Chapter 1
Introduction

The subject of this book is rural structures and services in tropical regions. Although it has been written with a special focus on the situation in eastern and southern Africa, the principles apply to most of the tropics, albeit with some modifications to cater to local conditions. In many parts of Africa rural structures, including farm buildings, have been built using traditional methods and materials. However, rural development and globalization are bringing about significant changes in rural areas of Africa.

Whereas in the past it was common to find only small thatched and/or mud houses, nowadays brick-walled houses roofed with corrugated iron sheets and/or tiles are quite common in many rural areas of eastern and southern Africa. Some of these new structures are an improved traditional design constructed using industrial building materials. Others are replications of urban building designs and often fail to cater to the special technical, biological, physical and economic characteristics of rural areas, where in most cases agricultural production is combined with processing and dwelling.

There is therefore a growing need for improved rural structures in most parts of Africa. In urban areas, there are town/municipal engineers responsible for enforcing the building code, while in rural areas, rural development officers are normally called upon to provide technical advice on improving rural structures. Rural dwellers, who in most parts of Africa are either crop and/or livestock farmers, rely on the technical advice of agricultural extension workers who, in most countries, also serve as general rural development practitioners. Improved rural structures and services are becoming increasingly important parts of the rural development agenda.

Rural structures also play a major role in increasing agricultural productivity and overall production. Rural buildings are used not only for storing agricultural inputs such as fertilizers, but also for preserving agricultural outputs. In Africa this is particularly important because a significant percentage of grain production is stored on the farm for own consumption. It is therefore important to develop methods and structures for effective storage, especially for the modern high-yielding grain varieties, which tend to be more susceptible to pests than the traditional types.

Improved management and breeding programmes to increase livestock production have also created a need for improved livestock housing and services. For instance, in parts of eastern Africa many small-scale farmers have invested in intensive dairy projects where the dairy cows are zero-grazed. In addition, general development, which has led to improved standards of living for the rural population, has led to increased demand for durable, comfortable and healthy dwellings with clean water, sanitation facilities, telecommunications and community infrastructure. Most of these facilities would normally be owned by the individual farmer, while some may be communally owned.

All these rural structures and services play a significant role in increasing agricultural production, helping countries to achieve food security. These are some of the most important investments that rural dwellers will make in their lifetime. FAO projections show that, over the next 40 years, significant investment must be made in rural infrastructure if the world is to feed a global population of more than nine billion.

The general thinking on the future of rural areas, and countries in general, is reflected in the various policies of developing countries, such as: Vision 2030 in Kenya; Vision 2025 in Tanzania and Uganda; Growth, Employment and Redistribution (GEAR) in South Africa; Vision 2016 in Botswana; and Vision 2020 in Nigeria. All these policy statements include the primary objective of accelerating rural development.

As an example, the aim of Vision 2030 is to transform Kenya into a newly industrializing, "middle-income country providing a high quality life to all its citizens by the year 2030". The vision aspires to a country firmly interconnected through a network of roads, railways, ports and airports by the year 2030. According to the vision statement, it will no longer be possible to refer to any region of Kenya as "remote" as investments in the nation's infrastructure will be given the highest priority.

Increasing value and incomes in rural areas by transforming agriculture and making it more productive is a major objective of most planners and policy makers in developing countries, especially those in eastern and southern Africa. They all aim to raise incomes in crop, livestock, forestry and fishery production, as industrial production and the service sector expand. This will be achieved partially through processing, which will add value to agricultural produce before it reaches the market.

All countries of the region want agricultural producers to be competitive not only nationally, but also regionally and globally. The aim is to accomplish this by means of an innovative, commercially oriented, modern style of agriculture that includes the crop, livestock, forestry and fishery sectors. Agricultural production should also be sustainable and every effort should be made to protect the environment.

The transformation of agriculture and other rural enterprises and livelihoods will require the planning, design, construction, operation and maintenance of a broad range of rural structures and infrastructure. Innovation is a key factor in the success of this endeavour because it will lead to the efficient and effective design and construction of rural structures. This is essential as there are major challenges, in particular limited financial resources.

