggregates (e. g. mathematics, physics, etc.) is irrelevant as far as the exercise is concerned. It does not matter, for instance whether «molecular biology» comes under «chemistry» or «biology» so long as it is included, and only once.

The level of expertise of each panelist should be such as to cover approximately from 5 to 10 second-level items.

In the example worked out in this paper, a 96-item nomenclature has been used (See S/D and S/S matrices in Annex 2). The nomenclature is shown in Table 8. Its entries correspond more or less to entries of the standard nomenclature mentioned above.

2.3.3 Types of inputs

The relevance of each item in the nomenclatures of disciplines to development objectives can be viewed from different standpoints, depending on the mode of operation which is envisaged.

As was mentioned in section 1.3.1 above, there are basically two modes of operation. One mode relates to activities aimed at innovation through generating new knowledge or adapting techniques applied elsewhere. This mode covers research activities carried out in the country as well as activities undertaken to transfer foreign science and technology. Relevance analysis according to this mode of operation reflects innovation needs.

A second mode of operation relates to activities aimed at providing the economy or the production system with specialized manpower. This mode essentially covers education and training activities, mainly in the higher education sector, i. e. universities and engineering schools. Relevance analysis according to this mode of operation reflects manpower needs.

Consider, for instance, the relevance of chemical engineering to the food industry (See the S/D matrix, Annex 2). The relevance can be interpreted in terms of the food industry's need for chemical engineers, or alternatively, in terms of the need for carrying out research work in the chemical engineering field.

Depending on the interests of the policy-making body responsible for the exercise, one mode or the other will be retained.

Theroretically, the exercise could be carried out twice, taking each mode in turn. Replication, however, can become operationally cumbersome. In this case, the exercise can be carried out according to the two modes simultaneously, i. e. the question «how relevant is (discipline ...) to (objective ...)» will be taken to have either meaning. Functional coverage is thus increased but information is reduced (e. g. a high over-all relevance mark will result from an undisclosed mix of the two modes of operations, making comparisons more difficult and leaving open the question as to which type of action the high relevance mark leads to).

In the S/D and S/S mock-up matrices of Annex 2, relevance marks have been ascribed on the assumption that both research and training were involved, i. e. taking into account both modes of operation.

2.3.4 Interdependence of disciplines

As will become clear later on, the relevance calculation tends to emphasize the importance of fields with the more direct impact on the objectives, that is of applied sciences. Most of the more basic sciences are eventually relegated to the low relevance group simply because they are less directly connected with concrete achievements in the development areas.

However, besides organizing the application of science to development, a balanced scientific effort should also be concerned with the development of a capability in the basic sciences, especially those which critically support the relevant applied sciences.

In order to disclose which of these merit support, a cross-support assessment is effected in similar fashion to the relevance assessment (see section 2.4.4 below), except that the nomenclature of objectives is replaced by the nomenclature of disciplines. An overall relevance number (cross-support number) is calculated and a profile is formed, which will tend to emphasize the importance of the basic sciences.

The S/S matrix (Annex 2) gives an example of such a cross-support assessment. This example is not meant to be authoritative, though it was carefully devised to be as plausible as possible.

The significance of the relevance marks shown in the S/S matrix is analogous to the significance of the relevance marks in the D/D matrix, and the matrix should be «read» in similar fashion. In the present case, one estimates the degree (critical, important, of interest, respectively represented by the symbols ■, ● and ○) to which expertise in or progress achieved in a given discipline (shown in a row) will affect expertise or progress in another discipline (shown in a column). For instance, reading down the first column, it is considered that "Agricultural chemistry" depends on the following disciplines:

■ critical:	(itself*)
	Geochemistry
● important:	Phytopathology
	Chemical Engineering
	Nuclear Engineering
	Soil Sciences
	Microbiology
	Plant Biology
	Analytical Chemistry
	Biochemistry
	Nuclear Chemistry
	Organic Chemistry
○ of interest:	Agronomy
	Geology
	Entomology
	Inorganic Chemistry
	Nuclear Physics

* By definition, an «item», whether a development objective or a field of S&T, is always considered essential to itself. See section 2.2.3 above.

Table 8: Nomenclature of disciplines of science and technology

Applied sciences

AGRICULTURAL SCIENCES	ENGINEERING AND TECHNOLOGY	ENVIRONMENTAL SCIENCES	MEDICAL SCIENCES
Agricultural chemistry	Aeronautical engineering	Atmospheric sciences	Clinical sciences
Agricultural engineering	Chemical engineering	Climatology	Epidemiology
Agronomy	Computer technology	Geochemistry	Internal medicine
Animal husbandry	Construction engineering	Geodesy	Nutrition
Fisheries	Electrical engineering	Geography	Occupational medicine
Forestry	Electronics engineering	Geology	Pathology
Horticulture	Environmental engineering	Geophysics	Pharmacology
Phytopathology	Food S&T	Hydrology	Psychiatry
Veterinary sciences	Industrial engineering	Meteorology	Public health
	Instrumentation and control	Oceanography	Surgery
	Materials (ceramics, wood, etc.)	Seismology	
	Mechanical engineering	Soil sciences	
	Metallurgy and metal products		
	Mining engineering		
	Motor vehicle technology		
	Naval engineering		
	Nuclear engineering		
	Petroleum engineering		
	Power technology		
	Railway technology		
	Space technology		
	Telecommunications engineering		
	Textile technology		
	Transportation engineering		

Basic sciences

LIFE SCIENCES	CHEMISTRY	PHYSICS	MATHEMATICS
Animal biology	Analytical chemistry	Astrophysics and astronomy	Logic
Anthropology	Biochemistry	Acoustics	Algebra
Biophysics	Inorganic chemistry	Electromagnetism	Analysis
Entomology	Macromolecular chemistry	Electronics	Computer sciences
Genetics and embryology	Nuclear chemistry	Fluid physics	Geometry
Human biology	Organic chemistry	Mechanics	Number theory
Human physiology	Physical chemistry	Molecular physics	Numerical analysis
Immunology		Nuclear physics	Operations research
Microbiology		Optics	Probability
Plant biology (botany)		Particle physics	Statistics
		Solid state physics	Topology
		Theoretical physics	
		Thermodynamics	

Conversely, it is considered that «Agricultural Chemistry» contributes to the following disciplines in the given degrees:

■ critical:	(Itself)
● important:	Agronomy
	Forestry
	Horticulture
	Phytopathology
○ of interest:	Food S&T
	Soil Sciences
	Entomology
	Plant Biology

2.4 Ends/means relationship : Relevance assessment

2.4.1 Two points of view

In assessing the relevance of a given input for a given objective, two points of view are considered, that of the scientist, or «producer» and that of the officer responsible for a development programme, or the «user».

The two views are complementary and should be reflected in the design of the scoring procedure for the disciplines' relevance.

The assessment therefore requires, as already noted, two types of panelists. A panelist specialized in one discipline scores it in terms of all development objectives, while a panelist interested in a particular development objective scores all disciplines with respect to it. Each panelist usually covers a number of disciplines or development objectives.

The two points of view, leading to qualitatively different assessments, are used to control individual assessments made on the basis of a single point of view. They are essential if priority profiles are to embody the reconciled, integrated views of both «producers» and «users».

2.4.2 Criteria of assessment

The criterion used to assess the relative merit of alternative inputs in the three cases treated with the method (D/D, S/D, S/S matrices) is, in this context, the relevance which means usefulness. It is tied to the concept of utility, or instrumentality of the means with respect to the ends.

Generally, an input is fully relevant when it constitutes either a necessary or a sufficient condition for a given outcome.

In assessing relevance, panelists must consider the broad policy goals which define the objectives' context. For example, automation techniques might not be relevant to a steel production objective under an overriding policy goal of full employment which would require the selection of labour intensive technologies, but would be highly relevant otherwise.

2.4.3 Judgement scales

Relevance judgements are made on an ordinal scale. The number of positions on the scale can be at most 6 or 7, the maximum number of different possibilities among which the human mind can meaningfully discriminate. An even number of positions should be used so that panelists will not avoid committing themselves to a difficult assessment by giving it a middle mark. Two positions would make for too coarse an instrument, while six is unnecessarily refined and would risk throwing assessment sessions into endless debates. Therefore a four-position scale is retained. It is shown in Table 9.

A discipline is ascribed a set of relevance marks (see 2.4.4 below), each representing the relevance of the discipline to an individual objective. The construction of an overall score for the discipline from the set of relevance marks requires a composition law, or algorithm. The simplest algorithm is a weighted sum. However, this algorithm requires the association of a numerical scale with the ordinal scale.

Algorithms which do not suffer from this constraint also exist. They come under the general heading of «multicriteria methods» (See general bibliography Annex 1), are much more complicated, and a computer is needed to process the data.

Experiments made on problems similar to the example, show that these more sophisticated methods do not give significantly different results. They have been discarded in favour of the simpler, weighted-sum algorithm because of their lack of visibility and their requirements for panel training and technical support.

The selection of a numerical scale to be associated with the ordinal scale is a matter of pratical convenience. Scales 0-1-2-3 (linear), 0-1-2-4 (mixed linear-exponential), 1-2-4-8 (exponential) have been used. In principle, the results - the relevance profile, see below - are independent of the two end points 0-3, 0-4, 1-8 in the scales mentioned, but could be sensitive to the numbers used for the two intermediate points. This matter is taken up in section 3.2.1.1 (sensitivity tests).

2.4.4 Generation of the relevance matrix

We are now in a position to construct the relevance matrix. Taking each discipline in turn, relevance marks are ascribed to the discipline for each objective of the development plan and displayed in matrix form as shown in Annex 2 (Matrix S/D).

Two panels are used to independently generate a full matrix each. The two matrices thus obtained (generally at variance) are then compared, the discrepancies negotiated and a final matrix that comprises the reconciled points of view of the two panels is formed.

(1) Panel of scientists (S-panel)

A panel of scientists and engineers is constituted; they are the specialists in the disciplines of the S&T nomenclature. Each specialist is to cover five to ten items at most, so approximately 10-20 specialists are needed to cover 100 items. More reliable results are obtained if each item is covered by two specialists with the same background, thus doubling the number of panelists. These specialists, as representatives of the scientific community, should provide a repository of technical expertise and should usually be actively involved in research and teaching work or technology transfer activities.

Table 9: Relevance assessment scale

Relevance mark R_{ij}	Descriptor	Description
		The application of science "i" (research, training, etc.) to the achievement of objective "j" is:
■	Critical	highly relevant; that is, a direct logical relationship is perceived; the action is estimated to be critical for the outcome, and to affect it massively, with a high level of confidence; it practically represents a necessary or sufficient condition for bringing about the outcome, that is for achieving the objective.
●	Important	consideraly relevant; that is, a close logical relationship is perceived between the action and the outcome, although it is not estimated to be likely to affect it overwhelmingly and unconditionally;
○	Of interest	moderately relevant; that is, relevance is well perceived, but it is estimated that the action would affect it under somewhat special circumstances;
blank	Irrelevant	either too remotely relevant or irrelevant to any practical extent.

The scale of judgement will almost inevitably vary from one individual to another, though these variances can be partially alleviated by the control of the other panel (see below).

The S-panelists tend to over-rate their field. Their point of view is opportunistically inclined towards the uses for their profession.

For any one panelist, filling in a line with relevance marks amounts to sorting out all the objectives among four categories, one for which a discipline input (in the given mode of operation, see section 2.3.3 above) is considered absolutely essential to achieve the objective (■), one for which it is considered very relevant, (●), and so on.

(2) Panel of planners (D-panel)

The panel of planners is composed of persons who can ably assess those S&T inputs relevant to the objective and the accompanying development programme. They are usually scientists or engineers who work in planning groups at the ministries responsible for the various objectives. If there were 10 groups of objectives, for example, and each were covered by one specialized group of panelists (with two specialists per group), the panel would require approximately 20 persons.

The view point of the D-panelists is unified from the vantage point of a particular objective, and their role in the negociation is to control the unrelated assessments of the S-panelists.

(3) Operations

The S-panel consists of a number of subpanels. For instance, in referring to the S/D matrix in Annex 2, there could presumably be a subpanel covering Agricultural Sciences, a subpanel covering Engineering and Technology, and so on. Each of these subpanels works independently of the others, filling in its own horizontal portion of the matrix. Then, in adding up these portions, the S-panel produces the entire matrix.

The D-panelists do likewise, except vertically. The D-panel is broken down into D-subpanels, such as one D-subpanel covering Agriculture, one covering Industry, and so on.

Then a confrontation is held between the S-panel and the D-panel.

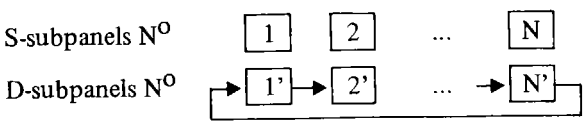
Let us ascribe a number to each subpanel, according to :

Fields of S&T	**S-subpanel N°**
Agricultural sciences	1
Engineering Sciences	2
Environmental Sciences	3
Medical Sciences	4
Biological Sciences	5
Chemical Sciences	6
Physical Sciences	7
Mathematical Sciences	8

Development objective	D-subpanel N°
Agriculture	1'
Industry	2'
Public works	3'
Communications	4'
Mining	5'
Education	6'
Health	7'
Manpower	8'

In the most general way, there will be N S-subpanels, and N' D-subpanels.

Each S-subpanel confronts a given D-subpanel and the relevance marks are brought in line through conventional negotiation on the merit of the case. Suppose S-subpanel N°1 is facing D-subpanel N°1', while 2 faces 2', and so on. When all are finished, 1, 2, ..., N stay put, while 1' moves to 2' then facing 2, and so on, N' reverting to 1'. The full matrix is complety negotiated when 1' reaches N and the exercise is terminated.



The end result of such an operation will be a single S/D matrix, analogous to the one shown in Annex 2.

2.4.5 Cross-support matrices

In the case of D/D and S/S matrices, the operational procedure described in the preceding section would differ only in that one panel, the D-panel or the S-panel, would fill in the matrix. However the double point of view and the control features remain. Indeed, each panelist will ascribe marks row-wise, having in mind the outputs which might be related to his particular speciality (development programme area, or field of S&T) considered as an input. Then he will ascribe marks column-wise with the reverse process in mind - making judgement on inputs related to his particular speciality considered as an output. The control phase is carried out in a similar fashion except that each panelist will then be confronted with members of the other subpanels of his own panel, instead of members of the other panel.

After this operation, a single D/D matrix and a single S/S matrix will have been completed.

In the D/D matrix, for example, only one panel is involved, the D-panel. The D-panel is broken down into D-subpanels each covering a given area of the development field. In the example used, (See the D/D matrix, Annex2), one subpanel could conceivably cover the field of Agriculture, one the field of Industry, and so on.

Each D-subpanel fills in its own horizontal portion of the matrix. In so doing, it will be responding to the question: «How relevant is the fulfillment of our own objective to the fulfillment of all the other objectives which are being considered?»

Then, each D-subpanel fills in its own vertical portion of the matrix, responding to the question: «How relevant is the fulfillment of all these other objectives to the fulfillment of our own objective?»

At that stage, two D/D matrices will have been produced, one obtained by adding the horizontal portions together, and one by adding the vertical portions. Then the two matrices are brought in line by conventional negotiation, as was described in the preceding section.

2.4.6 Construction of profiles and priority charts

At this stage of the exercise, three matrices (similar to those shown in Annex 2), have been filled in. The panelists' major task is now terminated and the rest is computation, exploitation and presentation of results. These results are embodied essentially in profiles and in various charts worked out from the matrices and from the associated profiles.

2.4.6.1 Profiles

Each type of matrix (D/D, S/D, S/S) gives rise to a corresponding family of profiles (D/D profiles, S/D profiles, etc.)

For any given type of matrix, there are two types of profile. One is obtained by summing row-wise, and is called *cross-support* profile in the case of D/D and S/S matrices, and *relevance* profile in the case of the S/D matrix. The other type is obtained by summing column-wise, and in all three cases is called a *dependence* profile.

The relevance profile will differ according to the distribution of weight numbers used for weighting the objectives. In this case two profiles have been worked out (see the S/D matrix in Annex 2), one with all weight numbers taken equal (the corresponding profile is called a *reference* profile), and one with weight numbers reflecting priority (the corresponding profile is called a *priority* profile). Two profiles have likewise been obtained for the S/S matrix. In the case of the D/D matrix only the reference profile is required, for the purpose of this exercise, although a priority profile could theoretically be worked out.

Let us consider in turn the relevance and dependence profiles of the S/D matrix, and then the cross-support profiles of the D/D and S/S matrices.

(a) Relevance profile of the relevance matrix

Let R_{ij} be the relevance mark linking discipline i to objective j, with w_j the weight of objective j. An overall relevance mark R_i for each discipline i is calculated by adding horizontally:

$$R_i = \sum_{j=1}^{N} w_j R_{ij} \qquad (N = \text{number of objectives})$$

In order to facilitate computational operations, the summation carried out to obtain R_i, and which runs over all objectives is rewritten in the following manner:

$$R_i = R_{\blacksquare} W^i_{\blacksquare} + R_{\bullet} W^i_{\bullet} + R_{\circ} W^i_{\circ} + R_b W^i_b ,$$

where $R_{\blacksquare}$ is the value in the numerical scale associated with the highest relevance mark (■) on the ordinal scale, and so on with $R_{\bullet}$ etc. R_b is the numerical value associated with a blank mark (corresponding to «irrelevant»). The W^i's are the relevance coefficients relating to discipline i: $W^i_{\blacksquare}$ is obtained by adding the individual weights, w_j, of all the objectives for which the highest

relevance mark (■) has been ascribed to discipline i, and so on.

The «priority» profile is obtained from the distribution of weight numbers associated with priority, as per section 2.2.4 above. For example, consider the second row of the S/D matrix, which contains the relevance marks of the Agricultural Engineering discipline. The relevance coefficients as is readily seen, are respectively:

$W_{■} = 4 + 4 = 8$
$W_{●} = 4 + 4 + 4 + 1.53 + 4 + 4 + 4 = 25.53$
$W_{○} = 1.08 + 1.53 = 2.61$

The numerical scale used in all calculations was the following:

ordinal scale	■	●	○	blank
numerical scale	4	2	1	0

i.e. $R_{■} = 4$, $R_{●} = 2$ etc.

The overall relevance score for Agricultural Engineering is then given by the overall relevance mark:

$$R = 4x8 + 2x25.53 + 1x2.61 = 85.67$$

This number is proportional to R (= 4 in our case), the maximum value of the numerical scale. It is also proportional to the total weight W, defined by:

$$W = \sum_{i=1}^{N} w_i \qquad \text{(105 in our case).}$$

In order to make the result independent of these two factors, the overall relevance mark is transformed into a relevance index obtained by factoring out the two factors, i.e.

$$\text{relevance index (of discipline i)} = \frac{R_i}{R_{■} \times W} \times (100)$$

Multiplying by 100 will confine the relevance index to the range 0-100.

In the above example, Agricultural Engineering would have a relevance index:

$$\text{relevance index: } \frac{85.67}{4x105} \times 100 = 20.40$$

and after rounding off

relevance index: 20

Relevance indices are always rounded off to the nearest integer. The index will be an integer in the range 0-100, independent of the particular values of $R_{■}$ and W. This is tantamount to expressing the numerical scale on a 0-1 range, and to normalizing the weights w_i according to :

$$\sum_{i=1}^{N} w_i = 1 \cdot$$

Relevance indices so expressed are then comparable, even though they may relate to different S/D matrices, (i.e. matrices differing in the total weight W of objectives, or in the value of $R_{■}$ used). It should be noted that a relevance index = 100 corresponds to the hypothetical case in which the discipline would be considered essential ($R = R_{■}$) to *all* objectives. Relevance indices together constitute the *relevance profile* of science and technology to development.

The relevance profile is obviously dependent on the particular weight coefficients used. In the S/D matrix, one particular relevance profile is derived from weight coefficients reflecting priorities of objectives (priority profile) and another profile is obtained from weight coefficients reflecting no priorities and correspondingly all taken equal to one (reference profile).

For each of the four columns relating to the three relevance coefficients and the overall relevance, the averages and standard deviations are shown at the bottom in normal form, after having factored out the total weight factor W, in the first three columns and the product $R_{■} \times W$ in the fourth column.

(b) Dependence profile of the relevance matrix

Likewise, a dependence number D_j for each objective j is calculated by adding vertically

$$D_j = \sum_{i=1}^{L} R_{ij} \cdot \quad (L = \text{number of disciplines})$$

Consider, for instance, the first column of the S/D matrix, which contains the relevance marks of the Rice objective. The dependence coefficients are respectively 3 (■), 12 (●) and 11 (○), and the overall dependence mark is

$$D = 4x3 + 2x12 + 1x11 = 47$$

Proceeding as for the relevance calculation, one obtains a dependence index

$$\text{dependence index (of objective j)} = \frac{D_j}{R_{■} x L} \times (100)$$

which, in the case of Rice, amounts to

$$D = \frac{47}{4 \times 96} \times 100 = 12.24$$

and after rounding off
dependence index : 12

In computing averages of dependence coefficients or overall dependence marks, each quantity must be weighted by the appropriate weight number, i.e. the average D is given by

