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RURAL TELECOMMUNICATIONS PROJECT PLANNING GUIDE

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Contents

Foreword

Telecommunications, a recognized element of the development process, improves efficiency and productivity in other sectors such as agriculture and transport, while simultaneously enhancing our quality of life. To be most effective the telecommunications network must be widely available both in terms of geographic distribution and low user cost.

Canadians understand these imperatives. By applying advanced but proven technologies to extend telecommunications service into the rural environment, they have successfully met these challenges, not only at home but in many countries throughout the world.

This booklet is offered as a guide for planners and engineers who are developing rural telecommunications projects. It outlines the steps and addresses the issues critical to planning in this vital sector. For ease of reference, all the figures mentioned in the various steps, as well as the glossaries for abbreviations and terms, have been placed in the appendices.

Inspiration and information for this guide have been derived from many sources in Canada and in the international community, specifically from telephone administrations in Africa and Asia. Although these sources are too numerous to acknowledge individually, this guide is dedicated to their collective vision of universal global telecommunications service.

Introduction

Canadian Technology in Rural Telecommunications Systems

Canada's 25 million people live in a few large cities and a multitude of small settlements, scattered across an immense area: 6 000 kilometres from the Atlantic to the Pacific Ocean, and nearly 5 000 kilometres from the North Pole to the United States border. With this challenge of distance on a grand scale, it was natural for Canadians to become pioneers in telecommunications. From the invention of the telephone in 1874 to the world's first domestic satellite system in 1972, Canada has been a technology leader. This heritage has led to the development and manufacture of equipment that is particularly appropriate for rural telecommunications.

As a result, today Canadians enjoy sophisticated telecommunication services. Telephone, business communications, and broadcast services are delivered by cable, microwave, fiber optics, and satellite systems. More than 160 000 route kilometres of microwave and more than 100 earth stations connect some 19 million telephones country-wide.

Domestic Experience

With Canada's small population spread over an immense area, economical telecommunication service depends on keeping the cost of transmission equipment low. In the early years, thousands of kilometres of open-wire line on wooden poles spanned the country, and extremely remote, small communities were served by HF radio.

Now a host of techniques are available to the network designer that minimize cost and maximize performance, including: VHF, UHF, and microwave radio, twisted pair, coaxial, and fiber optic cable; multiple access radio systems, and thin-route satellite service.

The advantages of digital telecommunication have long been recognized in Canada and fostered rapid development in that technology:

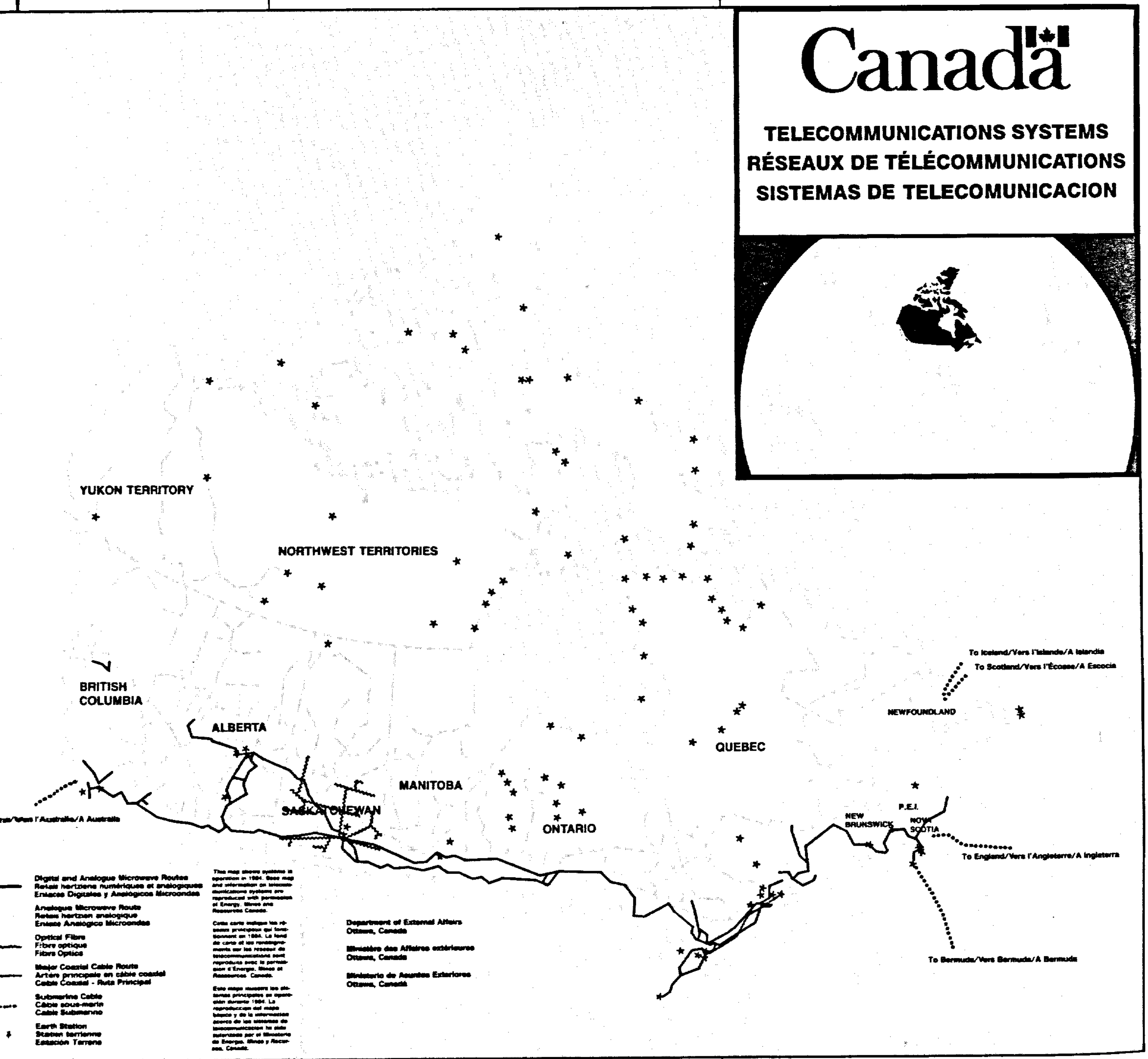
- In 1971 our first digital microwave transmission system was developed.
- In 1976 the first family of digital central office switching equipment was delivered.
- In 1977 the first public packet-switched network became operational.
- In 1982 a 6 000 kilometre, all-digital transcontinental multiplex transmission system went into full service.
- Time division multiplex access radio was developed in the late 1970s as a substitute for conventional outside plant.

Since these pioneer efforts, Canada has gone on to become a leader in the engineering, manufacture, and installation of such systems. The first system was installed in Newfoundland, where it replaced an outdated submarine cable and extended the province's telephone network into a number of villages.

A similar system was installed in Quebec to provide telephone service to a number of farms located on a small island. In Ontario, a precedent-setting project used this type of system to replace an obsolete central office telephone exchange. These systems are now found in virtually all areas of Canada: from the Arctic Ocean where temperatures can fall below −60°C, to arid southern regions where summer temperatures rise well above +40°C.

Satellite earth stations, using single-channel-per-carrier technology, have also become a major component in Canada's rural telecommunication programs. Such stations, located in all areas of the country, are linked through one of the Anik satellites to the national telecommunication network. Their applications in voice and data services range from off-shore drilling platforms, to remote community service, to portable emergency facilities that can be quickly transported to, and set up in, disaster areas.

Cable technology has developed along with radio technology. Although twisted-pair cables are still extensively used, the use of coaxial cable is becoming more wide-spread. It is used to extend television, data, and voice from national networks into small communities. Even optical fiber cable finds a place in rural telecommunications because of its almost unlimited growth capacity. As manufacturing costs decrease and distances between repeaters increase, fiber optics can be economically extended further into the rural sector.



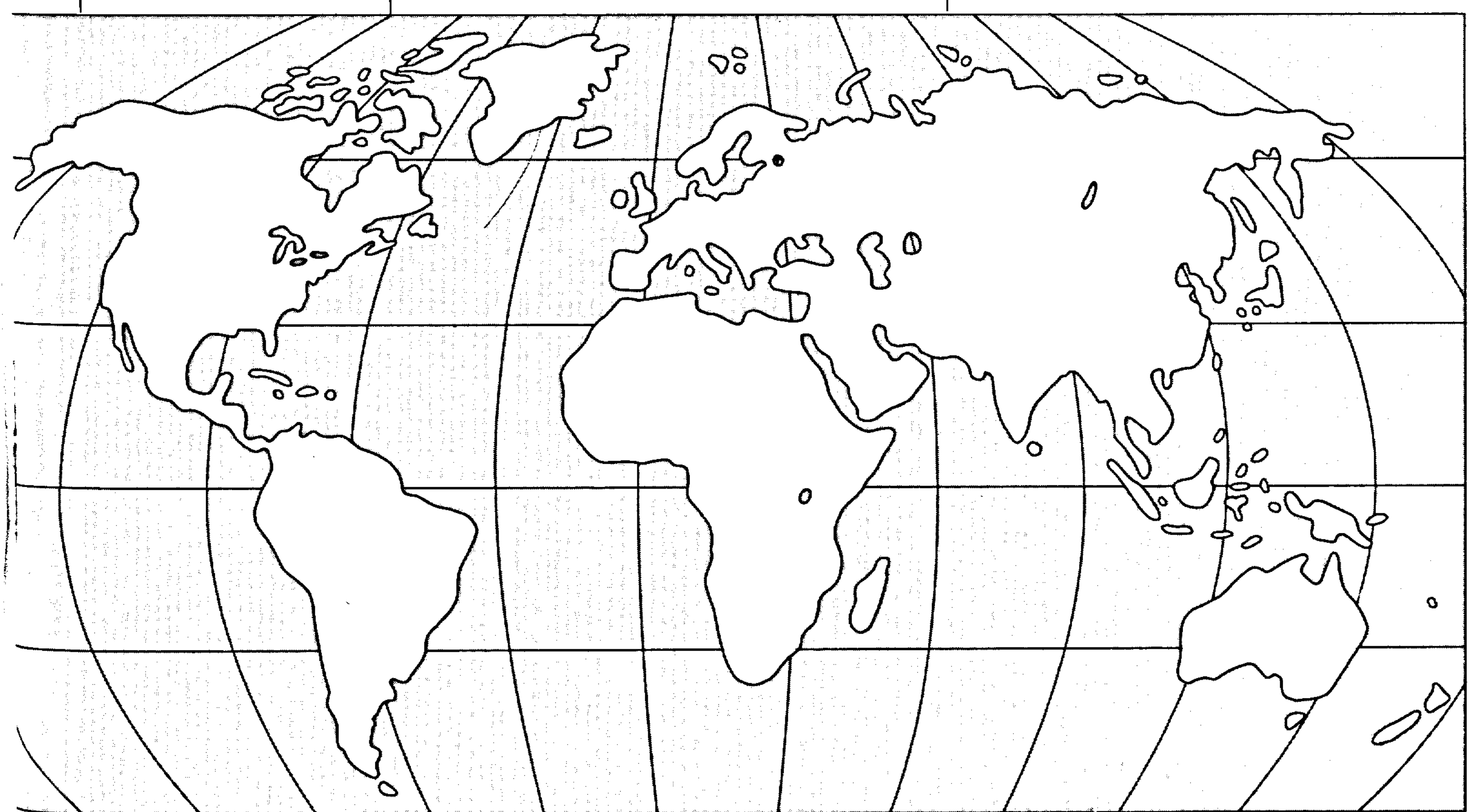
International Experience

The success of Canadian products in Canada has created a demand for these technologies in many other countries with a similar need for rural-type telecommunication facilities. For example, SR Telecom has delivered rural systems to about 50 countries, where this equipment has earned an enviable reputation through years of rugged use. Spar has provided China with advanced, thin-route satellite earth station facilities. In fact, 22 stations have been installed and another 11 are planned. Together they will become an important element in extending China's rapidly developing network into the underserviced regions.

Canada actively supports the activities of the International Telecommunications Union (ITU) in its leadership role of co-ordinating and assisting the development of modern telecommunications infrastructures throughout the world. The Canadian International Development Agency (CIDA) shares with the ITU the same priority of human resource development. Canada has renewed its commitments to ITU's training-sharing system and supports ITU's objective of bringing mankind within easy reach of a telephone by the early 2000s. Canada has been and remains a pioneer in developing appropriate technologies for remote and rural areas.

Canada is also a member of and contributor to the

- World Bank,
- African, Asian, and Inter-American Development Banks,
- Commonwealth Telecommunications Organization,
- Pacific Telecommunications Council,
- Inter-American Telecommunications Conference,
- Agence de Coopération Culturelle et Technique, and
- a number of other regional organizations.



Step 1

Preview of Rural Project Planning

Good planning is the key to successfully managing the details without losing track of the general objective. It is hoped that this guide will help rural telecommunications project planners and engineers find their way by pointing out the principal steps and highlighting the important issues and areas of consideration.

In this first step we will

- define the scope and focus of the guide,
- identify important prerequisites,
- give an overview of typical project steps, and
- review the general nature of planning.

1.1 Scope

This book was developed to assist communications planners and engineers to plan, design, specify, and implement telecommunications projects in the rural sector.

Taken as a whole, it begins essentially at the needs analysis stage and continues through to the preparation of bidding documentation. Although each step is a part of a general sequence, each should also be useful as an individual reference section.

Practical methods are presented with emphasis on useful and accepted techniques. Important planning factors and major considerations are identified. However, in-depth explanations of specific aspects, such as cable facility design, radio propagation and the like, are left to specialized references. In particular, readers are referred to the excellent handbooks prepared by the International Telecommunication Union (ITU) Working Groups. See Appendix B for a list of references.

This guide generally considers the rural network from the subscriber to the local exchange. Figure 1.1 illustrates this scope and also defines the structure of the rural network using definitions consistent with those used by the CCITT.

1.2 Rural Focus

Consistent with usage by the ITU, the term "rural" is used to denote an area comprising scattered groups of potential telecommunication users and having one or more of the following characteristics:

- lack of available power,
- lack of local technical skills,
- adverse topography,
- low level of economic activity, and
- harsh climate.

Typically, then, a rural zone would be fairly remote from main switching centres and providing service would be inconvenient because of physical obstacles, a thin population density, or lack of "direct" financial justification.

These characteristics necessitate cost-effective design solutions that consider such aspects as minimum power consumption, appropriate means of powering, flexibility to meet change, environmental protection, minimum life cycle costs, maintenance, and training.

1.3 Prerequisites

The following basic planning tasks are assumed to be complete and relatively up to date before beginning the steps described in this guide:

- Fundamental technical and development plans have been developed, including modernization and plans concerning analog to digital conversion.
- Long-term network planning and master plans are complete, including exchange locations and route dimensions for the junction and long-distance networks.

Before starting to plan the rural project, readers will want to obtain and carefully review these planning documents. If they have not been prepared, or are not up to date, this must be done before taking any other steps. The CCITT handbook *General Network Planning* (Geneva 1983) provides information on how to do this.

1.4 Project Overview

Although divided into many steps, this guide covers three broadly defined project phases:

- *Needs analysis*: defining the rural telecommunications requirement;
- *Feasibility study*: evaluating alternatives and deciding the best way to satisfy the defined need;
- *Detailed engineering*: detailing the conceptual design and preparing project work statements and system design specifications into contract bidding documents.

Figure 1.2 shows these typical phases and outlines the contents of this book.

1.5 Nature of Planning

The high cost of implementing and operating a telecommunications network and its long plant life make good planning essential. Inadequate planning can lead to misuse of resources, reduced service quality, and poor economic performance through loss of revenue and extra costs.

In concluding tnis preview, a quick review of some of the general characteristics and issues of planning is useful. Each of these is discussed again in more detail during later sections.

Iterative Nature. All parts of the planning process are iterative. Each phase should be undertaken first at a high level to broadly establish scope, possible solutions, and costs. Then a more detailed examination should be undertaken to refine the analysis and confirm the results. Later decisions must be fed back to earlier decisions to ensure consistency and validity.

Each iteration should move closer to an optimal solution, and an equitable match between project scope and available budget.

Multiple Solutions. Many rural networks have more than one optimal solution. Two different planners can arrive at two different, but equally valid, solutions.

Complex, Interrelated Variables. Planning a rural project means finding an optimal solution in the presence of a large number of complex and interrelated parameters and variables. The planning process must provide the organizing principle for resolving these into an optimal solution. The order in which steps are taken to arrive at a solution is often important to minimize the number of iterations needed.

Sophistication of Techniques. Data required as inputs to a rural network plan are often incomplete and uncertain; for example, traffic forecasts may be inaccurate or unavailable. The sophistication of solution techniques should take this into account. If accuracy is low, there is no point in using highly sophisticated techniques such as complex algorithms or specialized computer programs. Instead, a simple manual analysis will likely be adequate.

Long-Range Planning. Short-term solutions may impede orderly and economical network growth in the long run. Short-term economic analysis usually favours existing plant. Therefore, all planning must be based on a perspective that is sufficiently long term so that existing plant has only a minimal effect on the outcome of the economic study.

Long-range plans must be in place and periodically updated. Only then can they be used effectively to structure short-term plans, such as a project plan or a government 5-year development plan.

Step 2

Consider the Socio-economic Benefits

Rural development is of primary importance to Third World countries since most of the economic potential is found in rural areas, where 80 per cent of the population lives and where a significant part of the gross national product is generated. Frequently, two or three primary commodities produced in rural regions earn most, if not all, of the foreign currency. A good part of these earnings should be returned to the areas that generate them.

2.1 Background

Unfortunately, in spite of their importance, rural areas are often neglected in medium- and long-term development strategies because urban requirements are often articulated with more urgency. In the past, foreign aid donors and national governments have tended to undertake prestigious projects in the capital cities rather than projects in the rural areas that would strengthen agriculture and other rural activities. This is one reason for declining rural activity and the growing need to import agricultural products and to receive food aid.

The development of rural potential faces many obstacles. The major ones are scarcity of human resources, inappropriate institutional frameworks, adverse climatic and geographic conditions, high population growth, poor health, and inadequate infrastructure and services.

Efficiency in productive sectors must be improved, particularly in agriculture. Programs must be undertaken to create an appropriate rural infrastructure for supplying basic services in transportation, energy, water and sanitation, and telecommunications. People are becoming increasingly aware that more attention must be paid to rural development to make better use of national resources. No alternative will improve economic performance more quickly and will benefit more people.

The need for telecommunications within a well balanced rural infrastructure is often overlooked. But, particularly now that developed countries are changing to information societies, it is essential that other parts of the world recognize the importance of telecommunications to social and economic activities.

Providing telecommunication in rural and remote areas costs more than providing it in high-density urban settlements. Telecommunications companies refrain from investing in rural areas because of an insufficient rate of return. Sometimes they are even bound to do so because their statutes require operations to produce a minimum profit level. But projects should be appraised, not only on the basis of direct returns, but also according to benefits that occur outside the sector in the national economy, as has been done with other elements of the infrastructure.

2.2 Socio-economic Benefits

The role of telecommunications in socio-economic development has been the subject of many studies. One undertaken by the International Telecommunication Union identified numerous potential benefits of telecommunications, the most important of which are summarized here.

- Reliable, cost-efficient rural telecommunications can enhance output levels, employment, and foreign exchange earnings (in export sectors) by the more efficient use of resources.
- Skilled personnel and other scarce resources — for example, petroleum and transportation capacity — can be used more economically when a basic telecommunication network is available to co-ordinate decision-making at different stages of production, distribution, and exchange.
- The rate of information flow and business transactions can be increased, and better use can be made of machinery and other capital goods.

- Rural telecommunications can help reduce costs in all sectors and, in particular, improve the supply and delivery of public services in the fields of health, education, and agriculture.

A wide range of sectors can benefit, including agriculture, forestry, fishing, mining, manufacturing, infrastructure (for example, power, meteorology, civil aviation, and public works), banking and financial services, transportation in all its aspects, commerce, tourism, administration, health, and education.

External benefits of telecommunication services are therefore substantial. The fact that benefits are difficult to quantify should not obscure their existence. Once they have been recognized, appropriate policy instruments must be developed to encourage telecommunication infrastructures in rural areas. Relevant observations about socio-economic benefits that could occur should be included in project proposals and feasibility analyses, and decision makers should allow for cross-subsidization and concessionary terms of financing.

Step 3

Preview of the Needs Analysis Phase

Only when the problem is fully understood can we begin to solve it effectively.