The development of rural structures may be divided into four phases: planning; design; construction; operation and maintenance:

- **Planning:** This phase involves consideration of the various requirements and factors that affect the general layout and dimensions of the desired structures. It leads to the selection of one, or perhaps several, alternative types of structure that provide the best overall solution.

  The primary consideration is the structure's function. Secondary considerations include aesthetics, sociology, law, economics and the environment. In addition, structural and constructional requirements and limitations may affect the type of structure to be selected. Equipment and machinery to be installed in the structures also need to be factored in during the planning phase.
- **Design:** This phase involves the detailed consideration of the different options involved in the planning phase. It leads to the definition of the most suitable proportions, dimensions and details of the structural elements and connections required for constructing each option under consideration. Details of equipment and machinery to be installed in the structure also form part of the designs.
- **Construction:** This phase involves the procurement and transportation to the site of materials, equipment, machinery and personnel, as well as actual field erection. During this phase, some redesigning may be required due to unforeseen circumstances such as unavailability of specified materials or foundation problems.
- **Operation and maintenance**: During this period, the structure is in use. It requires planned and unplanned maintenance. Experience gained in this phase leads to the design of better structures in the future.

Engineers who specialize in designing rural buildings and services need to have a thorough knowledge of farming systems, crop and livestock production systems, climate factors and a genuine understanding of rural life and the farmer's social and economic situation. They should also be familiar with the full range of building materials and types of construction, from traditional indigenous to industrially produced, as applied to rural structures. They must be able to select appropriate installations and equipment for such buildings.

This knowledge will enable them to produce specifications, in cooperation with the farmer, for functional building designs that provide a good environment and durable construction, thereby contributing to efficient and economically sound farm operations. Further important tasks for the engineers responsible for rural structures and services are interpreting and explaining the drawings and technical documentation to farmers, as well as supervising construction work. However, engineers should be aware of the need to consult specialists in related fields where necessary.

This textbook is intended for the design and development of rural structures for agricultural production in the tropics. This single volume covers the basic procedures for planning, designing, constructing, operating and maintaining rural structures. Other topics include rural water supply, rural sanitation, rural energy and minor rural roads. In line with current and future requirements, the book presents modern methods of developing structures and infrastructure.

SCOPE OF THE TEXTBOOK

This textbook is intended as a resource for practitioners engaged in the planning, design, construction, operation and maintenance of rural structures and services in support of agricultural production. It focuses mainly on the structures and services required by smallholder farmers in rural areas of Africa. It is also designed to serve as a textbook for students enrolled in agriculture and engineering courses at colleges and universities.

The book is divided into four main parts. Part one deals with the fundamentals required by a professional responsible for providing technical advice on rural structures and services, such as graphical and geospatial techniques and the properties of construction materials. Part two deals with the principles of designing rural structures and services, including basic mechanics and structural design.

Part three deals with the elements of actual construction and building production. The final part, which is the largest, deals with the specifics of designing and constructing different types of rural structure (structures for livestock production, rural dwellings, structures for produce handling, conditioning and storage; rural infrastructure, such as rural roads, water and sanitation, and external services, such as fencing).

FURTHER READING

De Janvry, A., Key, N. & Sadoulet, E. 1997. *Agricultural and rural development policy in Latin America: new directions and new challenges*. University of California at Berkeley.

Federal Republic of Nigeria. 2010. *Vision 20: 2020* (available at http://www.npc.gov.ng).

FAO. 2009. *Capital requirements for agriculture in developing countries to 2050*. Rome.

Knight, R. 2001. *South Africa: economic policy and development* (available at http://richardknight.homestead.com/files/sisaeconomy.htm).

Nelson, G.L., Manbeck, H.B. & Meador, N.F. 1988. *Light agricultural and industrial structures: analysis and design*. AVI Book Co.

Republic of Botswana. 1997. *Vision 2016: Towards prosperity for all* (available at http://www.vision2016.co.bw).

Republic of Kenya. 2007. *Vision 2030* (available at http://www.brandkenya.co.ke/downloads/Vision2030_Abridged%20version.pdf).

Republic of Uganda. 1998. *Uganda vision 2025: A strategic framework for national development* National Long Term Perspective Studies Project, Ministry of Finance, Planning and Economic Development (Kampala).

United Republic of Tanzania. 2020. *The development vision 2025* (available at http://www.tanzania.go.tz/vision.htm).