Table 10: Cross-support of development objectives

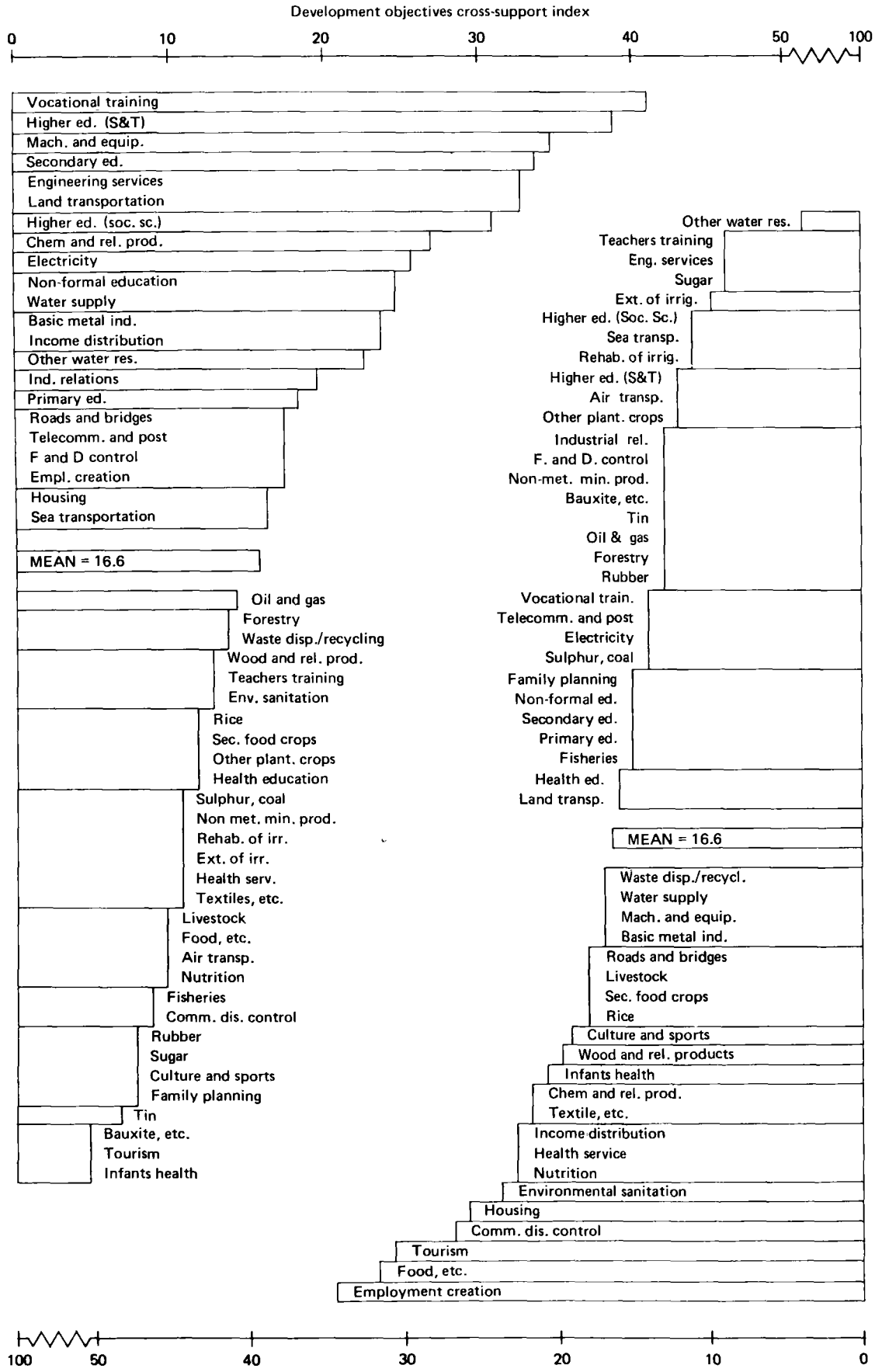


Table 11: Relevance of science and technology

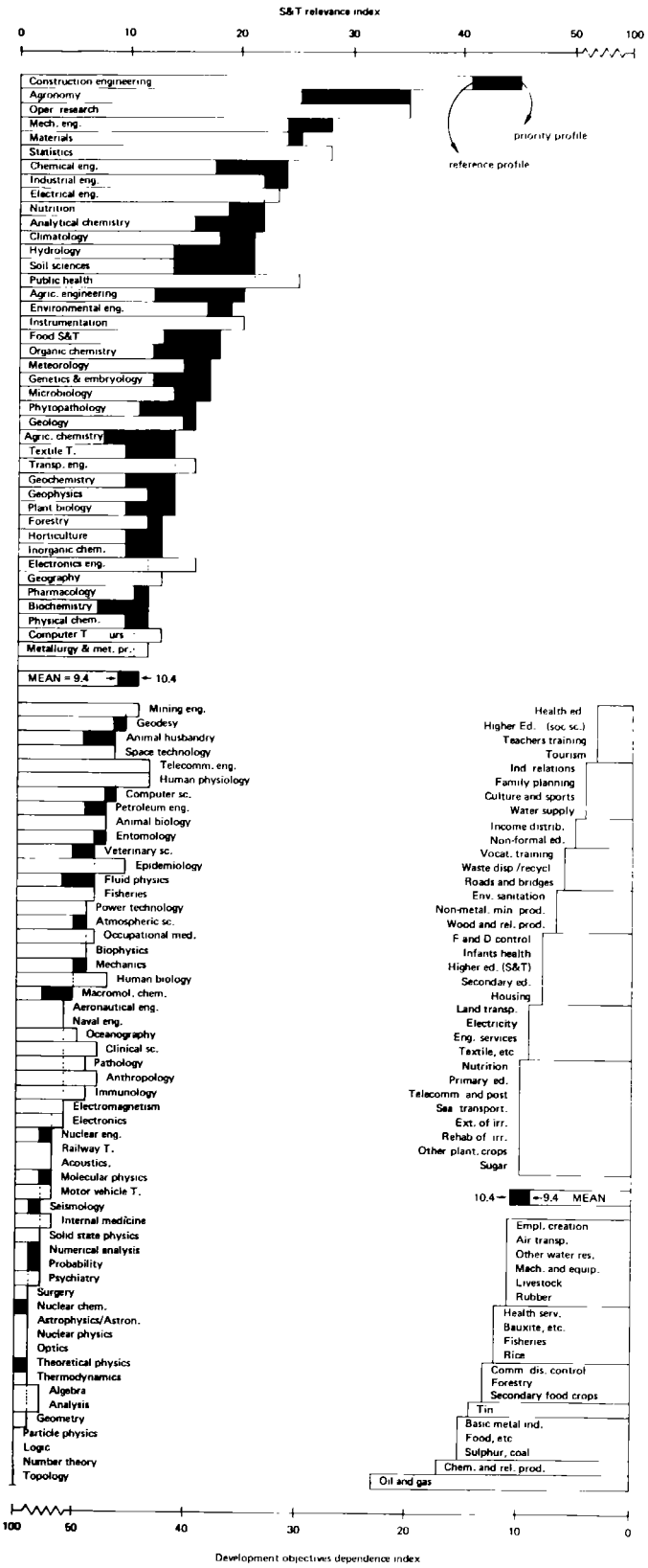


Table 12: Cross-support of fields of science and technology

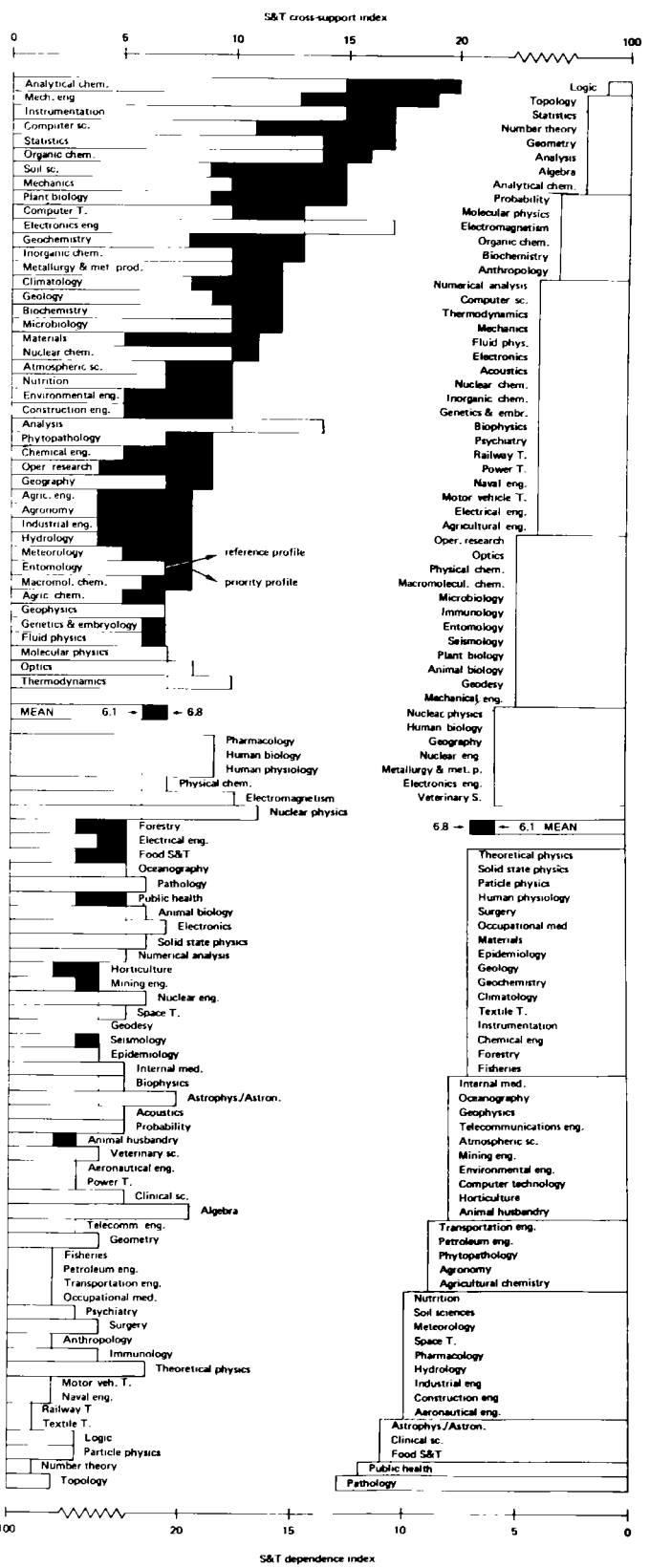


Table 13: Priority chart

Disciplines in column 5 are critical for none of the objectives; those in column 4 are critical for at least one priority-4 objective, but for none of greater priority objectives, and so on.

RELEVANCE INDEX

	1	2	3	4	5
100	45 Construction eng. 35 Operational research Agronomy				
30	28 Mechanical eng. 25 Materials 24 Industrial eng. Chemical eng. 22 Analytical chem. Nutrition 21 Soil sciences 20 Hydrology Agriculture eng.	25 Statistics 22 Electrical eng.	21 Public health		21 Climatology
20	19 Instrumentation 18 Food S&T Organic chemistry 17 Genetics 16 Geology Phytopathology 14 Geophysics Transportation eng. Textile T. 13 Horticulture Inorganic chem. 12 Pharmacology Physical chemistry Biochemistry 11 Metallurgy 10 Mining	13 Forestry 11 Computer technology 10 Geodesy	19 Environmental eng. 17 Microbiology	17 Meteorology 12 Electronics eng.	14 Plant biology Agricultural chemist. Geochemistry 12 Geography
10	9 Animal husbandry 8 Petroleum eng. Animal biology 7 Veterinary sciences	9 Computer sciences 6 Power technology	9 Human physiology 7 Epidemiology Fisheries 4 Naval eng. Clinical sciences Oceanography Immunology Pathology 3 Railway t. 2 Motor veh. t. Internal medecine	9 Telecommunic. eng. Space technology 4 Aeronautical eng.	8 Entomology 7 Fluid physics 6 Atm. sc. Biophysics, Mech., med. 5 Hum. biology, Macromol. Chemistry 4 Electro magn., Anthr. 3 Nuclear eng. Molecular phys., Electronics, Accoustics 2 Solid st. phys., Probabil., Numer. Anal., Seismology 1 Algeb., Anal., Psych., Nuclear phys., Optics, Nuclear chem. Astrophys. Geomet., Theor. physics Thermodynamics, Surgery 0 Part. Phys., Logic, Number theory Topology
0					

Table 14: Science/technology dependence chart of:

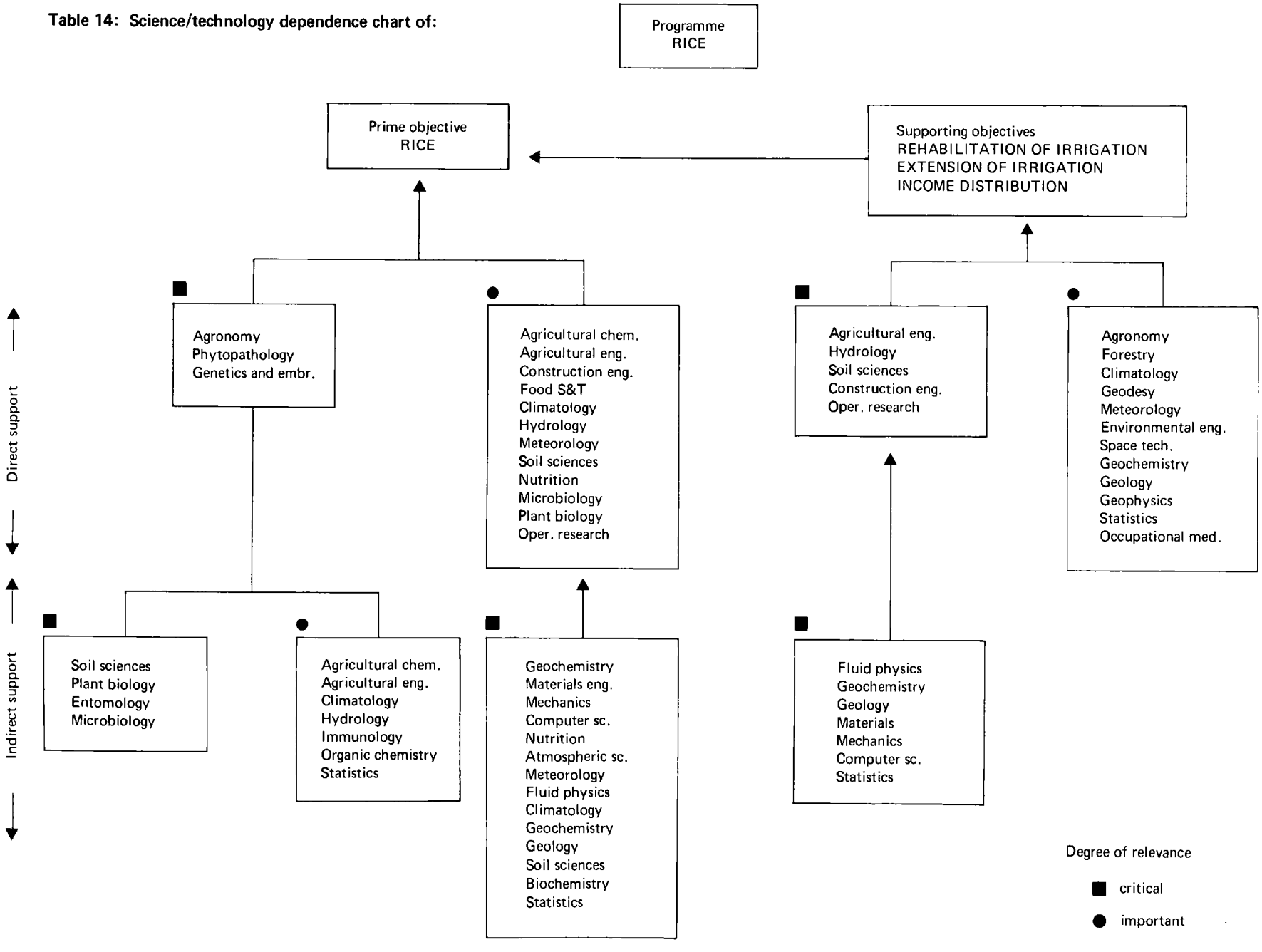


Table 15: Linkage chart of rice programme

(Derived from Table 14)

		To prime objective			To supporting objectives	
			Indirect support through			
		Direct support	Critical disciplines ■	Important disciplines ●	Direct support	Indirect support through critical disciplines ■
AGR	Agricultural chem.	●	●			
	Agricultural eng.	●	●		■	
	Agronomy	■			●	
	Forestry				●	
	Phytopathology	■				
ENG	Construction eng.	●			■	
	Environmental eng.				●	
	Food S&T	●				
	Materials eng.			■		■
	Space technology				●	
ENV	Atmospheric sc.			■		
	Climatology	●	●	■	●	
	Geochemistry			■	●	■
	Geodesy				●	
	Geology			■	●	■
	Geophysics				●	
	Hydrology	●	●		■	
	Meteorology	●		■	●	
	Soil sciences	●	■	■	■	
MED	Nutrition	●		■		
	Occupational med.				●	
BIO	Entomology		■			
	Genetics and embr.	■				
	Immunology		●			
	Microbiology	●	■			
	Plant biology	●	■			
CHM	Biochemistry			■		
	Organic chemistry		●			
PHY	Fluid physics			■		■
	Mechanics			■		■
MAT	Computer sc.			■		
	Operational research	●			■	
	Statistics		●	■	●	■

Degree of relevance:

■ critical

● important

Table 16: Relevance chart of a high relevance low-priority field

Climatology — Priority: 5
Relevance index: 21 (max: 45)

Is relevant to:	Depends on:	Affects the development of:
■	■ Atmospheric sciences Meteorology	■ Meteorology
● Rice Secondary food crops Rubber Sugar Other plantation crops Forestry Mechanical equipment Rehabilitation of irrigation Extension of irrigation Other water resources Roads and bridges Sea transportation Air transportation Health services	● Forestry Geography Fluid physics	● Agronomy Horticulture Environmental engineering Geography Hydrology Oceanography
○ Livestock Fisheries Food, etc. Textile, etc. Wood and related products Housing Community disease control Environmental sanitation Vocational training	○ Aeronautical eng. Environmental eng. Space technology Geochemistry Analytical chemistry Astrophys./Astronomy Probability Statistics	○ Animal husbandry Fisheries Forestry Geochemistry Geology Soil sciences Animal biology Anthropology Plant biology

Table 17: Relevance chart of a low relevance high cross-support field

Computer sciences — Relevance index: 9 (max: 45)
Cross-support index: 17 (max: 20)

Is relevant to:	Affects the development of:	Is made up of:
■ Engineering services	■ Computer technology Operational research	Accounting Algorithmic languages Analog computing Artificial intelligence Automated manufacturing systems Automated quality control systems Causal modelling Codes and coding systems Computer-assisted design Computer-assisted instruction Computer software Data banks Digital computing Environmental control systems Heuristics Hybrid computing Informatics Information systems; design and components Inventory control Medical monitoring systems Navigation and space telemetry systems Production control systems Programming languages Programming theory Sensor systems design Simulation
● Oil and gas Basic metal industries Machinery and equipment Electricity	● Aeronautical eng. Construction eng. Industrial eng. Space technology Transportation eng. Atmospheric sciences Geophysics Hydrology Meteorology Numerical analysis	
○ Tin Rehabilitation of irrigation Health services Employment creation Vocational training	○ Electrical eng. Electronics eng. Environmental eng. Telecommunications eng. Geodesy Oceanography Seismology Epidemiology Pathology Public health Probability Statistics	

$$\bar{D} = \frac{1}{W} \sum_{j=1}^{N} w_j D_j$$

Referring to the S/D matrix (with the priority weight numbers), we see that

$$\bar{D} = \frac{1}{105}(4x47 + 4x49 + 1.09x42 + \ldots + \ldots + 4x19 + 1x16) = 39.87$$

The normal form is obtained by factoring out $R_{\blacksquare}$ (= 4) and L (= 96) and multiplying by 100

$$\bar{D} = \frac{39.87}{4x96} \times 100 = 10.38$$

In the case of the reference profile, all weight numbers are equal, and set equal to one, the total weight W = 52, and D is given by

$$\bar{D} = \frac{1}{52} (1x47 + 1x49 + \ldots + 1x19 + 1x16)$$

$$\bar{D} = 36.02$$

which after reduction to normal form, gives

$$\bar{D} = \frac{36.02}{4x96} \times 100 = 9.38$$

(c) Cross-support profiles of the cross-support matrices

Calculations for the two cross-support matrices proceed as above, leading to cross-support profiles (in place of relevance profiles) and dependence profiles.

In the case of the D/D matrix, an unweighted sum of relevance marks is computed. This is mathematically equivalent to having all weight numbers equal to 1.

In the case of the S/S matrix, two profiles are computed, one with the sciences unweighted, and the other one with the relevance indices resulting from the S/D matrix (priority profile) used as weight numbers.

These various cases can be succinctly displayed graphically as shown in Tables 10-12. Table 10 shows the cross-support and dependence profiles obtained from the D/D matrix. Table 11 shows the relevance and dependence profiles derived from the S/D matrix. In the relevance profile, both the priority and reference profiles are shown, superimposed one upon the other. In Table 12, the same is done for the S/S matrix.

2.4.6.2 Priority and other charts

The priority and other charts are produced to show at a glance and in condensed form the relationship of disciplines to objectives.

First, the priority chart is constructed by breaking up the set of disciplines into five subsets. The disciplines in the first group have CRITICAL relevance marks for at least one of the objectives of first order priority. The disciplines in the second group have CRITICAL relevance marks for at least one of the objectives of second order priority, but none for the objectives of the preceding group, and so on. Then the disciplines are displayed on the chart as shown in Table 13.

For instance, referring to the S/D matrix (priority profile), it is seen that Climatology is critical (■ mark) for none of the objectives. It belongs to the fifth and last group as shown in Table 13. Its relevance index is 21. Consider next Meteorology; the objective of highest priority for which it is critical is Air Transport, a priority 4 objective according to Table 5. It therefore belongs to the fourth group, shown under the fourth column in Table 13, and so on.

Then, Science/Technology dependence charts are prepared for as many objectives as are required. The specific purpose of these charts is to disclose graphically the connexion of disciplines to given development programmes.

For instance, take Rice, a first priority objective. In order to be self-consistent, a development programme should take into account those other objectives which are essential for the Rice objective itself, i.e. rehabilitation of irrigation, extension of irrigation, and income distribution. (See the RICE column in the D/D matrix). Then referring to the S/D matrix, one identifies those disciplines which are CRITICAL, or at least IMPORTANT for the above objectives. Finally, referring to the S/S matrix, disciplines which support the above disciplines are identified. The result of this process is shown in Table 14. These results can be re-grouped under broad fields of science and technology (Agricultural sciences, etc.), which are more useful from an institutional stand point. The re-arranged results are shown in Table 15.

The charts described above can be made more comprehensive by including disciplines which are found to be only OF INTEREST, and so on. But then this would often amount to practically linking the entire gamut of scientific and technological specialities to any chosen objective, and would be unduly cumbersome. For this exercise, and considering the pre-occupations of the decision-makers for whom these charts are intended, the amount of information included in Tables 14 and 15 is fully adequate.

Other charts focusing on particular fields can be prepared in as many areas as is required. These charts would be intended as guides for directors of scientific and technological institutions. Two types of disciplines are particulary noteworthy, besides the obvious ones which are highly rated both in priority and in relevance.

The first type is found in disciplines which have low priority but high relevance. In the example (see Priority Chart, Table 13) Climatology is such a case. Such a field of research and training must be very closely examined before being discarded on the basis of its low priority, because of its overall contribution to a great number of development areas. The relevance Chart of Table 16 is constructed by transcribing the Climatology row of the S/D matrix, the Climatology column of the S/S matrix, and the Climatology row of the same matrix, in the left, centre and right columns of Table 16 respectively.

The second type is that of a discipline which has low or modest relevance for the objectives, but a high cross-support index. In the example, Computer sciences would fulfill these conditions. Here again, such a discipline should not be discarded hastily (this time because of relatively low relevance), since it is shown to be an important area of endeavour in support of other sciences which themselves are important for the development of the country. The relevance chart shown in Table 17 outlines the important features of the discipline. The left column is a transcription of the «Computer Sciences» row of the S/D matrix, the centre column is a transcription of the same row in the S/S matrix, and the right column is a list of specialities included under the broad heading «Computer Sciences» as defined in the nomenclature used (Annex 3.3)

3. Application of the method

In this section, practical considerations on the application of the method are given. These are of two kinds. A first set of considerations relates to the preparation and the conduct of an exercise. A second set focuses on the results and their use.

3.1 Operational sequence

3.1.1 Training

As was mentioned earlier, the use of formal methods in the policy-making process is relatively new. While the process itself has been scientifically investigated albeit only recently (policy sciences, group dynamics, etc.) the results of these investigations are relatively modest when compared to achievements in the engineering field, and must still be proved conclusively and be publicized before they gain general acceptance.

Therefore, those who are called upon to participate in such an exercise must be familiarized with the method. This could be done through exposés, or preferably through a mock-up exercise, because the best way for participants to master the process is by practising rather than by listening to lectures.

Experience has shown that participants need more than one briefing to grasp the approach. Mock-up exercises should be based on as realistic a working hypothesis as possible (particularly important is the list of development objectives used), otherwise participants would not be compelled to ask themselves relevant enough questions.

Generally, two half-day sessions will suffice to train any group. Depending on the number of instructors, the availability of the trainees, and the number of groups that have to be briefed, the training period might extend over several days, even sometimes over a few weeks.

3.1.2 Selection of panels

The selection of participants is a crucial step and a most delicate operation as is always the case with situations where outcomes based on personal opinions must be validated.

The outcomes of an exercise must be validated both from the scientific and from the political viewpoints. In other words, the panelists must be fully competent in their own specialized fields of expertise, but they must also be recognized as authorities by the policy-makers in general. These two conditions are sometimes difficult to fulfill simultaneously, and a delicate balance must be struck between the competence and the authority of the panelists.

Essentially two panels will have to be formed, one to cover fields of science and technology (referred to as the S-panel), and one to cover areas of development programmes (referred to as the D-panel). Each panel is broken down into specialized groups which will be entrusted only partial coverage, and in such a way that the cumulative expertise of the groups comprises a comprehensive coverage of the entire field. For instance, the S-panel will contain agronomists, engineers, medical scientists, physicists, and so on, with the agronomists covering their own specialized areas of the science and technology nomenclature (see Annex 3.3), and with the engineers and others likewise. As many panelists as necessary are recruited so that all the entries are covered by at least two of them. The D-panel will similarly contain government experts responsible for development programmes in the fields of agriculture, industry, health, and so on.

The profile of the D-panelists is more complicated than that of the S-panelists, for whom the selection criterion is simple: an established competence and recognized authority among their peers in a well-defined area of scientific knowledge. The D-panelist is a sort of spokesman for the general political community in its demand for science- and technology-based developmental innovations. This demand is expressed through the political process of government responsibility over development programmes, and hence the D-panelist must usually come from the government administration. As noted previously, he should ideally have a science/engineering background, in order to discern the implications for science and technology of development objectives set by the government. He should also have the authority to speak for the government in stating and priority-ranking these objectives (see section 2.2.2 above)

The D-panel, like the S-panel is broken down into subpanels each of which deals autonomously with a specific area of development activity. In the priority-ranking process, independent sets of objectives already ordered within each one's separate frame of reference must then be ordered with a common frame of reference. For instance, agricultural development objectives are ranked by the D-subpanel dealing with them, industrial development objectives likewise, and so on, but then the problem is to rank these groups of objectives with

respect to each other, resorting to an over-all policy criterion which is equally applicable to all of them. Therefore the D-panel must have, in addition to the subpanel experts, two or three panelists with arbitration power, who would generally come from the planning ministry.

3.1.3 Procedures

In this section, a recapitulation is made of the different steps involved in carrying out a priority determination exercise, from its inception marked by the selection of a moderator through its completion with the presentation of the final results to be used by the competent authorities. The end product is essentially an outline of major priority programmes of research, technology transfer and training in selected areas of science and technology, in support of each country's development programme. The identification of relevant programmes constitutes the basis for detailed planning and budgeting and should provide important guidelines for institutional build-up.

The operational sequence is displayed in short form in the flow-chart shown in Table 18. All the individual operations have been explained at length in the preceding sections. In the following, reference will simply be made as required under the various headings to the relevant sections above which give the necessary theoretical formulations, method of operation or calculation, and practical illustrations.

Description*

1 - Selection of moderator

The moderator will have general responsibility for the success of the exercise. He should be well acquainted with all the techniques which are used in it, especially operations research. He should be able to command authority among the panelists, who are high-level experts from the scientific, economic and government administrative establishments. He should be assisted by a small technical staff to help him organize training sessions and hold the exercise, assemble the relevant documentation, and carry out the various tasks involved in computations, drafting and design, reproduction, publication, etc.