Needs analysis is the process of defining a perceived need, here a specific need for telecommunications. Figure 3.1 shows the principal tasks that must be undertaken. Procedures and considerations for carrying out these tasks are addressed in Steps 4 through 8 of this guide.

The results of the needs analysis phase will be recorded in a document called the Definition of Requirements, which should define the rural need in the following terms:

- types of subscribers and their service needs;
- quantity and location of new subscribers;
- quantity and flow of traffic;
- quality of service objectives;
- general characteristics and requirements.

Figure 3.2 illustrates a typical structure for the definition of requirements. As we proceed through the steps of the needs analysis phase, we will be compiling the contents of this document.

The Definition of Requirements will be a primary input document to the next planning phase: the feasibility study.

Step 4

Establish Project Objectives and Service Areas

Setting project objectives, or reviewing objectives already established, is the starting point for a needs analysis. From these objectives, areas and locations for service can be determined. This section deals with typical project objectives and presents a method for selecting prospective areas for service.

4.1 Project Objectives

The project objectives provide an initial focus by defining the following:

- areas or types of areas to be served;
- quantity of service (the number of new lines, degree of demand to be satisfied, desired penetration to be achieved, or other indicators);
- types of subscribers to be served (residential, business, pay, public call office); and
- types of service to be offered (individual line service, party-line service, voice band data, medium-speed data, telex/gentex, facsimile, mobile, etc.).

Figure 4.1 outlines typical considerations used to establish project objectives. It shows that the objectives are shaped by considering all relevant high-level policies, issues, and needs. Policies and development plans may be from national ministries or from the telecommunication administration. They may state rural telecommunications needs in terms of specific objectives, or they may give broadly defined guidelines and priorities.

Broad guidelines could dictate general improvements in service availability, service quality, and economic efficiency. Project objectives that are more specific might be similar to some of the following typical sample statements:

- Provide service to all communities with a population over 10 000.
- Increase telephone penetration in the rural sector to 1 telephone per 1000 persons.
- Provide one public call office (PCO) for every 10 000 persons in the rural sector.
- Provide an accessible telephone within 10 km of all rural inhabitants.
- Provide ordinary telephone and telex service only.

In view of the high investment cost and low financial return of most rural telecommunications programs, these objectives will likely be justified by expected socio-economic benefits.

Generally, initial rural programs are designed to provide only basic services, so that budgets can provide as much service (and hence value) as possible.

If clear objectives are not handed down from the appropriate level of authority (ministerial or corporate planning), these objectives have to be formulated and approval for them sought from the appropriate level before continuing.

4.2 Service Locations

Unless the specific rural locations to receive new or expanded service have been determined at a higher level of authority, prospective areas for service have to be determined.

The following is a general method for developing a relatively detailed inventory of areas requiring service. This inventory can be divided into priorities and can thus form the basis of a long-range rural plan. The inventory may be periodically updated and projects generated from it.

1. Develop a selection criterion based on the rural program objectives.
2. Prepare worksheets that feature the characteristics relevant to the selection criterion. Figure 4.2 shows a typical worksheet.

3. Using the worksheets, list the communities in the rural areas and prepare an inventory of the appropriate local facilities and economic activity.
4. Apply a grading and weighting scheme and select prospective locations for service, and if necessary, assign priorities.

The selection criterion is shaped, and in some cases rigidly defined, by the rural program objectives. Often selection is based on a set of factors that are individually scored and then combined using a multiplier to weight factors according to importance (for example 60 per cent on economic activity and 40 per cent on population size). Arranging the list of locations by state, district, or administrative division may be an advantage.

Project budget or time constraints could make it necessary to assign priorities. Priorities can be assigned to provide a more dispersed service to widely distributed points (for example countrywide), or to provide a more comprehensive service on a regional basis.

Proceeding region by region usually provides a better return on investments; however, a widely distributed approach may be necessary to satisfy a need for broad initial coverage; for example, to meet national security and government administrative or social program needs.

4.3 Information Sources

The following are typical data sources that can be used, if available, in putting together a list of prospective locations:

- government publications and studies (maps, charts, data from all levels and departments of government);
- national development plans (covering economic and social aspects as well as specific infrastructure such as roads, water, electrification, and tourism);
- demographic studies;
- economic studies and forecasts;
- topographic maps, road maps, aerial photographs; and
- studies and plans prepared by consultants and external agencies such as regional co-ordinating bodies and the ITU.

Information can be solicited from the rural regions by circulating carefully worded questionnaires to the appropriate local governments. When reliable data are scarce, the expense of sending out a survey team is often justified.

The degree of research that must be done depends on how definitive the project objectives are. If they are general, more information is needed to decide which locations should receive new or expanded service.

Step 5

Determine Subscriber Demand

The next step in the needs analysis is to assess subscriber demand in the areas selected for service. In this section, the impact of investment on demand, growth rates, and accuracy are discussed.

5.1 Demand and Investment

When sufficient investment is available, market forces govern the number of subscribers served, and the cost of service compared to the disposable income of potential subscribers is the primary demand determinant.

In the rural sector, however, the scarcity of investment usually limits the amount of subscriber demand that can be satisfied. In this case, the amount of investment and project objectives determine the number of subscribers served.

The number of subscribers should be tabulated by location (see Figure 5.1 for a sample worksheet) and shown on a map. When preparing a table for this data, it may be convenient to extract relevant portions of the worksheet developed in the previous section (Step 4, Figure 4.2).

5.2 Growth Forecasts

As with initial subscriber demand, growth rates in the rural sector often depend on the availability of investment.

When investment is sufficient to satisfy demand, growth rates should be estimated from such considerations as the historical telephone growth rate, trends and forecasts for economic growth, population growth, and population shifts due, for example, to urbanization or decentralization. The CCITT handbook *General Network Planning* (Geneva 1983) provides detailed guidance in forecasting this type of growth.

However, growth in the rural network, particularly in its early stages of development, is often limited by the amount of investment available. In this case, growth estimates should be based on investment policies and forecasts.

Growth should be forecast over a sufficiently long period so that network decisions can be based on a valid economic study period. (This aspect is discussed again in a later step in this guide.) Typically, forecasts will cover some 15 to 25 years. Figure 5.2 shows possible growth curves and Figure 5.3 is an example of a table of annual growth rates.

Typical annual growth rates could lie between 2 and 25 per cent, depending on specific conditions. The lowest growth rates generally reflect situations where investment is limited. Or, in a well developed network, low growth rates may indicate market saturation. The highest growth rates generally reflect situations where sufficient investment has become available and suppressed demand is being met.

The growth forecasts should be applied to the initial figures for subscriber demand. Figure 5.4 shows these data added as new columns to the previous worksheet.

5.3 Accuracy

Provisioning decisions are based on the estimates of subscriber demand, traffic, and growth. Since these decisions ultimately affect customer satisfaction, accuracy is important.

Checking estimates against other forecasts, and rationalizing any differences, can improve accuracy and confidence levels.

One common consistency check involves comparing the forecast trends at the local level to overall national trends or objectives. That could, for example, mean a comparison of

- expected local telephone service penetration levels (say, the number of lines per 100 persons) relative to national trends or objectives for the rural sector;

- predicted local population movements and trends relative to national trends; and
- expected growth in local economic activity relative to expected or planned national growth (particularly for the rural sector).

Another consistency check involves comparing short-, medium-, and long-term estimates, assuming they have been forecast independently. Any differences should be rationalized and harmonized by graph smoothing between forecast terms.

Comparing these predicted penetration growth rates to those experienced in other countries, particularly neighboring countries or countries with similar conditions, is also a valid consistency check.

When forecasts are based on unreliable input data, the level of accuracy should be estimated for growth rates and the number of subscribers. The growth rate is often the greatest source of error because it is usually the most difficult to estimate and because errors in rates can quickly overtake any errors in starting point data.

A convenient way to bracket overall accuracy is to estimate the growth rate for each of the following:

- most probably growth (best guess);
- highest likely growth; and
- lowest likely growth.

The high and low estimates can be used later in the feasibility study when examining the economic sensitivity of design alternatives to changes in growth.

Step 6

Forecast Traffic Flow

Traffic in the rural network must be estimated so that all traffic-sensitive elements can be provisioned. This step discusses ways of estimating the intensity of traffic, its distribution in the network, and growth.

Traffic intensity is normally measured in Erlangs (E) during the busy hour. One Erlang during the busy hour is equivalent to one circuit being fully occupied for one hour. What is often meant by a busy hour is the average busy hour during the busy season.

6.1 Traffic Estimates

Ideally, traffic estimates should be based on traffic statistics for similar situations. If no data are available, a trial, particularly if the rural network project is a large one, should be considered.

If relevant statistics cannot be obtained, educated estimates must suffice. One method involves developing traffic models to represent each subscriber type. The model will estimate the number of calls (N) during the busy hour and their average duration (D) in minutes. Thus, busy hour (BH) traffic in Erlangs is given by

$$\text{BH traffic} = (N \cdot D)/60 \text{ Erlangs}$$

Alternatively, the model can estimate the traffic for a normal busy day (a week day for business customers) and some percentage of this total traffic applied to the busy hour. Typically 8 to 12 per cent of the total daily traffic will occur in the busy hour, with 10 per cent representing a reasonable rule of thumb.

When only a limited number of telephones are available, usage might be relatively high. In a busy public call office (PCO), where customers are waiting, usage per telephone line could approach the theoretical maximum of one Erlang (60 minutes occupancy during the busy hour).

If traffic estimates are made using models, it might be useful to compare the estimates to some typical figures suggested by other sources, such as other administrations, consultants, and system suppliers. Figure 6.1 gives typical ranges for different subscriber types. These traffic figures are provided for comparison only. Whether they are representative depends on the conditions encountered in a specific situation.

6.2 Distribution

To dimension trunk groups and to examine the impact of the rural traffic on the long-distance network, you need to estimate the distribution between local and long-distance traffic (see Figure 6.2).

If the rural network is small compared to the existing national long-distance network, the rural traffic will probably have little impact on the existing network.

The amount of internal traffic depends on community interest factors, such as prevailing social and kinship customs and relations, and the presence of large industrial, commercial, educational, or military institutions.

Rural networks usually have a high percentage of long-distance traffic (higher than a corresponding urban network). This traffic is generally to the main commercial centre of the area or to the capital. Again, in the absence of statistics, a model can be used to determine the proportion of long-distance traffic. About 50 per cent could be reasonable for a typical rural network.

6.3 Other Services

If services, other than basic telephones, are to be provided, the traffic contribution of these must be considered.

Telex generally adds one circuit to provisioning levels since up to 24 telex circuits are often multiplexed into a single voice channel.

If data links or special services, such as sound programs, private lines, and other non-switched circuits are required, then additional channels must be provisioned according to these needs when the circuit groups are dimensioned.

6.4 Forecasts

Because the provisioning problem involves growth, future traffic has to be forecast. If the traffic per subscriber is expected to remain the same, this can be done by simply multiplying the traffic estimates (per subscriber type) times the number of subscribers forecast. But if the traffic per subscriber is expected to change significantly with time (as it could, for example, with the introduction of subscriber trunk dialing or a rate change), then this change in traffic per subscriber should be anticipated and included in the forecast.

The traffic forecasts can be tabulated by extending the previous worksheet. Refer to Figure 6.3 which shows a forecast that assumes the traffic per subscriber remains essentially constant.

Traffic Matrices

The preparation of traffic matrices is not discussed in this guide for the following reasons:

- The national network development plans are prerequisites to the level of planning presented in this guide; thus, the exchange locations and network routing and dimensioning will have been prepared for the junction and long-distance networks.
- This guide considers each rural network a local network within the larger national network-planning framework.
- The developing rural network usually has a simple star or tree configuration due to traffic patterns and the desire to minimize implementation costs.

Step 7

Establish Service Quality Objectives

In addition to the types and amount of service required, the quality of service should be considered and documented as part of the needs analysis. Figure 7.1 shows the factors that determine basic service quality.

To ensure that basic objectives are adequately served, fundamental plans and policies must be consulted when setting objectives for each of these factors. Although rural objectives should be consistent with urban objectives, some allowances might be made considering the need for low cost, subscribers' possibly higher tolerance to impairments, and the fact that future improvements are anticipated or planned.

Some typical objectives for subscriber access systems are given in the following subsections. Objectives for trunk systems should be higher, because more subscribers would be affected by any single system problem. Trunk objectives are part of the administration's policy; they are covered extensively in the CCITT and CCIR recommendations and reports.

7.1 Grade of Service

Grade of service is usually expressed in terms of the probability that a call request will be blocked or not satisfied because of lack of network resources during the normal busy hour.

If calls blocked by a lack of resources are cleared from the system (not held), then typical grade of service objectives range from P = 0.01 to P = 0.05 (that is, the probability of a call being blocked equals 1 to 5 per cent, respectively). The higher probabilities are often applied to small trunk groups and might be suitable for rural conditions where channel capacities are limited.

Higher probabilities should not be used as design objectives without careful consideration. Calls that are not evenutally placed represent lost revenue and cause customer dissatisfaction. As the probability of blocking exceeds about 10 per cent (P = 0.10), network congestion can increase rapidly with recurring call attempts. A high proportion of customers may be turned away.

When blocked calls are held until the necessary network resources become available, the grade of service objective is often stated as an average waiting time expressed as a ratio of the average call holding time. A ratio of 1:10 is typically used (often expressed as a percentage; i.e. 10 per cent). This corresponds to an average waiting time of 12 to 18 seconds if call holding times are averaging 120 to 180 seconds.

Alternatively, when blocked calls are held, the grade of service objective can be stated as the probability that delay will exceed some set time. For example, with a probability of 1 per cent, blocked calls will be delayed more than 10 seconds. In other words, 99 per cent of all calls delayed will be satisfied within 10 seconds.

Because the grade-of-service objective along with the traffic estimates governs dimensioning and because dimensioning has significant cost implications, the grade-of-service objective must be chosen with care. If confidence in the traffic forecasts is low, a conservative grade-of-service objective, which allows some margin, is probably a good idea.

7.2 Equipment Availability

Equipment availability is usually expressed as a probability that the system will not be degraded by an equipment-related problem or failure. Degradations may be circuit quality impairments or service outages. The objective for this factor must be set based on the exact definition chosen.

For example, the equipment availability for a rural subscriber access system could be defined as "the probability (with a 90 per cent confidence level) that all necessary equipment connecting any subscriber is functional and operating within maintenance limits".

According to this definition, an objective of around 99.9 per cent could be selected. This corresponds to an estimated end-to-end mean time between failure of 20 000 hours and a mean time to restore service of 24 hours – both achievable figures for unprotected radio configurations. Other definitions of availability are possible, but they would alter the objective.

The availability objective is used during detailed design to balance such aspects as the reliability of the equipment, the location of maintenance centres, the level of maintenance personnel staffing, and the level of spares held.

7.3 Propagation Reliability

When radio systems are used, paths must be designed to a defined objective for propagation reliability. These objectives are usually stated as a probability that some noise or bit error rate will not be exceeded during any month (thus implying the worst propagation month).

Usually, two objectives are used: the first corresponds to the probability that circuit quality will be degraded below some reasonably acceptable level, and the second corresponds to the probability that circuit quality will be degraded to such a level that the channel is considered unusable and thus has failed.

Objectives for the first factor (probability of degradation below some reasonably acceptable circuit quality) are addressed in the next subsection (Noise or Bit Error Rate).

Objectives for the second factor (channel unusable) could be in the order of 99.5 to 99.95 per cent for a subscriber access system. It depends on the type of equipment, the paths encountered, and the subscriber's expectations.

If a channel is degraded to the following levels, the circuit is generally considered unusable (failed):

- noise of 10^6 pWO for analog systems and
- bit error rate of 10^{-3} or 10^{-4} for digital systems.

7.4 Noise or Bit Error Rate

Because a rural network generally has more transmission equipment between the exchange and the subscriber than that in an urban centre, the allowable noise for a rural network can be higher than that for the urban network. The CCITT handbook *Rural Telecommunications* (Geneva 1979) suggests that the distribution of noise shown in Figure 7.2 may be practical.

Since noise levels are referenced to the zero test level point (0TLP), the noise levels received by a subscriber is reduced by the amount of attenuation in the subscriber's loop. Thus, higher referenced noise levels can be tolerated by the subscriber when his or her line has higher attenuation.

Noise is statistically distributed; this is particularly evident when analog radios form part of the link. Therefore, the noise objectives should be stated as probabilities. Normally, these are given as noise values not to be exceeded for some percentage of the time. Often 20 per cent of any month is used, but 50 per cent or a median value is also common because of its convenience in propagation calculations.

When digital links are used, the concept of noise needs to be considered somewhat differently since, unlike analog facilities, a generally linear relationship between noise and received signal level does not exist. In the presence of a falling receive signal level (fading), a digital facility has low noise, although an increasing number of "clicks" can be heard, until eventually the bit error rate reaches some critical low value where the system loses synchronization and fails (typically around 10^{-3} or 10^{-4}). Bit error rates of 10^{-6} or 10^{-8} are often deemed good quality for voice; transmission designs are usually based on bettering these values more than 99 per cent of any month.

Since noise is a more direct measure of what is perceived by the subscriber (as opposed to bit error rate), it is probably a good idea to at least state a noise objective at this stage of planning. However, as digital links are becoming more prevalent in rural subscriber access systems, bit error rate objectives should also be addressed.

7.5 Allowable Loss

Allowable loss is the amount of attenuation permitted between the exchange and the subscriber. The objective for this must be extracted from reference equivalents of the fundamental transmission plan (see Figure 7.3).

The maximum allowable loss in the subscriber network ranges typically from 6 to 8 dB. For long loops, it may be impractical to meet the loss objective. Therefore a second, less stringent objective should be derived for use on a case-by-case basis. This relaxed objective could be as high as 10 to 12 dB, depending on other national network factors such as the number of 4-wire switches in the hierarchy.

7.6 Frequency Response

Frequency response is an important network parameter. However, in the subscriber loop, frequency response performance may be relaxed from the stringent requirements applied to long-distance transmission facilities.

In the subscriber loop, good cable design practice should be followed for voice-frequency cable plant. When low-cost subscriber multiplex or carrier systems are used, the frequency response should be specified corresponding to the available state of the art for these classes of systems.

Step 8

Compile the General Project Requirements

The final step in assessing the rural telecommunications need is to examine the general conditions that affect system design. These include environmental conditions, infrastructure, system design requirements, operational requirements, and equipment requirements. Each of these is discussed in this section.

8.1 Environmental Conditions

The environment influences many aspects of system design and equipment selection. Therefore a reasonably detailed assessment of the environment should be compiled. Typically, the following conditions should be included:

- average monthly temperature highs, lows, and extremes,
- highest relative humidity and temperature combination,
- highest wind speed (steady and gusts) and prevailing direction,
- frequency of electrical storms (lightning),
- precipitation rates (rain, hail, snow),
- dust, insects, fungus,
- corrosive atmospheres or pollutants,
- insolation data (for solar power), and
- seismic activity.

Statistics of the yearly distribution and location should be collected if available. Minimum and maximum values should be those normally encountered, since it is generally impractical to design to extreme, but rarely encountered, conditions.

8.2 Infrastructure

The existing infrastructure and needed infrastructure profoundly affect system design, equipment selection, and project costs. The following should be considered carefully:

- existing telecommunications infrastructure including all relevant exchanges and transmission facilities;
- availability of power from commercial sources and its quality in terms of voltage and frequency variation and the probable occurrence and average duration of outages;
- physical access to sites for construction, installation, and operation; and
- land acquisitions for buildings and towers as well as rights of way for cables, power lines, and road access.

8.3 System Design Requirements

The following is a checklist of considerations to address when identifying system design requirements:

- distribution of demand in terms of the size of subscriber clusters (the number of subscribers and the radius of the cluster) and the distance between clusters;
- topography and geography, including soil type and conductivity, to determine suitability for cable or radio systems;
- availability of radio frequencies in discreet channels or blocks and who coordinates and assigns them; and
- policy and plans, including fundamental technical plans, fundamental development plans, modernization plans, analog-to-digital conversion plans, master plans, etc.

8.4 Operational Requirements

Operational requirements are concerns of the administration and its policies. They affect how the network is operated and maintained. The importance of the following operational factors to project planning must not be underestimated:

- the basic organizational structure of the telecommunications administration;
- skill levels of present personnel, availability of training facilities and other training opportunities, and potentials for recruiting personnel; and
- implementation of maintenance policies, including the location of maintenance centres, alarm and trouble reporting methods, repair facility and policy, sparing levels and policy, test equipment and calibration policy, etc.