Chapter 2
Planning farm and rural structures

INTRODUCTION

A major constraining factor in the design and construction of farm and rural structures in the tropics is the need to implement such projects in an environment where most farms are small and fragmented. Additional limiting factors include severe financial constraints and the need for agricultural mechanization and rural transformation. These challenges can be met, in part, by producing standard designs and case studies for target groups. These case studies can be modified thereafter to suit each individual need.

As buildings and other rural structures are fixed assets that have a relatively long lifespan and require a relatively large amount of resources to construct, it is important that they are planned and designed for efficient and profitable use throughout their life. Once a building is erected, however, it is expensive to make changes. A plan for an individual farm is influenced by a number of factors over which the farmer has no direct control, e.g. climate, soil fertility, government policies, state of knowledge about agricultural techniques and the value of inputs and outputs.

Functional planning is essential for the realization and achievement of the goals set. A good plan should provide an understanding of the situation and how it can be changed and thus assist farmers to see the problems, analyse them and be able to make sound decisions when choosing between alternative uses of their resources. While farm management planning helps farmers to choose the type and quantity of commodities to produce, advice from crop and livestock production specialists is required to help them decide how to produce them in an efficient way. When an enterprise requires buildings or other structures, the rural building specialist will suggest alternative designs for the efficient use of resources. The best plan for the whole farm operation is normally the result of interaction between the various farm planning disciplines.

Similarly, engineers can produce standard designs that are suitable for a large number of farms in an area, either as they are or with small modifications. However, the number of case studies and designs must be sufficient to allow all farmers to be given advice reflecting their individual situation, and which they are likely to adopt.

What is planning? An overview

The term 'planning' is a very general one. Its various definitions cover a wide range but do not provide a consensus. Various scholars have come up with different definitions, such as:

"…. Planning is the making of an orderly sequence of action that will lead to the achievement of stated goals" (Hall, 1974).

"…. Planning is an activity by which man in society endeavours to gain mastery over himself and shapes his collective future through conscious reasoned effort" (Friedmann, 1966).

The above definitions notwithstanding, there are also other schools of thought on planning. These include:

(i) Planning as a basic human activity

This looks at planning as a basic activity that pervades (informs every aspect of) human behaviour: "….a plan is any hierarchical process in the organism that can control the order in which a sequence of operations is to be performed".

Miller *et al.* (1960) concluded that each action is the result of a complex preliminary process, which they called a TOTE (Test Operate Test Exit) unit. This means that each action is preceded by an assessment of the situation and a visualization of the action to be undertaken (test); next the action is carried out (operated); its results are evaluated (test); then the sequence is concluded (exit); and a new one begun …

(ii) Planning as a rational choice

(a) This confines planning to matters of deliberate choice. A rational choice is one that meets certain standards of logic.
(b) In this case, planning becomes "a process for determining appropriate future actions through a sequence of choices" (Davidoff and Reiner, 1962).
(c) There is, however, a difference between rationality and planning as processes. Whereas both attempt to achieve a preferred and – through deliberate choice – comprehensive approach and link to action, planning can be distinguished by its emphasis on the future orientation of any decision.
(d) The weakness of this view of planning is its almost sole focus on choice, with only a vague link to action (if a group makes plans but does

not commit to implementing them, is this still planning?).

Such planning aims to apply the methods of rational choice for determining the best set of future actions to address novel problems in complex contexts. Furthermore, it is attended by the power and intention to allocate and commit often scarce social and economic resources (and to act as necessary) to implement the chosen strategy.

(iii) Planning as a control of future action
This definition embodies what could be seen as the antithesis of the narrowness of the above definition. It implies that planning does not exist when the process does not include implementation.

"…Planning may be seen as the ability to control the future consequences of present action. The more consequences of controls, the more one has succeeded in planning. The purpose is to make the future different from what it would have been without this intervention" (Wildavsky, 1973).

"… The problem is no longer how to make a decision more rational but how to improve the quality of the action" (Friedmann, 1966).

This view of planning is equally flawed. For instance, is it planning when someone pays the water bill? (Because this influences the future actions of the water company and commits resources to continued supply).

If so, then the definition of planning becomes so diluted that it may set standards so high that they become impossible to meet.