2 - Selection of panels

2.4.4 The moderator on behalf of the sponsor of the
3.1.2 exercise, selects the panelists from the scientific etablishment and government administration. Eventually, the D-panel might comprise individuals from sectors of the industrial or business community which are significant «users» of science and technology.

3 - Training sessions

3.1.1 Training sessions are held to familiarize the panelists with the method. This will include demonstrations as well as practice in a mock-up situation. Several sessions would probably have to be held to accommodate the time-tables of panelists.

4 - Selection of nomenclatures

2.1.2 The panel of scientists (S-panel) selects the
2.2.1 nomenclature of fields of science and tech-
2.3.1 nology it will be working with. The subject matter covered by each panelist should be clearly defined, and care taken that all subjects are covered, resorting to outside expertise if required. A table similar to Table 8 is drawn up. The panel of development planners (D-panel) selects the nomenclature of objectives, and the development areas covered by each panelist are likewise clearly defined. A table similar to Table 1 is drawn up, and a document prepared which gives explanations for each of the items included in the list.

5 - Briefing of panels on nomenclatures

It is important that each panelist has a detailed understanding of the «language» used by members of the other panel. Documents describing the notional content of the nomenclatures used should be circulated to the panelists in advance of the session.

6 - Generation of matrices

2.2.3 The particular mode of operation retained for
2.3.3 the relevance analysis is set.
2.3.4 The D-panel is convened to fill in the D/D and
2.4.4 S/D matrices. The former will appear in final
2.4.5 form in the course of the operation, while the latter will remain to be confronted with the one generated by the S-panel. The objectives need not be priority-ordered at this stage. This can be done afterwards, if this is found more convenient, for some reason or other.

The S-panel is convened likewise, but independently, and fills in the S/S and S/D matrices.

7 - Confrontation of two panels

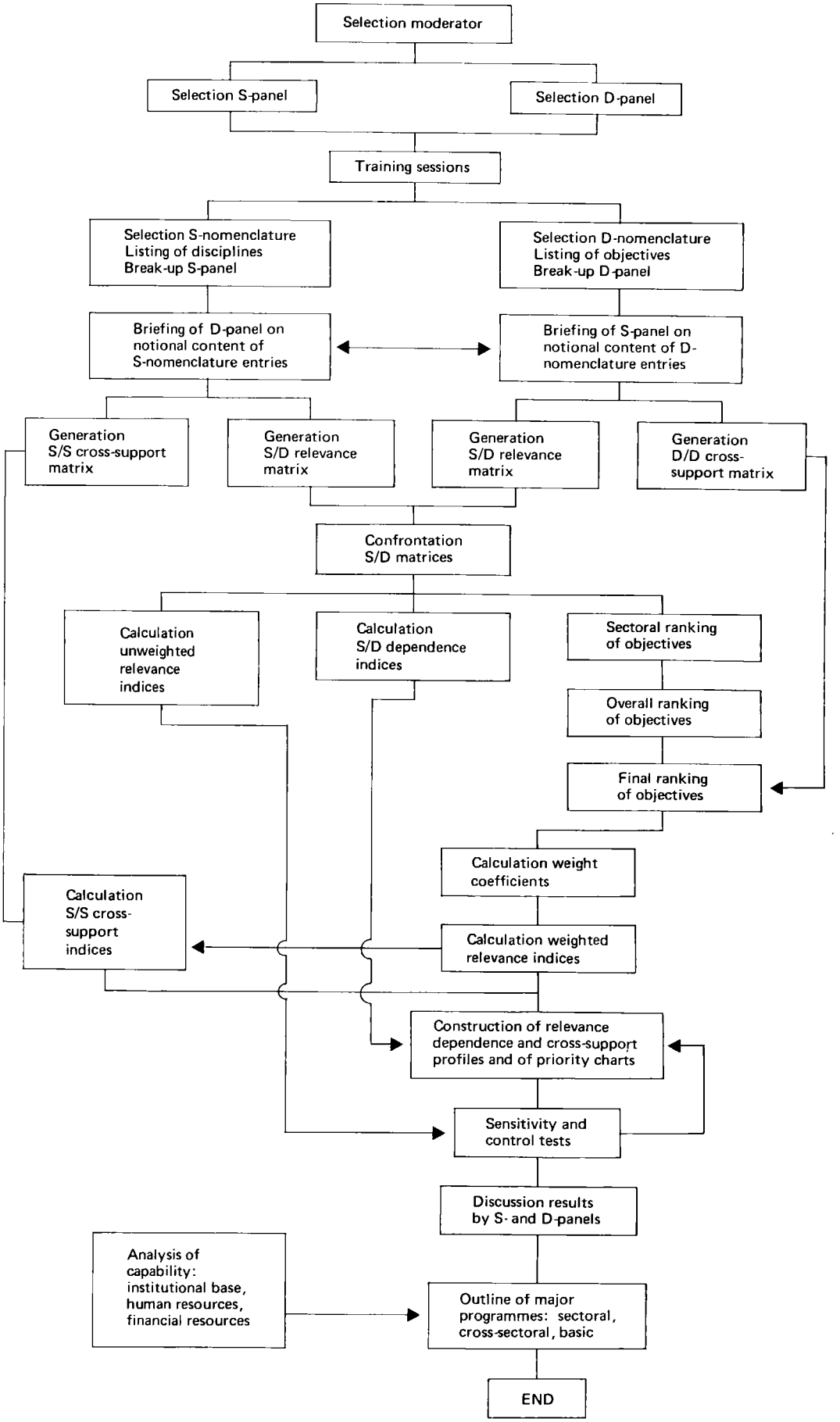
2.4.4 A session is held for both panels together, to confront the science and technology relevance matrix (S/D matrix) which they generated independently, and argue out their differences. At the end of the process, a reconciled S/D matrix is produced, together with the other two matrices already in final form.

8 - Ranking of objectives

2.2.2 The D-panel proceeds to the priority-ordering of
2.2.3 development objectives. In a first phase, sectoral
2.2.4 objectives are ordered by each subpanel (Table 2). In a second phase, the subpanels together with the arbitration panelists rank-order the objectives within a common frame of reference and produce the initial rank-order as shown in Table 3. In a third phase, the D/D matrix is used to make the order consistent, and the final rank-order is produced, as shown in Table 5.

* The relevant section numbers are indicated in the margin.

Table 18: Flow-chart of priority determination exercise



9 - Calculation of profiles

2.4.3 This is a purely computational phase, involving
2.4.6 the technical staff working under the moderator. This phase (as well as the next one, See 10) can be entirely computerized, if desired, and the results obtained instantaneously by a push-button operation.

Weight numbers are calculated for the objectives, using the algorithm of section 2.2.4. A numerical scale is adopted (the scale 0-1-2-4 has been used widely until now). Then the relevance index of disciplines and dependence index of objectives in the S/D matrix are calculated, first by taking all weight numbers equal (to 1 for convenience), and then by taking the weight numbers derived from priorities. The relevance indices obtained in the latter case are then used as weight numbers for the disciplines in the S/S matrix, and cross-support indices are calculated.

Additional calculations are optional: horizontal and vertical summations of relevance marks in the D/D matrix (assuming equal weight numbers for the objectives) and the vertical summation of relevance marks in the S/S matrix; calculation of S/S cross-support indices, assuming the weight numbers of the disciplines to be all equal (= 1 for convenience).

10 - Construction of profiles and charts

2.4.6 The priority charts of disciplines (Tables 13 and
3.2.3 21) and profile charts (Tables 10 to 12) are drawn up. Finally, charts similar to those shown in Tables 14 to 17 are drawn up for as many objectives and disciplines as is felt required by the moderator and the panelists.

11 - Sensitivity and control tests

3.2.1 This part is also mechanical and could theoretically be computerized. First, a test is made of the numerical scale to check its reliability. Then the weighted and unweighted relevance profiles are compared, and highly relevant disciplines which are found to undergo significant changes are identified. The interaction strengths are calculated and finally the panel reliability tested.

12 - Discussion of results

Panelists discuss the results shown in the various charts mentioned under 10 above to check whether they reconcile with more intuitive approaches to the problems dealt with. Some further justifications might be spelt out in the process, modifications (properly justified, against the backdrop of the exercise) brought to the results, complementary information supplied to qualify the statements underlying the various charts or making them more specific, and so on. This is required because the over-all product of the exercise must ultimately be collectively endorsed by the panelists as if they were conclusions which they had arrived at on their own. The method is merely a means for them to discuss more systematically and constructively and to sort out issues more clearly.

13 - Capability analysis

For each of the objectives and disciplines singled out as deserving priority attention (see 10 above), some indications must be provided on the existing innovative capability in the country, in terms of institutions, manpower, financial resources, information and equipment. This is essentially a measure on the scientific and technological potential of the country. This subject is treated at lenght in a Unesco publication (reference 12 in the Bibliography, Annex 1).

14 - Outline of major programmes

This is the end product of the priority determination exercise.

The capability analysis mentioned in number 13 allows the broad determination of the needs for increasing staff, procuring equipment, building institutions, obtaining information and securing funds according to the tasks assigned to the national community of scientists and engineers determined by the results emerging from the exercise (see 12 above).

Broadly speaking, there will be three types of programmes: sectoral programmes aimed at a specific development objective; cross-sectoral programmes which are linked to several objectives, and which are relevant over-all, although never critical for any one objective; and finally basic programmes, which are important through their over-all support to the progress of the two first types of programmes.

In the subsequent phases of planning and budgeting, the above-mentioned programme outlines will be fed back to all concerned for detailed programme write-ups and cost assessments. This in turn would provide important basic elements in any exercise aimed at preparing a functional budget for science and technology. (See section 3.2.4. below).

3.2 Use of results

In policy-making and planning fields, a method or technique is only as good as the action it helps to bring about. It is important, therefore, to ensure that the information generated during an exercise does lead policy-makers to action. This means that the reliability of the information, its comprehensiveness and form, as well as the users of the information must be considered.

3.2.1 Evaluation of results

A number of control tests can be performed to check the sensitivity of results to certain working hypotheses or working conditions. These tests will generally indicate what degree of confidence can be accorded to the results and, in some cases, how it can be improved.

3.2.1.1 Sensitivity to R-scale

The relevance marks ascribed by the panelists to the disciplines with respect to the objectives are set on an

ordinal scale i.e. high, considerable, moderate, nil. A numerical scale is associated to this ordinal scale for computational purposes, i.e. to allow working out an overall relevance mark R. This numerical scale is, to a certain extent, arbitrary.

The overall relevance mark R has no particular significance in itself, only in relation to other relevance marks. In other words, the only significant quantity is the ratio R_i/R_j which discriminates between two entries i and j (disciplines in our case). The discriminating power of the particular scale used can thus be measured by the quantity:

$$Q = \sum_i \left(\frac{R_i}{\bar{R}} - 1 \right)^2$$

where the sum runs over all entries. R_i is the relevance mark of entry i, and $\bar{R}$ is the average value of R_i, i.e.

$$\bar{R} = \frac{1}{N} \sum_i R_i$$

where N is the total number of entries, i.e. the number of disciplines in the nomenclature.

In the most general way, the numerical scale is defined by four numbers

$$X_1 > X_2 > X_3 > X_4 \geqslant 0$$

corresponding to the four marks of the relevance assessment (X_1 for CRITICAL, X_2 for IMPORTANT, and so on).

For any entry, the overall relevance mark R can be written as:

$$R = W_1 X_1 + W_2 X_2 + W_3 X_3 + W_4 X_4$$

where W_1 is the cumulative weight number of all the objectives for which the entry (the discipline) has been marked CRITICAL, and so on for W_2, W_3 and W_4. The W's are normalized, i.e.

$$W_1 + W_2 + W_3 + W_4 = 1$$

It can easily be seen that Q is a function of only three parameters:

$$\frac{X_2 - X_4}{X_1 - X_4}, \quad \frac{X_3 - X_4}{X_1 - X_4}, \quad \frac{X_4}{X_1 - X_4}.$$

The numerical scale should be chosen so as to maximize Q. It can be shown that this implies taking $X_4 = \emptyset$. Therefore, the numerical scale will be $\emptyset$, X_1, X_2, X_3 with X_1 arbitrary, and X_2 and X_3 determined by solving the system

$$\frac{\partial Q}{\partial \alpha} = 0 \quad \frac{\partial Q}{\partial \beta} = 0 \text{ where } \alpha = \frac{X_2}{X_1}, \quad \beta = \frac{X_3}{X_1}$$

The parameters α and β are seen to be the ordinates of the intermediate points X_2 and X_3 on a 0-1 scale (0 corresponding to IRRELEVANT, and 1 to CRITICAL).

The above system of equations would have to be solved numerically on a computer. It is doubtful whether such a sophisticated procedure would greatly improve the over-all results. In practice, any scale found convenient for computational or other purposes is chosen and one or two checks are made after with a couple of other scales to find out whether the quantity Q varies widely.

In the example worked out in this document, the scale 0-1-2-4 (corresponding to $\alpha = 1/2$, $\beta = 1/4$) has been used. Tests were made on the S/D matrix with two other scales and Q-values computed, with the following results:

	Scale		
	0-1-2-4	0-1-2-3	1-2-4-8
Q =	0.85	0.84	0.31

It is seen that Q is insensitive to any practical extent to the difference in the two first scales, and is considerably smaller for the last scale, in which the end point $X_4 = 1$, confirming the general result stated previously.

3.2.1.2 Sensitivity to ranking of objectives

Altering the ranking of objectives among the four priority groups will alter the relevance index through the weight numbers of the objectives.

It is interesting to know to what extent relevance numbers are sensitive to a particular weight profile of the objectives, which is contingent upon current policies, and these are by no means constant over-time! This can be measured by the ratio

$$\sum_j R_{ij} W_j \Big/ \sum_j R_{ij}$$

for any entry «i», where the numerator is the relevance based on a priority-ordered set of objectives, and the denominator is the relevance based on an unweighted set. An unweighted set, equivalent to a no-priority world, is the benchmark against which policy-dependent quantities are measured.

When ratios are calculated for all disciplines, it is possible to spot those disciplines for which the ratio is relatively far away from 1, indicating the most sensitive ones. This is significant for only those disciplines which are important, i.e. have high relevance indices, for whether weakly relevant disciplines are sensitive or not to policies is irrelevant in any case.

Spotting priority-sensitive disciplines can also be done at a glance by examining Table 11. On the left of that table, the priority-dependent profile and the reference profile appear one against the other, and by scanning the profile it is easy to find those disciplines which have been significantly upgraded or downgraded in the process.

The same operation can be made for the S/S cross-support profiles, by scanning Table 12.

Table 19: Science and technology relevance profile (%)

broken down by subpanels

	S-subpanel	D-panel	After confrontation
Agricultural sciences	14	9	12
Engineering sciences	16	41	38
Environmental sciences	20	14	17
Medical sciences	10	6	8
Biological sciences	10	3	8
Chemical sciences	4	6	4
Physical sciences	4	9	5
Mathematical sciences	2	12	8
TOTAL	100	100	100

Table 20: Science and technology dependence profile

broken down by subpanels

Development programme area	S-panel	D-subpanel	After confrontation
Agriculture	.23	.04	.11
Industry	.26	.13	.18
Public works	.16	.09	.10
Communications	.22	.21	.27
Mining	.26	.39	.36
Education	.09	.05	.05
Health	.12	.04	.09
Manpower	.05	.18	.08

3.2.1.3 Interaction strengths

The quantity

$$\Omega = \frac{100}{R_{\blacksquare}} \times \frac{1}{N_1} \times \frac{1}{N_2} \times \sum_i \sum_j R_{ij}$$

(N_1 and N_2 are the number of entries over which i and j run respectively) measures the interaction strength. The number Ω is such that $0 < \Omega < 100$. This number can be computed for the three matrices S/D, S/S, D/D. In the two latter cases, it measures a self-interaction.

Interaction strength numbers are generally in the range 5 to 20. A greater value would indicate that the nomenclatures used are unsuitable for the problem at hand, with a resulting breakdown in the approach.

3.2.1.4 Panel reliability.

The interaction strength number Ω is just as much an indicator of a panel's perception as it is an objective characteristics of the relationship. The numbers Ω for anyone matrix (S/S, D/D, S/D) can be compared prior and after confrontation. Too big a discrepancy between the two (say more than 20 per cent) would indicate highly diverging perceptions of the groups, taken as a whole.

A detailed analysis can be made of the behaviour of the subpanels by disaggregating Ω into parts accruing from each individual one. This is illustrated in Tables 19 and 20 for a case adapted from an actual exercise. It shows at a glance each subpanel's reliability in arguing its case when confronted with the other panel in its entirety.

Consider, for instance, Agricultural Sciences, Table 19. Before confrontation, the relative share of relevance numbers (in percentages accruing to agricultural sciences in the matrix filled in by the S-subpanel covering these sciences) came out to be 14 per cent. The relative share ascribed by the D-panel as a whole came out to be 9 per cent. After confrontation, the relative share was 12 per cent, a reasonable mid-point between the two starting points. In the case of physical sciences, it is seen that the corresponding S-subpanel was convincing in arguing its case against the entire D-panel.

3.2.2 Complementary information

Formally, the exercise produces a set of numbers and charts which give justice to only a very small fraction of the information retrieved implicitly or explicitly in the assessment process. For instance, relevance marks are ascribed for reasons which are never made explicit, except verbally in the confrontation phase. The development objectives which are the highest marked, or have first priority, are described by only a few words.

It is essential, therefore, to complement the exercise with descriptive information relating to first priority objectives, and to those disciplines and objectives linked through the highest relevance mark, because these data will have a major influence on the results.

In the case of relevance marks, especially important pieces of information are the time frames involved, the nature of the input or mode of operation (research, or technology transfer on the one hand, education and training on the other), the scale of effort, in terms of manpower or financial resources (big or small, by whatever standard one wishes to measure them), and so on.

3.2.3 Presentation of results

Four broad categories of results constitute the outcome of an exercise.

First there are the two priority charts showing the ranking of the more applied disciplines according to their direct support to the development programme, as well as the ranking of the (more basic) disciplines according to their support to the former. The latter are obtained through the S/S matrix, and shown in Table 21, the former through the S/D matrix, and shown in Table 13.

Secondly, for each first priority objective, a chart describing the objective and the related development programmes should be prepared, showing both the broad policy goals from which it derives, and the list of relevant disciplines, the nature of the operations envisaged under each one of them, and details on current capability to carry out these operations, especially the scientific institutions involved. Such charts should also be prepared for objectives of lesser priority (second, eventually third) with a high dependence index (say in the top third).

Thirdly, for each discipline in the top priority group, a chart should show the other disciplines on which it depends, the objectives which it supports, the research and training capability in the field. Charts should also be prepared for those disciplines which are of lesser priority, but have a high relevance index (say in the top third).

Finally, referring to the S/S profile, a chart should be established for each discipline in the top 20 per cent group (i.e. whose cross-support index is greater than 80 per cent of the maximum) showing the disciplines which it supports, the institutions involved, the type of work, etc.

From the above, programme outlines can be prepared. These will be of three types. Sectoral programmes will be defined by the co-ordination or integration of all the inputs relating to one objective. Cross-sectoral programmes will be defined by a discipline-based effort, in direct support of a set of several objectives. Basic programmes are also discipline-based, but they are in support of science and technology itself.

3.2.4 Link with planning and budgeting

As mentioned previously, the priority setting exercise is meant to take place at an early stage in the planning and budgeting process. It aims at drawing in outline and within a comprehensive and consistent framework, the major orientations of the scientific effort and the related needs for increasing the scientific and technological capability, especially as regards institutions. The exercise essentially provides a working hypothesis from which detailed planning can start, and it is therefore important that it be made part of the planning and budgeting procedures from the beginning. This implies proper phasing, formating of the information generated, and so on.

Table 21: Cross-support priority chart

CROSS-SUPPORT INDEX	
20	Analytical chemistry (22)
19	Mechanical engineering (28)
18	
17	Instrumentation (19), *Computer sciences* (9), Statistics (25)
16	Organic chemistry (18)
15	Soil sciences (21), *Mechanics* (6), *Plant biology* (14)
14	
13	*Computer technology* (11), *Electronics engineering* (12), Geochemistry (14) *Inorganic chemistry* (13)
12	*Metallurgy* (11), Climatology (21), Geology (16), *Biochemistry* (12), Microbiology (17)
11	Materials engineering (25), *Nuclear chemistry* (1)
10	*Atmospheric sciences* (6), Nutrition (22), *Analysis* (Mathematical) (1), Construction eng. (45), Environmental eng. (19)

The disciplines which are in italiques have a cross-support index greater than or equal to their relevance index, shown in parentheses (compare with Table 13).

As concerns using the conclusions of an exercise for the purpose of budgeting, one must notice that scientific and technological activities are usually invisible components in the budgets of most countries. Traditional budgets show the total appropriations, ministry by ministry, in administrative rather than functional terms, which do not allow individual activities and their components to be identified.

The concept of functional budgeting, with science and technology singled out as a separate function, not only introduces visibility into the national budget; it also makes it easier to avoid arbitrary budgetary decisions. While cuts or increases are usually made only at the level of the ministries concerned in traditional types of budget, such decisions can be rationalized if they are related to actual functions and programmes which, in addition, may be ranked in priority order.

In order to produce a comprehensive budgetary balance sheet for R&D and STS across the board, including indications of financial flows and distribution of funds, the consolidated presentation of the R&D and STS activities of the various ministries is needed in terms of contributions to national objectives, i.e. in the form of programme-budgets.

A national science and technology budget prepared in such terms not only allows for the harmonious performance of scientific and technological activities in various branches of government and the economy at large, but also provides a rational basis for governmental decision-making regarding the optimal size of the national science and technology budget. Unesco is at present working with an international study team on the preparation of a manual on science and technology budgeting.

3.2.5 Follow-up

The results of an exercise should be widely circulated among participants for their final comments, and then presented to the authorities responsible for science and technology policy-making and those responsible for over-all development planning and budgeting. A standard reporting format is shown in Annex 4.

During the exercise the panelists will have acquired considerable knowledge about future plans and programmes, and they should therefore be involved to the greatest extent possible in the later phases of the planning and budgeting process. Ideally, a procedure should evolve whereby plans and budgets in their final form are made consistent with the outlines deriving from the exercise, and, when they are at variance, that the case is well documented and argued.

The remake of an exercise can take place before the next planning cycle whenever the situation warrants it, for instance if some subpanels were found to have questionable reliability, or if the profile of development objectives has changed significantly in the meantime. But generally, the major results are not expected to be altered considerably.

4. Final considerations

The method described in this publication is an attempt to structure the dialogue between the national community of practising scientists and engineers on the one hand, and the government authorities responsible for over-all development planning and budgeting on the other hand, with a view to rationalizing the consensus forming process about complex policy issues, by making as much of it as possible both explicit and objective.

Although one should not expect novel approaches to be adopted overnight, the relative paucity of well-established methods and techniques in the field of science and technology planning and budgeting, underlines the potential interest of the present method. Its use will lead the practitioners to develop it further and to modify it to suit the particular conditions of their country.

The method at its present stage of development could naturally afford to be improved. The major lines of improvement are the definition of development objectives and the disclosure of their implicit hierarchical structure, as well as the organic linking of the exercise with planning and budgeting.

It is hoped that improvements reached by the practitioners will be reported to the Unesco Secretariat, so as to ensure by proper feed-back that the method does gradually respond better to the needs and conditions of its users.

Annex 1

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Annex 2

Model matrices

In this Annex, three model matrices* are presented, to illustrate the method. Their content is fictitious, but adapted from real situations.

The three matrices are:
D/D matrix: Cross-support of development objectives,
S/D matrix: Science and technology relevance,
S/S matrix: Cross-support of fields of science and technology.

In the S/D matrix, two profiles are shown, one based on a weighting of the development objectives according to their priority (priority profile), and one with the development objectives unweighted (reference profile).

In the S/S matrix, two profiles are shown likewise, one based on a weighting of the disciplines according to their priority-dependent relevance (priority profile) and one with disciplines unweighted (reference profile).

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* The matrices are contained in the back cover envelope.

Annex 3

Standard nomenclatures

This annex contains models of the various nomenclatures which are required in a priority determination exercise. There are four broad types of nomenclatures:

1. Development objectives;
2. Areas of socio-economic activities;
3. Scientific and technological disciplines;
4. Scientific and technological institutions.

ANNEX 3.1

Classifications of development objectives
being proposed or already used by various
international organizations.

(1) UNESCO

Source: Unesco Questionnaire for the "Survey of Scientific and Technological Activities", document UNESCO/STS/Q/751, Unesco, Paris, May 1975.

Major aims of national R&D

1. Exploration and assessment of the earth, the seas, atmosphere and space.
2. Development of agriculture, forestry and fishing.
3. Promotion of industrial development.
4. Production, conservation and distribution of energy.
5. Development of transport and communication.
6. Development of education services.
7. Development of health services.
8. Social development and other socio-economic services.
9. Protection of the environment.
10. General advanced of knowledge.
11. Other aims.
12. Defence.