8.5 Equipment Requirements

The following equipment attributes might be important, depending on specific conditions:

- designed according to general equipment standards of the CCITT/CCIR and the administration or to be compatible with equipment that has been standardized;
- designed for unattended operation (high reliability, fail-safe failure modes, and secure from vandalism); and
- designed in a modular format so that the equipment is easy to transport, install, expand, and maintain.

Step 9

Preview of the Feasibility Study Phase

With the needs analysis phase complete (according to Steps 4 through 8) and documented in the Definition of Requirements (according to Step 3), the next phase is to conduct a feasibility study. This section previews the feasibility study tasks covered by Steps 10 through 14 and reviews relevant time period definitions.

9.1 General

The feasibility study seeks a technically and economically appropriate means of satisfying the need described in the Definition of Requirements.

The feasibility study is critical to overall project success because management uses its results to decide whether and how to proceed. Figure 9.1 shows the principal feasibility study tasks; the major ones are explained in Steps 10 through 14.

A successful feasibility study hinges on an accurate definition of requirements with full assessment of existing facilities (from the needs analysis phase), a comprehensive examination of available equipment and systems, and a careful consideration of the sensitivity of the study results to possible inaccuracies in the input data.

Time plays a central role in the feasibility study: how much equipment should initially be installed to meet growth, how many years of growth should be accommodated by the equipment before its design capacity is reached, and what time frame should the economic evaluation embrace. Figure 9.2 shows these concepts on a time line and the following subsections discuss them in more detail.

9.2 Study Period

The feasibility study must extend across some period of time, generally referred to as the study period. The economic study will consider life cycle costs during this period. Usually this period is no shorter than the expected design life of the equipment under consideration. It should actually be long enough so that any existing facilities have negligible value, thereby ensuring that the economic analysis does not unrealistically favour existing facilities.

9.3 Equipment Design Life

Usually, the equipment is chosen according to the growth it can accommodate during its expected service or design life (Figure 12.1 in Step 12 presents typical service lives for various items of plant).

However, there can be cases in the development of a rural network when it may be advantageous to allow growth to overtake the maximum capacity of the system before the end of its expected design life. Typical situations for this would be when

- growth is speculative (for example, due to insufficient or unreliable forecasting data) or
- demand suddenly increases (for example, due to the discovery of oil).

These cases should be served with equipment that is easily taken out of service, transported, and installed in new locations.

9.4 Provisioning Period

Growth of subscriber demand (and, consequently, traffic growth) creates the need for plant expansions from time to time — and eventual replacement. The initial equipment and each expansion will cover growth for some period. Of course, the preferred provisioning period is the one with the lowest overall cost.

Logically, smaller expansions mean shorter provisioning periods and lower costs for each expansion; however, taken over a long period, the mobilization costs associated with each expansion favours longer provisioning periods.

Optimal provisioning periods vary with the type of plant and expected growth rates. Generally, longer provisioning periods are favoured when extensions have low equipment costs but high labour costs and when the interest rate on capital is low.

Step 10

Assess Available Equipment and Systems

The first major step in the feasibility study is to survey the technical solutions available to the system designer. For convenience, they can be functionally grouped into the following categories (see Figure 10.1):

- subscriber apparatus,
- subscriber access systems,
- exchange and collection point systems,
- transfer and trunk transmission systems, and
- remote power systems (when applicable).

This section briefly surveys the different equipment types and suggests some factors to consider during assessment.

10.1 Equipment Types

Within each category are many types of equipment suitable for rural applications. Some common ones are listed here:

Subscriber Apparatus

- standard wall and desk telephone sets,
- coin-box telephone sets,
- telephone sets with metering devices, and
- party-line telephone sets;

Subscriber Access

- open-wire lines,
- aerial and buried cable,
- HF radio,
- VHF and UHF single-channel radio,
- frequency division multiple access radio,
- time division multiple access radio, and
- satellite;

Exchange and Collection Point

- rural exchanges,
- satellite exchanges,
- remote switching units,
- remote line units, and
- subscriber multiplex;

Trunk and Transfer

- open-wire carrier,
- PCM cable,
- light route analog radio,
- light route digital radio, and
- satellite;

Remote Power Systems

- solar photovoltaics,
- wind-driven generator,
- thermo-electric pile,
- diesel engine generator set, and
- hybrid systems.

For a comprehensive list and descriptions of systems for rural networks, consult the CCITT handbook and supplement on rural telecommunications.

Detailed information must be compiled on suitable systems, including equipment and installation costs. Contact suppliers for information.

10.2 Assessment Factors

Suitability of equipment and systems should be based on consideration of what is required and what is available for such factors as the following:

- *capacity:* minimums, maximums, and expansion increments for lines or channels;
- *range:* typical minimum and maximum distances as well as factors that affect range, such as terrain and the use of repeaters;
- *spectrum:* frequency band and spectral efficiency of equipment, considering the availability of spectrum;
- *compatibility:* technical compatibility for interworking with existing network facilities; consistent with standards established by the administration and the CCITT and CCIR; and consistent with any network modernization and analog-to-digital conversion plans;
- *general design:* suitable for local conditions such as environment, power, and source of skill levels; and
- *commercial availability:* equipment in production, field-proven, and available from multiple sources for competitive procurement.

When compiling an inventory of available technical solutions, characterize each product offering in the context of these factors. Figure 10.2 shows sample worksheets for typical product types.

Step 11

Develop and Optimize Design Alternatives

The feasibility study is a logical process of developing practical alternatives, evaluating them from economic and technical viewpoints, and then selecting the most advantageous one for implementation. In this step we present ways of developing and optimizing design alternatives (see Figure 11.1).

The method is an interactive process that involves judgment and a sound knowledge of the requirements, existing facilities, and available technical solutions. Basically the method involves determining systems for the following network elements:

- subscriber access medium,
- exchange and collection point equipment, and
- trunk and transfer transmission medium.

A promising system design is selected for each of these elements in turn. Then an optimization process is applied to ensure that the configuration that gives the lowest life cycle cost over the study period has been found. This optimization process is briefly explained in the next subsection.

If the project is large, i.e., covers many local networks, the feasibility study should use a model of a local rural network or, if conditions are sufficiently variable, a set of models. The model or models must be carefully constructed to represent average conditions, ensuring that valid system design decisions and accurate cost extrapolations can be made by using them.

> ***Use of Computers***
> Computerized network analysis programs can assist in optimizing the network, provided the program is designed to accommodate the characteristics of a rural network. However, caution must be exercised in interpreting the results, if the input data are based on estimates with wide margins of error or of unknown accuracy.
>
> Computers can also speed up the repetitive calculations and minimize computational errors. Recommended is a good electronic spreadsheet program on a microcomputer.

11.1 The Optimization Process

The objective of the optimization process is to find the configuration with the lowest life cycle cost over the study period. The following steps outline the procedure.

1. Describe the design under test in terms of the equipment types, quantities, capacities, and locations.
2. Estimate the implementation costs, including land, right of way, power, construction, equipment procurement, installation, and commissioning.
3. Estimate expansion costs and when, according to forecast growth, expansion is required.
4. Estimate replacement costs and residual value as applicable.
5. If changing the configuration alters any recurring costs, such as commercial power consumption or maintenance, then these costs must be estimated. Note: Any costs and incomes common to every configuration may be omitted from optimization calculations, because they do not affect the relative order when comparisons are made.
6. Prepare an annual cash flow, find the current worth of the total for each year, and sum these over the study period to find the total accumulated current worth.
7. Examine the configuration and decide whether any changes in equipment types, quantities, capacities, or locations could mean a lower cost. If so, then make the changes and begin again at Step 2. But if a minimum appears to have been found, select this lowest cost solution.

Configurations for the subscriber access system, exchange and collection point equipment, and trunk and transfer transmission system are optimized separately to minimize the number of variables that must be dealt with during calculations.

This is an interactive process of trial and error. It entails much work. The effort can be minimized by carefully preparing cost equations for the different equipment solutions (see Figure 11.2) and by using a computer (see foregone boxed-in information). The time spent in finding an optimum will nearly always be paid back several times over by the savings that result from finding the optimum.

11.2 Subscriber Access

The distribution of subscribers in the service area usually exerts the most influence on the process of selecting a subscriber access system.

Subscriber distribution refers to

- the total number of subscribers in the area to be served,
- the physical size of the area to be served,
- the number of subscriber clusters,
- the subscriber demand (number of telephone lines needed) in each cluster,
- the physical size (radius) of clusters,
- distances between clusters, and
- any significant distribution patterns.

Figure 11.3 shows various distribution possibilities.

By examining subscriber distribution, you can select a likely subscriber access system and lay it out in a promising configuration. If the total subscriber base in the service area is large (say over 200), then all large clusters (say with more than 50 subscribers) should be considered for collection points or rural exchanges.

The flowchart in Figure 11.4 shows a typical decision-making process. Each system design should be tested against all key requirements, some of which could include:

- future growth (capacity needed in 5 to 10 years),
- subscriber loop attenuation and signalling limits,
- availability of sufficient spectrum (for radio systems),
- traffic handling capacity (for systems with concentration), and
- power consumption.

As described in the preceding subsection, a few iterations may be required to optimize the configuration of the subscriber access system.

11.3 Exchanges and Collection Points

If optimizing the subscriber network indicates that the larger clusters should be considered for collection point or exchange equipment, the next step is to select systems for these locations. Ideally, these locations should be close to existing transmission facilities, have access to commercial power, and have land available for an equipment building, container, or cabinet.

Subscriber multiplex systems, remote line units, remote switching units, and satellite exchanges may be used at collection points. The distinction between these different systems is somewhat arbitrary. Sophisticated digital multiplex systems can flexibily provide concentration, stand-alone switching, and direct digital interfacing to suitable host exchanges as well as standard analog line interfacing with any exchange. This class of equipment can reduce inventories of different equipment types, while maintaining maximum flexibility.

A rural exchange, as opposed to remote units or subscriber multiplex, may be indicated, if the following conditions exist:

- high subscriber demand or high growth rate;
- high community interest, therefore a high incidence of local calling; and
- long or difficult transmission path to the nearest host exchange.

Where an existing host exchange is analog, capping its growth and installing an adjacent digital exchange may be economically advantageous. The digital exchange can provide an efficient host for remote units and eventually replace the analog exchange. The final decision between systems will likely be based on cost over the study period and consideration of any analog-to-digital conversion policy.

11.4 Trunking and Transfer

The following conditions commonly characterize the rural situation:

- subscriber and traffic densities are too low to justify alternative or high usage routes;
- the costs of transmission facilities compared to switching equipment costs are relatively high; and
- traffic tends to be between large and small centres rather than among small centres.

Under these conditions, traffic routing is usually optimized by using a minimum-length star or tree configuration (see Figure 11.5). After each link has been dimensioned according to traffic levels, a transmission medium and physical path can be selected.

As stated before, an optimal arrangement over the study period needs to be sought by doing a few iterations.

11.5 Final Alternatives

The subscriber access system, exchange and collection point equipment, and trunking and transfer systems should be optimized independently so that the number of variables to be dealt with at any one time would be manageable. This procedure generally converges to an acceptable overall optimal solution. However, it is advisable at this stage to consider whether any net advantage can be gained by trading off any of these optimums.

Logically the optimization process should have eliminated the impractical network design solutions and fine-tuned the practical ones. At this stage, however, probably more than one practical and contending alternative has been derived. Since engineering problems seldom have only one possible solution, two or more alternatives should be selected to undergo a more detailed financial and technical evaluation.

For example, satellite-based and land-based alternatives should be further examined and compared; or perhaps, a cellular radio-based system compared with separate mobile and fixed-service radio systems. Often, contending alternatives have to be closely examined, to find out, for example, whether one has low capital costs but high annually recurring costs, whereas the other has the opposite characteristics of high capital costs but low annually recurring costs.

The next two steps in this guide describe how to undertake a financial and technical evaluation of contending alternatives.

Step 12

Evaluate the Financial Return

An evaluation is undertaken to appraise the financial impact on the administration of the final contending design alternatives selected during the preceding step.

Only direct financial return is treated in this step. A poor financial rate of return means that indirect social and economic benefits may be needed for justification (refer to Step 2).

For simplicity, a discounted cash flow method is used, whereby a present worth (PW) calculation is applied to the annual cash flow of the project during the study period. This method is recommended, unless the administration or funding agency requires some other method. Any good text about engineering economics explains this method in detail.

12.1 Financial Appraisal

To determine the financial impact on the administration, answers to such questions as the following are needed:

- How much investment capital will be required initially to implement the project?
- How much capital for expansion and replacements will be needed in the future?
- What are the estimated operating and maintenance costs?
- What is the expected income from the project?
- Will subsidies be needed to supplement the income, and if so, approximately how much? (Socio-economic benefits may need to be quantified or qualified to justify subsidies — refer to Step 2.)
- Is the project financially feasible?

The alternatives being compared should provide equal service and should be terminated at the end of the study period with a residual value allowed. All cost burdens and incomes must be included.

Investment Costs. Initial and expansion costs include those for all different types of switching and transmission equipment, spares, test equipment, shipping, civil works, buildings, land, rights of way, installation, engineering, training, and project management.

Operating Costs. These include power consumption, maintenance staff, vehicle operating costs, factory repair, consumption of consumables, test equipment maintenance and calibration, rents and leases, etc.

Residual Value. Use straight line depreciation unless the administration's policy is different, and deduct salvage or removal costs if applicable. Refer to Figure 12.1 for determining typical average service lives.

Income. These include one-time service fees, monthly service charges, estimated long distance charges, subsidy (if necessary), etc.

A detailed cash flow should be developed for each contending alternative. Figure 12.2 and 12.3 show a typical cash flow worksheet and bar chart diagram. If the accumulated present worth of the cash flow at the end of the study period is a positive number, then the project is feasible (at the chosen discount or interest rate). However, if the number is negative, then subsidies are indicated. Subsidies to make the project feasible might be justified by the socio-economic benefits explained in Step 2 of this guide.

12.2 Shadow Price

To assess the value of an imported item against the loss of foreign exchange from the central bank, the government sometimes multiplies the landed price of the item (in local currency) by some factor, commonly refered to as the shadow price.

If the shadow price is applicable, it may have to be used in the economic evaluation to adjust the cost of foreign exchange. This could alter the outcome of the analysis in favour of alternatives with higher local content.

12.3 Sensitivity

The entire economic analysis is based on various sets of assumptions, including the following:

- discount rate,
- average service life,
- study period,
- capital costs,
- operating costs,
- estimated income,
- residual values, and
- demand and traffic forecasts

It is important to know whether the analysis is particularly sensitive to errors in any of the major assumptions for each alternative. To find this out, vary each parameter independently by, say, 1 per cent; then review the corresponding percentage change in the outcome for each alternative. The figures produced are called sensitivity coefficients.

If error margins have been estimated for some items, sensitivity can be checked by examining the effect of the error extremes on the outcome of each alternative. Specifically, does the order of ranking the alternatives change? If it does, re-examine the probability that this degree of error will occur. If the accuracy cannot be improved, strong consideration should be given to the alternative with the most flexibility. (Flexibility is discussed in the next step of this guide.)

12.4 Funding Plans

A funding plan is a necessary input to, and consideration for, the feasibility study generally (see Figure 9.1). Normally both foreign exchange and local currency components will be needed to fund the project.

Sources of foreign exchange can include foreign aid agencies, development banks, and sometimes supplier credit (contractor financing).

From Canada, the Export Development Corporation (EDC) provides loans to finance Canadian products and services for international projects. The Canadian International Development Agency (CIDA) also provides funds for international projects, usually in the form of grants. CIDA also makes untied financial contributions to UN organizations and to international financial institutions for development. Information can be obtained from any Canadian High Commission or Canadian Embassy.

There are many development banks with world or regional mandates. Generally a development bank requires that certain evaluations be undertaken and certain information gathered during the feasibility study. And the bank may use the feasibility study to help appraise the project, assessing the eligibility of the project and the bank's interest in it.

The bank might also impose certain conditions on the project, such as the retention of consultants, training requirements, and competitive bidding, any or all of which could affect project planning and implementation.

Step 13

Evaluate the Technical Aspects

In addition to a financial evaluation, you must also evaluate intangible technical aspects that cannot be easily reduced to monetary terms, such as:

- implementation risk,
- flexibility,
- operational considerations, and
- reliability.

Evaluating each alternative against these terms reveals which alternatives may have added value and will ensure that each alternative is generally suited to the requirements.

13.1 Implementation Risk

Implementation risk can be examined by asking such questions as:

- Is all equipment field-proven and in production, or is some being developed, or still to be developed? Are lists of users and contacts available to verify field performance?
- Does the alternative depend on other projects being completed on time?
- Does implementation depend on the availability of special equipment, transportation, labour, or suitable weather?
- How complex are field installation and alignment procedures?

13.2 Flexibility

Flexibility refers to the technical and economic ease with which an alternative solution can accommodate, or be adapted to, changing conditions or requirements.

The need for flexibility stems from uncertainty in forecasts for demand, service requirements, technological change, etc. The longer the time span, the more uncertain the forecasts and, thus, the greater the need for flexibility.

In examining the flexibility of an alternative, ask questions such as:

- What are the minimum expansion increments and how expensive are they to procure and install?
- What is the maximum capacity before replacement is necessary?
- Can the product be enhanced to provide additional features and capability, such as ISDN?
- Will the supplier support product evolution with backward compatibility?
- What are the equipment and labour costs to reconfigure circuits or change operation?
- Can the system be easily taken out of service and relocated or reused to expand facilities at other locations?

13.3 Compatibility

Compatibility can be examined by asking the following questions:

- Is there compatibility with existing facilities for successful interworking (signalling,numbering, charging, etc.)?
- Is the system compatible with CCITT and CCIR recommendations to help ensure continuing compatibility with future developments?
- Does the system conform to the administration's technical standards as well as with national standards and safety codes?
- Is there compatibility with regulatory constraints and policy?

13.4 Operational Considerations

Operational considerations include such aspects as training, maintenance, operations, and sparing.

New technologies imply, to varying degrees, new training requirements and perhaps maintenance and repair personnel with different skills. In any event, new staffing levels need to be considered and these requirements specifically must be included in the feasibility study.

The types and total quantity of spares that must be held increases if the number of types and versions of equipment in the network is increased.

Operational considerations generally encourage maximizing standardization. However, arguments for standardization should not be allowed to impede unnecessarily the long-term and cost-effective evolution of the entire network.

13.5 Reliability

Reliability has many aspects. Some typical questions to ask include:

- Are failure modes soft or hard (degraded performance or total outage)?
- How often and for how long will service likely fail? Is there any diversity or protection available?
- How quickly can service be restored considering the way troubles are detected and reported as well as travel times and on-site repair or restoral procedures?
- Has the system demonstrated reliable operation in your environmental conditions?

Step 14

Prepare the Feasibility Report

The final step in the feasibility study phase is to document the results in a report. The review of this report by management will decide the fate of the project. So the report must state clearly what needs to be done and the best way to do it.

The administration may have specific formats to follow and the funding agency may have specific requirements, but normally at least the information outlined in the following subsections needs to be included in the Feasibility Report.

Summary. The Feasibility Report should start with a brief statement of the purpose of the study, the main results, and the principal recommendations.

Background. The report should be introduced with such information as

- the reasons for the study,
- mandate and authority under which the study was conducted,
- description of the rural telecommunication situation, and
- the general scope of the study.

Requirements Definition. A section of the report should state concisely the defined requirement, preferably illustrated with maps and tables. The complete definition of requirements documented, produced, and approved — as a part of the needs analysis phase — can be appended to the report for completeness.

Design Alternatives. The contending alternatives should be functionally described, including a time line description, supported with block diagrams and equipment lists, of any required expansions and replacements.

Justification should be offered for any major alternatives eliminated during the earlier part of the study, and consequently not evaluated and compared in detail.

Study Data. To qualify and lend credibility to the study results, all assumptions should be stated and justified, and the sources of all data and information identified; for example, other departments, government agencies, supplier's budgetary quotations, etc.

Methodology. The methods and criteria for the financial and technical evaluations must be clearly stated and explained.

Results. The results for each alternative should be tabulated and illustrated for ease of review and comparison. Typically, graphs should be used to compare accumulated present worth, investment cash flows, annual operating costs during the study period, and sensitivity analyses (see Figure 14.1). Accuracy should be discussed.

Recommendations. One of the alternatives is recommended for implementation. The choice should be obvious and justified directly on the basis of the results. Further actions needed to implement the selected alternative should also be recommended, including what needs to be done, when it needs to be done, and how it should be done.