(iv) Planning as a spatial kind of problem-solving
Whereas the above definitions were process-oriented (addressing the 'what' and 'how' aspects of planning), this definition is more situational (addressing the specific realm in which planning activity occurs).

One opinion defines planning as problem-solving aimed at very particular kinds of problems referred to as 'wicked'. A wicked problem has no definitive formulation, no clear rules, no true or false answers (can only be better or worse) and no clear test for the solution. Each problem is unique but, at the same time, a symptom of another deeper, more extensive malady (disease, illness). Worse still, unlike the scientific experimenter, the problem-solving planner cannot afford mistakes.

Henry Hightower goes beyond wicked problems in defining planning, accommodating the planner's need to question values, institutions and given decision rules. He isolates the planning aspect, which uses rough, imprecise data, in contrast to the exact data used in science and engineering, and planning has an action orientation.

The weakness of this approach is that it is too inclusive; solving wicked problems is not restricted to planners but could also be applied to entrepreneurs, administrators and politicians.

(v) Planning is what planners do
This definition describes the contribution of planners, as technical experts, to public policy-making. This includes:

Defining the problem, stating the terms in which problems are solvable and comparing the importance of the (always) conflicting values inherent in any solution. Although this definition has the merit of being simple and obvious, the reality is that planners are not merely people who plan.

FORMS OF PLANNING

Regional planning

What is a region?
Essentially, it is a tract of land which, by virtue of geographical, political, economic, administrative, historical and other factors, or a combination of these, is distinguishable as a unit, a separate entity. This unit may be:

(i) geographical, e.g. lake district;
(ii) social/political, e.g. a state in Nigeria;
(iii) single-function area, e.g. coalfield;
(iv) a farming region, e.g. wheat fields;
(v) a river catchment area, e.g. Congo River Basin;
(vi) a metropolitan area, e.g. Johannesburg.

A clear delineation of regional units for land-use planning is still lacking. For instance, there is a dilemma concerning whether to adopt administrative or geographical/ecological units (e.g. cross-border resource management for Lake Victoria, Mara/Amboseli, etc.).

Regional planning seeks not to achieve any specific objective (though specific regional strategies do have their various objectives) but to regulate the relationship between human and environmental factors.

(i) Interregional – concerned with activity between central government and the regions and between one region and another;
(ii) Intraregional – between a region and the localities it contains.

Urban planning
Urban planning is the physical planning of concentrated human settlements designated as urban areas. It is a special case of planning that indicates that a certain degree of detail is required of the planner.

Urban planning requires the designation of an urban planning region with a base resident population not less than that stipulated in the policy document to indicate an official town or urban area. On a larger scale, it becomes city planning.

Urban plans are represented in the same way as physical plans but they normally include more detail, including:

- infrastructure network
- spatial organizational structures

- detailed action area plans
- density distribution
- zoning regulations for the areas
- location of functions in the urban system including population, industry, commerce, institutions, recreational facilities, utilities, natural resources, environmental action plans and other essential information thought to be important for the future growth of the urban region.

Urban plans are essential tools for town management, which need constant updating because of the complexity of urban regions.

Rural planning

A rural region, like an urban region, is another category of region for planning purposes. In developing countries in particular, rural areas tend to be home to as much as 80 percent of the country's population, and therefore urban planning becomes secondary to rural planning.

Rural planning is carried out in the national interest to improve living conditions, match agricultural production to demand and conserve natural resources. Many factors in the national or regional plans may directly influence the choice of production on farms and thus the requirements for buildings.

The aims of planning strategies in rural areas are based on political decisions. These may include:

1. Provision of support services such as extension education, market development, processing and credit.
2. Development of infrastructure such as roads, electricity and water supplies.
3. Self-help activities to develop community facilities.
4. Increased non-farm employment opportunities.

Rural plans try to define the best strategy for rural areas in order to mobilize their resources to produce the assets required for development in the regions. As rural regions are generally large, it is necessary to delimit subregions (i.e. through administrative boundaries), on which the plan will focus.

A rural plan therefore lays down rural region specifics:

- Land-use systems and activities (at policy level).
- Identification and definition of resource utilization policies.
- Linkages between the specific rural region and other regions.
- Local initiatives for administration and management of the region.
- Strategic environmental management for the region.
- Population management activities of the region.
- It is also important for the rural plan to show how the political structure of the region integrates with the larger regional political system.