(2) OECD

Source: "The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development (Frascati Manual 1975)", Working paper, Directorate for Science, Technology and Industry, OECD, Paris, October 1975.

Classification by socio-economic objectives

1. Development of agriculture, forestry and fishing.
2. Promotion of industrial development.
3. Production and rational use of energy.
4. Transport and telecommunications.
5. Urban and rural planning.
6. Protection of the environment.
7. Health (excluding pollution).
8. Social development and services.
9. Exploration and exploitation of the earth and atmosphere.
10. General advancement of knowledge.
11. Civil space.
12. Defence.

(3) OAS

Source: "Revised Draft Standards for Statistics on Science and Technology", in Report of the I Session, Subcommittee on Statistics on Science and Technology, Organization of American States, Washington D.C., 1975.

Areas of application

1. Agriculture, forestry, hunting and fishing.
2. Extractive industries.
3. Manufacturing industries.
4. Energy.
5. Space.
6. Defence and national security.
7. Environment and natural resources.
8. Information, automation and documentation.
9. Urban and regional development.
10. Socio-economic structure.
11. Health and hygiene.
12. Trade and services.
13. Basic knowledge (science for the sake of science, general acquisition of knowledge without a specific practical objective).

(4) EEC

Source: "Nomenclature for the analysis and comparison of scientific programmes and budgets (NAPS)" working paper No. Eurostat/200/75 "Statistics" Subcommittee of the Committee on Scientific and Technical Research, European Economic Community, Brussels, 1975.

Nomenclature

1. Exploration and exploitation of the earth and its atmosphere.
2. Planning of the human environment.
3. Protection and improvement of human health.
4. Production, distribution and rational utilization of energy.
5. Agricultural productivity and technology.
6. Industrial productivity and technology.
7. Social and sociological problems.
8. Exploration and exploitation of space.
9. Defence.
10. General promotion of knowledge.

ANNEX 3.2

Areas of activity (ISIC nomenclature)

Division	Major group	Title of category
		Major Division 1. Agriculture, Hunting, Forestry and Fishing
11		Agriculture and hunting
	111	Agricultural and livestock production
	112	Agricultural services
	113	Hunting, trapping and game propagation
12		Forestry and logging
	121	Forestry
	122	Logging
13	130	Fishing
		Major Division 2. Mining and Quarrying
21	210	Coal mining
22	220	Crude petroleum and natural gas production
23	230	Metal ore mining
29	290	Other mining
		Major Division 3. Manufacturing
31		Manufacture of food, beverages and tobacco
	311-312	Food manufacturing
	313	Beverage industries
	314	Tobacco manufactures
32		Textile, wearing apparel and leather industries
	321	Manufacture of textiles
	322	Manufacture of wearing apparel, except footwear
	323	Manufacture of leather and products of leather, leather substitutes and fur, except footwear and wearing apparel
	324	Manufacture of footwear, except vulcanized or moulded rubber or plastic footwear
33		Manufacture of wood and wood products, including furniture
	331	Manufacture of wood and wood and cork products, except furniture
	332	Manufacture of furniture and fixtures, except primarily of metal
34		Manufacture of paper and paper products, printing and publishing
	341	Manufacture of paper and paper products
	342	Printing, publishing and allied industries
35		Manufacture of chemicals and chemical, petroleum, coal, rubber and plastic products
	351	Manufacture of industrial chemicals
	352	Manufacture of other chemical products
	353	Petroleum refineries
	354	Manufacture of miscellaneous products of petroleum and coal
	355	Manufacture of rubber products
	356	Manufacture of plastic products not elsewhere classified
36		Manufacture of non-metallic mineral products, except products of petroleum and coal
	361	Manufacture of pottery, china and earthenware
	362	Manufacture of glass and glass products
	369	Manufacture of other non-metallic mineral products
37		Basic metal industries
	371	Iron and steel basic industries
	372	Non-ferrous metal basic industries
38		Manufacture of fabricated metal products, machinery and equipment
	381	Manufacture of fabricated metal products, except machinery and equipment
	382	Manufacture of machinery except electrical
	383	Manufacture of electrical machinery apparatus, appliances and supplies
	384	Manufacture of transport equipment
	385	Manufacture of professional and scientific and measuring and controlling equipment not elsewhere classified, and of photographic and optical goods
39	390	Other manufacturing industries
		Major Division 4. Electricity, Gas and Water
41	410	Electricity, gas and steam
42	420	Water works and supply
		Major Division 5. Construction
50	500	Construction
		Major Division 6. Wholesale and Retail Trade and Restaurants and Hotels
61	610	Wholesale trade
62	620	Retail trade
63		Restaurants and hotels
	631	Restaurants, cafés and other eating and drinking places
	632	Hotels, rooming houses, camps and other lodging places

Division	Major group	Title of category
		Major Division 7. Transport, Storage and Communication
71	-	Transport and storage
	711	Land transport
	712	Water transport
	713	Air transport
	719	Services allied to transport
72	720	Communication
		Major Division 8. Financing, Insurance, Real Estate and Business Services
81	810	Financial institutions
82	820	Insurance
83		Real estate and business services
	831	Real estate
	832	Business services except machinery and equipment rental and leasing
	833	Machinery and equipment rental and leasing
		Major Division 9. Community, Social and Personal Services
91	910	Public administration and defence
92	920	Sanitary and similar services
93		Social and related community services
	931	Education services
	932	Research and scientific institutes
	933	Medical, dental, other health and veterinary services
	934	Welfare institutions
	935	Business, professional and labour associations
	939	Other social and related community services
94		Recreational and cultural services
	941	Motion picture and other entertainment services
	942	Libraries, museums, botanical and zoological gardens, and other cultural services not elsewhere classified
	949	Amusement and recreational services not elsewhere classified
95		Personal and household services
	951	Repair services not elsewhere classified
	952	Laundries, laundry services, and cleaning and dyeing plants
	953	Domestic services
	959	Miscellaneous personal services
96	960	International and other extra-territorial bodies
		Major Division 0. Activities not adequately defined
0	000	Activities not adequately defined.

ANNEX 3.3

Proposal for an International Standard Nomenclature
of Fields of Science and Technology*

Major Field Headings

11. Logic
12. Mathematics

21. Astronomy and astrophysics
22. Physics
23. Chemistry
24. Life sciences
25. Earth and space sciences

31. Agriculture sciences
32. Medical sciences
33. Technological sciences

51. Anthropology
52. Demography
53. Economic sciences
54. Geography
55. History
56. Juridical sciences and law
57. Linguistics
58. Pedagogy
59. Political sciences
61. Psychology
62. Sciences of arts and letters
63. Sociology

71. Ethics
72. Philosophy

* Reproduced from document UNESCO/NS/ROU/257 rev.1, December 1973.

11. LOGIC

1101 Application of logic

1102 Deductive logic

- 1102.01 Analogy
- 1102.02 Boolean algebra
- 1102.03 Formal logic
- 1102.04 Formalized languages
- 1102.05 Formal systems
- 1102.06 Foundations of mathematics
- 1102.07 Generalization
- 1102.08 Mathematical logic
- 1102.09 Modal logic
- 1102.10 Model theory
- 1102.11 Proof theory
- 1102.12 Propositional calculus
- 1102.13 Recursive functions
- 1102.14 Symbolic logic
- 1102.15 Theory of formal languages
- 1102.99 Other (specify)

1103 General logic

1104 Inductive logic

- 1104.01 Induction
- 1104.02 Intuitionism
- 1104.03 Probability (see 1208)
- 1104.99 Other (specify)

1105 Methodology

- 1105.01 Scientific method
- 1105.99 Other (specify)

1199 Other specialties relating to logic

12. MATHEMATICS

1201 Algebra

- 1201.01 Algebraic geometry
- 1201.02 Axiomatic set theory
- 1201.03 Category theory
- 1201.04 Differential algebra
- 1201.05 Fields, rings, algebra
- 1201.06 Groups, generalizations
- 1201.07 Homological algebra
- 1201.08 Lattices
- 1201.09 Lie algebra
- 1201.10 Linear algebra
- 1201.11 Matrix theory
- 1201.12 Non-associative algebras
- 1201.13 Polynomials
- 1201.14 Representation theory
- 1201.99 Other (specify)

1202 Analysis and functional analysis

- 1202.01 Algebra of operators
- 1202.02 Approximation theory
- 1202.03 Banach spaces and algebras
- 1202.04 Calculus of variations
- 1202.05 Combinatorial analysis
- 1202.06 Convexity, inequalities
- 1202.07 Difference equations
- 1202.08 Functional equations
- 1202.09 Functions of a complex variable
- 1202.10 Functions of real variables
- 1202.11 Functions of several complex variables
- 1202.12 Global analysis
- 1202.13 Harmonic analysis
- 1202.14 Hilbert spaces
- 1202.15 Integral equations
- 1202.16 Integral transforms
- 1202.17 Measure, integration, area
- 1202.18 Operational calculus
- 1202.19 Ordinary differential equations (see 1206.12)
- 1202.20 Partial differential equations (see 1206.13)
- 1202.21 Potential theory
- 1202.22 Series, summability
- 1202.23 Special functions
- 1202.24 Subharmonic functions
- 1202.25 Topological linear spaces
- 1202.26 Trigonometric series and integrals
- 1202.99 Other (specify)

1203 Computer Sciences (see 3304)

- 1203.01 Accounting
- 1203.02 Algorithmic languages
- 1203.03 Analog computing
- 1203.04 Artificial intelligence
- 1203.05 Automated manufacturing systems
- 1203.06 Automated quality control systems
- 1203.07 Causal modelling
- 1203.08 Codes and coding systems
- 1203.09 Computer-assisted design (see 3304.06)
- 1203.10 Computer-assisted instruction
- 1203.11 Computer software
- 1203.12 Data banks
- 1203.13 Digital computing
- 1203.14 Environmental control systems
- 1203.15 Heuristics
- 1203.16 Hybrid computing
- 1203.17 Informatics
- 1203.18 Information systems; design and components
- 1203.19 Inventory control
- 1203.20 Medical monitoring systems
- 1203.21 Navigation and space telemetry systems
- 1203.22 Production control systems
- 1203.23 Programming languages (see 5701.04)
- 1203.24 Programming theory
- 1203.25 Sensor systems design
- 1203.26 Simulation
- 1203.99 Other (specify)

1204 Geometry

- 1204.01 Affine geometry
- 1204.02 Complex manifolds
- 1204.03 Convex domains
- 1204.04 Differential geometry
- 1204.05 Extremum problems
- 1204.06 Euclidean geometry
- 1204.07 Finite geometries
- 1204.08 Foundations
- 1204.09 Non-Euclidean geometries
- 1204.10 Projective geometry
- 1204.11 Riemannian geometry
- 1204.12 Tensor analysis
- 1204.99 Other (specify)

1205 Number theory

- 1205.01 Algebraic number theory
- 1205.02 Analytic number theory
- 1205.03 Diophantine problems
- 1205.04 Elementary number theory
- 1205.05 Geometry of numbers
- 1205.99 Other (specify)

1206 Numerical analysis

- 1206.01 Algorithm construction
- 1206.02 Differential equations
- 1206.03 Error analysis
- 1206.04 Functional equations
- 1206.05 Integral equations
- 1206.06 Integro-differential equations
- 1206.07 Interpolation, approximation and curve fitting
- 1206.08 Iterative methods
- 1206.09 Linear equations
- 1206.10 Matrices
- 1206.11 Numerical differentiation
- 1206.12 Ordinary differential equations (see 1202.19)
- 1206.13 Partial differential equations (see 1202.20)
- 1206.14 Quadrature
- 1206.99 Other (specify)

1207 Operations research

- 1207.01 Activity analysis
- 1207.02 Control systems
- 1207.03 Cybernetics

1207.04 Distribution and transport
1207.05 Dynamic programming
1207.06 Game theory (see 1209.04)
1207.07 Integer programming
1207.08 Inventory
1207.09 Linear programming
1207.10 Network flow
1207.11 Non-linear programming
1207.12 Queuing
1207.13 Scheduling
1207.14 Systems formulation
1207.15 Systems reliability
1207.99 Other (specify)

1208 Probability (see 1104.03)

1208.01 Actuarial mathematics
1208.02 Analytic probability theory
1208.03 Application of probability
1208.04 Foundations of probability
1208.05 Limit theorems
1208.06 Markov processes
1208.07 Plausibility
1208.08 Stochastic processes (see 1209.11)
1208.09 Subjective probabilities
1208.99 Other (specify)

1209 Statistics (see 5207.10, 6105.04 and 6305.03)

1209.01 Analytical statistics
1209.02 Computing for statistics
1209.03 Data analysis
1209.04 Decision procedures and theory (see 1207.06)
1209.05 Design and analysis of experiment
1209.06 Distribution-free and non-parametric methods
1209.07 Distribution and probability theory
1209.08 Foundations of statistical inference
1209.09 Multivariate analysis
1209.10 Sampling theory and techniques
1209.11 Stochastic theory and time series analysis (see 1208.08)
1209.12 Techniques of statistical association
1209.13 Techniques of statistical inference
1209.14 Techniques of statistical prediction
1209.15 Time series
1209.99 Other (specify)

1210 Topology

1210.01 Abstract spaces
1210.02 Cohomology
1210.03 Differential manifolds
1210.04 Fibre bundles and spaces
1210.05 General topology
1210.06 Homology
1210.07 Homotopy
1210.08 Lie groups
1210.09 Piecewise linear topology
1210.10 Point-set topology
1210.11 Three dimensional topology
1210.12 Topological groups
1210.13 Topological dynamics
1210.14 Topological embedding
1210.15 Topological manifolds
1210.16 Transformation groups

1299 Other mathematical specialities (specify)

21. ASTRONOMY & ASTROPHYSICS

2101 Cosmology and cosmogony

2101.01 Binary stars
2101.02 Clusters
2101.03 Cosmic rays (see 2501.15)
2101.04 Galaxies
2101.05 Gravitation (see 2212.05)
2101.06 Nebulae
2101.07 Novae
2101.08 Pulsars
2101.09 Quasars
2101.10 Stars
2101.11 Stellar evolution and HR-diagram
2101.12 Stellar composition
2101.13 Super-novae
2101.14 Variable stars
2101.15 X-ray sources (see 2202.12)
2101.99 Other (specify)

2102 Interplanetary medium (see 2512 and 3324)

2102.01 Interplanetary fields
2102.02 Interplanetary matter
2102.03 Interplanetary particles
2102.99 Other (specify)

2103 Optical astronomy (see 2209)

2103.01 Position astronomy (see 2504.01)
2103.02 Telescopes (see 3311.11)
2103.03 Spectroscopy
2103.99 Other (specify)

2104 Planetology (see 2512 and 3324)

2104.01 Comets
2104.02 Meteorites
2104.03 Planetary atmospheres
2104.04 Planetary geology
2104.05 Planetary physics
2104.06 Planetary magnetic fields
2104.07 Planets
2104.08 Satellites
2104.09 Tektites
2104.10 The Moon
2104.99 Other (specify)

2105 Radio-astronomy (see 2202.09)

2105.01 Antennae (see 3307.01)
2105.02 Radio-telescopes
2105.99 Other (specify)

2106 Solar system

2106.01 Solar energy (see 3322.05)
2106.02 Solar physics
2106.03 Solar wind (see 2501.24)
2106.04 The Sun
2106.99 Other (specify)

2199 Other astronomical specialities (specify)

22. PHYSICS

2201 Acoustics

2201.01 Acoustic properties of solids
2201.02 Architectural acoustics
2201.03 Hearing (physics of) (see 2411.13)
2201.04 Music (physics of) (see 6203.06)
2201.05 Noise (see 2501.04)
2201.06 Shock waves
2201.07 Sonar (see 3307.15)
2201.08 Speech (physics of) (see 5701.10 and 5705.06)
2201.09 Ultrasonics (see 3307.22)
2201.10 Underwater sounds (see 2510.11)
2201.11 Vibrations (see 3301.11)
2201.99 Other (specify)

2202 Electro-magnetism

2202.01 Conductivity
2202.02 Electrical quantities and their measurement
2202.03 Electricity
2202.04 Electromagnetic waves (see 2212.13)
2202.05 Gamma rays
2202.06 Infrared, visible and ultraviolet radiation (see 2209.09, 2209.22 and 2209.23)
2202.07 Interaction of electromagnetic waves with matter
2202.08 Magnetism
2202.09 Propagation of electromagnetic waves (see 2105)
2202.10 Radiowaves and microwaves (see 3307.08, 3307.12 and 13)
2202.11 Superconductivity (see 2211.27)
2202.12 X-rays (see 2102.15 and 3307.23)
2202.99 Other (specify)

2203 Electronics (see 3307)

- 2203.01 Circuits (see 3307.03)
- 2203.02 Circuit elements (see 3307.03)
- 2203.03 Electron tubes (see 3307.05)
- 2203.04 Electron microscopy
- 2203.05 Electron states (see 2211.10)
- 2203.06 Electron transport (see 2211.11)
- 2203.07 Integrated circuits (see 3307.03)
- 2203.08 Photoelectricity (see 3307.09)
- 2203.09 Piezo-electricity
- 2203.99 Other (specify)

2204 Fluids (physics of)

- 2204.01 Colloids (see 2210.04)
- 2204.02 Dispersions
- 2204.03 Fluid flow
- 2204.04 Fluid mechanics (see 2205.04)
- 2204.05 Gases
- 2204.06 High pressure phenomena (see 2210.15 and 2213.03)
- 2204.07 Ionisation
- 2204.08 Liquids (see 2210.18)
- 2204.09 Magnetofluid dynamics
- 2204.10 Plasmas (physics of) (see 2208.09)
- 2204.11 Quantum fluids
- 2204.99 Other (specify)

2205 Mechanics

- 2205.01 Analytical mechanics
- 2205.02 Continuous mechanics
- 2205.03 Elasticity
- 2205.04 Fluid mechanics (see 2204.04)
- 2205.05 Friction (see 2211.30)
- 2205.06 Many body theory
- 2205.07 Measurement of mechanical properties
- 2205.08 Plasticity
- 2205.10 Solid mechanics
- 2205.11 Statistical mechanics (see 1209)
- 2205.99 Other (specify)

2206 Molecular physics

- 2206.01 Free radicals (see 2306.09)
- 2206.02 Inorganic molecules (physics of)
- 2206.03 Macromolecules (physics of)
- 2206.04 Mesic and muonic molecules
- 2206.05 Molecular beams
- 2206.06 Molecular ions
- 2206.07 Molecular spectroscopy (see 2210.20)
- 2206.08 Molecular structure
- 2206.09 Organic molecules (physics of)
- 2206.10 Polymers (physics of)
- 2206.99 Other (specify)

2207 Nuclear physics (see 3320)

- 2207.01 Atomic beams
- 2207.02 Atomic ions
- 2207.03 Atomic physics
- 2207.04 Atoms with $Z > 2$
- 2207.05 Collision processes
- 2207.06 Electron beams
- 2207.07 Electron paramagnetic resonance
- 2207.08 Electron spin resonance
- 2207.09 Energy conversion
- 2207.10 Fission (nuclear) (see 3320.04)
- 2207.11 Helium atom
- 2207.12 Hydrogen atom
- 2207.13 Isotopes (see 2305.06 and 07, and 3320.01 and 02)
- 2207.14 Nuclear decay
- 2207.15 Nuclear energy
- 2207.16 Nuclear magnetic resonance
- 2207.17 Nuclear reaction and scattering
- 2207.18 Nuclear reactors (see 3320.04 and 05)
- 2207.19 Nuclear structure
- 2207.20 Radioisotopes (see 3320.01 and 02)
- 2207.21 Thermonuclear fusion (see 2208.03 and 3320.05)
- 2207.99 Other (specify)

2208 Nucleonics

- 2208.01 Beam handling
- 2208.02 Beam sources
- 2208.03 Fusion reactors (see 2207.21 and 3320.05)
- 2208.04 Nuclei
- 2208.05 Particle accelerators
- 2208.06 Particle detectors
- 2208.07 Particle physics (see 2212.02)
- 2208.08 Particle sources
- 2208.09 Plasma containment (see 2204.10)
- 2208.99 Other (specify)

2209 Optics (see 3311.11)

- 2209.01 Absorption spectroscopy (see 2301.01)
- 2209.02 Cinematography (see 3325.03 and 6203.01)
- 2209.03 Colorimetry
- 2209.04 Emission spectroscopy
- 2209.05 Fibre optics
- 2209.06 Geometric optics
- 2209.07 Holography
- 2209.08 Illumination (see 3306.04)
- 2209.09 Infrared radiation (see 2202.06)
- 2209.10 Lasers (see 3307.07)
- 2209.11 Light (see 2209.23 and 24)
- 2209.12 Microscopes (see 2301.12)
- 2209.13 Non-linear optics
- 2209.14 Optical properties of solids (see 2211.24)
- 2209.15 Optometry
- 2209.16 Photographic instrumentation (see 3311.12)
- 2209.17 Photography (see 6203.08)
- 2209.18 Photometry
- 2209.19 Physical optics
- 2209.20 Radiometry
- 2209.21 Spectroscopy (see 2301)
- 2209.22 Ultra-violet radiation (see 2202.06)
- 2209.23 Visible radiation (see 2202.06, 2209.11 and 2212.11)
- 2209.24 Vision (physics of) (see 2209.11 and 2411.15)
- 2209.99 Other (specify)

2210 Physical chemistry

- 2210.01 Catalysis
- 2210.02 Chemical and phase equilibria
- 2210.03 Chemical kinetics
- 2210.04 Colloid chemistry (see 2204.01)
- 2210.05 Electrochemistry (see 3303.09, 3315.03 and 3316.04)
- 2210.06 Electrolytes
- 2210.07 Electronic spectroscopy (see 2203)
- 2210.08 Emulsions
- 2210.09 Energy transfer
- 2210.10 Fast reactions; explosives
- 2210.11 Flames (see 3303.06)
- 2210.12 Fuel cells (theory of)
- 2210.13 Fused salts
- 2210.14 Gas phase physics
- 2210.15 High temperature chemistry (see 2204.06 and 2213.04)
- 2210.16 Interfacial chemistry
- 2210.17 Ion exchange
- 2210.18 Liquid state physics (see 2204.08)
- 2210.19 Membrane phenomena
- 2210.20 Molecular spectroscopy (see 2206.07)
- 2210.21 Phase equilibria
- 2210.22 Photochemistry
- 2210.23 Quantum theory (see 2212.12)
- 2210.24 Radiation chemistry
- 2210.25 Relation processes
- 2210.26 Scattering phenomena
- 2210.27 States of matter
- 2210.28 Solid state chemistry
- 2210.29 Solid state physics (see 2211)
- 2210.30 Solutions
- 2210.31 Thermochemistry
- 2210.32 Thermodynamics (see 2213)
- 2210.33 Transport phenomena
- 2210.34 Valence theory
- 2210.99 Other (specify)

2211 Solid state physics (see 2210.29)

- 2211.01 Alloys
- 2211.02 Composites
- 2211.03 Crystal Growth

2211.04 Crystallography
2211.05 Crystal structure
2211.06 Dendrites
2211.07 Dielectrics
2211.08 Diffusion in solids
2211.09 Electron carrier properties
2211.10 Electron states (see 2203.05)
2211.11 Electron transport properties (see 2203.06)
2211.12 Imperfections
2211.13 Interaction of radiation with solids
2211.14 Interfaces
2211.15 Lattice mechanics
2211.16 Luminescence
2211.17 Magnetic properties
2211.18 Magnetic resonance
2211.19 Mechanical properties
2211.20 Metallic conductors
2211.21 Metallurgy
2211.22 Metallography
2211.23 Non-crystalline states
2211.24 Optical properties (see 2209.14)
2211.25 Semiconductors (see 3307.14)
2211.26 Solid state devices (see 3307.19)
2211.27 Superconductors (see 2202.11)
2211.28 Surfaces
2211.29 Thermal properties of solids
2211.30 Tribology (see 2205.05 and 3310.04)
2211.99 Other (specify)

2212 Theoretical physics

2212.01 Electromagnetic fields
2212.02 Elementary particles (see 2008.07)
2212.03 Energy (physics)
2212.04 Fields
2212.05 Gravitation (see 2101.05 and 2507.02)
2212.06 Gravitational fields
2212.07 Gravitons
2212.08 Hadrons
2212.09 Leptons
2212.10 Mass
2212.11 Photons (see 2209.23)
2212.12 Quantum field theory (see 2210.23)
2212.13 Radiation (electromagnetic) (see 2202.04)
2212.14 Theory of relativity
2212.99 Other (specify)

2213 Thermodynamics (see 2210.32)

2213.01 Changes of state
2213.02 Heat transfer (physics of)
2213.03 High pressure (see 2204.06 and 2210.15)
2213.04 High temperature (see 2210.15)
2213.05 Kinetic theory
2213.06 Low temperatures (see 3328.26)
2213.07 Phase transition
2213.08 Thermal measurement techniques
2213.09 Thermodynamic equilibria
2213.10 Thermodynamic relationships
2213.11 Transport phenomena
2213.99 Other (specify)