Step 15

Analyze Contractual Needs

A contractual needs analysis determines how the project should be divided into contracts, what types of contracts should be let, and whether prequalification procedures are warranted. The results of the feasibility study are used as an input to the Project Definition document, discussed in the next step.

Contractual needs analysis can be considered a 3-part process.

1. Break the project down into its component tasks, and examine the functional relationship of these tasks (see Figure 15.1).

2. Review in-house resources to determine their capability and availability to undertake any of the tasks (at least the internal project management function must be undertaken by the administration).

3. Group the various tasks into logical contracts.

The scope of each contract should be designed to maximize constructive competition, while keeping related work together to ease management and control. Typically, separate contracts can be let for the provision of electronic equipment, power equipment, and such civil works as site preparation, buildings, access roads, towers, and fences.

How the work is divided among contractors depends mainly on the availability of personnel within the administration to administer and control contracts. The more contracts let, the greater the resources needed to manage them.

15.1 Contract Classifications

Contracts may be classified according to what is provided, and all combinations are possible:

- engineering,
- equipment,
- installation,
- engineer and furnish,
- furnish and install,
- engineer and install, and
- engineer, furnish and install.

Usually the availability of resources within the administration determines which of these functions to include in any contract.

Engineer-furnish-and-install (turnkey) contracts have the advantage of making a single contractor totally responsible for completion and performance. But these contracts can be difficult to control, if the specifications are not absolutely complete, correct, and clear. Turnkey contracts also tend to reduce the amount and quality of competition.

Which engineering functions, and how much of each, are turned over to the contractor should be carefully considered. The contractor's engineer has a vested interest in the contract and consequently may be biased. Be particularly wary of how you specify items that are not readily measurable during the term of the contract, such as propagation and noise performance.

Furnish-and-install contracts can be advantageous, or even mandatory, when installing specialized equipment. And they have the advantage of making the contractor responsible for the installed performance of the equipment. However, separate contracts for the furnish and the install phases often increase competition.

When the administration has the manpower to install a system, but not the specialized expertise, it might consider undertaking the installation under the direction of supervisors provided by the manufacturer.

Independent engineering services are also available on a contract basis (outside of the equipment supply and installation contract). These services may be flexibly provided to the administration to suit their specific needs — from full project engineering responsibility to the provision of advisors or supplemental engineering capability. Care must be taken to procure these services based on qualifications, because an engineering mistake can cost a great deal more to correct later than the original cost of the engineering.

15.2 Prequalification Procedures

Depending on the final division of the project into contracts as well as the requirements of the administration and funding agency, it may be advisable to prequalify contractors. Generally, large projects that include installation services, such as turnkey or furnish-and-install contracts, should involve prequalification.

The purpose is to ensure that only contractors who can successfully complete the work be allowed to bid. Prequalification should be based on the following criteria for each interested firm:

- experience and past performance on similar contracts;
- capabilities with respect to personnel, equipment, and plant; and
- financial position.

The invitation to prequalify should outline the work, provide abbreviated specifications, and clearly state the minimum requirements for prequalification.

Step 16

Prepare the Project Definition Document

Once management has approved the recommended system design for implementation and the contractual needs analysis is complete, the next step is to prepare a Project Definition document.

A project manager should be assigned at this point, if this has not already been done. This position should carry the authority to commit budgeted resources on behalf of the administration.

The project definition defines the project in terms of system design, schedule, and resource requirements. The following are typical topics to be covered.

- *System Design Description:* Locations, technology, system descriptions, equipment lists, etc. supported by maps, diagrams, and tables.
- *Work Breakdown:* The functional structure of the project, its breakdown into specific tasks, and the grouping of tasks into contracts. (Refer to Figure 15.1 for a typical breakdown structure and Figure 16.1 for a typical task network.)
- *Organization and Staffing:* A chart of the project organization with staff assignments including brief terms of reference for each position and noting when the position should be activated.
- *Schedule:* A project schedule showing tasks, activities, and major milestone events (manpower and other resource requirements may be shown). A high-level bar chart is appropriate, but it should be supported with a critical path or precedence-type network diagram.
- *Resource Requirements:* Overall budgets, cash flow projections, manpower and special equipment needs, and any specific breakdowns required by the administration or funding agency.
- *Project Control:* Cost and schedule control methods, such as monitoring actuals and updating forecasts against original budgets and schedules.

Since the Project Definition document is the implementation plan and fundamental control document for the project, it should be reviewed and approved by the appropriate management level.

Step 17

Preview of the Detailed Engineering Phase

During the detailed engineering phase, the system designs in the project definition must be transformed into sufficiently detailed commercial conditions and technical specifications to enable contractors to prepare bids for all necessary equipment and services.

These conditions and technical specifications form the contract bidding documents, the Requests for Proposal (RFP). This step previews the contents of the RFP and discusses the prerequisite survey and final design work.

The parts of the project to be implemented using in-house resources; i.e., parts not contracted, will need to have appropriate technical specifications prepared but, of course, commercial conditions are not needed.

17.1 Request for Proposal

Preparing the RFP entails developing the following documents for each contract identified in the project definition:

- Scope of Work,
- Technical Requirements,
- Equipment Specifications,
- Supporting Information,
- Bidding Requirements, and
- Contract Forms and Contract Conditions.

These documents must be carefully developed to ensure that they

- accurately describe the work and performance required;
- encourage competitive bids from eligible suppliers;
- allow submitted proposals to be efficiently and effectively evaluated; and
- create a manageable contract framework.

Steps 18 and 19 provide checklists and considerations to help the engineer write specifications and requirements for international competitive bidding.

17.2 Surveys and Final Design

Depending on the type of contract to be let, various engineering efforts are needed before writing the technical specifications. Furnish-only contracts require the most in-house engineering, and turnkey contracts the least.

Field surveys are needed to verify any previous design assumptions and to obtain the following data:

at existing sites

- space for an equipment room,
- power capacity available and its characteristics,
- tower adequacy for additional antennas and feeder lines (loading and space),
- cable tray and duct capacity, and
- waveguide building entry ports;

at new sites

- site access for installation and maintenance,
- power,
- path profile if radio is to be used,
- cable route if cable is to be used,
- soil type for foundation designs, and
- any special conditions, obstacles, security issues, etc.

If a model was used in the feasibility study, examine each service area and specify in detail the equipment quantities, locations, and physical routes. If a model was not used, review and verify the original design quantities, locations, etc.

Step 18

Prepare the Technical Specifications

The technical specifications of the Request for Proposal can usually be divided into the following parts:

- Scope of Work,
- Technical Requirements (for services supplied),
- Equipment Specifications (for goods supplied), and
- Supplemental Information.

In this section, the intent and contents of each of these divisions are discussed.

18.1 Scope of Work

The Scope of Work is a key document of the Request for Proposal in general, and the technical specifications in particular. Thus, draft it first because this helps in organizing and formulating the other bid request documents.

The Scope of Work document specifies the contracted quantities of equipment, scope of services, locations of work, and completion schedules. Typically it is divided into the following sections:

- Project Overview,
- Work Statements,
- Equipment Quantities,
- Schedules, and
- Responsibilities.

Price breakdowns requested and contract payment terms should correlate with the tasks, equipment quantities, and milestones stipulated in the Scope of Work.

Work Statements. The work should be broken down into two sets of specific tasks:

- those involved in providing goods, and
- those involved in providing services.

Each task should be keyed to specific sections that completely describe and qualify the work to be done or equipment to be supplied. Thus, tasks related to providing goods refer to equipment specification sections, and tasks that provide services refer to technical requirements sections (where appropriate terms of reference are stipulated).

Optional tasks should be identified as such. It should be clear whether it is a bidder's option to offer or not, or whether it is the purchaser's option to accept or not, with the offer being mandatory.

Equipment Quantities. Tables can be used to present quantities of equipment and documentation. Matrices can be used to show how equipment is to be distributed among the various locations.

Schedules. Contract milestones and target completion dates for phases (or areas) of the work should be stipulated. Dates for design reviews and dates for submission of documentation should be included. These may be referenced to contract milestones; for example, recommended acceptance procedures due 4 weeks prior to the start date of final acceptance.

Responsibilities. The document should delineate specific responsibilities for those involved in the contract: the purchaser, contractor, funding agency (if applicable), and engineer (if applicable).

Responsibilities at interface points must be clearly drawn. For example, where and how does the contractor interact with existing facilities or with facilities provided by other groups.

18.2 Technical Requirements

The Technical Requirement sections should provide terms of reference that describe fully the requirements of each service the contractor is asked to provide. Depending on the type of contract contemplated, technical requirements may need to be written for the following services:

- engineering,
- civil works,
- installation,
- spares and test equipment,
- documentation,
- training, and
- technical support.

Engineering. If the contract is turnkey, define the contractor's engineering responsibilities and provide all necessary engineering design objectives and system performance requirements. Depending on the scope of the engineering entrusted to the contractor, the following items may be included:

- end-to-end transmission performance objectives in terms of noise and/or bit error rate,
- grade-of-service objectives, and
- reference equivalents for circuit attenuation.

Installation. To avoid misunderstandings about methods and quality expected, general installation instructions should be provided for such items as:

- planning and coordination;
- general methods concerning cable practice, earthing practice, equipment stenciling and cable tag practice, etc.;
- installation tests;
- supply of tools and test equipment;
- changes and additions to the approved specifications and drawings; and
- supervision or on-the-job training of personnel, if applicable.

Acceptance. Factory acceptance testing or field acceptance testing, or both, may be required of the contractor, depending on the type of contract.

Notification requirements for factory and field acceptance as well as provision of procedures, equipment, forms, and reports should be stipulated.

Factory test certificates are usually requested and the right to witness factory tests should be reserved. Minimum factory tests may be specified.

Field acceptance tests may be conducted independently or jointly. They should ensure that the contract requirements have been fully satisfied. Minimum functional and performance tests may be specified. Basically, acceptance should ensure that

- the correct types and quantities of equipment have been provided;
- the installation is complete and of acceptable quality;
- the system is demonstrated to be fully functional; and
- the system meets performance specifications (proof of performance).

Training. Since staff must be prepared to operate and maintain the systems after commissioning, training is almost always needed. When new equipment and technologies are involved, training is absolutely essential. Courses should be requested for the following types of training and implemented as appropriate:

- engineering course: to enable expansion planning;
- field maintenance course: for on-site fault finding and repair;
- repair centre course: if repair at component level is anticipated;
- installation course: if installation will be undertaken; and
- instructor courses.

All staff to be involved in the installation or acceptance phase of the project must receive suitable training before participating in these phases.

The number of candidates for each course as well as their education and experience should be stated.

Documentation. At a minimum, the contractor should be required to submit manuals for all equipment provided. Depending on the type of contract, shop drawings, test procedures, site documentation, recommended spares and test equipment lists, and other submissions may be required from the contractor. The submittal of some of these may be requested in preliminary form with the bid.

The contractor should be asked to submit installation procedures and site drawings for review and approval before installing any equipment. Likewise, the contractor should submit acceptance test procedures before beginning acceptance tests.

General site drawing requirements should be stipulated to ensure that essential information is provided and that standard or preferred formats are observed. Full-size reproducible masters of all as-built drawings should be requested for submission at contract completion.

18.3 Equipment Specifications

The equipment specifications should be divided into convenient sections based on units of procurement or manufacture. If an item of equipment or plant, for example, antennas, cables, generator sets may need to be procured in the future, outside of the contract, then a relatively self-contained specification section should be developed for this item. If a type or class of equipment is typically manufactured by a single manufacturer, then a relatively self-contained specification section should also be developed for this. For example, a battery manufacturer usually does not make chargers and vice versa. Divisions along these lines give flexibility in arranging and re-using the specifications, and it also helps the contractor in dividing the work to subcontractors.

If the technical requirements are written to include engineering design and system performance requirements (for a turnkey contract) and if the Scope of Work defines the equipment quantities and locations, then the equipment specifications can be written as simple procurement-only specifications. This is often a good idea, because it usually simplifies revisions to the scope of the contract and it also makes reuse of the equipment specifications convenient.

Typically, each equipment specification should be divided into major sections such as the following:

- Scope,
- References,
- Environmental Conditions/Requirements,
- Functional/Operational Requirements,
- Physical/Mechanical Requirements,
- Electrical Power Requirements, and
- Performance, including parameters, units, and how they are measured.

Usually, equipment specification clauses can be divided into mandatory requirements, desirable requirements, and information requests.

Mandatory Requirements. A mandatory requirement is a minimum functional capability or performance specification that must be met or exceeded. Failure to achieve these requirements may be cause for rejecting the bid.

Mandatory requirements can include options that must be offered by the bidder but whose acceptance is the purchaser's option.

Desirable Requirements. Desirable requirements are preferred functional capabilities or performance specifications that will be favoured in the evaluation, but are not considered essential. These could be considered bidder options. The bidder should be requested to state whether compliance is inherent in his product or whether it can be added as an option at extra cost.

Information Requests. Information requests are generally made in regard to secondary capabilities or performance specifications. The information is usually requested to help evaluate the bid and to ensure that full specifications are divulged. The full specifications are needed from the successful bidder because, in addition to meeting the mandatory requirements, his work should be accepted against these other specification parameters and performance levels.

18.4 Supporting Information

Supporting information includes all associated data that bidders need to prepare responsive proposals. The following list identifies typical items:

- maps,
- climatological data and statistics,
- detailed interface descriptions for existing facilities,
- path profiles,
- site plans, and
- soil reports.

Step 19

Prepare the Commercial Conditions

The Commercial Conditions part of the Request for Proposal can usually be divided into the bidding requirements and contract matters. In this section the intent and contents of each of these divisions are discussed.

19.1 Bidding Requirements

Full instructions regarding the content and format of proposals should be provided. The following sections are typically covered:

- Invitation to Bid,
- General Instructions,
- Special Instructions,
- Bid Form, and
- Price Tables.

Invitation to Bid. The invitation to bid should include at least the following:

- name and location of the project,
- brief description of the work (type of contract, application, technologies, approximate scale, etc.), and
- time and place for receiving bids.

Instructions to Bidders. The instructions to bidders provide details on requirements pertaining to the submission of bids. Often these instructions are divided into general and special. The special instructions concern the preparation of the management proposal, the technical proposal, and the price proposal.

The following is a checklist of items to include in the bidder's instructions:

- bidder qualifications or eligibility,
- visits to site,
- examination of, and familiarity with, the contract documents,
- submission date, place, number of copies, and means, if applicable (for example, hand-delivered),
- bid opening (public or private),
- right of rejection,
- partial and/or complete bids,
- right of partial acceptance,
- bid validity period,
- pricing (currency, foreign exchange, escalations, lump sums, unit costs, taxes, duties, shipping),
- substitutions,
- alternatives,
- enquiries and clarifications (contacts, deadlines, meetings),
- evaluation,
- proposed schedule of dates (bid invitation, bid closing, contract award),
- bid bond,
- bid form,
- proposal preparation (management, technical, cost, use of forms and tables),
- compliance (define the meaning of compliance statements to be used).

Price Tables. The price tables should include sufficient cost breakdowns to enable the bid to be adjusted during negotiations and to enable the contract to be adjusted after the contract has been awarded. Therefore, price breakdowns should reflect the contractor's tasks stated in the Scope of Work as well as unit costs for equipment and services.

19.2 Contract Forms and Conditions

A pro forma contract should be included for the bidder to review and comment on. The procurement or purchasing department should make available general contract conditions along with sample supplemental conditions.

Verify that the standard conditions are applicable to the type of contract being contemplated (for example, turnkey).

- Supplemental conditions usually need to be reviewed and amended as required to suit the specific contract needs. In particular, terms of payment should reflect the appropriate contract milestones.

Afterword

This guide leaves off where contractor selection and physical project implementation begins.

Experience shows that contractors find many ways to surprise the purchaser during contract execution. Some of these are pleasant, but unfortunately, some are not. However, good planning and design, leading to a clearly defined and completely specified contract, go a long way toward minimizing the number of unpleasant surprises, as well as making those that do occur easier to control.

To keep the project on track throughout the implementation phase, a careful watch must be maintained specifically by

- monitoring progress and tracking the completion of milestones;
- inspecting the civil works construction and equipment installation; and
- reviewing for deficiences and acceptance testing the completed works.

Concise but complete progress reporting on a regular basis is probably the best tool to manage the implementation. In particular, problems that may occur, or that have occurred, should be highlighted and treated.

This guide will have achieved its purpose, if it helps in any one, or all, of the steps necessary to take a rural telecommunications project from planning conception to implementation inception.