Note that, in many developing countries, rural plans are often non-existent or very limited because all that exists is often a 'top-down' regional plan that only recognizes the rural areas as components in the larger regional plans, rather than as key actors in plan preparation. This model has often contributed to stagnating rural regions because 'top-down' systems often lead to poor identification of the most pressing needs at rural level. Later approaches, such as Participatory Rural Appraisal (PRA), Action Research (AR) and Participatory Approval (PA), are ways and means through which development actors have tried to make local levels active in achieving their planning priorities.

Infrastructure planning

Physical planning involves the distribution of goals, objects, functions and activities in space. The content of physical planning continues to change, yet the approach has been fairly consistent. Physical planning can be regarded as the nuts and bolts of the way the built environment is conceived. One of the components of physical planning includes infrastructure planning. The historic origins in many a region relate to a somewhat different tradition – that of municipal and civil engineering and public works. Today it is not unknown for these aspects to remain separately institutionalized in terms of recruitment, organization and statutory mandates.

Infrastructure planning involves planning for the provision of roads, water services, energy, health and education facilities and other utilities that are necessary for the effective functioning of communities. Their provision contributes greatly to rural transformation and improved standards of living for the population. Transport planning, in particular, interacts closely with land-use planning. Transport planning covers a range of geographic levels from the region to the street intersection or multimodal node, and also deals with the various modes of transportation – from air travel to bicycle routes – either separately or in combination. The two are interconnected in that land use generates travel demand, and access boosts the development potential of land. Transport planners follow much the same generic process as land-use planners.

An improved road network may, for example, make new urban markets accessible, thus making it feasible for farmers to go into vegetable or milk production. This in turn may require housing for animals and stores for produce and feed. It would therefore be advisable to investigate any plans for rural development in an area during the planning stages at an individual farm, or to implement an extension campaign promoting improved building designs in that area. Government policy is often an important factor in determining long-term market trends and thus the profitability of market production, and it is therefore of special importance when planning for production operations involving buildings.

Environmental planning

The broad objective of the planning process is to promote the welfare of citizens through the creation and maintenance of a better, healthier, more efficient and more attractive living environment. Economic forces in a free-market economy are not a reliable guide for directing urban activities towards the desired healthier life because they tend to maximize profits or individual wellbeing at the expense of societal wellbeing.

Moreover, human development activities, especially in low-technology areas, have tended to exploit rather than generate resources. Where exploitation continues unchecked, depletion will follow.

Environmental planning has become a necessary component of planning at all levels, to act as a check on market forces and to press for more health-oriented planning, more consideration for human social institutions, more awareness of resource conservation and more efficient utilization systems. Environmental planning covers a wide range of concerns, but essentially has the following main objectives:

- To minimize threats to human health and life by organizing activities in such a way as to reduce the spatial concentration of pollutants in our water by limiting dangerous and hazardous areas.
- To preserve resources for future use, e.g. minimizing soil erosion and deforestation.
- To achieve recreational goals such as preserving certain areas in their natural state.
- To minimize damage to the environment for its own sake rather than for humanity's sake, e.g. by preserving the habitat of a rare species that has no known or readily foreseeable use to us.

Environmental planning has previously been included in planning, but recently greater efforts have been made in this field because of impending major threats to the human population.

Economic planning and feasibility

All countries carry out economic plans to forecast how the economy will manage the scarce resources available to the population. Such plans may be yearly, two-yearly or five-yearly. Most nations have five-year plans.

Smaller regions of a country may also have economic plans for much the same reason as the country, but on a much smaller scale and in greater detail.

Economic plans are largely statistical, indicating sectors, financial expenditure and revenue and forecasts for the subsequent plan periods. They are largely policy-oriented. Economic plans are also carried out by smaller bodies, such as local authorities. In this case the plan will comprise an inventory of how the community earns a living and where it is heading in terms of resource stability.

Most community economic plans are divided into two segments: the export base and the secondary base. The export base is made up of those goods and services that the community exports to other towns or regions in order to bring in money. This will enable the community to grow. Secondary base businesses serve the local community. If the size of the community is small, the size of the local community may not grow much.