2214 Units and constants

2214.01 Constants (physics)
2214.02 Metrology
2214.03 Standard units
2214.04 Unit calibration
2214.05 Unit conversion
2214.99 Other (specify)

2299 Other physical specialities (specify)

23 CHEMISTRY

2301 Analytical chemistry

2301.01 Absorption spectroscopy (see 2209.01)
2301.02 Biochemical analysis
2301.03 Chromatographic analysis
2301.04 Electrochemical analysis
2301.05 Emission spectroscopy (see 2209.04)
2301.06 Fluorimetry
2301.07 Gravimetry
2301.08 Infrared spectroscopy
2301.09 Magnetic resonance spectroscopy
2301.10 Mass spectroscopy
2301.11 Michrochemical analysis
2301.12 Microscopy (see 2209.12)
2301.13 Microwave spectroscopy
2301.14 Phosphorimetry
2301.15 Polymer analysis (see 2304.16)
2301.16 Radiochemical analysis
2301.17 Raman spectroscopy
2301.18 Thermal analytical methods
2301.19 Volumetry
2301.20 X-ray spectroscopy
2301.99 Other (specify)

2302 Biochemistry (see 2306)

2302.01 Alkaloids
2303.02 Amino acids
2302.03 Antimetabolites
2302.04 Biochemical genetics
2302.05 Biosynthesis
2302.06 Chemotherapy (see 3208.06)
2307.07 Clinical chemistry
2302.08 Co-enzymes
2302.09 Enzymology
2302.10 Essential oils
2302.11 Fatty acids
2302.12 Fermentation (see 3302.02 and 3309.01)
2302.13 Feedback regulation
2302.14 Glucides (see 2304.19, 2306.06 and 3309.26)
2302.15 Hormones
2302.16 Immunochemistry (see 2412.07, 3207.10 and 3208.05)
2302.17 Intermediary metabolism
2302.18 Lipids (see 3309.28)
2302.19 Metabolic processes
2302.20 Microbiological chemistry (see 3302.03)
2302.21 Molecular biology (see 2415)
2302.22 Molecular pharmacology (see 3209)
2302.23 Nucleic acids
2302.24 Peptides
2302.25 Photosynthesis
2302.26 Physical biochemistry
2302.27 Proteins (see 2304.18 and 3309.21)
2302.28 Starch (see 3309.24)
2302.29 Steroids (see 2306.17)
2302.30 Terpenes
2302.31 Trace-elements (see 3206.14)
2302.32 Vitamins (see 3206.15)
2302.33 Waxes
2302.99 Other (specify)

2303 Inorganic chemistry (see 3303)

2303.01 Actinide chemistry
2303.02 Alkaline earths
2303.03 Alkaline elements
2303.04 Boron compounds
2303.05 Carbon
2303.06 Chlorine compounds
2303.07 Co-ordination compounds
2303.08 Electron deficient compounds
2303.09 Electropositive elements
2303.10 Fluorine compounds
2303.11 Germanium
2303.12 Graphite
2303.13 Halogens
2303.14 Hydrogen (see 2207.13)
2303.15 Hydrides
2303.16 Inorganic reactions (mechanisms of)
2303.17 Lead compounds
2303.18 Metals
2303.19 Metal alkyls
2303.20 Nitrogen compounds
2303.21 Organo-metallic compounds (see 2306.11)
2303.22 Phosphorus compounds
2303.23 Pigment chemistry
2303.24 Rare earths
2303.25 Sodium compounds
2303.26 Structure of inorganic compounds
2303.27 Sulphur compounds
2303.28 Synthetic elements
2303.29 Transition elements
2303.30 Transuranium elements
2303.31 Water chemistry (see 2508.11)
2303.99 Other (specify)

2304 Macromolecular chemistry (see 3312.10)

- 2304.01 Cellular plastics
- 2304.02 Cellulose
- 2304.03 Composite polymers
- 2304.04 Elastomers
- 2304.05 Gums
- 2304.06 High polymers
- 2304.07 Inorganic polymers
- 2304.08 Macromolecules
- 2304.09 Modification of macromolecules
- 2304.10 Monomer chemistry
- 2304.11 Natural fibres
- 2304.12 Network polymers
- 2304.13 Polyelectrolytes
- 2304.14 Polyesters
- 2304.15 Polyethylene
- 2304.16 Polymer analysis (see 2301.15)
- 2304.17 Polymers in dispersed form
- 2304.18 Polypeptides and proteins (see 2302.27)
- 2304.19 Polysaccharides (see 2302.14 and 2302.28)
- 2304.20 Polystyrene
- 2304.21 Polyurethanes
- 2304.22 Stability of macromolecules
- 2304.23 Synthesis of macromolecules
- 2304.24 Synthetic fibres (see 3326.05)
- 2304.99 Other (specify)

2305 Nuclear chemistry

- 2305.01 Hot atom chemistry
- 2305.02 Isotope tracers
- 2305.03 Marked molecules
- 2305.04 Radiation chemistry
- 2305.05 Radiochemistry
- 2305.06 Radioisotopes
- 2305.07 Separation of isotopes (see 2207.13)
- 2305.99 Other (specify)

2306 Organic chemistry (see 2302, 3303 and 3321.10)

- 2306.01 Aliphatic hydrocarbons
- 2306.02 Aromatic hydrocarbons
- 2306.03 Benzene derivatives
- 2306.04 Bicyclic chemistry
- 2306.05 Carbanion chemistry
- 2306.06 Carbohydrate chemistry (see 2302.14)
- 2306.07 Carbonium chemistry
- 2306.08 Dyestuff chemistry (see 3309.08)
- 2306.09 Free radicals (see 2206.01)
- 2306.10 Heterocyclic compounds
- 2306.11 Organometallics (see 2303.21)
- 2306.12 Organophosphorus chemistry
- 2306.13 Organosilicon chemistry
- 2306.14 Organosulphur chemistry
- 2306.15 Reaction mechanics
- 2306.16 Stereochemistry and conformational analysis
- 2306.17 Steroid chemistry (see 2302.29)
- 2306.18 Structure of organic molecules
- 2306.99 Other (specify)

2307 Physical chemistry (see 2210)

2399 Other chemical specialities (specify)

24. LIFE SCIENCES

2401 Animal Biology (Zoology) (see 3109)

- 2401.01 Animal anatomy (see 3109.01)
- 2401.02 Animal behaviour (see 2401.06)
- 2401.03 Animal communication (see 5621)
- 2401.04 Animal cytology
- 2401.05 Animal development
- 2401.06 Animal ecology
- 2401.07 Animal embryology
- 2401.08 Animal genetics (see 3109.02)
- 2401.09 Animal growth
- 2401.10 Animal histology
- 2401.11 Animal pathology (see 3109.07)
- 2401.12 Animal parasitology
- 2401.13 Animal physiology (see 2401.13)
- 2401.14 Animal taxonomy
- 2401.15 General zoology
- 2401.16 Herpetology
- 2401.17 Invertebrates
- 2401.18 Mammology
- 2401.19 Marine zoology (see 2510.05)
- 2401.20 Ornithology
- 2401.21 Primatology (see 2402.11 and 2402.12)
- 2401.22 Protozoology
- 2401.23 Vertebrates
- 2401.99 Other (specify)

2402 Anthropology (physical) (see 51)

- 2402.01 Anthropological archives
- 2402.02 Anthropological genetics (see 2409.03)
- 2402.03 Anthropometry and forensic anthropology
- 2402.04 Body composition
- 2402.05 Body constitution
- 2402.06 Ethnology
- 2402.07 Medical anthropology
- 2402.08 Nutritional habits
- 2402.09 Osteology
- 2402.10 Population biology (see 5206.04)
- 2402.11 Primate behaviour
- 2402.12 Primate somatology (see 2401.21)
- 2402.13 Racial biology (see 5906.04 and 6310.06)
- 2402.14 Somatic growth
- 2402.15 Somatic ageing
- 2402.99 Other (specify)

2403 Biochemistry (see 2302)

2404 Biomathematics

- 2404.01 Biostatistics
- 2404.99 Other (specify)

2405 Biometrics

2406 Biophysics

- 2406.01 Bioacoustics
- 2406.02 Bioelectricity
- 2406.03 Bioenergetics
- 2406.04 Bio-mechanics
- 2406.05 Bio-optics
- 2406.06 Medical physics
- 2406.99 Other (specify)

2407 Cell biology

- 2407.01 Cell culture
- 2407.02 Cell genetics
- 2407.03 Cell morphology
- 2407.04 Cytology
- 2407.05 Tissue culture
- 2407.99 Other (specify)

2408 Ethology

- 2408.01 Animal
- 2408.02 Human (see 6106 and 6114)
- 2408.03 Insect (see 2413)
- 2408.99 Other (specify)

2409 Genetics (see 2107.02, 2410.07 and 3201.02)

- 2409.01 Embryology
- 2409.02 Genetic engineering
- 2409.03 Population genetics (see 2402.02 and 5206.08)
- 2409.99 Other (specify)

2410 Human biology (see 32)

- 2410.01 Blood groups
- 2410.02 Human anatomy
- 2410.03 Human cytology
- 2410.04 Human development
- 2410.05 Human ecology
- 2410.06 Human embryology
- 2410.07 Human genetics
- 2410.08 Human histology
- 2410.09 Human neuro-anatomy
- 2410.10 Human physiology (see 2411)
- 2410.11 Sensory organs
- 2410.12 Systemic anatomy
- 2410.13 Topographic anatomy
- 2410.99 Other (specify)

2411 Human physiology (see 2410.10)

- 2411.01 Attitude physiology
- 2411.02 Anaesthesiology
- 2411.03 Cardio-vascular physiology
- 2411.04 Endocrine physiology
- 2411.05 Environmental physiology
- 2411.06 Exercise physiology
- 2411.07 Gastro-intestinal physiology
- 2411.08 Human metabolisms
- 2411.09 Human temperature regulation
- 2411.10 Muscle physiology
- 2411.11 Neurophysiology
- 2411.12 Physiology of the central nervous system
- 2411.13 Physiology of hearing (see 2201.03)
- 2411.14 Physiology of speech (see 5701.10)
- 2411.15 Physiology of vision (see 2209.24)
- 2411.16 Reproduction physiology
- 2411.17 Respiration physiology
- 2411.18 Transport physiology
- 2411.99 Other (specify)

2412 Immunology (see 2302.16, 3109.03, 3207.10 and 3208.05)

- 2412.01 Antigens
- 2412.02 Antibodies
- 2412.03 Antigen-antibody reaction
- 2412.04 Antibody formation
- 2412.05 Hypersensitivity
- 2412.06 Immunisation
- 2412.07 Immunochemistry (see 2302.16)
- 2412.08 Organ transplantation
- 2412.09 Tissue antibodies
- 2412.10 Vaccines
- 2412.99 Other (specify)

2413 Insect Biology (Entomology) (see 2408.03 and 3101.07)

- 2413.01 General entomology
- 2413.02 Insect development (see 3308.03
- 2413.03 Insect ecology
- 2413.04 Insect morphology
- 2413.05 Insect physiology
- 2413.06 Insect taxonomy
- 2413.99 Other (specify)

2414 Microbiology (see 3109.05, 3201.03 and 3302.03)

- 2414.01 Antibiotics (see 3302.01)
- 2414.02 Bacterial physiology
- 2414.03 Bacterial metabolism
- 2414.04 Bacteriology
- 2414.05 Bacteriophage (see 2420.02)
- 2414.06 Fungi (see 3108.05)
- 2414.07 Microbial metabolism
- 2414.08 Microbial processes (see 3302.03)
- 2414.09 Molds
- 2414.10 Mycology (yeasts)
- 2414.99 Other (specify)

2415 Molecular biology (see 2302.21)

2416 Palaeontology

- 2416.01 Animal palaeontology
- 2416.02 Invertebrate palaeontology
- 2416.03 Palinology
- 2416.04 Plant palaeontology (see 2417.10)
- 2416.05 Vertebrate palaeontology
- 2416.99 Other (specify)

2417 Plant Biology (Botany) (see 3103)

- 2417.01 Bryology
- 2417.02 Dendrology
- 2417.03 General botany
- 2417.04 Limnology
- 2417.05 Marine biology (see 2510.04 and 05)
- 2417.06 Mycology (mushrooms)
- 2417.07 Phycology
- 2417.08 Phytobiology
- 2417.09 Phytopathology (see 3108)
- 2417.10 Palaeobotany (see 2416.04)
- 2417.11 Plant anatomy
- 2417.12 Plant cytology
- 2417.13 Plant ecology
- 2417.14 Plant genetics
- 2417.15 Plant growth (see 3101.10)
- 2417.16 Plant histology
- 2417.17 Plant nutrition
- 2417.18 Plant parasitology
- 2417.19 Plant physiology
- 2417.20 Plant taxonomy
- 2417.21 Pteridology
- 2417.99 Other (specify)

2418 Radiobiology (see 3201.12, 3204.01 and 3207.15)

2419 Symbiosis

2420 Virology (see 3108.09 and 3109.11)

- 2420.01 Arbor viruses
- 2420.02 Bacteriophages (see 2414.05)
- 2420.03 Dermatropic viruses
- 2420.04 Enteric viruses
- 2420.05 Neurotropic viruses
- 2420.06 Pantropic viruses
- 2420.07 Pox viruses
- 2420.08 Respiratory viruses
- 2420.09 Viscerotropic viruses
- 2420.99 Other (specify)

2499 Other biological specialities (specify)

25. EARTH AND SPACE SCIENCES

2501 Atmospheric sciences (see 2502 and 2509)

- 2501.01 Aeronomy
- 2501.02 Airglow
- 2501.03 Air-sea interaction (see 2510.08)
- 2501.04 Atmospheric acoustics (see 2201)
- 2501.05 Atmospheric chemistry
- 2501.06 Atmospheric dynamics
- 2501.07 Atmospheric electricity
- 2501.08 Atmospheric optics (see 2209)
- 2501.09 Atmospheric radioactivity (see 2208.06 and 2212.13)
- 2501.10 Atmospheric structure
- 2501.11 Atmospheric thermodynamics
- 2501.12 Atmospheric turbulence
- 2501.13 Aurora
- 2501.14 Cloud physics
- 2501.15 Cosmic rays (see 2101.03)
- 2501.16 Diffusion (atmospheric)
- 2501.17 Geomagnetic pulsations
- 2501.18 Ionosphere
- 2501.19 Magnetospheric particles
- 2501.20 Magnetospheric waves
- 2501.21 Numerical modelling
- 2501.22 Precipitation physics
- 2501.23 Radiotiative transfer
- 2501.24 Solar wind (see 2106.03)
- 2501.99 Other (specify)

2502 Climatology (see 2501 and 2509)

- 2502.01 Analytical climatology
- 2502.02 Applied climatology
- 2502.03 Bioclimatology
- 2502.04 Microclimatology
- 2502.05 Palaeoclimatology
- 2502.06 Physical climatology
- 2502.07 Regional climatology
- 2502.99 Other (specify)

2503 Geochemistry

- 2503.01 Cosmochemistry (see 2101.12, 2102.02 and 2104.04)
- 2503.02 Experimental petrology
- 2503.03 Exploration geochemistry
- 2503.04 Geochronology and radio isotopes
- 2503.05 High temperature geochemistry
- 2503.06 Low temperature geochemistry
- 2503.07 Organic geochemistry
- 2503.08 Stable isotopes
- 2503.09 Trace elements distribution
- 2503.99 Other (specify)

2504 Geodesy

- 2504.01 Geodetic astronomy (see 2103.01)
- 2504.02 Geodetic cartography
- 2504.03 Geodetic navigation
- 2504.04 Geodetic photogrammetry
- 2504.05 Geodetic surveying
- 2504.06 Physical geodesy
- 2504.07 Satellite geodesy (see 3324.01)
- 2504.08 Theoretical geodesy
- 2504.99 Other (specify)

2505 Geography (see 54)

- 2505.01 Biogeography (see 5403)
- 2505.02 Geographical cartography
- 2505.03 Geography of natural resources
- 2505.04 Land utilization (see 5401.03)
- 2505.05 Location theory
- 2505.06 Medical geography
- 2505.07 Physical geography
- 2505.08 Topographical geography
- 2505.99 Other (specify)

2506 Geology

- 2506.01 Areal geology
- 2506.02 Coal geology (see 3318.01 and 3321)
- 2506.03 Engineering geology
- 2506.04 Environmental geology
- 2506.05 Geohydrology (see 2508)
- 2506.06 Geological surveys
- 2506.07 Geomorphology (see 5301.01)
- 2506.08 Geothermal processes and energy (see 3322.05)
- 2506.09 Glacial geology (see 2508.03)
- 2506.10 Mineral deposits
- 2506.11 Mineralogy
- 2506.12 Petroleum geology (see 3321)
- 2506.13 Petrology, igneous and metamorphic
- 2506.14 Petrology, sedimentary
- 2506.15 Photogeology
- 2506.16 Remote sensing (geology)
- 2506.17 Rock mechanisms
- 2506.18 Sedimentology
- 2506.19 Stratigraphy (see 5505.12)
- 2506.20 Structural geology
- 2506.21 Volcanology
- 2506.22 Well log analysis
- 2506.99 Other (specify)

2506 Geophysics

- 2507.01 Geomagnetism and magnetic exploration
- 2507.02 Gravity (earth) and gravity exploration (see 2212.05)
- 2507.03 Heat flow (earth)
- 2507.04 Palaeomagnetism
- 2507.05 Seismology and seismic exploration
- 2507.06 Solid-earth geophysics
- 2507.07 Tectonics
- 2507.99 Other (specify)

2508 Hydrology (see 2510.04 and 2506.05)

- 2508.01 Erosion (water)
- 2508.02 Evaporation
- 2508.03 Glaciology (see 2506.09 and 2508.07)
- 2508.04 Ground water
- 2508.05 Hydrobiology
- 2508.06 Hydrography
- 2508.07 Ice (see 2508.03 and 2510.09)
- 2508.08 Limnology
- 2508.09 Permafrost
- 2508.10 Precipitation
- 2508.11 Quality of water (see 2303.31, 3308.06 and 3308.11)
- 2508.12 Snow
- 2508.13 Soil moisture
- 2508.14 Surface waters
- 2508.15 Transpiration
- 2508.99 Other (specify)

2509 Meteorology (see 2501 and 2502)

- 2509.01 Agricultural meteorology
- 2509.02 Air pollution (see 3308.01)
- 2509.03 Extended weather forecasting
- 2509.04 Hydrometeorology (see 2508)
- 2509.05 Industrial meteorology
- 2509.06 Marine meteorology (see 2510.08)
- 2509.07 Mesometeorology
- 2509.08 Micrometeorology
- 2509.09 Numerical weather prediction
- 2509.10 Observation briefing (weather)
- 2509.11 Operational forecasting (weather)
- 2509.12 Polar meteorology
- 2509.13 Radar meteorology
- 2509.14 Radio meteorology
- 2509.15 Rocket meteorology
- 2509.16 Satellite meteorology (see 3324.01)
- 2509.17 Synoptic meteorology
- 2509.18 Tropical meteorology
- 2509.19 Weather analysis
- 2509.20 Weather modification
- 2509.99 Other (specify)

2510 Oceanography

- 2510.01 Biological oceanography
- 2510.02 Chemical oceanography
- 2510.03 Descriptive oceanography
- 2510.04 Marine botany (see 2417.05)
- 2510.05 Marine zoology (see 2401.19)
- 2510.06 Ocean-bottom processes (see 5603.04)
- 2510.07 Physical oceanography
- 2510.08 Sea-air interactions (see 2501.03 and 2509.06)
- 2510.09 Sea ice (see 2508.07)
- 2510.10 Shore and near-shore processes
- 2510.11 Underwater sounds (see 2201.10)
- 2510.99 Other (specify)

2511 Soil Science (see 3103.12 and 3103.13)

- 2511.01 Soil biochemistry
- 2511.02 Soil biology
- 2511.03 Soil cartography
- 2511.04 Soil chemistry
- 2511.05 Soil classification
- 2511.06 Soil conservation
- 2511.07 Soil engineering
- 2511.08 Soil mechanics (agriculture)
- 2511.09 Soil microbiology
- 2511.10 Soil mineralogy
- 2511.11 Soil morphology and genesis
- 2511.12 Soil physics
- 2511.99 Other (specify)

2512 Space Sciences (see 2102, 2104 and 3324)

- 2512.01 Exobiology
- 2512.02 Space medicine
- 2512.03 Space physiology (see 2411)
- 2512.99 Other (specify)

2599 Other Earth, Space or Environmental specialities (specify)

31. AGRICULTURAL SCIENCES

3101 Agricultural chemistry

- 3101.01 Dairy products
- 3101.02 Fertilizer processing
- 3101.03 Fertilizer utilization
- 3101.04 Fish products
- 3101.05 Fungicides (see 3108.05)
- 3101.06 Herbicides (see 3103.15)
- 3101.07 Insecticides (see 2413)
- 3108.08 Non-food crop products
- 3101.09 Pesticides
- 3101.10 Plant growth regulators (see 2417.15)
- 3101.99 Other (specify)

3102 Agricultural engineering

- 3102.01 Agricultural mechanics (see 3313.06)
- 3102.02 Drainage (see 3305.08)
- 3102.03 Farm construction (see 3305)
- 3102.04 Farm equipment (see 3313.06)
- 3102.05 Irrigation (see 3305.19)
- 3102.99 Other (specify)

3103 Agronomy (see 2417 and 5312.01)

- 3103.01 Crop breeding
- 3103.02 Crop hybridisation
- 3103.03 Crop management
- 3103.04 Crop protection
- 3103.05 Cultural engineering
- 3103.06 Field crops
- 3103.07 Forage crops
- 3103.08 Management for plant production
- 3103.09 Ornamental crops
- 3103.10 Pasture
- 3103.11 Seeds
- 3103.12 Soil behaviour under alternative uses (see 2511)
- 3103.13 Soil fertility (see 2511)
- 3103.14 Turf
- 3103.15 Weed control (see 3101.06)
- 3103.99 Other (specify)

3104 Animal husbandry

- 3104.01 Apiculture
- 3104.02 Bovine
- 3104.03 Breeding
- 3104.04 Care and management
- 3104.05 Equine
- 3104.06 Nutrition (see 3309.02)
- 3104.07 Ovine
- 3104.08 Porcine
- 3104.09 Poultry farming
- 3104.10 Products
- 3104.11 Reproduction
- 3104.12 Selection
- 3104.13 Sericulture
- 3104.99 Other (specify)

3105 Fish and wildlife (see 5312.01)

- 3105.01 Controls
- 3105.02 Fish farming
- 3105.03 Fish finding
- 3105.04 Fish preservation
- 3105.05 Fish processing
- 3105.06 Fishing mechanics
- 3105.07 Food habits
- 3105.08 Game
- 3105.09 Habitat influences
- 3105.10 Population dynamics
- 3105.11 Propagation and management
- 3105.12 Wild life conservation and management
- 3105.99 Other (specify)

3106 Forestry (see 3312.13 and 5312.01)

- 3106.01 Conservation
- 3106.02 Cultural engineering
- 3106.03 Erosion control
- 3106.04 Management
- 3106.05 Products
- 3106.06 Protection
- 3106.07 Range management
- 3106.08 Sylviculture
- 3106.09 Watershed management
- 3106.99 Other (specify)

3107 Horticulture

- 3107.01 Breeding
- 3107.02 Cultural engineering
- 3107.03 Floriculture
- 3107.04 Fruit
- 3107.05 Hybridisation
- 3107.06 Vegetables
- 3107.99 Other (specify)

3108 Phytopathology (see 2417.09)

- 3108.01 Bacteria
- 3108.02 Disease control, biological
- 3108.03 Disease control, chemical
- 3108.04 Disease control, environmental
- 3108.05 Fungi (see 2414.06)
- 3108.06 Nematodes
- 3108.07 Physiogenesis
- 3108.08 Plant susceptibility, resistance
- 3108.09 Viruses (see 2420)
- 3108.99 Other (specify)

3109 Veterinary sciences (see 2401)

- 3109.01 Anatomy (see 2401.01)
- 3109.02 Genetics (see 2401.08)
- 3109.03 Immunology (see 2412)
- 3109.04 Internal medicine (see 3205)
- 3109.05 Microbiology (see 2414)
- 3109.06 Nutrition (see 3206)
- 3109.07 Pathology (see 2401.11)
- 3109.08 Pharmacology (see 3209)
- 3109.09 Physiology (see 2401.13)
- 3109.10 Surgery (see 3213)
- 3109.11 Virology (see 2420)
- 3109.99 Other (specify)

Specify Bovine, Caprine, Equine, Ovine, Porcine, Other.