RURAL

TELECOMMUNICATIONS

PROJECT

PLANNING

GUIDE

Appendices

Appendix A

Figures

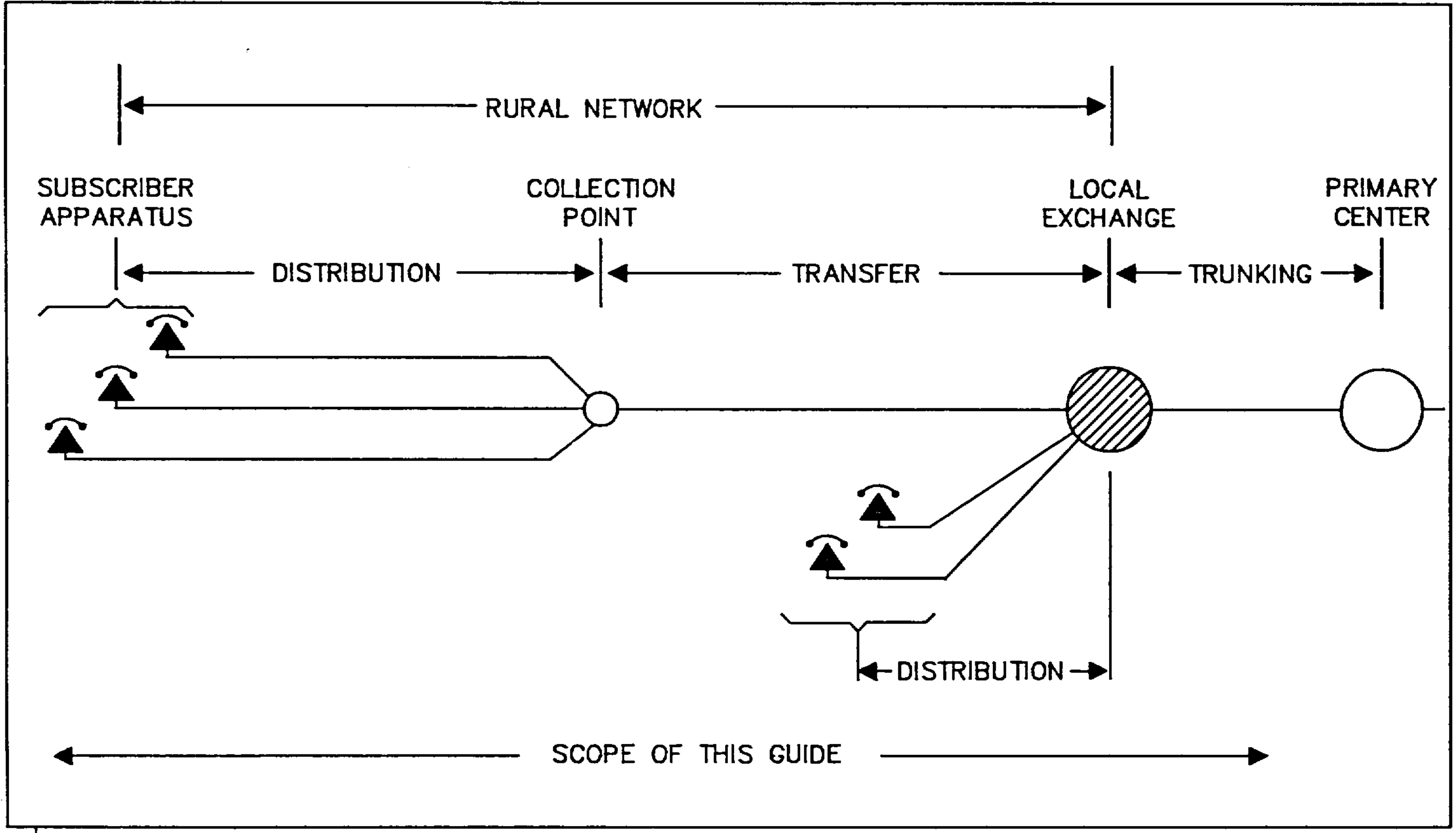


FIG 1-1 Rural Network Structure and Definitions

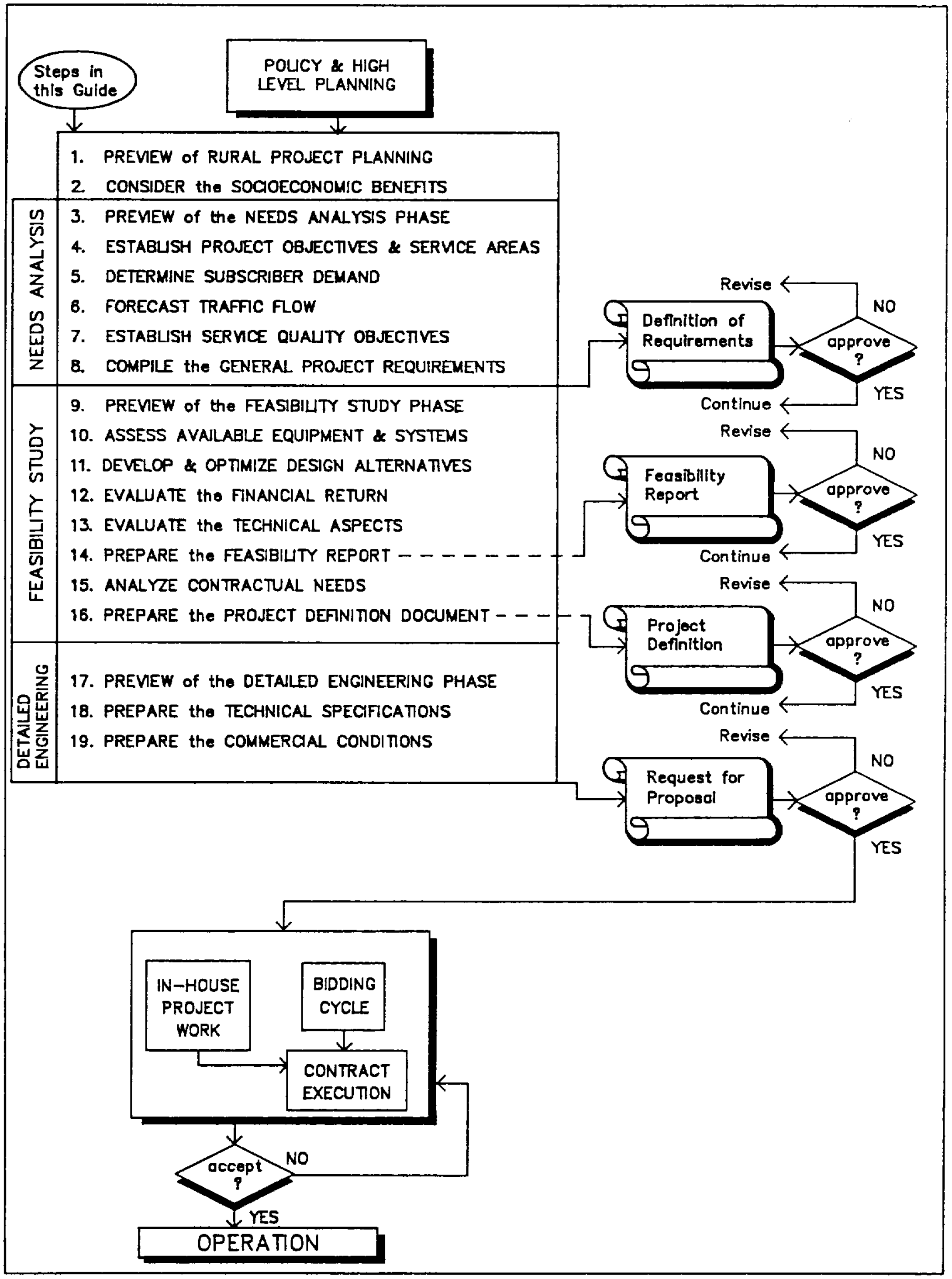


FIG 1-2 Project Overview

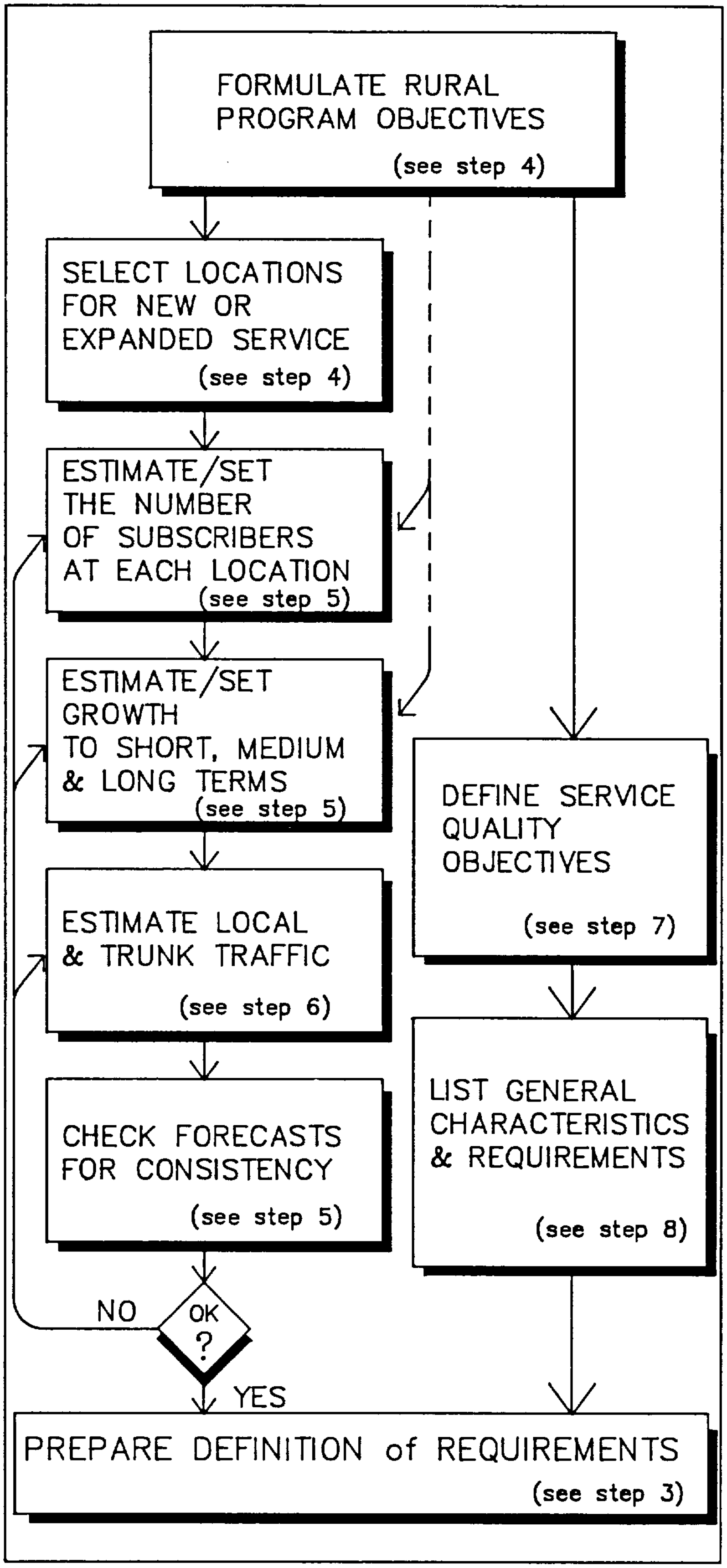


FIG 3-1 Needs Analysis Overview

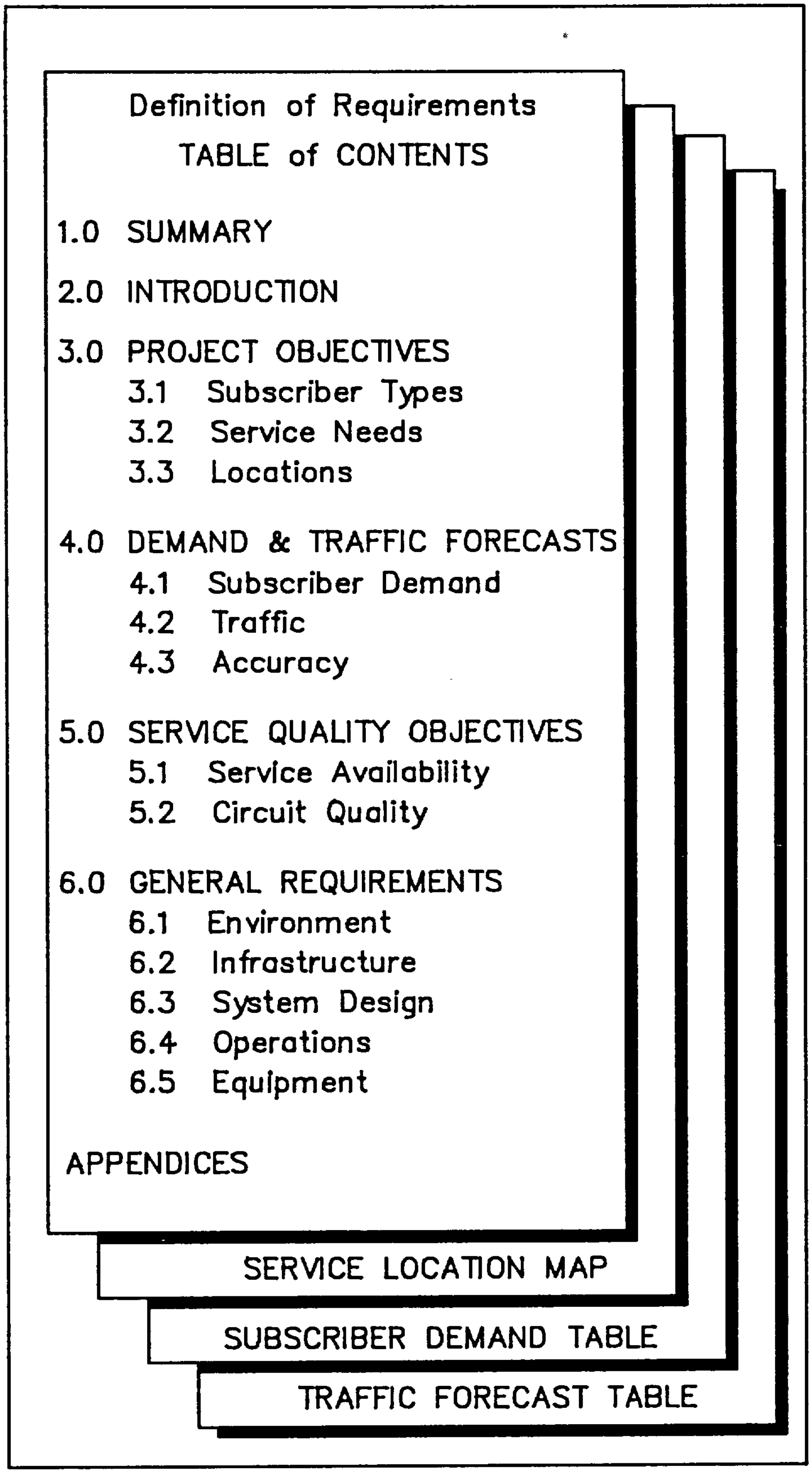


FIG 3–2 Typical Table of Contents for Definition of Requirements

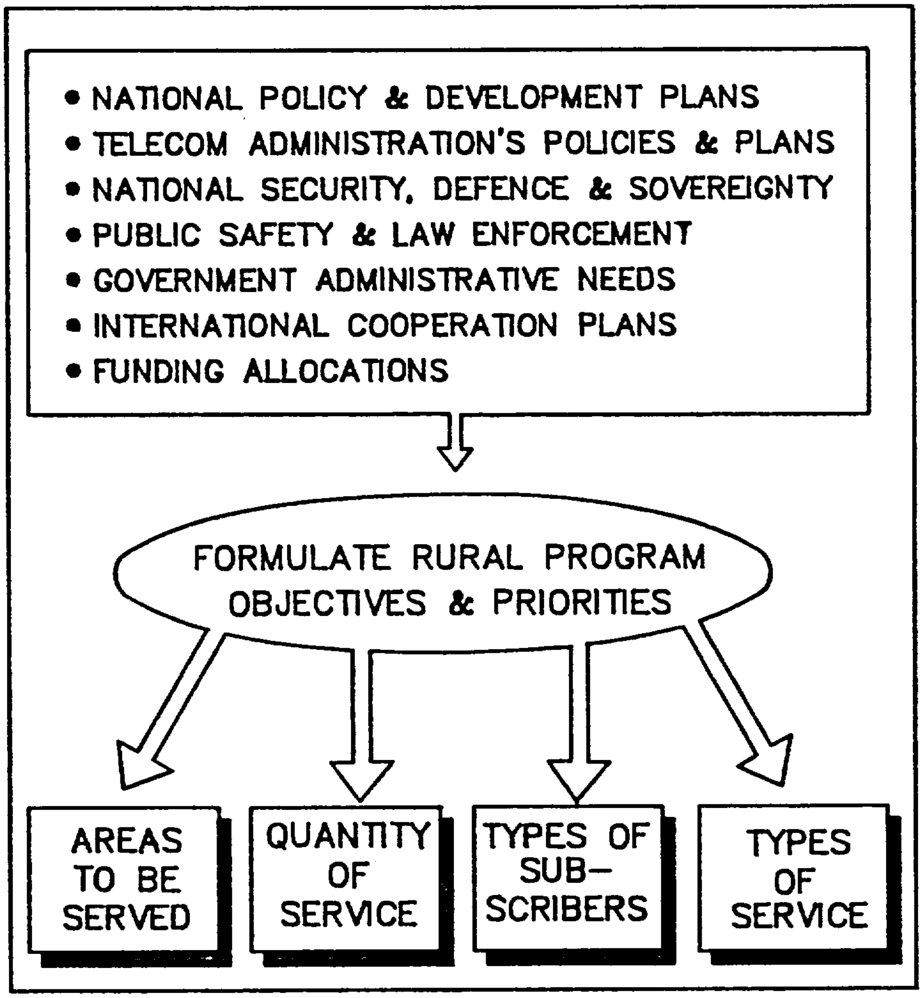


FIG 4-1 Inputs & Considerations for Project Objectives

	GENERAL				ECONOMIC ACTIVITY						FACILITIES																			
COMMUNITY OR LOCATION NAME	POPULATION OF SETTLEMENT	POPULATION OF SERVING AREA	SIZE OF SETTLEMENT (km^2)	SIZE OF SERVING AREA (km^2)	COMMERCE (SHOPS & MARKETS)	MANUFACTURING	MINING	AGRICULTURE & FISHING	TOURISM	EXPANSION TREND	SECURITY NEED ASSESSMENT	GOVERNMENT OFFICES	POLICE	MEDICAL	ROAD ACCESS	BUS SERVICE	RAIL SERVICE	AIR SERVICE	SCHOOLS	LIBRARY	POST OFFICE	TELEPHONE SERVICE (km TO NEAREST)	RADIO/TV	HOTELS/RESORTS	COMMERCIAL POWER	WATER/SEWERAGE				NOTES

CODES: MEDICAL FACILITIES: H–HOSPITAL, C–CLINIC, D–DISPENSARY, A–AMBULANCE
SCHOOLS: P–PRIMARY, S–SECONDARY, V–VOCATIONAL
COMMERCIAL POWER: C–CONTINUOUSLY AVAILABLE, 4–AVAILABLE 4 HOURS PER DAY

FIG 4-2 Typical Worksheet to Inventory Potential Locations for New or Expanded Telephone Service

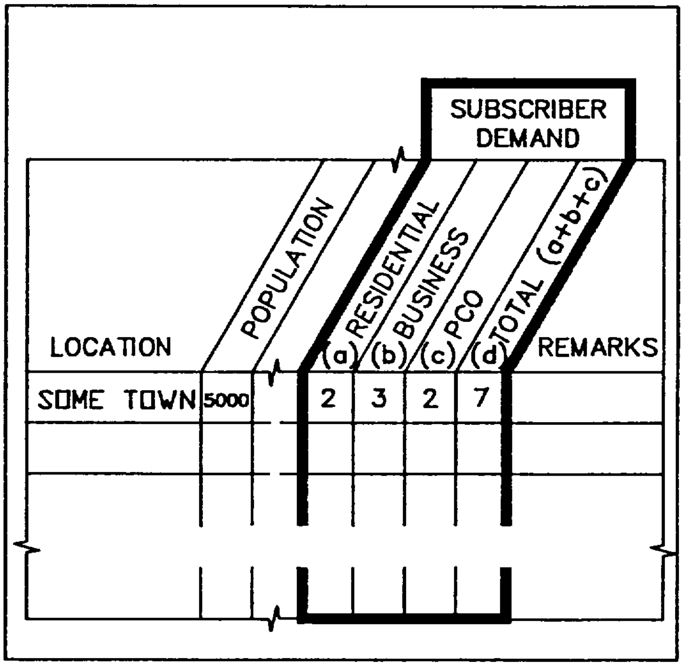


FIG 5–1 Typical Worksheet for Subscriber Demand

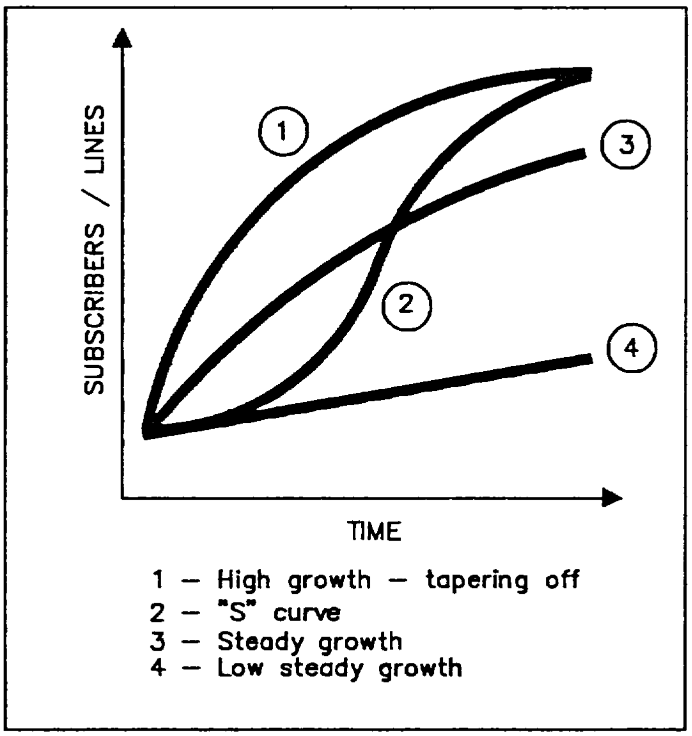


FIG 5–2 Growth Curves

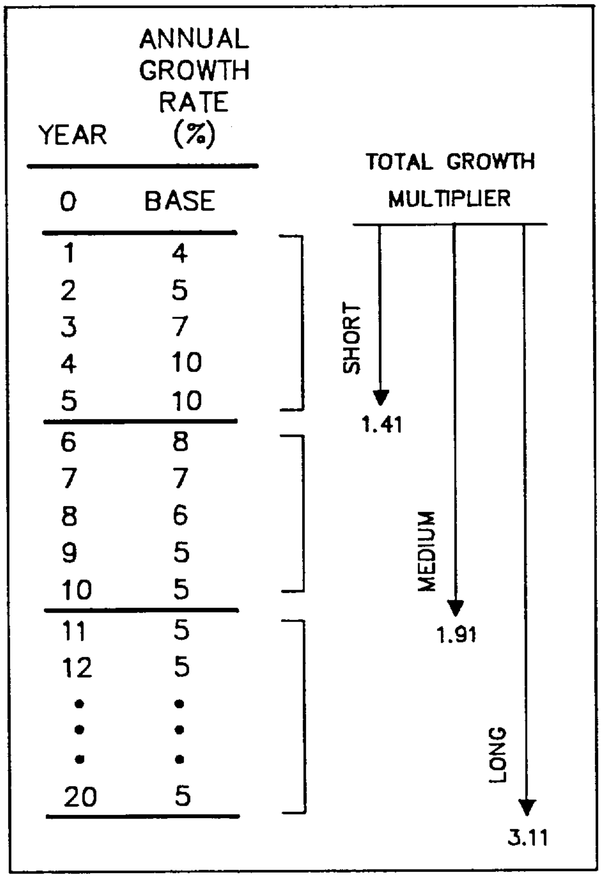


FIG 5-3 Example Growth Rate Table

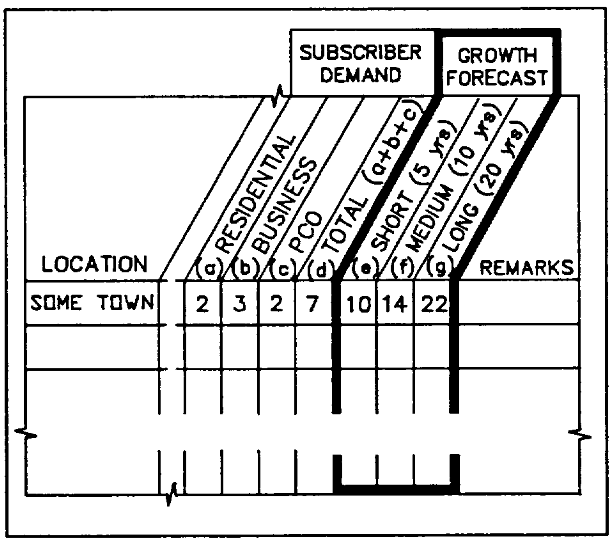


FIG 5-4 Typical Worksheet for Growth Forecast

SUBSCRIBER TYPE	TYPICAL BH TRAFFIC in ERLANGS per SUBSCRIBER LOW RANGE	HIGH RANGE
RESIDENTIAL	0.01	0.03
BUSINESS	0.06	0.12
PAY TELEPHONE	0.02	0.39
PUBLIC CALL OFFICE	0.30	0.50