Feasibility

There are three golden rules in formulating a project:

(i) Ensure that all the factors necessary for its success are taken into account from the outset.
(ii) Carry out careful preinvestment studies.
(iii) Build in flexibility.

When the scope of the project has been determined, five main aspects must be taken into account:

(a) *Technical feasibility:* Have all the alternatives been considered? Is there a need for the project at all? For example, could better dry-farming techniques and moisture conservation increase output just as much as irrigation? Are the proposed methods, design and equipment the best for the purpose? Are the cost estimates realistic and can the successive phases of the project be carried out in the time allowed?
(b) *Economic viability:* Does the chosen technical solution offer the highest economic and social returns of all the technically and financially feasible alternatives?
(c) *Financial:* Are the necessary funds available? Will the project be able to meet its financial obligations when it is in operation? For example, will the farmer have sufficient income to cover repayments and interest on a loan?
(d) *Administration:* Will the administrative structure proposed for the project and its staff be adequate to keep the project on schedule and manage it efficiently? Will interdepartmental rivalries be an obstacle and, if so, can the proposed coordination machinery ensure an organized flow of decisions and the assignment of responsibilities within the chain of command?
(e) *Commercial:* What are the arrangements for buying materials for the project? Where will they come from? How will they be funded? How will the output of the project be sold?

Economic planning of the farm operation

Most textbooks on agricultural economics describe methods of economic planning for commercial farms in developed western countries, but very few deal with methods relevant to African agriculture, which is, and will for the foreseeable future be, dominated by smallholder farmers. Although the principles of economic theory may be relevant when reviewing African small-scale farms, their applications will undoubtedly differ from those used when reviewing large commercial farms.

Traditional applications assume, for example, that crops and livestock can be analysed separately, that the concept of farm size can be unequivocally defined, that the farmer makes all the decisions concerning farm operations, and that increasing cash income is the major objective. However, in most cases African agriculture is traditional and based on communal land ownership. In quite a number of cases this includes a multifamily situation in which two or more wives each have their own plots but also participate in joint enterprises and are subordinate to the husband's general decisions. This situation would make an approach to local community groups more relevant than emphasizing individual farms.

A multiple cropping system or a livestock-feed crop system may serve to reduce risk and result in a more uniform supply of food and cash, as well as family labour demand and, although the yields of the individual enterprises may be low, it may provide an acceptable overall result.

Money is the commonly used – and often the most convenient – medium of exchange in economic calculation. However, other units may occasionally be more relevant when small farms, with limited cash flow and strong non-monetary relations between production operations and the household, are analysed. Subsistence farmers may, for example, value the security of having their own maize production, so much so that they will produce enough for the household even if an alternative enterprise using the land and labour would generate more than enough cash to buy the maize at the market.

The principles of economic theory are valid whatever appropriate medium of exchange is used to specify the quantities, e.g. units of labour used to produce units of grain or meat. The difficulty or challenge, depending on the perspective, is to find a suitable alternative unit to use where the gains and losses are a mixture of money and non-money elements and to take into consideration farmers' personal beliefs so that the resulting plans reflect their individual goals and value system. There are usually a variety of reasons for reviewing the economic planning for the entire farming operation.

The plan will establish the resources available, as well as the limitations and restrictions that apply to the construction of a proposed building. A comprehensive economic plan for a farm, whether an actual farm or a case-study farm, may include the following steps:

1. Establishment of individual farmers' objectives, priorities and constraints for their farm operation. The objectives should preferably be quantified so that it can be determined whether they are being, or can be, achieved.
2. Analysis of financial resources, i.e. the farmer's assets as well as the cost and possibility of obtaining loans.
3. Listing of all available resources for the farming enterprises, quantifying them and describing their qualities, e.g. quantity and quality of land, water resources, tools and machines; roster of labour including a description of training and skills; existing buildings and evaluation of their serviceability; and the farmer's management skills.
4. Description of all factors in the physical, economic and administrative environment that directly influence the farming enterprises, but over which the farmer has no direct influence, e.g. laws and regulations, rural infrastructure, market for produce, availability of supplies, prices and market trends.
5. Individual analysis of each type of farm enterprise, whether crop or animal production, to determine