3199 Other agricultural specialities (specify)

32. MEDICAL SCIENCES

(see 2302, 2410, 2411 and 5101.13)

3201 Clinical sciences

- 3201.01 Cancerology (see 3207.03 and 3207.03)
- 3201.02 Clinical genetics (see 2409)
- 3201.03 Clinical microbiology (see 2414)
- 3201.04 Clinical pathology
- 3201.05 Clinical psychology (see 3211, 6101.04 and 6103)
- 3201.06 Dermatology
- 3201.07 Geriatrics (see 2618)
- 3201.08 Gynaecology
- 3201.09 Ophthalmology
- 3201.10 Pediatrics
- 3201.11 Radiology
- 3201.12 Radiotherapy (see 2418 and 3207.15)
- 3201.13 Syphilography
- 3201.99 Other (specify)

3202 Epidemiology (see 2414 and 2420)

3203 Forensic medicine (see 2402.03 and 6614.09)

3204 Occupational medicine

- 3204.01 Nuclear medicine (see 2418 and 3207.15)
- 3204.02 Occupational diseases
- 3204.03 Occupational health
- 3204.04 Rehabilitation (medical)
- 3204.99 Other (specify)

3205 Internal medicine

- 3205.01 Cardiology (see 3207.04)
- 3205.02 Endocrinology
- 3205.03 Gastro-enterology
- 3205.04 Haematology (see 3207.08)
- 3205.05 Infectious diseases (see 2414, 2420 and 3202)
- 3205.06 Nephrology
- 3205.07 Neurology
- 3205.08 Pulmonary diseases
- 3205.09 Rheumatology
- 3205.99 Other (specify)

3206 Nutrition sciences (see 3309)

- 3206.01 Digestion
- 3206.02 Energy metabolism
- 3206.03 Natural toxicants
- 3206.04 Food deficiencies
- 3206.05 Food pathogens
- 3206.06 Food requirements
- 3206.07 Mineral elements in food
- 3206.08 Nutrients
- 3206.09 Nutrient values
- 3206.10 Nutritional diseases
- 3206.11 Toxicity of food
- 3206.14 Trace elements in foods (see 2302.31)
- 3206.15 Vitamins (see 2302.32)
- 3206.99 Other (specify)

3207 Pathology

- 3207.01 Allergies
- 3207.02 Atherosclerosis
- 3207.03 Carcinogenesis (see 3201.01 and 3207.13)

3207.04 Cardio-vascular pathology (see 3205.01 and 3207.18)
3207.05 Comparative pathology
3207.06 Endotoxins
3207.07 Experimental pathology
3207.08 Haematology (see 3205.04)
3207.09 Histopathology
3207.10 Immunopathology (see 2412 and 2302.16)
3207.11 Neuropathology
3207.12 Parasitology
3207.13 Oncology (see 3201.01 and 3207.03)
3207.14 Osteopathology
3207.15 Radiation pathology (see 2418, 3201.12 and 3204.01)
3207.16 Stress
3207.17 Teratology
3207.18 Thrombosis (see 3207.04)
3207.99 Other (specify)

3208 Pharmacodynamics

3208.01 Absorption of drugs
3208.02 Action of drugs (see 3208.08 and 6103.04)
3208.03 Activation, multiple processes
3208.04 Active locations, receptors
3208.05 Catalysis, autocatalysis, immunocatalysis
3208.06 Chemotherapy (see 2302.06)
3208.07 Interaction of antigens
3208.08 Mechanism of drug action (see 3208.02 and 6113.04)
3208.09 Metabolic processes of drugs
3208.99 Other (specify)

3209 Pharmacology (see 2302.22)

3209.01 Analysis of pharmaceuticals
3209.02 Composition of drugs
3209.03 Evaluation of drugs
3209.04 Naturally occurring drugs (see 5101.13)
3209.05 Pharmacognosy
3209.06 Pharmacopoeas
3209.07 Phytopharmaceuticals
3209.08 Preparation of drugs
3209.09 Psychopharmacology (see 6113)
3209.10 Radiopharmaceuticals
3209.11 Standardization of drugs
3209.12 Synthetic drugs
3209.99 Other (specify)

3210 Preventive medicine

3211 Psychiatry (see 3201.05, 6103.06 and 6103.07)

3212 Public health

3213 Surgery

3213.01 Abdominal surgery
3213.02 Aesthetic surgery
3213.03 Anaesthesiology
3213.04 Bone surgery
3213.05 Ear-nose-throat surgery
3213.06 Experimental surgery
3213.07 Heart surgery
3213.08 Neurosurgery
3213.09 Ocular surgery
3213.10 Orthopaedic surgery
3213.11 Physiotherapy
3213.12 Proctology
3213.13 Stomatology-orthodonty (see 3311.03)
3213.14 Transplantation surgery
3213.15 Traumatology
3213.16 Urology
3213.17 Vascular surgery
3213.99 Other (specify)

3214 Toxicology

3299 Other medical specialities (specify)

33. TECHNOLOGICAL SCIENCES

3301 Aeronautical technology and engineering

3301.01 Aerodynamics
3301.02 Aerodynamic loads
3301.03 Aerodynamic theory
3301.04 Aircraft
3301.05 Aircraft fuels, combustion
3301.06 Aircraft structures
3301.07 Air cushion devices (see 3319.01)
3301.08 Airports and air transport (see 3305.02)
3301.09 Compressors and turbines
3301.10 Flight test and research
3301.11 Flutter and vibration (see 2201.11)
3301.12 Hydrodynamics
3301.13 Instrumentation (aviation)
3301.14 Landing loads
3301.15 Propulsion systems
3301.16 Propulsion system materials
3301.17 Rotary wing
3301.18 Stability and control
3301.99 Other (specify)

3302 Biochemical technology (see 3309)

3302.01 Antibiotics technology (see 2414.01)
3302.02 Fermentation technology (see 3309.01, 05 and 29)
3302.03 Industrial microbiology (see 2414 and 2302.20)
3302.99 Other (specify)

3303 Chemical technology and engineering (see 2303, 2304 and 2306)

3303.01 Catalysis technology
3303.02 Chemical economics
3303.03 Chemical processes
3303.04 Chemical separation
3303.05 Chemical synthesis
3303.06 Combustion technology (see 2210.11)
3303.07 Corrosion technology (see 3303.13)
3303.08 Deionisation (see 3328.06)
3303.09 Electrochemical operations (see 2210.05)
3303.10 Electroplating
3303.11 Industrial chemistry
3303.12 Nuclear-chemical processes
3303.13 Preservation technology (see 3303.07)
3303.14 Protective coatings
3303.15 Refractory coating
3303.16 Water repellent coatings
3303.99 Other (specify)

3304 Computer technology (see 1203)

3304.01 Analog computers
3304.02 Analog-digital convertors
3304.03 Arithmetic and machine instructions
3304.04 Central processing units
3304.05 Character recognition systems
3304.06 Computer architecture (see 1203.09)
3304.07 Computer peripherals
3304.08 Computer reliability
3304.09 Computer serviceability
3304.10 Computer terminals, graphic display devices and plotters
3304.11 Computing systems design
3304.12 Control devices
3304.13 Data transmission devices
3304.14 Digital computers
3304.15 Hybrid computers
3304.16 Logic design
3304.17 Real-time systems
3304.18 Storage devices
3304.99 Other (specify)

3305 Construction technology (see 3312 and 3313.04 and 5312)

3305.01 Architectural design (see 6201.01)
3305.02 Airport construction (see 3301.08)

3305.03 Buildings, large and skyscrapers
3305.04 Bridges
3305.05 Concrete (technology of)
3305.06 Civil engineering
3305.07 Dams
3305.08 Drainage (see 3102.02)
3305.09 Excavations
3305.10 Foundations
3305.11 Harbours
3305.12 Heavy constructions
3305.13 Highways (see 3305.29 and 3317.10)
3305.14 Houses
3305.15 Hydraulic engineering (see 3313.11)
3303 16 Hyperstatic systems
3305.17 Industrial and commercial buildings
3305.18 Inland waterways
3305.19 Irrigation (see 3102.05)
3305.20 Light constructions
3305.21 Metallic constructions
3305 22 Metrology of building
3305.23 Organization of works
3305.24 Prefabricated constructions
3305.25 Prestressed concrete
3305.26 Public buildings
3305.27 Railway construction (see 3323)
3305.28 Regulations, codes and specifications (see 3329.01)
3305.29 Road construction (see 3317.10)
3305.30 Sewers and water purification (see (see 3308.09, 10 and 11)
3305.31 Soil mechanics (construction)
3305.32 Structural engineering
3305.33 Structural strength
3305.34 Topography of building
3305.35 Tunnels
3305.36 Underground works (see 3313.11)
3305.37 Urban planning (see 6201.03)
3305.38 Water supply
3305.39 Wood constructions (see 3212.13)
3305.99 Other (specify)

3306 Electrical technology and engineering

3306.01 Direct current power utilization
3306.02 Electricity applications
3306.03 Electric motors
3306.04 Electric lighting (see 2209.08)
3306.05 Insulated conductors
3306.06 Manufacture of electrical equipment
3306.07 Rotating machinery
3306.08 Switchgear
3306.09 Transmission and distribution
3306.99 Other (specify)

3307 Electronic technology (see 2202, 2203, 3311.07 and 3325)

3307.01 Antennae (see 2105.01)
3307.02 Audio-electronics (see 2201 and 3325.01)
3307.03 Circuit design (see 2203.01 and 02 and 2203.07)
3307.04 Electro-acoustic transducers
3307.05 Electron tubes (see 2203.03)
3307.06 Filter design
3307.07 Laser devices (see 2209.10)
3307.08 Microwave devices (see 2202.10 and 3325.04)
3307.09 Photo-electric devices (see 2203.08)
3307.10 Radar
3307.11 Radio receivers (see 3325.05)
3307.12 Radio transmitters (see 3325.05)
3307.13 Recording devices
3307.14 Semi-conductor devices (see 2211.25)
3307.15 Sonar devices (see 2201.07)
3307.16 Sonic devices
3307.17 Thermo-electric devices
3307.18 Thermo-ionic devices
3307.19 Transistors (see 2211)
3307.20 TV emitters (transmitters)
3307.21 TV receivers
3307.22 Ultrasonic devices (see 2201.09)
3307.23 X-ray devices (see 2202.12)
3307.99 Other (specify)

3308 Environmental technology and Engineering

3308.01 Air pollution control (see 2509.02)
3308.02 Industrial wastes
3308.03 Insect control technology (see 2413.02 and 3301.07)
3308.04 Pollution engineering
3308.05 Radio active wastes disposal
3308.06 Reclamation of water (see 2508.11)
3308.07 Refuse disposal
3308.08 Rodent control technology
3308.09 Sanitary engineering (see 3305.30)
3308.10 Sewage technology (see 3305.29)
3308.11 Water pollution control (see 3305.30 and 2508.11)
3308.99 Other (specify)

3309 Food technology (see 3302 and 3206)

3309.01 Alcoholic beverages (see 3302.02 and 6113.01)
3309.02 Animal feed (see 3104.06)
3309.03 Antioxydants in food
3309.04 Bakery
3309.05 Brewing (see 3302.02)
3309.06 Canning
3309.07 Cereal products
3309.08 Colour (see 2306.08)
3309.09 Dairy products
3309.10 Flavour
3309.11 Flour milling (see 3328.24)
3309.12 Food additives
3309.13 Food preservation
3309.14 Food processing
3309.15 Food sanitation
3309.16 Freeze-drying (see 3328.14)
3309.17 Lyophilisation
3309.18 Non-alcoholic beverages
3309.19 Pasteurisation
3309.20 Properties of food
3309.21 Protein food (see 2302.27)
3309.22 Refrigeration (see 3313.26 and 3328.26)
3309.23 Stabilisers
3309.24 Starch (see 2302.28)
3309.25 Sterilisation of food
3309.26 Sugar (see 2302.14)
3309.27 Synthetic foods
3309.28 Vegetable oils and fats (see 2302.18)
3309.29 Wine (see 3302.02)
3309.99 Other (specify)

3310 Industrial technology (see 5311)

3310.01 Industrial equipment
3310.02 Industrial machinery (see 3213.12)
3310.03 Industrial processes
3310.04 Maintenance engineering (see 2211.30)
3310.05 Processing engineering
3310.06 Process specifications
3310.07 Time and motion study (see 5311.09)
3310.99 Other (specify)

3311 Instrumentation technology

3311.01 Automation technology
3311.02 Control engineering
3311.03 Dental instruments (see 3213.13)
3311.04 Electro-optical devices
3311.05 Electrical test equipment
3311.06 Electrical instruments
3311.07 Electronic instruments (see 3307)
3311.08 Laboratory equipment
3311.09 Lenses
3311.10 Medical instruments (see 3213 and 3314)
3311.11 Optical instruments (see 2103 and 2209)
3311.12 Photographic and cinematographic equipment (see 2209.p6, 3325.03 and 6203.08)
3311.13 Scientific apparatus
3311.14 Servomechanisms
3311.15 Telechiric techniques
3311.16 Temperature measurement instruments (see 2213.08)
3311.17 Test equipment

3311.18 Thermostatic instruments
3311.19 Timing devices
3311.99 Other (specify)

3312 Materials technology

3312.01 Abrasives
3312.02 Cements
3312.03 Ceramics
3312.04 Cermets
3312.05 Clay products
3312.06 Glass
3312.07 Limes
3312.08 Material properties
3312.09 Material resistance
3312.10 Plastics (see 2304)
3312.11 Refractories (see 3315.17)
3312.12 Testing of materials
3312.13 Wood technology (see 3106 and 3305.39)
3312.99 Other (specify)

3313 Mechanical Engineering and technology

3313.01 Air blowers
3313.02 Air compressors (see 3328.04)
3313.03 Bearings
3313.04 Construction equipment (see 3305)
3313.05 Dies, jigs and patterns
3313.06 Farm machinery (see 3102.01 and 04)
3313.07 Food machinery (see 3309)
3313.08 Gas engines
3313.09 Gears
3313.10 Heating equipment (see 3328.16)
3313.11 Hydraulic machinery (see 3305.15)
3313.12 Industrial machinery and equipment (see 3210.01 and 02)
3313.13 Internal combustion engines (general)
3313.14 Machine tools and accessories
3313.15 Machine design
3313.16 Materials handling machinery (see 3328.15)
3313.17 Mechanized applications
3313.18 Mining machinery (see 3318)
3313.19 Nuclear machinery (see 3320)
3313.20 Papermaking machinery
3313.21 Petroleum extracting machinery (see 3321)
3313.22 Pneumatic equipment
3313.23 Power transmission equipment (mechanical) (see 3322.04)
3313.24 Printing and duplicating machinery
3313.25 Pumps and liquid handling equipment
3313.26 Refrigerating equipment (see 3309.22 and 3328.11)
3313.27 Specialized industrial machinery
3313.28 Steam engines
3313.29 Textile machinery (see 3326)
3313.30 Turbines
3313.31 Vending and service machinery
3313.99 Other (specify)

3314 Medical technology (see 3311.10)

3314.01 Artificial organs
3314.02 Prosthetic devices
3314.99 Other (specify)

3315 Metallurgical technology

3315.01 Aluminum
3315.02 Copper
3315.03 Electrometallurgical products
3315.04 Foundries (general)
3315.05 Iron and steel mills, foundries and forges
3315.06 Lead and zinc
3315.07 Metallurgical products (special)
3315.08 Metallurgical services
3315.09 Non-ferrous smelting, refining and processing
3315.10 Non-ferrous castings
3315.11 Powder metallurgy
3315.12 Precious metals
3315.13 Precision casting
3315.14 Radioactive metals
3315.15 Rare metals
3315.16 Refining, including zone refining
3315.17 Refractory metals (see 3312.11)
3315.99 Other (specify)

3316 Metal products technology

3316.01 Autoclaves and boilers (see 3316.10)
3316.02 Cans and containers
3316.03 Distilling equipment (see 3328.07)
3316.04 Electroplated and coated products (see 2210.05)
3316.05 Furnaces, ovens, kilns
3316.06 Hardware
3316.07 Machined, and turned products
3316.08 Metal fabrication services
3316.09 Pipes, fittings and valves (see 3328.20)
3316.10 Pressure vessels (see 3316.01)
3316.11 Sheet metal products
3316.12 Stampings
3316.13 Structural steel products
3316.14 Weldings
3316.15 Wire products
3316.99 Other (specify)

3317 Motor vehicle technology

3317.01 All terrain vehicles
3317.02 Automobiles
3317.03 Buses, lorries and trailers
3317.04 Diesel engines (see 3313.13)
3317.05 Motor cycles
3317.06 Motor transport services
3317.07 Parts and accessories
3317.08 Piston engines (see 3313.13)
3317.09 Rotating engines
3317.10 Traffic engineering (see 3305.13 and 3327.02)
3317.99 Other (specify)

3318 Mining technology (see 3313.18 and 5312.09)

3318.01 Coal mining (see 2506.02 and 3321.02)
3318.02 Concentration of ores (see 3228.11)
3318.03 Iron ores
3318.04 Mining services
3318.05 Non-ferrous metal ores
3318.06 Non-metallic minerals
3318.07 Quarry products
3318.08 Sulphur
3318.09 Uranium and radioactive ores
3318.99 Other (specify)

3319 Naval technology

3319.01 Air cushion devices (see 3301.07)
3319.02 Boats
3319.03 Inland waterway craft
3319.04 Marine auxiliaries
3319.05 Marine engines
3319.06 Marine transportation
3319.07 Merchant ships
3319.08 Naval architecture
3319.09 Ocean transport (see 3319.06)
3319.10 Propellers
3319.11 Shafting
3319.12 Shipbuilding
3319.13 Underwater craft (see 5603.04)
3319.99 Other (specify)

3320 Nuclear technology (see 2207 and 3313.19)

3320.01 Isotope applications (see 2207.13 and 20
3320.02 Isotope separation and 3328.12)
3320.03 Nuclear explosions
3320.04 Nuclear fission reactors (see 2207.18)
3320.05 Nuclear fusion reactors (see 2208.03)
3320.06 Nuclear tests
3320.99 Other (specify)

3321 Petroleum and coal technology (see 2506.02, 2506.12 and 3313.21)

3321.01 Asphaltic materials
3321.02 Coal chemicals (see 3318.01)
3321.03 Crude petroleum
3321.04 Gas pipelines
3321.05 Liquefied gas
3321.06 Lubricating oil and grease
3321.07 Natural gas

3321.08 Oilfield equipment
3321.09 Oilfield services
3321.10 Oil pipelines
3321.11 Petrochemicals
3321.12 Petroleum products: petrol, oils, waxes
3321.13 Refinery's Design
3321.14 Storage (oil and gas)
3321.99 Other (specify)

3322 Power technology (see 2212.03 and 5312.05)

3322.01 Power distribution
3322.02 Power generation
3322.03 Power generators
3322.04 Power transmission (see 3313.23)
3322.05 Unconventional sources of energy (see 2106.01 and 2506.08)
3322.99 Other (specify)

3323 Railway technology (see 3305.27)

3323.01 Locomotives
3323.02 Railroad equipment
3323.03 Railway services
3323.04 Rapid transit
3323.05 Rolling stock
3323.99 Other (specify)

3324 Space technology (see 2512 and 5603.03)

3324.01 Artificial satellites (see 2504.07, 2509.16 and 3325.06)
3324.02 Missiles: launching and recovery
3324.03 Missile facilities
3324.04 Rocket engines
3324.05 Space craft
3324.06 Space tracking
3324.07 Vehicle control
3324.99 Other (specify)

3325 Telecommunications technology (see 2202, 2203, 3307 and 5312.12)

3325.01 Broadcasting, sound and television (see 3307.02)
3325.02 Cable television
3325.03 Cinematography (see 2209.02, 3311.12 and 6203.01)
3325.04 Microwave links (see 3307.08)
3325.05 Radiocommunications (see 3307.11 and 12)
3325.06 Satellite communications (see 3324.01)
3325.07 Telegraph
3325.08 Telephone
3325.09 Television (see 3307.20 and 21)
3325.99 Other (specify)

3326 Textile technology (see 3313.29)

3326.01 Cotton
3326.02 Flax
3326.03 Jute
3326.04 Spinning
3326.05 Synthetic textiles (see 2304.24)
3326.06 Weaving
3326.07 Wool
3326.99 Other (specify)

3327 Transportation systems technology (see 3329.07 and 5312.12)

3327.01 Airlines operations, air-traffic control
3327.02 Traffic analysis (see 3317.10)
3327.03 Urban Transit systems (see 3305.37 and 6201.03)
3327.04 Combinations of systems
3327.99 Other (specify)

3328 Unit operations technology

3328.01 Absorption
3328.02 Agitation
3328.03 Centrifugation
3328.04 Compressing (see 3313.02)
3328.05 Crystallisation
3328.06 Deionisation (see 3303.08)
3328.07 Distillation and condensation (see 3316.03)
3328.08 Drying
3328.09 Evaporation
3328.10 Filtration
3328.11 Flotation (see 3318.02)
3328.12 Flow through porous media
3328.13 Fluidization of solids
3328.14 Freeze-drying (see 3309.16)
3328.15 Handling of solids (see 3313.16)
3328.16 Heat transfer (see 3313.10)
3328.17 Liquid-liquid extraction
3328.18 Mass transfer
3328.19 Mixing
3328.20 Pipes, fittings and valves (see 3316.09)
3328.21 Pumping (see 3313.25)
3328.22 Screening
3328.23 Sedimentation
3328.24 Size-reduction
3328.25 Solid-liquid extraction
3328.26 Refrigeration (see 2213.06, 3309.22 and 3313.26)
3328.27 Vapor-liquid transfer
3328.99 Other (specify)

3329 Urban Planning

3329.01 Building codes (see 3305.28)
3329.02 Communications
3329.03 Community organization
3329.04 Land Use
3329.05 Regional development
3329.06 Sanitary services
3329.07 Transportation (see 3327)
3329.08 Urban environment
3329.09 Urban-rural relations (see 6311.04 and 06)
3329.99 Other (specify)

3399 Other Technological specialities (specify)

51. ANTHROPOLOGY (see 2402)

5101 Cultural anthropology

5101.01 Adornment
5101.02 Clothing
5101.03 Dances, feasts (see 6203.02)
5101.04 Ethno-musicology
5101.05 Ethnolinguistics
5101.06 Museology
5101.07 Myths
5101.08 Magic
5101.09 Poems, stories
5101.10 Religion (see 5403.04, 5506.20, 5601, 5906.05, 6301.10, 7102.05 and 7204.04)
5101.11 Sorcery
5101.12 Symbolism (see 6308.03)
5101.13 Traditional medicine (see 3209.04)
5101.14 Tradition
5101.99 Other (specify)

5102 Ethnography and Ethnology

5102.01 Agriculture
5102.02 Arms
5102.03 Barter
5102.04 Exchange
5102.05 Habitat
5102.06 Handicraft
5102.07 Hunting
5102.08 Fishing
5102.09 Foraging
5102.10 Metallurgy
5102.11 Stockraising
5102.99 Other (specify)

5103 Social anthropology

5103.01 Chiefdom, royalty
5103.02 Descent, family, kinship
5103.03 Nomadism
5103.04 Slavery, bondage
5103.05 War (see 6304.03)
5103.99 Other (specify)

5199 Other anthropological specialities (specify)

52. DEMOGRAPHY

5201 Fertility

- 5201.01 Birth rate
- 5201.02 General fertility
- 5201.03 Illegitimacy
- 5201.04 Marriage rate (see 6309.04)
- 5201.05 Sterility and fecundity
- 5201.99 Other (specify)

5202 General demography

- 5202.01 Methodology of research
- 5202.02 Methodology of analysis
- 5202.03 Theory
- 5202.99 Other (specify)

5203 Geographical demography (see 5403.02)

- 5203.01 Internal mobility and migrations
- 5203.02 International mobility and migrations
- 5203.03 Local demography
- 5203.04 Regional demography
- 5203.05 Rural demography
- 5203.06 Urban demography
- 5203.99 Other (specify)

5204 Historical demography

- 5204.01 Fertility and marriage rate
- 5204.02 Methodological aspects
- 5204.03 Migrations
- 5204.04 Mortality
- 5204.05 Sources of observation
- 5204.06 Theoretical aspects
- 5204.99 Other (specify)

5205 Mortality

- 5205.01 Causes of mortality
- 5205.02 General mortality
- 5205.03 Infant mortality
- 5205.04 Prenatal and perinatal mortality
- 5205.05 Related variables
- 5205.99 Other (specify)

5206 Population characteristics

- 5206.01 Active population
- 5206.02 Age distribution
- 5206.03 Ageing of the population
- 5206.04 Biological characteristics (see 2402.10)
- 5206.05 Epidemiological characteristics
- 5206.06 General demographic structures
- 5206.07 Morbidity
- 5206.08 Population genetics (see 2409.03)
- 5206.09 Sex
- 5206.10 Socio-economic characteristics
- 5206.99 Other (specify)

5207 Population size and demographic evolution

- 5207.01 Computational demography (see 1203)
- 5207.02 Demographic transition
- 5207.03 Observational demography
- 5207.04 Population censuses and other data collection
- 5207.05 Population estimates
- 5207.06 Population forecasts
- 5207.07 Population growth
- 5207.08 Population models
- 5207.09 Population projections
- 5207.10 Statistics of population (see 1209)
- 5207.99 Other (specify)

5299 Other demographic specialities (specify)

53. ECONOMIC SCIENCES

5301 Domestic fiscal policy and public finance

- 5301.01 Fiscal policy and public debt
- 5301.02 Public finance (budget)
- 5301.99 Other (specify)

5302 Econometrics

- 5302.01 Economic indicators
- 5302.02 Econometric models
- 5302.03 Economic projection
- 5302.04 Economic statistics (see 1209)
- 5302.05 Economic time-series
- 5302.99 Other (specify)

5303 Economic accounting

- 5303.01 Financial accounts
- 5303.02 National wealth and balance sheets
- 5303.03 National income accounting
- 5303.04 Input - output
- 5303.05 Social accounts
- 5303.99 Other (specify)

5304 Economic activity

- 5304.01 Consumption, savings, investment
- 5304.02 Distribution
- 5304.03 Domestic trade
- 5304.04 Foreign trade (see 5310.09)
- 5304.05 Insurance
- 5304.06 Money and banking
- 5304.07 Production
- 5304.08 Re-distribution
- 5304.99 Other (specify)

5305 Economic systems

- 5305.01 Capitalist economic systems
- 5305.02 Collectivist economic systems
- 5305.03 Comparative economic systems
- 5305.04 Socialist economic systems
- 5305.99 Other (specify)

5306 Economics of technological change (see 6407.07)

- 5306.01 Economics of research and experimental development (see 5312.10)
- 5306.02 Technological innovation
- 5306.03 Transfer of technology
- 5306.99 Other (specify).