FIG 6-1 Sample Range of Traffic Figures

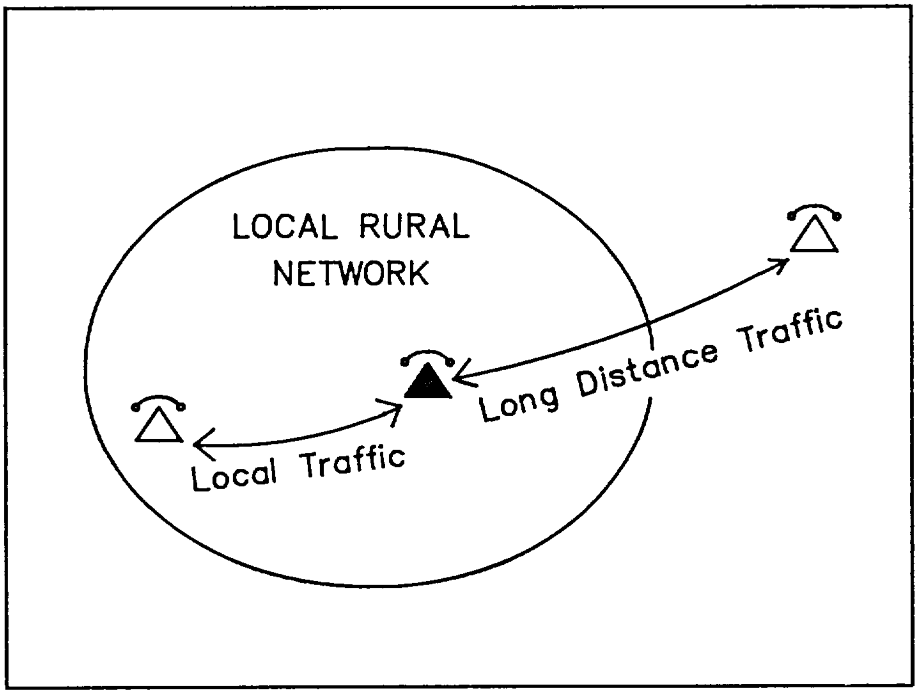


FIG 6-2 Traffic Distribution

		GROWTH FORECAST			TRAFFIC							
LOCATION	TOTAL (d)	SHORT TERM (5 years) (e)	MEDIUM TERM (10 years) (f)	LONG TERM (20 years) (g)	Average Erlang per LINE (h)	BASE YEAR TRAFFIC (E) (hxd) (i)	SHORT TERM TRAFFIC (E) (hxe) (j)	MEDIUM TERM TRAFFIC (E) (hxf) (k)	LONG TERM TRAFFIC (E) (hxg) (l)	% LONG DISTANCE (m)	OTHER SERVICES (n)	REMARKS
SOME TOWN	7	10	14	22	0.159	1.1	1.6	2.2	3.5	50	—	

FIG 6–3 Typical Worksheet for Traffic Forecasts

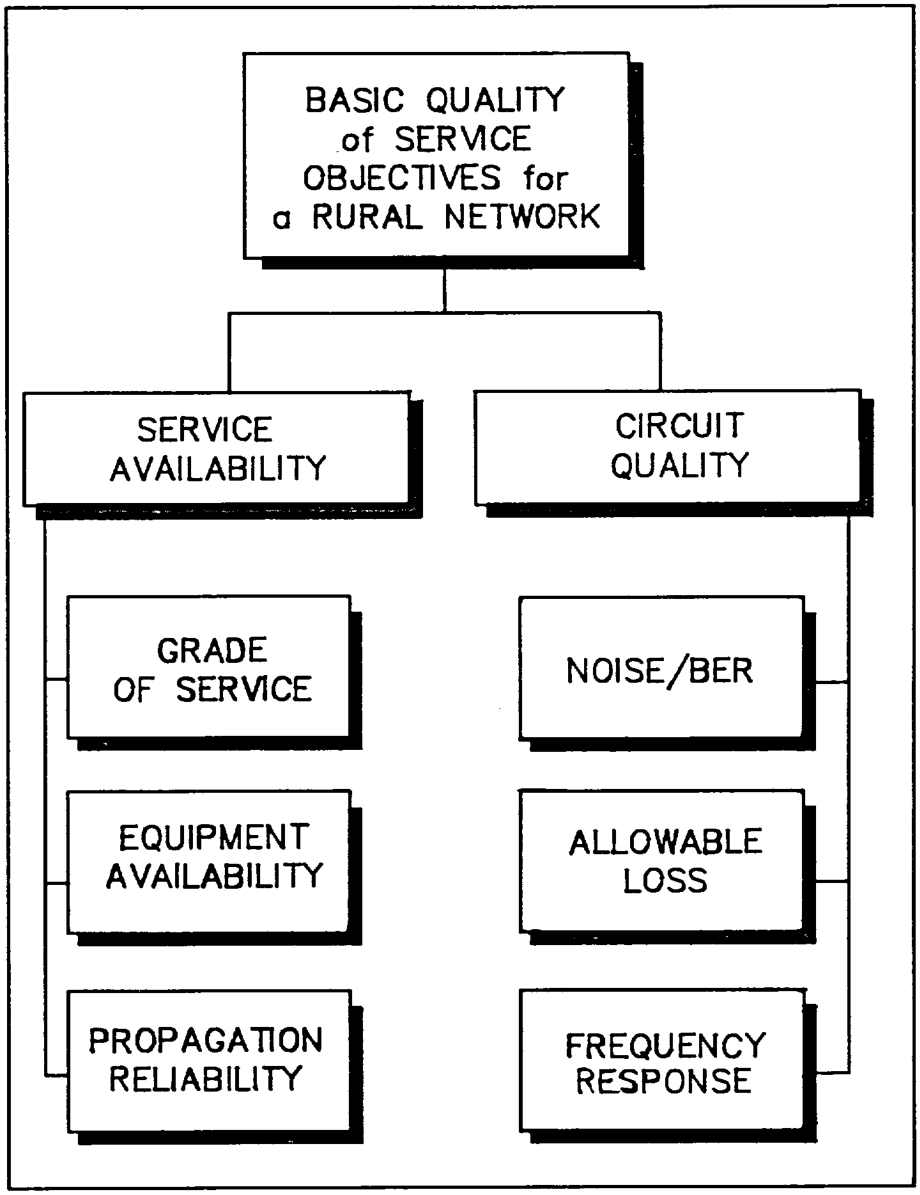


FIG 7–1 Rural Network Service Quality Objectives

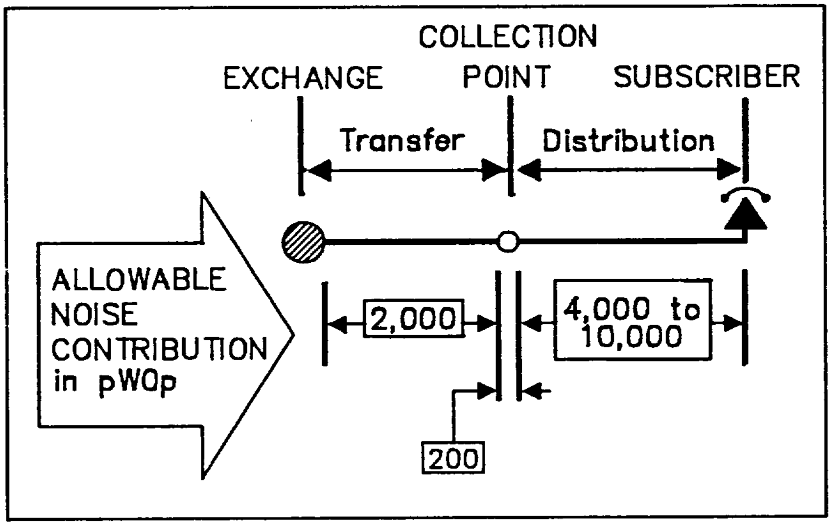


FIG 7-2 Typical Noise Allocations for Rural Subscriber Loop

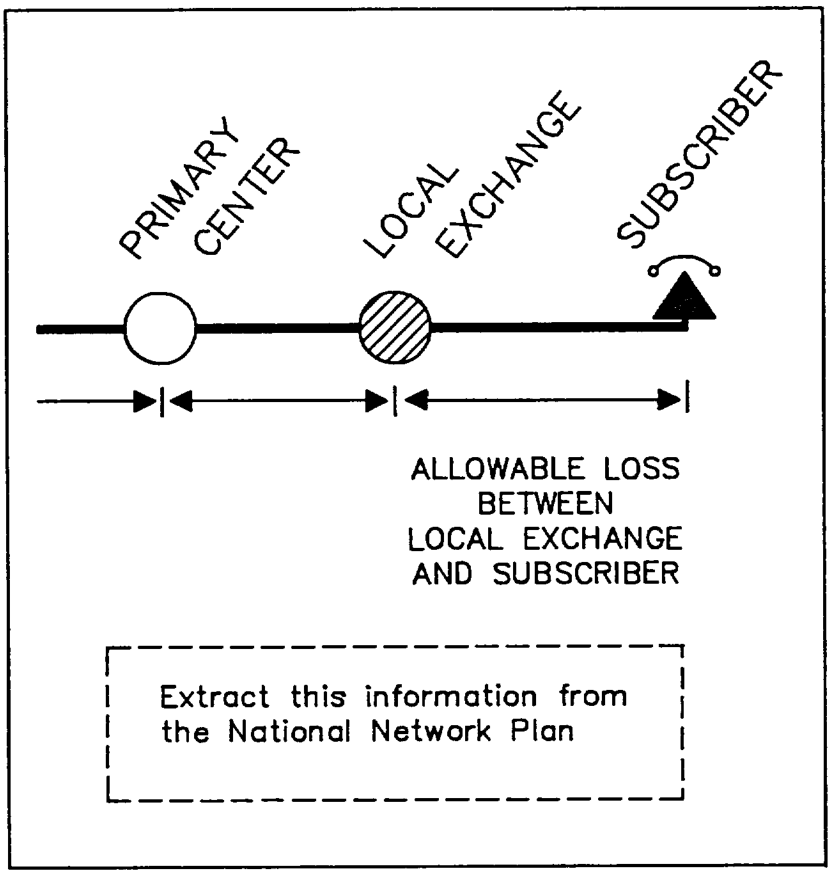


FIG 7-3 Reference Equivalent

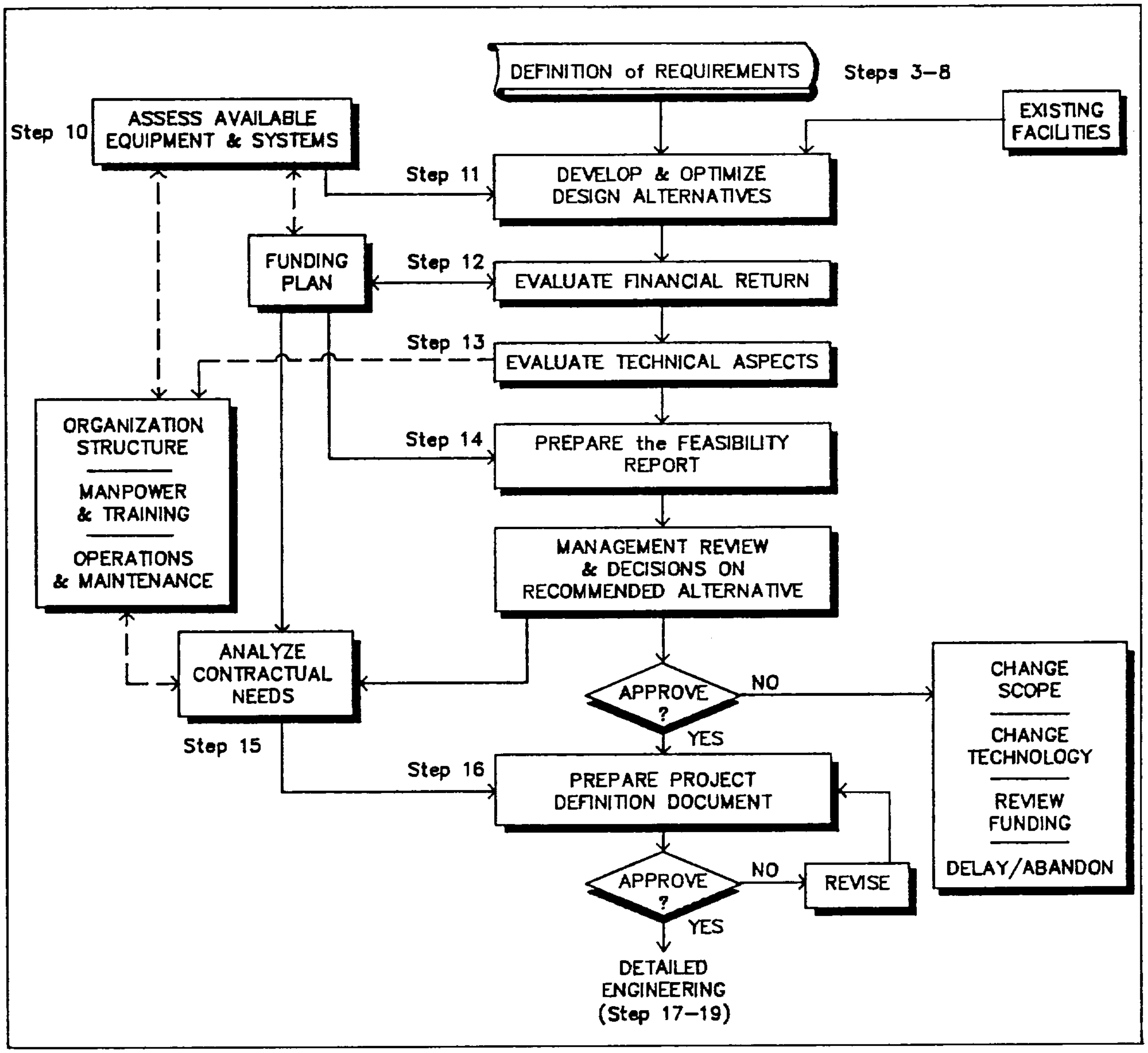


FIG 9–1 Feasibility Study Overview

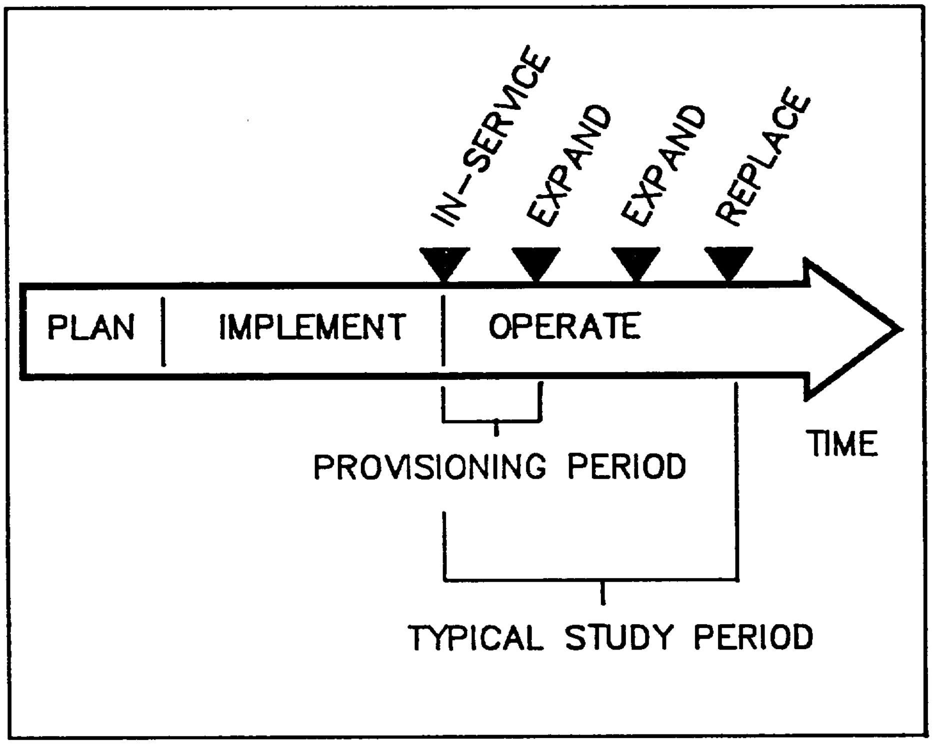


FIG 9–2 Sample Study Time Line

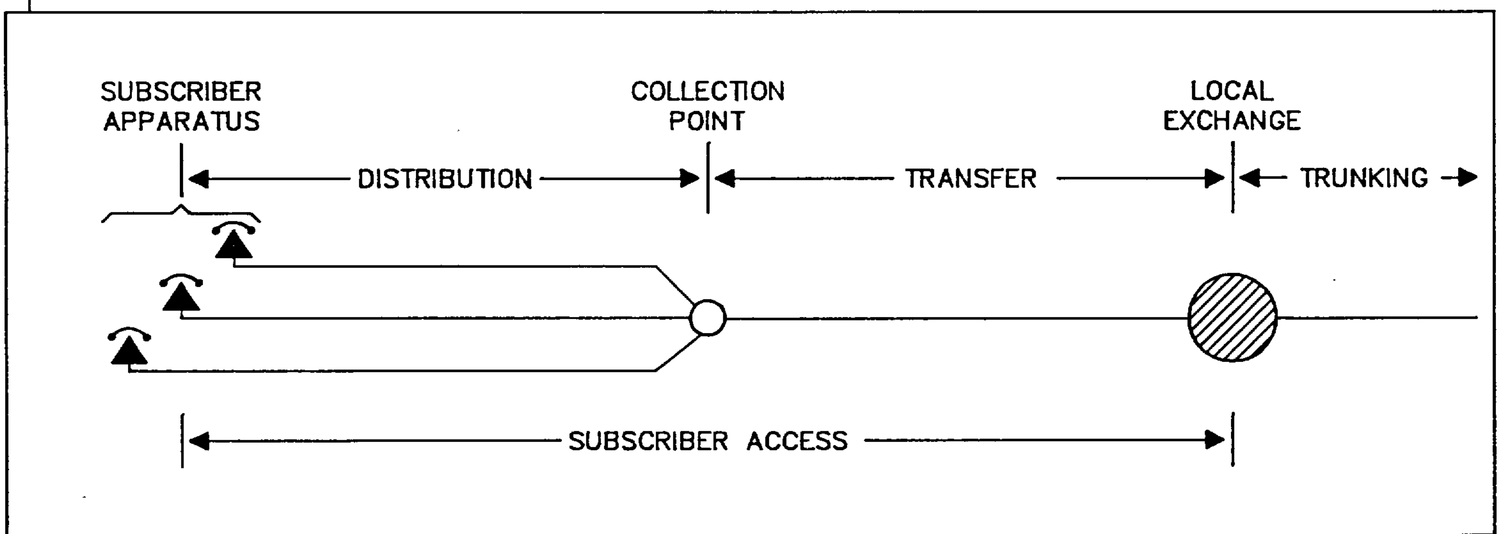


FIG 10–1 Functional Definitions

TDMA PRODUCT SUMMARY TABLE			
PARAMETER		PRODUCT "A"	PRODUCT "B"
MAXIMUM REMOTES PER CENTRAL		80	500
MAXIMUM LINES PER CENTRAL			
MAXIMUM LINES PER REMOTE			
GROWTH INCREMENTS	MODULE		
	SHELF		
	CABINET		
FEATURES	TIME-OUT		
	PRE-ASSIGNMENT		
	QUEUING		
	INTRA-CALL		
LINES	POTS		
	AC METER		
	DC METER		
MAXIMUM RANGE			
	TIME DELAY		
	REPEATERS		
MAX LOOP RESISTANCE			
SYSTEM GAIN (dB)			
RF CHANNEL SPACING			
POWER REQUIREMENTS			
COSTS: BASE STATION			

LIGHT ROUTE RADIO		
PARAMETER		PRODU
MAXIMUM CAPACITY		
GROWTH INCREMENTS	MODULE	
	SHELF	
	CABINET	
FEATURES	ORDER-WIRE	
	ALARMS	
	PROTECTION	
	DIVERSITY	
INTERFACE REQUIREMENTS		
SYSTEM GAIN (dB)		
RF CHANNEL SPACING (MHZ)		
POWER REQUIREMENTS		
COSTS: BASIC 2 Mb/S STANDBY INSTALLATION		

SUBS	
PARAM	
MAXIM PER	
MAXIM PER C	
MAXIM PER R	
GROWT INCRE	
MAXIM RANGE	
EMERG SWITC	
LINES	PO
	AC
	DC

FIG 10-2 Typical Product Summary Worksheets

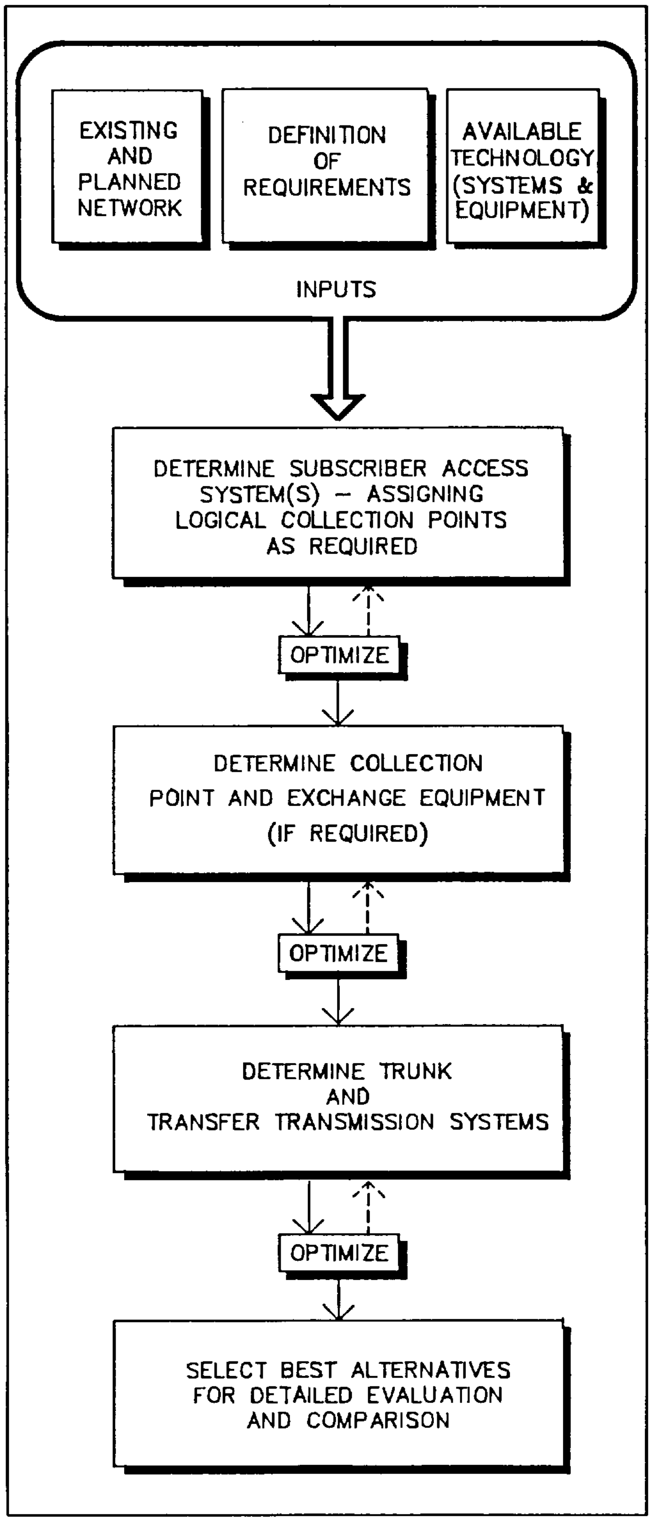


FIG 11–1 Developing & Optimizing Design Alternatives

2 PAIR CABLE	MULTIPLE ACCESS SUBSCRIBER RADIO	600–1000 LINE EXCHANGE	
Aa+Bb +	Cc+Dd+Ee+Ff +	Gg+Hh +	Jj . . .

WHERE:

A = cost of cable terminations at both ends of a 2 pair cable

a = number of 2 pair cables

B = cost per km for 2 pair cable including poles/burial, splices, accessories, installation

b = total length of 2 pair cable in km

C = cost per central station for common equipment, installation & testing

c = number of central stations

D = cost per repeater station

d = number of repeater stations

E = cost per remote station for common equipment

e = number of remote stations

F = cost per subscriber line for interface modules at the exchange and subscriber ends

f = number of multiple access radio subscribers

G = cost per 600 – 1000 line exchange for all common equipment (fully installed)

g = number of 600 – 1000 line exchanges

H = cost per subscriber line

h = number of exchange subscribers to be provisioned for

•
•
•

FIG 11–2 Form of Typical Cost Equations

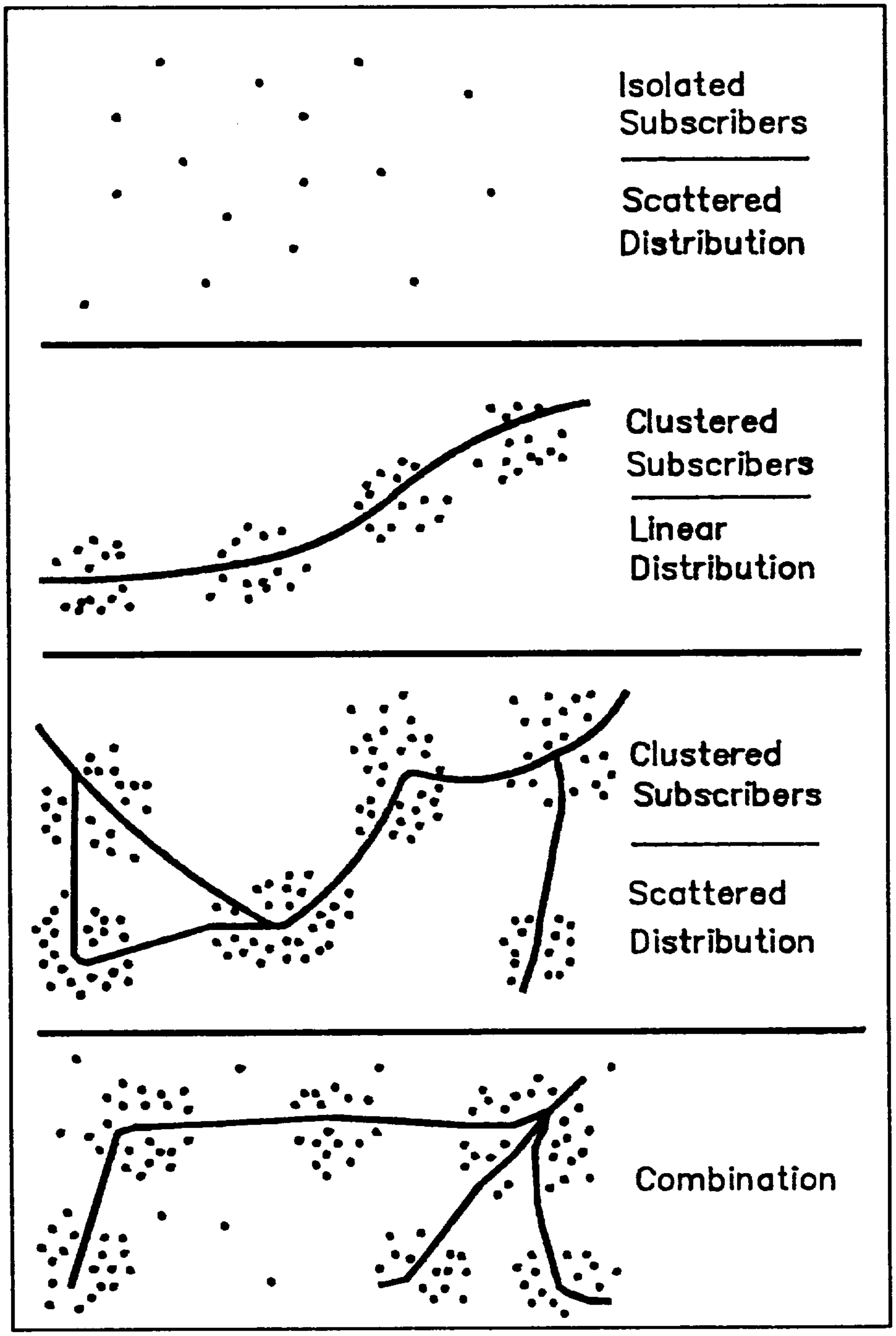


FIG 11–3 Types of Subscriber Distributions

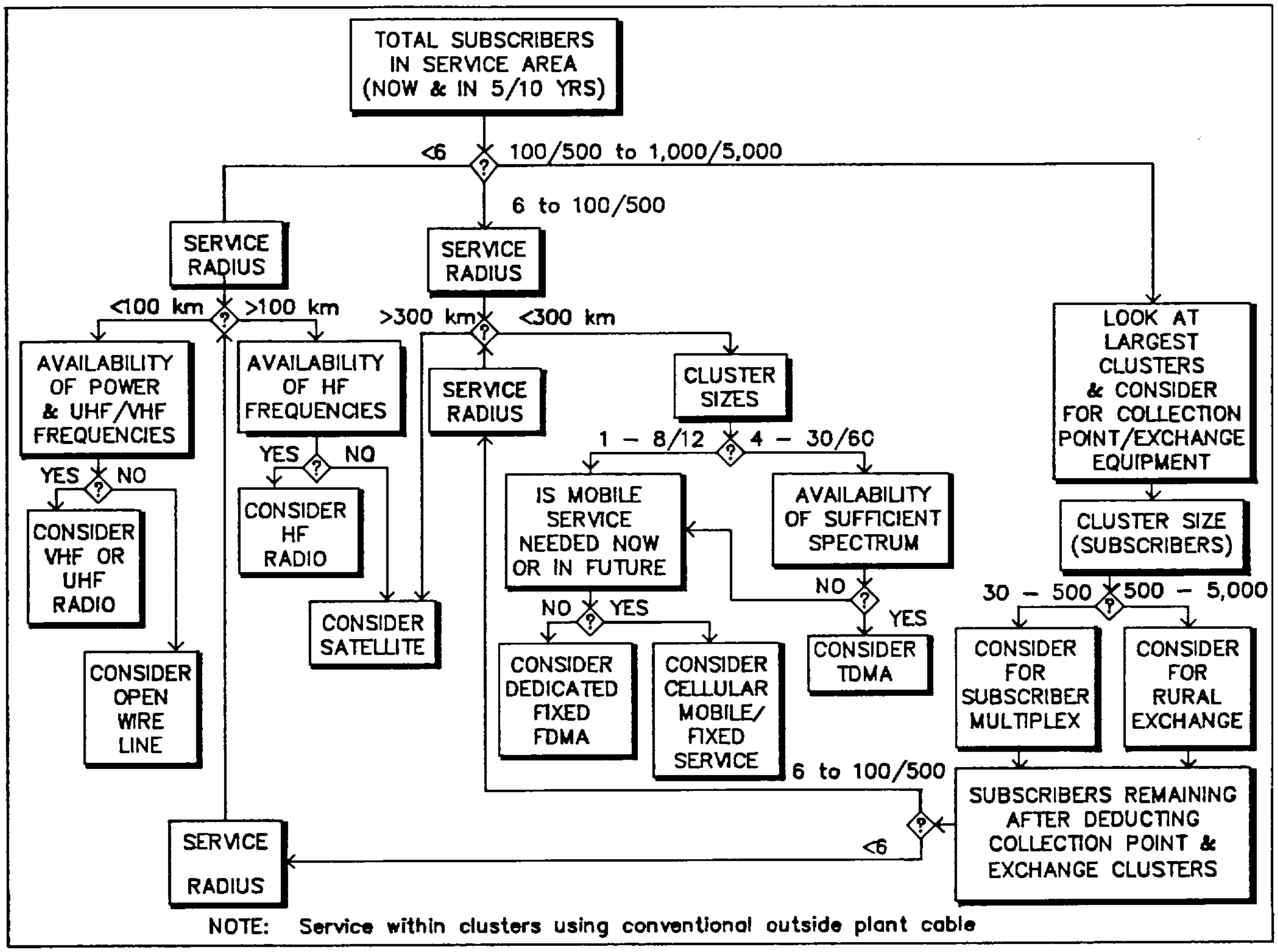


FIG 11–4 Example Flowchart for Creating Possible Alternatives

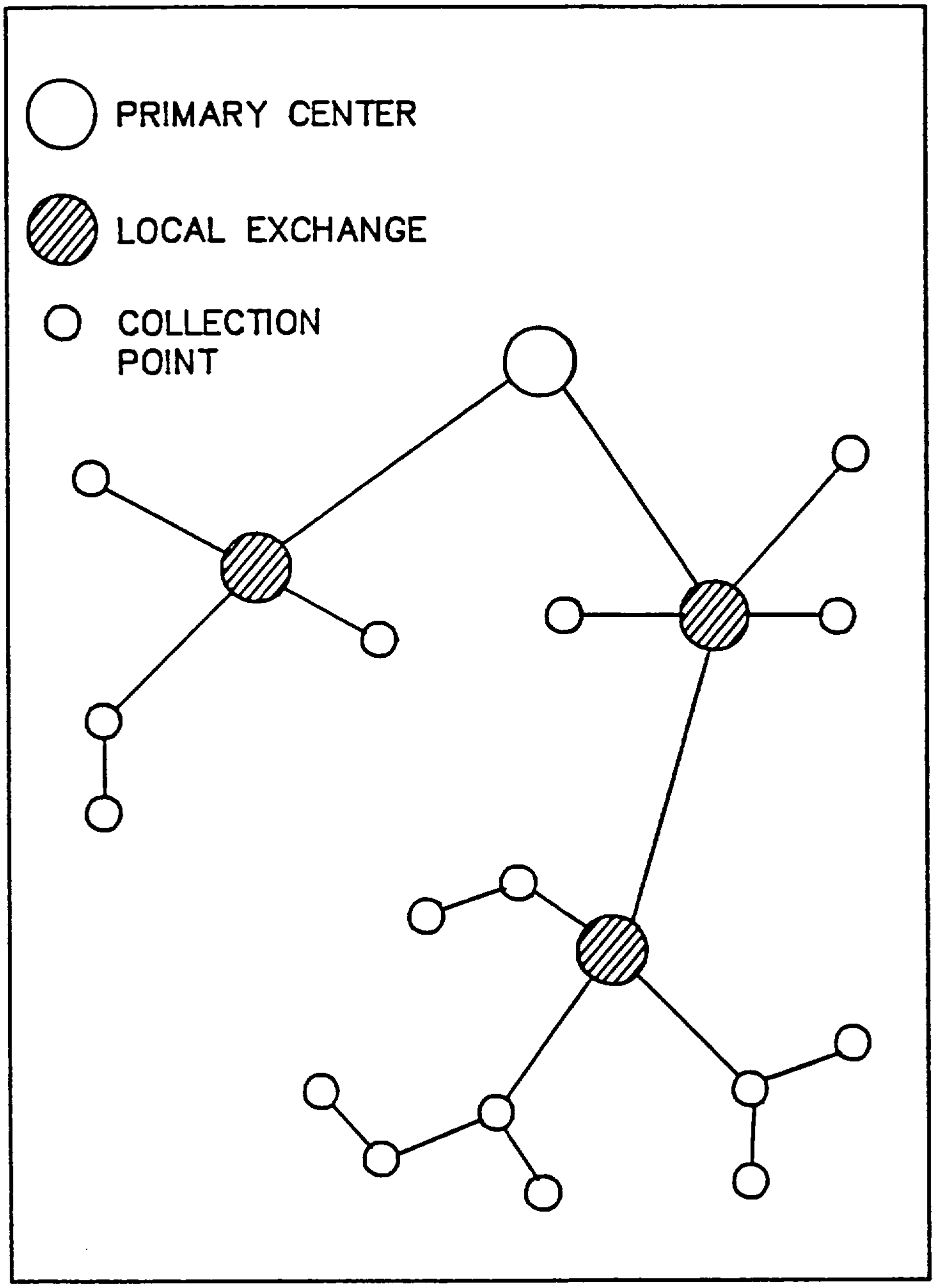


FIG 11–5 Minimum Tree Configuration

CATEGORY	YEARS
SUBSCRIBER APPARATUS	
Telephone Set	10
Coin Telephone	5
CABLE PLANT	
Poles	25
Open Wire	15
Aerial Cable	20
Buried Cable	40
Cabinets	20
Ducts	60
INSIDE PLANT	
Exchange	20
Transmission	20
Power	20
Batteries	10

FIG 12–1 Typical Average Service Life

CASH FLOW FOR ALTERNATIVE: . . . . DISCOUNT RATE (r): . . . . . %

ITEM	YEARS (n) ANNUAL AMOUNTS in CONSTANT DOLLARS										TOTALS
	0	1	2	3	4	5	6	7		20	
INVESTMENT											
Subscriber Access Equipment											
Exchange Equipment											
Transmission Equipment											
Power Equipment											
Subscriber Apparatus											
Cable Plant											
Buildings											
Towers											
Land											
Sub Total											
PW Sub Total											
OPERATIONS											
Labor											
Vehicles											
Power											
Factory Repairs											
Sub Total											
PW Sub Total											
RESIDUAL VALUE											
Electronic Equipment											
Subscriber Apparatus											
Cable Plant											
Buildings											
Towers											
Land											
Sub Total											
PW Sub Total											
INCOME											
Connection Fee											
Monthly Charge											
Usage Charge											
Sub Total											
PW Sub Total											
CONSTANT DOLLAR TOTALS											
PW FACTOR $(1+r)^{-n}$											
PW (DISCOUNTED) TOTALS											
CUMULATIVE PW TOTALS											

FIG 12-2 Typical Cash Flow Table

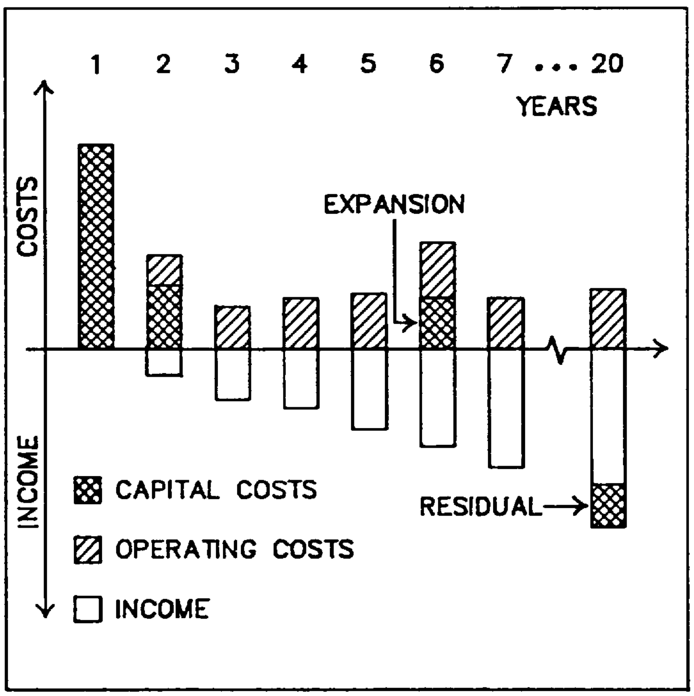


FIG 12-3 Typical Cash Flow Diagram

ITEM		ALTERNATIVES A	B	C
INVESTMENT	Constant Dollars Present Worth			
OPERATIONS	Constant Dollars Present Worth			
RESIDUAL VALUES	Constant Dollars Present Worth			
INCOMES	Constant Dollars Present Worth			
TOTALS	Constant Dollars Present Worth			
SENSITIVITY COEFFICIENTS Investment Operations Income Discount Rate	 +1% +1% +1% +1% −1%			