5307 Economic theory

- 5307.01 Capital formation
- 5307.02 Credit theory
- 5307.03 Economic development models and theories
- 5307.04 Economic development studies
- 5307.05 Economic equilibrium
- 5307.06 Economic fluctuations
- 5307.07 Economic forecasting
- 5307.08 Economic growth theory
- 5307.09 Economic planning theory
- 5307.10 Employment theory and models
- 5307.11 Fiscal theory
- 5307.12 International trade theory (see 5310.09)
- 5307.13 Investment theory
- 5307.14 Macro-economic theory
- 5307.15 Micro-economic theory
- 5307.16 Monetary theory
- 5307.17 Savings theory
- 5307.18 Stabilisation theories
- 5307.19 Welfare theory
- 5307.99 Other (specify)

5308 General economics

- 5308.01 Economic methodology
- 5308.02 Consumer Behaviour (see 6114.06)
- 5308.03 History of economic thought (see 5506.06)
- 5308.99 Other (specify)

5309 Industrial organization and public policy

- 5309.01 Economic concentration
- 5309.02 Economic integration
- 5309.03 Government regulation of the private sector
- 5309.04 Market structure
- 5309.05 Monopoly and competition
- 5309.06 Public enterprises
- 5309.07 Public utilities
- 5309.99 Other (specify)

5310 International economics

- 5310.01 Balance of payments
- 5310.02 Foreign aid
- 5310.03 International aid

5310.04 International business
5310.05 International economic policy
5310.06 International finance
5310.07 International investment
5310.08 International monetary arrangements
5310.09 International trade relations (see 5307.12)
5310.99 Other (specify)

5311 Organization and management of enterprises (see 3310)

5311.01 Advertising (see 6114.01)
5311.02 Financial management
5311.03 Industry studies
5311.04 Manpower management
5311.05 Marketing
5311.06 Market studies
5311.07 Operations research
5311.08 Optimum production levels
5311.09 Organization of production (see 3310.07)
5311.10 Sales management
5311.99 Other (specify)

5312 Sectorial economics

5312.01 Agriculture, forestry, fishing (see 3103, 3105, 3106)
5312.02 Community, social and personal services
5312.03 Construction (see 3305)
5312.04 Education (see 5802.03)
5312.05 Energy (see 3322)
5312.06 Finance and insurance
5312.07 Health
5312.08 Manufacturing
5312.09 Mining (see 3318)
5312.10 Research and development (see 5306.01)
5312.11 Trade and commerce
5312.12 Transport and communication (see 3325 and 3327)
5312.99 Other (specify)

5399 Other economic specialities (specify)

54. GEOGRAPHY

5401 Economic geography

5401.01 Distribution of natural resources
5401.02 Geography of economic activities
5401.03 Land utilisation (see 2505.04)
5401.04 Regional development
5401.99 Other (specify)

5402 Historical geography

5403 Human geography (see 2505.01)

5403.01 Cultural geography
5403.02 Demo-geography (see 5203)
5403.03 Linguistic geography (see 5703)
5403.04 Geography of religion (see 5101.10)
5403.05 Political geography
5403.06 Social geography
5403.99 Other (specify)

5404 Regional geography

5404.01 Urban geography
5404.02 Rural geography
5404.99 Other (specify)

5499 Other geographical specialities (specify)

55. HISTORY

5501 Biographies

5502 General history

5502.01 Comparative history
5502.02 Historiography
5502.03 Historical monographs
5502.04 Theories and methods
5502.99 Other (specify)

5503 History of countries

5503.01 Local history
5503.02 Regional history
5503.99 Other (specify)

5504 History by epochs

5504.01 Ancient history
5504.02 Contemporary history
5504.03 Mediaeval history
5504.04 Modern history
5504.05 Prehistory
5504.99 Other (specify)

5505 Sciences auxiliary to history

5505.01 Archaeology
5505.02 Ceramology
5505.03 Epigraphy
5505.04 Heraldry
5505.05 Iconography
5505.06 Numismatics
5505.07 Onomastics
5505.08 Palaeography
5505.09 Papyrology
5505.10 Philology (see 5702)
5505.11 Sigillography
5505.12 Stratigraphy (see 2506.19)
5505.99 Other (specify)

5506 Specialized histories

5506.01 History of architecture
5506.02 History of art
5506.03 History of astronomy
5506.04 History of biology
5506.05 History of chemistry
5506.06 History of economics (see 5308.03)
5506.07 History of education
5506.08 History of geography
5506.09 History of geology
5506.10 History of international relations
5506.11 History of journalism
5506.12 History of law and legal institutions
5506.13 History of literature
5506.14 History of linguistics (see 5602)
5506.15 History of logic
5506.16 History of the magistrature
5506.17 History of medicine
5506.18 History of philosophy (see 7207.02)
5506.19 History of physics
5506.20 History of political ideas
5506.21 History of religions (see 5101.10 and 7204.04)
5506.22 History of science
5506.23 History of sociology (see 6303.02)
5506.24 History of technology
5506.25 History of war (see 6304.03)
5506.99 Other (specify)

5599 Other historical specialities (specify)

56. JURIDICAL SCIENCES & LAW

5601 Canon law (see 5101.10)

5602 General theory and methods

5602.01 Common law
5602.02 Comparative law
5602.03 Jurisprudence
5602.04 Law of antiquity
5602.05 Natural law
5602.06 Statute law
5602.99 Other (specify)

5603 International law

5603.01 Aviation law
5603.02 Maritime law
5603.03 Outer-space law
5603.04 Sea-bed law (see 2510.06)
5603.99 Other (specify)

5604 Legal organization

- 5604.01 Court officials and procedures
- 5604.02 Magistrature
- 5604.03 Tribunals
- 5604.99 Other (specify)

5605 National law and legislation

- 5605.01 Administrative law
- 5605.02 Civil law
- 5605.03 Commercial law
- 5605.04 Constitutional law
- 5605.05 Criminal law
- 5605.06 Fiscal law
- 5605.07 Public legislation
- 5605.08 Private law
- 5605.99 Other (specify)

5699 Other juridical specialities (specify)

57. LINGUISTICS

5701 Applied linguistics

- 5701.01 Abstracting
- 5701.02 Automated documentation
- 5701.03 Bilinguism
- 5701.04 Computational linguistics (see 1203)
- 5701.05 Documentary languages
- 5701.06 Documentation
- 5701.07 Language and literature
- 5701.08 Language of children
- 5701.09 Machine translation
- 5701.10 Speech pathology and correction (see 2201.08 and 6102.05)
- 5701.11 Teaching of languages
- 5701.12 Translation
- 5701.99 Other (specify)

5702 Diachronic linguistics

- 5702.01 Historical linguistics (see 5505.10)
- 5702.02 Etymology
- 5702.99 Other (specify)

5703 Linguistic geography (see 5403.03)

5704 Linguistic theory

5705 Synchronic linguistics

- 5705.01 Comparative linguistics
- 5705.02 Ethnolinguistics
- 5705.03 Lexicography
- 5705.04 Lexicology
- 5705.05 Phonetics
- 5705.06 Phonology (see 2201.08, 2411.14 and 15)
- 5705.07 Psycholinguistics (see 6104.04)
- 5705.08 Semantics
- 5705.09 Semiology
- 5705.10 Sociolinguistics (see 6308.02)
- 5705.11 Spelling
- 5705.12 Stylistics (style and rhetoric) (see 6202.03 and 05)
- 5705.13 Syntax, syntactic analysis
- 5705.99 Other (specify)

5799 Other linguistic specialities (specify)

58. PEDAGOGY

5801 Educational theory and methods

- 5801.01 Audio-visual methods
- 5801.02 Comparative pedagogy
- 5801.03 Curriculum development
- 5801.04 Educational theories (see 6104.03)
- 5801.05 Experimental pedagogy
- 5801.06 Pupil and student assessment
- 5801.07 Pedagogical methods (see 6104.02)
- 5801.08 Programmed instruction
- 5801.99 Other (specify)

5802 Organization and planning of education

- 5802.01 Adult education
- 5802.02 Educational institutions; organization and management
- 5802.03 Educational planning and financing (see 5312.04)
- 5802.04 Levels and subjects of education
- 5802.05 Special education; handicapped, mentally retarded (see 6102.03 and 6103.05)
- 5802.06 Statistical analysis, modelling and projection (see 1209)
- 5802.07 Vocational education and training
- 5802.99 Other (specify)

5803 Teacher training and employment

- 5803.01 Career and status of teachers
- 5803.02 Training of teachers
- 5803.99 Other (specify)

5899 Other pedagogical specialities (specify)

59. POLITICAL SCIENCE

5901 International relations (see 7103.05)

- 5901.01 International co-operation
- 5901.02 International organizations
- 5901.03 International politics
- 5901.04 International treaties and agreements
- 5901.05 Problems of international relations (see 6304)
- 5901.99 Other (specify)

5902 Policy sciences (see 6112.03)

- 5902.01 Agricultural policy
- 5902.02 Cultural policy
- 5902.03 Commercial policy
- 5902.04 Communications policy
- 5902.05 Demographic policy
- 5902.06 Economic policy
- 5902.07 Educational policy
- 5902.08 Environmental policy
- 5902.09 Foreign policy
- 5902.10 Health policy
- 5902.11 Industrial policy
- 5902.12 Information policy
- 5902.13 Policy planning
- 5902.14 Science and technology policy
- 5902.15 Social policy
- 5902.16 Transport policy
- 5902.99 Other (specify)

5903 Political ideologies (see 7207.04 and 05)

5904 Political institutions

- 5904.01 Executive power
- 5904.02 Judiciary power
- 5904.03 Legislative power
- 5904.04 Relations between the powers
- 5904.99 Other (specify)

5905 Political life

- 5905.01 Elections
- 5905.02 Political behaviour
- 5905.03 Political groups
- 5905.04 Political leadership
- 5905.05 Political movements
- 5905.06 Political parties
- 5905.99 Other (specify)

5906 Political sociology

- 5906.01 Human rights
- 5906.02 Languages
- 5906.03 Minorities
- 5906.04 Race (see 6310.06)
- 5906.05 Religion (see 5101.10, 6301.10 and 7204.04)
- 5906.06 Social conflicts (see 6310.10)
- 5906.99 Other (specify)

5907 Political systems

5908 Political theory

5909 Public administration

- 5909.01 Administrative management
- 5909.02 Central institutions
- 5909.03 Civil service
- 5909.04 Public services
- 5909.05 Regional institutions
- 5909.99 Other (specify)

5910 Public opinion (see 6114.15)

- 5910.01 Information
- 5910.02 Mass media
- 5910.03 Press (see 3313.24)
- 5910.04 Propaganda
- 5910.99 Other (specify)

5999 Other political science specialities (specify)

61. PSYCHOLOGY

6101 Abnormal psychology (see 3211)

- 6101.01 Behaviour disorders
- 6101.02 Deviant behaviour
- 6101.03 Mental deficiency
- 6101.04 Psychopathology (see 3201.05, 3211 and 6103)
- 6101.99 Other (specify)

6102 Adolescent and child psychology

- 6102.01 Development psychology
- 6102.02 Learning disabilities
- 6102.03 Mental retardation (see 5802.05 and 6103.05)
- 6102.04 School psychology
- 6102.05 Speech pathology (see 2201.08 and 5701.10)
- 6102.99 Other (specify)

6103 Counselling and guidance (see 3211)

- 6103.01 Behaviour therapy
- 6103.02 Consulting psychology
- 6103.03 Educational counselling and guidance
- 6103.04 Group therapy
- 6103.05 Mental retardation (see 6102.03)
- 6103.06 Psychoanalysis (see 3211)
- 6103.07 Psychotherapy (see 3201.05 and 3211)
- 6103.08 Rehabilitation
- 6103.09 Vocational guidance
- 6103.99 Other (specify)

6104 Educational psychology

- 6104.01 Cognitive functioning
- 6104.02 Educational methods (see 5801.07)
- 6104.03 Laws of learning (see 5801.04)
- 6104.04 Psycholinguistics (see 5705.07)
- 6104.99 Other (specify)

6105 Evaluation and measurement in psychology

- 6105.01 Differential psychology
- 6105.02 Experimental design
- 6105.03 Measurement theory
- 6105.04 Statistics (see 1209)
- 6105.05 Psychometrics
- 6105.06 Scale analysis
- 6105.07 Test construction
- 6105.08 Test theory
- 6105.09 Test validation
- 6105.99 Other (specify)

6106 Experimental psychology

- 6106.01 Brain function
- 6106.02 Comparative psychology
- 6106.03 Emotion
- 6106.04 Experimental analysis of behaviour
- 6106.05 Levels of function
- 6106.06 Memory processes
- 6106.07 Mental processes
- 6106.08 Motivation
- 6106.09 Perception processes
- 6106.10 Physiological psychology
- 6106.11 Reaction, reflexes
- 6106.12 Sensory processes
- 6106.99 Other (specify

6107 General psychology

- 6107.01 Methodology
- 6107.02 Theory and systems
- 6107.99 Other (specify)

6108 Geriatric psychology (see 3201.07)

- 6108.01 Death
- 6108.02 Maturity
- 6108.03 Senescence
- 6108.99 Other (specify)

6109 Occupational and personnel psychology

- 6109.01 Accident prevention
- 6109.02 Attitudes and morale
- 6109.03 Job design and evaluation
- 6109.04 Labour/management relations
- 6109.05 Organizational behaviour
- 6109.06 Personnel selection
- 6109.07 Performance evaluation
- 6109.99 Other (specify)

6110 Parapsychology

- 6110.01 Extra-sensory perception
- 6110.02 Hypnosis
- 6110.99 Other (specify)

6111 Personality

- 6111.01 Creativity
- 6111.02 Culture and personality
- 6111.03 Personality development
- 6111.04 Personality measurement
- 6111.05 Structure and dynamics of personality
- 6111.06 Theory of personality
- 6111.99 Other (specify)

6112 Psychological study of social issues

- 6112.01 Discrimination
- 6112.02 Minority group phenomena
- 6112.03 Public policy (see 5902)
- 6112.99 Other (specify)

6113 Psychopharmacology (see 3209.09)

- 6113.01 Alcoholism (see 3309.01)
- 6113.02 Behavioural response
- 6113.03 Drug abuse
- 6113.04 Drug function (see 3208.02)
- 6113.05 Drug therapy
- 6113.99 Other (specify)

6114 Social psychology (see 6302.02)

- 6114.01 Advertising (see 5311.01)
- 6114.02 Attitudes
- 6114.03 Collective behaviour
- 6114.04 Community psychology
- 6114.05 Conflict resolution (see 6304.02)
- 6114.06 Consumer behaviour (see 5308.02)
- 6114.07 Culture and personality
- 6114.08 Decision processes and theory
- 6114.09 Forensic psychology (see 3203)
- 6114.10 Group interaction
- 6114.11 Group processes
- 6114.12 Leadership
- 6114.13 Marketing
- 6114.14 Political behaviour
- 6114.15 Public opinion (see 5910)
- 6114.16 Rôle behaviour
- 6114.17 Social perceptions and movements
- 6114.18 Symbolic communication
- 6114.99 Other (specify)

6199 Other psychological specialities (specify)

62. SCIENCES OF ARTS & LETTERS

6201 Architecture

- 6201.01 Architectural design (see 3305.01)
- 6201.02 Parks and gardens
- 6201.03 Urbanism (see 3305.37 and 3327.03)
- 6201.99 Other (specify)

6202 Literary theory, analysis and criticism

- 6202.01 Criticism of texts
- 6202.02 Literary analysis
- 6202.03 Literary style and aesthetics (see 5705.12)
- 6202.04 Literary vocabulary
- 6202.05 Rhetoric (see 5705.12)
- 6202.99 Other (specify)

6203 Fine arts theory, analysis and criticism

- 6203.01 Cinematography (see 2209.02 and 3311.12 and 3325.03)
- 6203.02 Dance, choreography (see 5101.03)
- 6203.03 Decorative arts
- 6203.04 Drawing, engraving
- 6203.05 Fine art aesthetics
- 6203.06 Music, musicology (see 2201.04 and 5101.06)
- 6203.07 Painting
- 6203.08 Photography (see 2209.17 and 3311.12)
- 6203.09 Sculpture
- 6203.10 Theatre
- 6203.99 Other (specify)

6299 Other artistical specialities (specify)

63. SOCIOLOGY

6301 Cultural sociology

- 6301.01 Cultural evolution
- 6301.02 Cultural relations
- 6301.03 Folklore
- 6301.04 Inter-ethnic relations
- 6301.05 Language and culture
- 6301.06 National characters and civilisation
- 6301.07 Sociology of art
- 6301.08 Sociology of law (see 6306.06)
- 6301.09 Sociology of literature
- 6301.10 Sociology of religion (see 5101.10 and 6301.10)
- 6301.99 Other (specify)

6302 Experimental sociology

- 6302.01 Field data collection
- 6302.02 Social psychology (see 6114)
- 6302.03 Social survey design
- 6302.04 Social survey methods
- 6302.99 Other (specify)

6303 General sociology

- 6303.01 Comparative sociology
- 6303.02 Historical sociology (see 5506.23)
- 6303.03 Methodology
- 6303.04 Sociography
- 6303.05 Theory
- 6303.99 Other (specify)

6304 International disorganization (see 5901.05)

- 6304.01 Conflicts
- 6304.02 Conflict resolution (see 6114.05)
- 6304.03 War and peace (see 5103.05 and 5506.25)
- 6304.99 Other (specify)

6305 Mathematical sociology

- 6305.01 Measurement and index construction
- 6305.02 Model building
- 6305.03 Statistical analysis (see 1209)
- 6305.99 Other (specify)

6306 Occupational sociology

- 6306.01 Bureaucracy
- 6306.02 Educational sociology (see 6306.05)
- 6306.03 Industrial sociology
- 6306.04 Medical sociology
- 6306.05 Sociology of education (see 6306.02)
- 6306.06 Sociology of law (see 6301.08)
- 6306.07 Sociology of mass-media
- 6306.08 Sociology of science (see 7102.05)
- 6306.99 Other (specify)

6307 Social change and development

- 6307.01 Evolution of societies
- 6307.02 Developing countries
- 6307.03 Social policy
- 6307.04 Social security
- 6307.05 Social services
- 6307.06 Socio-economic development
- 6307.07 Technology and social change (see 5306)
- 6307.99 Other (specify)

6308 Social communications

- 6308.01 Signs
- 6308.02 Sociolinguistics (see 5705.10)
- 6308.03 Symbols (see 5101.12)
- 6308.99 Other (specify)

6309 Social groups

- 6309.01 Casts
- 6309.02 Elites
- 6309.03 Family, kinship
- 6309.04 Marriage (see 5201.04)
- 6309.05 Social classes
- 6309.06 Social mobility
- 6309.07 Social stratification
- 6309.08 Tribes
- 6309.09 Woman's status
- 6309.99 Other (specify)

6310 Social problems - Social disorganization

- 6310.01 Crime
- 6310.02 Delinquency
- 6310.03 Disease
- 6310.04 Famine
- 6310.05 Handicapped
- 6310.06 Inter-racial relations (see 2402.13, 5906.04)
- 6310.07 Maladjusted
- 6310.08 Poverty
- 6310.09 Quality of life
- 6310.10 Social conflict and accommodation (see 5906.06)
- 6310.11 Social welfare
- 6310.12 Standard of living
- 6310.13 Terrorism
- 6310.14 Unemployment
- 6310.99 Other (specify)

6311 Sociology of human settlements

- 6311.01 Community studies
- 6311.02 Ecological sociology
- 6311.03 Local sociology
- 6311.04 Rural sociology (see 3329.09)
- 6311.05 Slums
- 6311.06 Urban sociology (see 3329.09)
- 6311.99 Other (specify)

6399 Other sociological specialities (specify)

71. ETHICS

7101 Classical ethics

7102 Ethics of individuals

- 7102.01 Codes of values
- 7102.02 Codes of ethical conduct
- 7102.03 Motivation
- 7102.04 Philosophical ethics
- 7102.05 Religious ethics (see 5101.10)
- 7102.99 Other (specify)

7103 Group ethics

- 7103.01 International Declarations
- 7103.02 National ethics
- 7103.03 Economic ethics
- 7103.04 Ethics of science (see 6306.08)
- 7103.05 Transnational ethics (see 5901)
- 7103.99 Other (specify)

7104 Prospective ethics

7199 Other specialities relating to ethics (specify)

72. PHILOSOPHY

7201 Philosophy of knowledge

- 7201.01 Aporetics
- 7201.02 Epistemology
- 7201.03 Theory of concept
- 7201.04 Theory of judgement
- 7201.05 Theory of perception
- 7201.06 Theory of reason
- 7201.99 Other (specify)

7202 Philosophical anthropology

- 7202.01 Esthetics
- 7202.02 Hermeneutics
- 7202.03 Mind-body problem
- 7202.04 Philosophy of action
- 7202.05 Philosophy of imagination
- 7202.06 Philosophy of intersubjectivity
- 7202.07 Philosophy of language
- 7202.08 Philosophy of will
- 7202.99 Other (specify)

7203 General philosophy

- 7203.01 Dialectical logic
- 7203.02 Dialectical materialsim
- 7203.03 Metaphysics, ontology
- 7203.04 Natural theology
- 7203.99 Other (specify)

7204 Philosophical systems

- 7204.01 Ancient philosophy
- 7204.02 Modern philosophy
- 7204.03 Present-day philosophy
- 7204.04 Theologico-philosophical systems (see 5101.10, 5506.21 and 5906.05)
- 7204.99 Other (specify)

7205 Philosophy of science

- 7205.01 Philosophy of biology
- 7205.02 Philosophy of logic
- 7205.03 Philosophy of mathematics
- 7205.04 Philosophy of physics
- 7205.05 Philosophy of the social sciences
- 7205.99 Other (specify)

7206 Philosophy of nature

- 7206.01 Philosophy of life
- 7206.02 Philosophy of matter
- 7206.03 Philosophy of space and time
- 7206.99 Other (specify)

7207 Social philosophy

- 7207.01 Philosophy of culture
- 7207.02 Philosophy of history (see 5506.18)
- 7207.03 Philosophy of techniques
- 7207.04 Political philosophy (see 5903)
- 7207.05 Theory of ideologies (see 5903)
- 7207.99 Other (specify)

7208 Philosophical doctrines

7299 Other philosophical specialities (specify)

ANNEX 3.4

Nomenclature of Scientific and Technological Institutions[1]

A. NATIONAL POLICY-MAKING BODIES IN SCIENCE AND TECHNOLOGY

1. Central science policy-making body.

   National body for overall science policy-planning centre for survey of national scientific and technological potential (STP).

2. R&D promoting and co-ordinating bodies (including academies of science and engineering).

   National body for planning and co-ordination of R&D in basic sciences.
   National body for planning and co-ordination of agricultural research.
   National body for planning and co-ordination of industrial research.
   National body for planning and co-ordination of medical research.
   National body for atomic energy research.
   National body for social sciences research.

B. HIGHER EDUCATION INSTITUTIONS IN SCIENCE AND TECHNOLOGY

1. Science faculties in universities.

   University faculties of basic sciences.
   University departments in the classical disciplines of the basic sciences.
   Interdisciplinary university departments in the basic sciences.

2. "Third level" polytechnic schools and schools of engineering (including university faculties of applied sciences or technology).

   "Third level" polytechnic schools and schools of engineering specialized departments in "third level" polytechnic schools or schools of engineering.

3. "Third level" schools of agriculture (including university faculties of agronomy).

   "Third level" schools of agriculture.
   Specialized departments in "third level" schools of agriculture.

4. Schools or university faculties of medicine.

   "Third level" schools of medicine.
   Specialized departments in "third level" schools of medicine.

C. TECHNICIAN TRAINING INSTITUTIONS

1. Technological training institutions.

   General "second level" technician training institutions.
   Specialized "second level" technician training institutions.

2. Agricultural training institutions.

   General "second level" agricultural technician training institutions.
   Specialized "second level" agricultural technician training institutions.