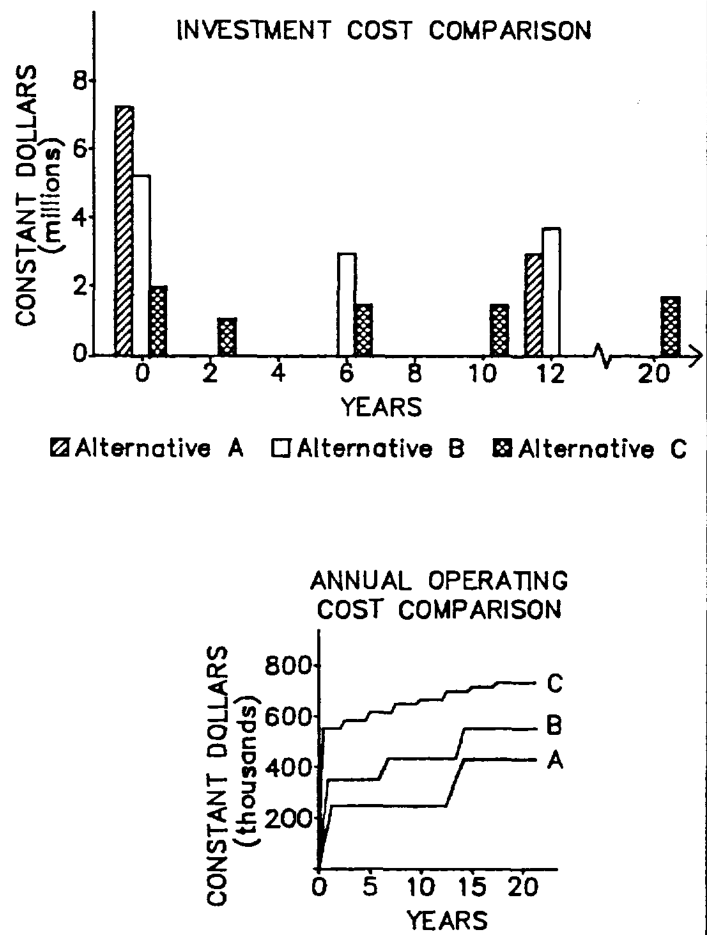


FIG 14-1 Typical Presentation of Economic Comparisons

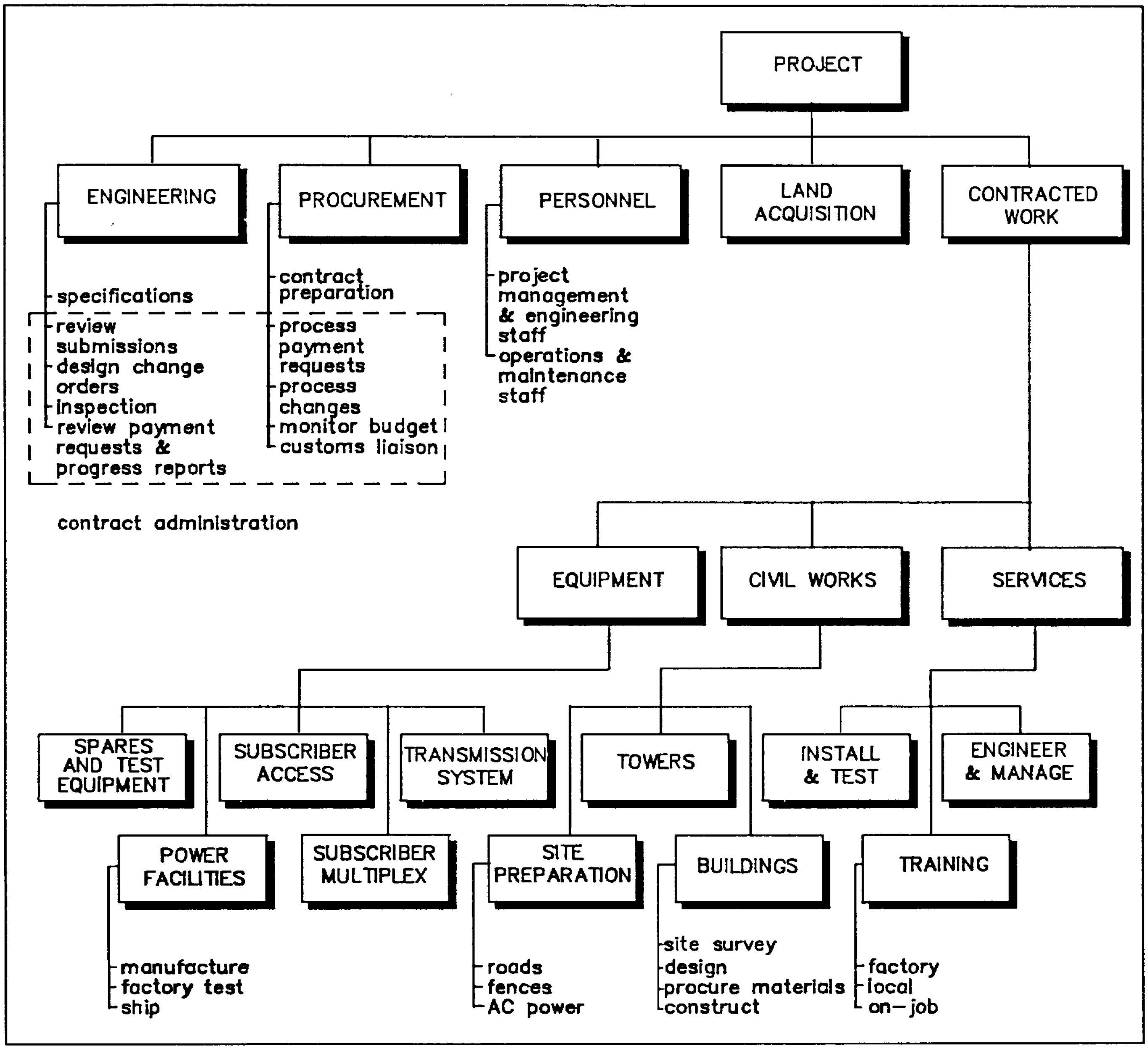


FIG 15-1 Typical Work Breakdown Structure

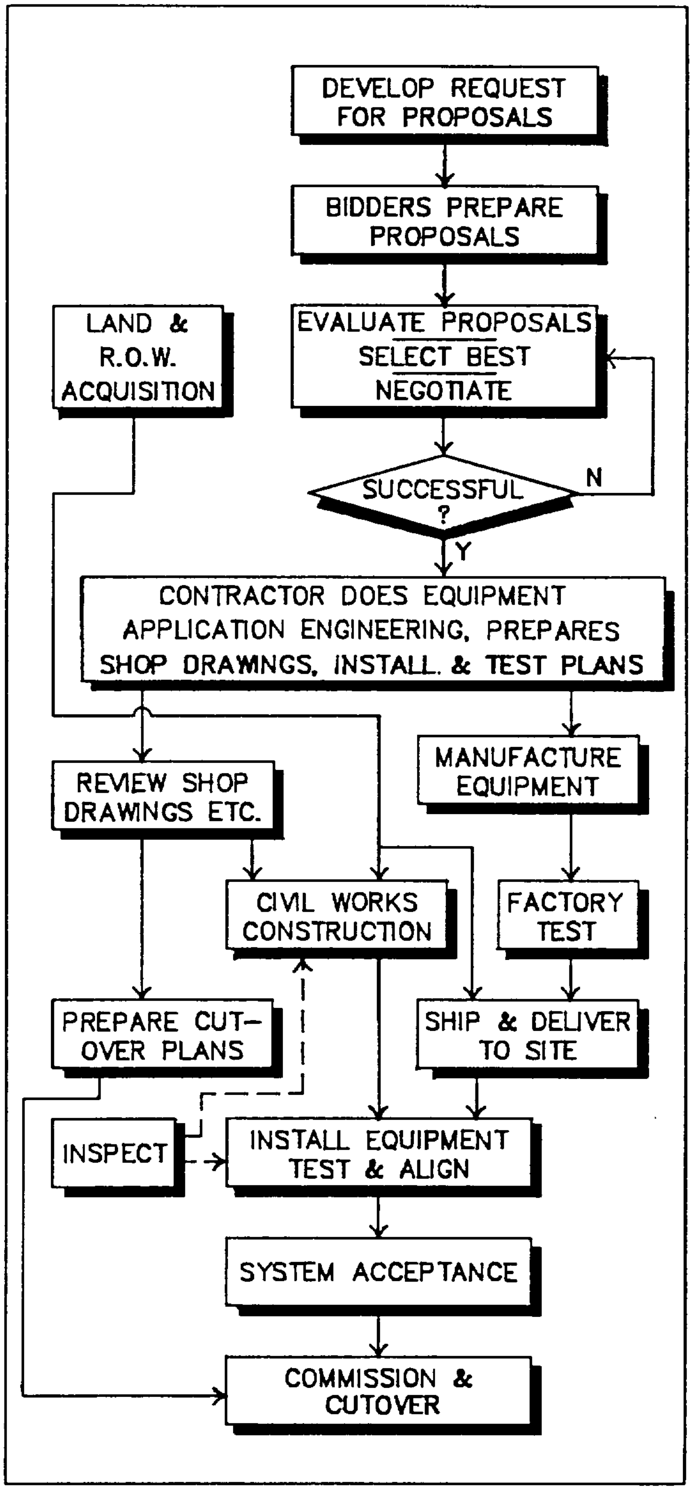


FIG 16-1 Typical Project Activity Network

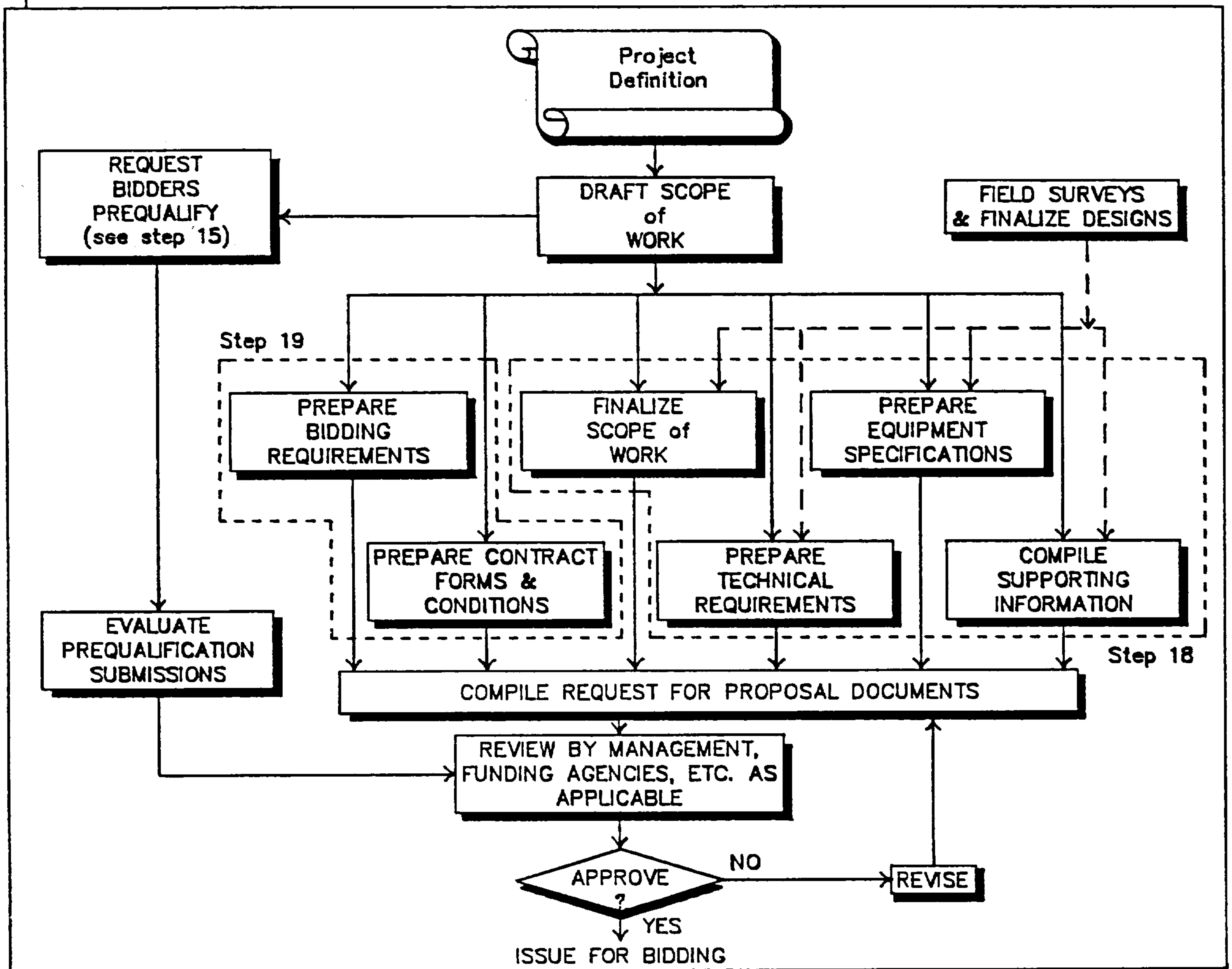


FIG 17–1 Detailed Engineering Overview

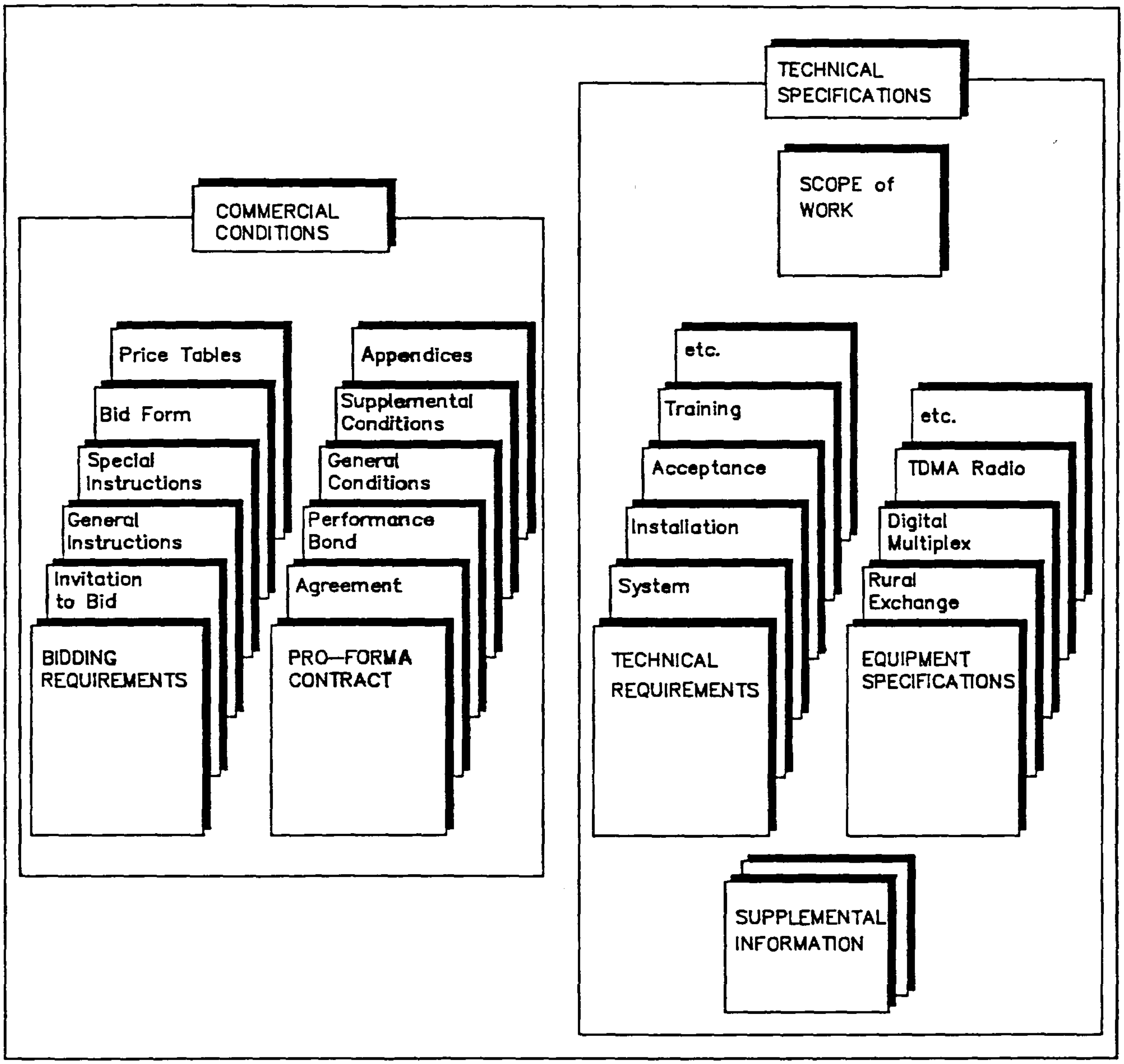


FIG 17–2 Typical RFP Sections

Appendix B

Glossary of Abbreviations

BER	*bit error rate*
CCIR	*The International Radio Consultative Committee*
CCITT	*The International Telegraph & Telephone Consultative Committee*
C.O.	*central office*
FDMA	*frequency division multiple access*
FM	*frequency modulation*
HF	*high frequency*
ISDN	*integrated services digital network*
ITU	*International Telecommunication Union*
PCM	*pulse code modulation*
PCO	*public call office*
POTS	*plain old telephone service*
PW	*present worth (for a definition, see the Glossary)*
pW0	*pico watts referenced to the zero test level point*
pW0p	*pico watts referenced to the zero test level point, psophometric weighted*
RFP	*request for proposal*
TDMA	*time division multiple access*
UHF	*ultra high frequency*
UN	*United Nations*
VCU	*voice channel unit*
vf	*voice frequency*
VHF	*very high frequency*

Appendix C

Glossary of Terms

Administration. A term used throughout this guide to refer to a telecommunications utility or telephone operating company that is responsible for providing telephone services; includes government agencies (such as Post, Telephone and Telegraph Departments) as well as private operating companies that have been mandated to provide service.

Busy Hour. The busy hour refers to the 60 consecutive minutes when the traffic volume or number of call attempts is highest at an exchange or on a circuit group. Generally it is based on an average of a certain number of the busiest days of the year, but excluding unusual peaks caused by disasters, some holidays, and the like.

Call Attempt. A single successful or unsuccessful bid by a caller or device to establish a telephone call to another subscriber.

Call Holding Time. The time interval between seizure and release of a circuit or switching equipment.

Dimensioning. The process of optimizing the size of a facility, taking into consideration the forecasted traffic requirements and the grade-of-service objectives.

Integrated Services Digital Network (ISDN). An integrated digital network in which the same digital switches and digital paths are used to establish connections for different services: for example, voice, data, etc. Essentially it is based on achieving a fully digital path from subscriber to subscriber. The CCITT has established standards governing interfaces and transmission quality.

Iterative. The term relates to a computational procedure in which replication of a cycle of operations produces results which with each cycle approach the desired result more and more closely.

Junction Network. A network of circuits interconnecting local exchanges, including local transit exchanges.

Local Exchange. An exchange in which subscriber's lines are terminated.

Local Network. A network of lines connecting subscriber premises to a local exchange.

Local Transit Exchange. An exchange used as a switching point for traffic between local exchanges within a multi-exchange area.

Long-Distance Network. That part of the network beyond the local exchange, which connects different local areas.

Present Worth. Present worth refers all economic events, income and expenditures to the same point of time, using an appropriate discounting rate and expresses them in the form of a single value. Present worth is sometimes known as present value in other manuals. The terms are synonymous.

Provisioning Period. The period of time a given extension of plant will provide for anticipated increases in demand.

Reference Equivalent. A method of measuring attenuation which involves the use of reference circuits with which real circuits are compared.

Subscriber Network. A network of lines connecting subscriber premises to a local exchange. The term is synonymous with local network.

Appendix D

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Note: The last entry refers to a book; all the other entries to publications.

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