3. Medical training institutions.

   General "second level" training institutions for auxiliary medical research.
   Specialized "second level" training institutions for auxiliary medical personnel.

D. RESEARCH AND EXPERIMENTAL DEVELOPMENT INSTITUTIONS

(R&D performers)

1. Fundamental research institutes.

   University-linked institutes for fundamental research.
   Autonomous fundamental research institutes.

2. Applied research and experimental development institutes.

   Agricultural research institutes.
   Industrial or technological research institutes.
   Medical research institutes.
   Atomic energy research institutes.
   Multipurpose (specify) R&D institutes.

E. SCIENTIFIC AND TECHNOLOGICAL PUBLIC SERVICE (STS)

1. Natural resources and environment services.

   Topographic and scientific mapping services.
   Hydrology or water supply services.
   Geological survey and mining services.
   Energy services (such as water, fuel, wind, solar, geothermal, atomic, tidal etc.).

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1. This nomenclature is taken from the "Plan for Annotated International Summaries in the Field of Science and Technology". See the World Plan of Action UN, 1971, pp. 89-91.

Soil sciences services.
Services for integrated land-systems surveys (including land resources analysis and conservation).
Marine and fisheries services.
Meteorological services.
Astronomical and time services.
Seismological and vulcanological services.

2. Information and documentation services.

   National scientific and technological information centres.
   Industrial information centres.
   Data banks and information processing services.
   National science and technology library.
   Scientific journals, bulletins and abstracts.
   Patent offices and clearing houses for available patents.
   Scientific conference centres.

3. Museums and collections.

   Science and/or technology museums.
   Travelling science and/or technology exhibits.
   Scientific collections (anthropological, archaeological, geological, botanical, zoological, entomological, etc.).

4. Standards, norms and instrumentation.

   National bureaux of standards.
   National metrology services.
   National centres for the manufacture, loan and maintenance of scientific instruments.

5. Extension and innovation services.

   Agricultural services (such as land-use development, rural engineering, agricultural extension work, forestry and livestock services, etc.).
   Technological transfer and innovation services.
   University polyclinics.

Annex 4

Standard format of report

1. Introduction

A brief introduction should give indications on the aim of the exercise, its sponsor, its use in the overall planning and budgeting procedure, and so on.

2. Methodology

A brief description will be made of the method used for determining priorities (with reference as required to more elaborate discussions of the method), and of the specific working hypotheses adopted (i.e. nomenclatures used for disciplines and objectives, with all supporting information).

3. Conduct of the exercise

A description will be made of the organization of the sessions, with the identification of the panelists, their subject coverage, etc.

4. Results

A presentation will be made of the various charts and diagrams mentioned in section 3.1.3. (10), with comments as appropriate on the significance of these formal results.

5. Capability

An assessment will be made of the capability in the country in each of the priority areas mentioned under Part 4 above.

6. Conclusions

Conclusions will be drawn as to priority actions needed in building up the scientific and technological potential, especially institutions.

Annexes

1. List of participants.
2. List of objectives.
3. List of disciplines.
4. The filled in matrices (D/D, S/D, S/S).

Annex 5

Sample working forms

Three types of forms required in an exercise are shown in the following. The first type is used by panelists when they fill in their portion of the matrix. The two other forms are used by the moderator to compile results and present them in global form.

Noms/Names

Sous-matrice remplie par/
Sub-matrix filled in by :

S	
D	

Sous-groupe/Sub-panel

Matrice/Matrix

D/D

S/D

S/S

Priorité/Priority

Référence/Reference

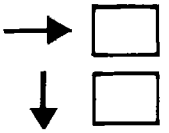
Poids/Weights

Sous-groupe/Sub-panel

Dépendance/Dependence

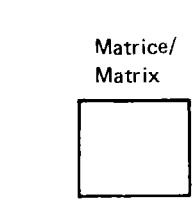
Totaux/Totals

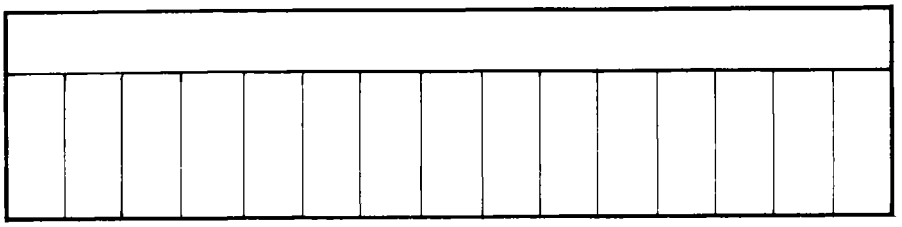
compilation

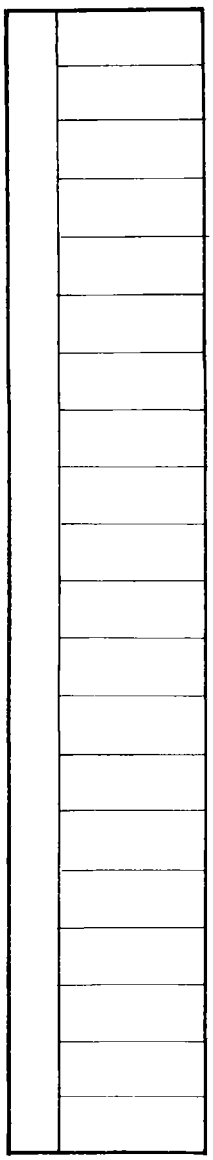


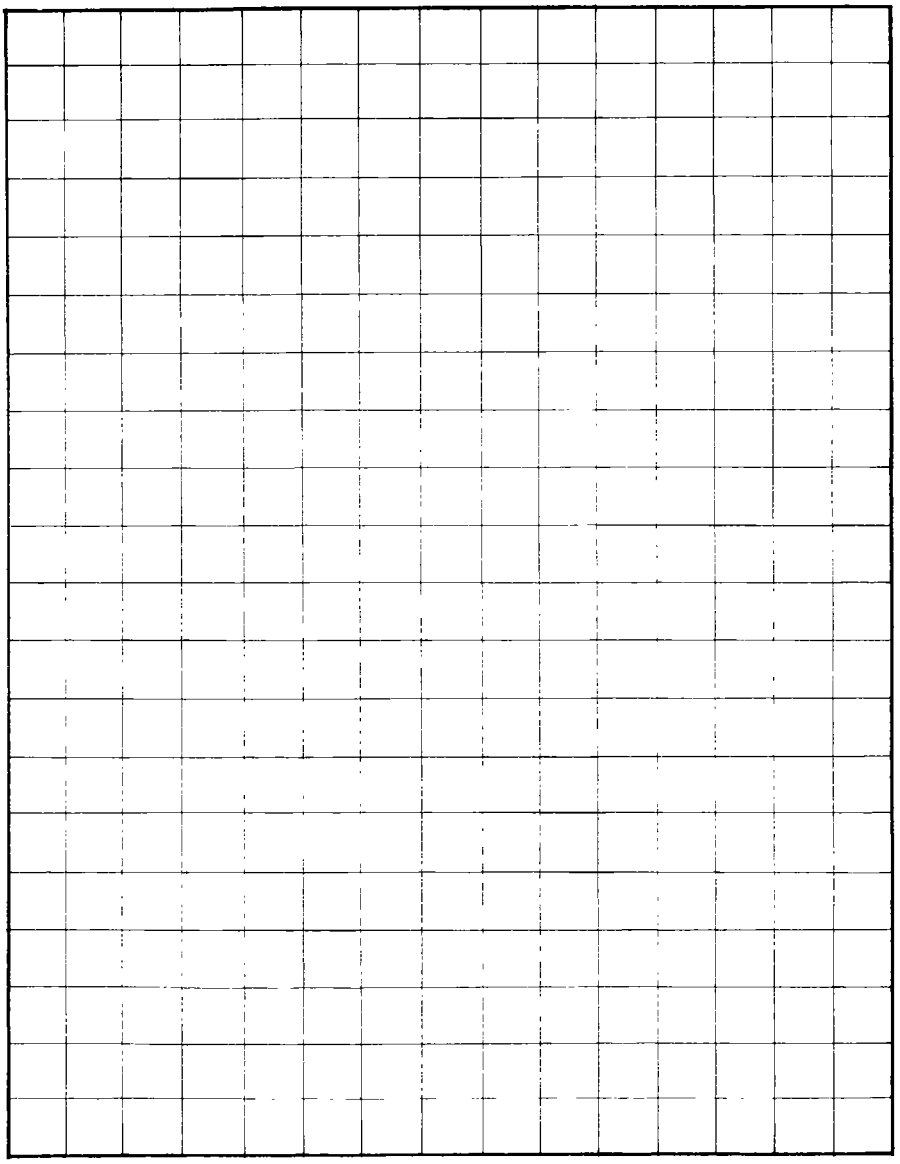
de/of

Matrice/
Matrix

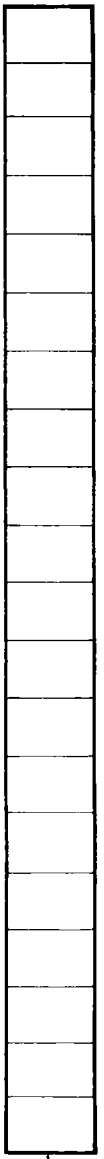




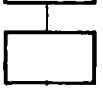


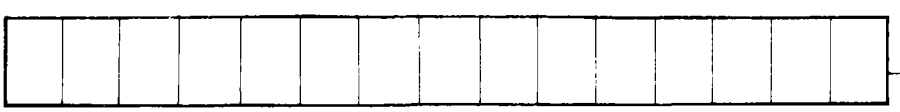


P



R





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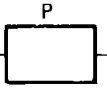

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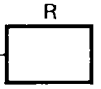
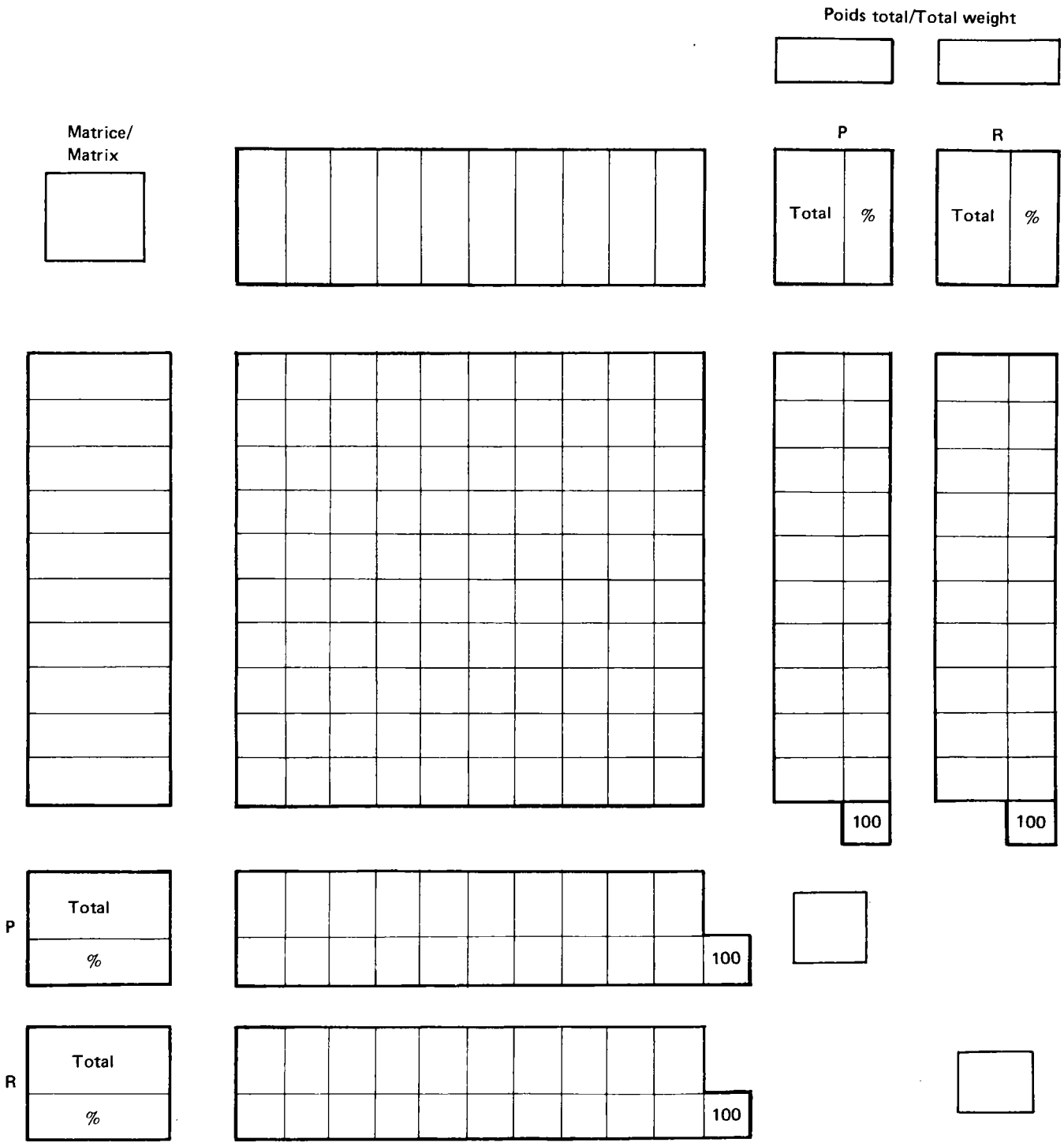


résumé


Poids total/Total weight
Matrice/
Matrix
P
R
Total
%
Total
%
100
100
P
Total
%
100
R
Total
%
100

RELEVANCE OF SCIENCE AND TECHNOLOGY

S/D MATRIX

DEVELOPMENT OBJECTIVES

	AGRICULTURE							MINING			INDUSTRY									PUBLIC WORKS									COMM.				EDUCATION								HEALTH								MANPOWER							
	Rice	Secondary Food crops	Rubber	Sugar	Other plant. crops	Livestock	Fisheries	Forestry	Oil and Gas	Tin	Bauxite, etc.	Sulphur, coal	Food, etc.	Textile, etc.	Wood and rel. prod.	Chem. and rel. prod.	Non metal. min. prod.	Basic metal ind.	Mach. and equip.	Rehab. of irr.	Ext. of irr.	Other water res.	Roads and bridges	Eng. Services	Housing	Water supply	Waste disp./recycl.	Electricity	Land transp.	Sea transp.	Air transp.	Telecom. and post	Tourism	Primary ed.	Secondary ed.	Teachers training	Higher ed. (Soc. Sc.)	Higher ed. (S and T)	Non formal ed.	Culture and sports	Family planning	Comm. dis. control	Env. sanitation	Health serv.	Nutrition	Health ed.	Infants health	F and D control	Empl. creation	Vocat. trainint	Income distr.	Ind. relations			
Weight coefficients	4	4	1.08	4	1.53	4	1.08	1.53	4	1.53	1.53	1.08	4	4	1	4	1	4	1.53	4	4	4	1.53	1.53	1.08	1.08	1.53	1.08	1.08	1	1	1	1.53	1.53	1.53	1.53	1.53	1	1.53	1.08	1.08	1.08	1.08	1.08	1.08	4	1.53	1.53	4	1			

PRIORITY PROFILE

REFERENCE PROFILE*

		TOTAL WEIGHT	RELEVANCE COEFFICIENTS ■	●	○	OVERALL RELEVANCE NUMBER	BREAKDOWN (%)	RELEVANCE INDEX	TOTAL WEIGHT*	RELEVANCE COEFFICIENTS ■	●	○	OVERALL RELEVANCE NUMBER	BREAKDOWN (%)	RELEVANCE INDEX
APPLIED SCIENCES	AGRICULTURAL SC.	Agricultural Chem.	105						52						
		Agricultural Eng.													
		Agronomy													
		Animal Husbandry													
		Fisheries													
		Forestry													
		Horticulture													
		Phytopathology													
		Veterinary Sc.													
	ENGINEERING AND TECHNOLOGY	Aeronautical Eng.													
		Chemical Eng.													
		Computer T.													
		Construction Eng.													
		Electrical Eng.													
		Electronics Eng.													
		Environmental Eng.													
		Food S & T													
		Industrial Eng.													
		Instrumentation													
		Materials													
		Mechanical Eng.													
		Metallurgy & Met. Prod.													
		Mining Eng.													
		Motor Vehicle T.													
		Naval Eng.													
		Nuclear Eng.													
		Petroleum Eng.													
		Power T.													
		Railway T.													
		Space T.													
		Telecommunications Eng.													
		Textile T.													
		Transportation Eng.													
	ENVIRONMENTAL SC.	Atmospheric Sc.													
		Climatology													
		Geochemistry													
		Geodesy													
		Geography													
		Geology													
		Geophysics													
		Hydrology													
		Meteorology													
		Oceanography													
		Seismology													
		Soil Sciences													
	MEDICAL SC.	Clinical Sc.													
		Epidemiology													
		Internal Med.													
		Nutrition													
		Occupational Med.													
		Pathology													
		Pharmacology													
		Psychiatry													
		Public Health													
		Surgery													
BASIC SCIENCES	LIFE SC.	Animal Biology													
		Anthropology													
		Biophysics													
		Entomology													
		Genetics & Embr.													
		Human Biology													
		Human Physiology													
		Immunology													
		Microbiology													
		Plant Biology													
	CHEMISTRY	Analytical Chem.													
		Biochemistry													
		Inorganic Chem.													
		Macromol. Chem.													
		Nuclear Chem.													
		Organic Chem.													
		Physical Chem.													
	PHYSICS	Astrophys/Astron.													
		Acoustics													
		Electromagnetism													
		Electronics													
		Fluid Physics													
		Mechanics													
		Molecular Physics													
		Nuclear Physics													
		Optics													
		Particle Physics													
		Solid State Phys.													
		Theoretical Phys.													
		Thermodynamics													
	MATHEMATICS	Logic													
		Algebra													
		Analysis													
		Computer Sc.													
		Geometry													
		Number Theory													
		Numerical Anal.													
		Oper. Research													
		Probability													
		Statistics													
		Topology													
			A→	3.17	9.67	9.49	10.38	100	10	C	A	2.78	8.89	8.61	9.38	100	9	C
			↓ B	4.36	9.75	8.08	8.99				B	3.46	9.02	6.88	7.95			

	■	●	○	OVERALL DEPENDENCE NUMBER	DEPENDENCE BREAKDOWN (%)	DEPENDENCE INDEX	C	A	B
DEPENDENCE COEEFICIENTS	3	12	11	47	23	12	13	3.17	3.94
	4	11	11	49		13	11		
	1	13	12	42		11	10		
	1	12	12	40		10	10		
	1	11	12	38		11	11		
	4	9	10	44		12	12		
	2	12	13	45		13	13		
	3	14	10	50		13	13		
	8	19	20	90	23	23	23	9.68	8.83
	3	13	16	54		14	14		
	3	11	11	45		12	12		
	5	12	15	59		15	15		
	6	12	10	58	23	15	15	9.49	8.94
	1	11	9	35		9	9		
	2	4	12	27		7	7		
	8	8	4	66		17	17		
	2	15	8	28		7	7		
	5	11	5	58		15	15		
	4	6	2	43		11	11		
	3	6	13	37	17	10	10	10.38	9.79
	4	10	4	40		10	10		
	3	9	13	43		11	11		
	4	3	5	23		6	6		
	5	6	3	35		9	9		
	3	4	12	32		8	8		
	-	4	4	16		4	4		
	1	6	7	23		6	6		
	3	9	3	33		9	9		
	4	6	7	35	4	9	9	100	100
	4	6	8	38		10	10		
	6	2	5	41		11	11		
	6	9	3	39		10	10		
	-	12	8	12		3	3		
	-	-	-	-	5	0	0		
	-	-	-	-		0	0		
	-	-	-	-		0	0		
	-	-	-	-		0	0		
	-	-	-	-		0	0		
	-	-	-	-		0	0		
	1	14	7	37	9	10	10	9.38	4.05
	7	12	5	32		8	8		
	5	4	4	11		3	3		
	5	10	3	30		8	8		
	5	7	3	30		8	8		
	-	16	10	42	5	11	11	100	100
	3	5	5	24		6	6		
	-	2	2	19		4	4		
	3	7	7	16		5	5		
DEPENDENCE BREAKDOWN (%)*					19				
					13				
					17				
					15				
					9				
					9				
					13				
					5				

A : Normal form of averages
B : Normal form of standard deviations
C : Interaction strength number

SCALE

4 2 1 0
■ ● ○ blank

★ For the reference profile, all weight numbers are taken equal to one, with consequent changes in the total weight, and in the relevance profile coefficients and indices. Dependence numbers and indices remain unchanged, except the associated quantities A, B, C and the dependence breakdown.

D/D MATRIX

DEVELOPMENT OBJECTIVES CROSS SUPPORT

DEVELOPMENT OBJECTIVES

AGRICULTURE	MINING	INDUSTRY	PUBLIC WORKS	COMM.	EDUCATION	HEALTH	MANPOWER
Rice	Oil and gas	Food, etc.	Rehab. of irr.	Land. transp.	Primary ed.	Family planning	Empl. creation
Sec. food crops	Tin	Textile, etc.	Ext. of irr.	Sea transp.	Secondary ed.	Comm. dis. control	Vocat. training
Rubber	Bauxite, etc.	Wood and rel. prod.	Other water res.	Air transp.	Teachers training	Env. sanitation	Income distr.
Sugar	Sulphur, coal	Chem. and rel. prod.	Roads and bridges	Telecomm. and post	Higher ed. (Soc. Sc.)	Health serv.	Ind. relations
Other plant. crops		Non met. min. prod.	Eng. services	Tourism	Higher ed. (S and T)	Nutrition	
Livestock		Basic metal ind.	Housing		Non formal ed.	Health ed.	
Fisheries		Mach. and equip.	Water supply		Culture and sports	Infants health	
Forestry			Waste disp./recycl.			F and D control	
			Electricity				

Weight coefficients — (All weight numbers taken equal to 1)

52 - TOTAL WEIGHT

CROSS-SUPPORT COEFFICIENTS: ■ ● ○

DEVELOPMENT OBJECTIVES

		CROSS-SUPPORT NUMBER	BREAKDOWN (%)	CROSS-SUPPORT INDEX
AGRICULTURE	Rice	24		12
	Sec. food crops	24		12
	Rubber	17		8
	Sugar	16	10	8
	Other plant. crops	25		12
	Livestock	20		10
	Fisheries	18		9
	Forestry	29		14
MINING	Oil and gas	32		15
	Tin	15	4	7
	Bauxite, etc.	11		5
	Sulphur, coal	22		11
INDUSTRY	Food, etc.	20		10
	Textile, etc.	23		11
	Wood and rel. prod.	28		13
	Chem. and rel. prod.	56	15	27
	Non met. min. prod.	22		11
	Basic metal ind.	49		24
	Mach. and equip.	72		35
PUBLIC WORKS	Rehab. of irr.	22		11
	Ext. of irr.	23		11
	Other water res.	47		23
	Roads and bridges	38		18
	Eng. services	68	20	33
	Housing	35		17
	Water supply	51		25
	Waste disp./recycling	29		14
	Electricity	55		26
COMM.	Land transp.	69		33
	Sea transp.	36		17
	Air transp.	20	10	10
	Telecomm. and post	38		18
	Tourism	11		5
EDUCATION	Primary ed.	89		19
	Secondary ed.	70		34
	Teachers training	26	19	13
	Higher ed. (Soc. Sc.)	64		31
	Higher ed. (S and T)	81		39
	Non formal ed.	51		25
	Culture and sports	16		8
HEALTH	Family planning	16		8
	Comm. dis. control	18		9
	Env. sanitation	26		13
	Health serv.	22	10	11
	Nutrition	20		10
	Health ed.	25		12
	Infants health	11		5
	F and D control	37		18
MANPOWER	Empl. creation	37		18
	Vocat. training	85	12	41
	Income distr.	50		24
	Ind. relations	41		20
A →		5.07	16.12	14.05	16.64	100	17	C
B		2.80	13.29	8.51	9.28			

DEPENDENCE COEFFICIENTS: ■ ● ○

OVERALL DEPENDENCE NUMBER	37 38 26 19 25 37 32 27	28 27 28 29	66 45 42 46 26 36 36	22 21 9 37 18 55 36 35 30	34 22 25 29 64	32 32 19 22 24 32 39	32 56 50 47 48 34 43 28	72 29 47 27	16.64 6.11
DEPENDENCE BREAKDOWN (%)	13	6	17	15	10	11	19	10	100
DEPENDENCE INDEX	18 18 13 9 12 18 15 13	13 13 13 14	32 22 20 22 13 17 17	11 10 4 18 9 28 17 17 14	16 11 12 14 31	15 15 9 11 12 15 19	15 27 24 23 23 16 21 13	35 14 23 13	17
C									

A : Normal form of averages
B : Normal form of standard deviations
C : Interaction strength number

SCALE

4 2 1 0
■ ● ○ blanck

SCIENCE & TECHNOLOGY CROSS SUPPORT