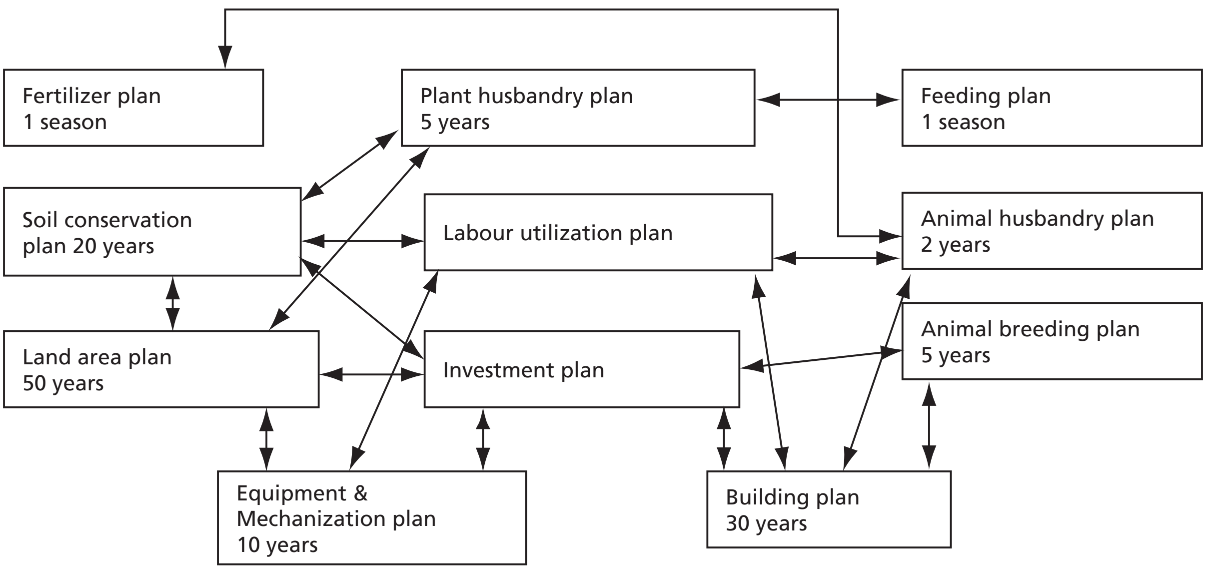


Figure 2.1 **Schedule of a sub-plan in a farming enterprise**

its allowance of total capital. Note that where multiple cropping is practiced, the mix of various crops grown together is considered to be one enterprise.
6. Determining the optimum mix of enterprises that satisfies the farmer's objectives and makes the best use of resources.

The resulting plan will be an expression of the farmer's intentions for the future development of the family farm. The plan will contain several interrelated subplans as shown in Figure 2.1.

Note that the subplans in the Figure 2.1 may interact in many more ways than have been illustrated. Many of these interrelationships are of great importance when trying to maximize the result of the total production at the farm, whether or not the product is sold. Optimization of each individual enterprise may not necessarily mean that the total farming enterprise is optimized.

If farmers already operate their farm according to a sound economic plan, a less ambitious approach, involving analysis of only the enterprise requiring a new or remodelled building and an investment appraisal, may suffice. A number of investment appraisal methods have been advocated for use in agriculture to give a rough indication of the merits of an investment. However, smallholders generally hesitate to risk cash for investment in fertilizer, pesticides and feed concentrate, as well as improved buildings and machinery, until enough food for the household is produced, a market with a cash economy is readily available and farmers are confident of their own technical, agricultural and economic skills. Money therefore, may not always be the most relevant unit to use in the calculations.

BOX 2.1

Building process in Kenya

The establishments that undertake planning and building in Kenya range from households to large state and non-state actors.

There are numerous laws that govern the building process. The laws that govern building in rural and urban Kenya include Local Government Act Cap 265, Physical Planning Act Cap 286, EMCA Act of 1999, Public Health Act Cap 242, Architect and Quantity Surveyors Registration Act, Cap 525 and Engineers Registration Act Cap 530. These laws provide the basis on which planning and building can be carried out in a systematic way. They provide for registration and professional development of key staff in the sector. Furthermore, the laws provide a basis for undertaking sustainable developments.

The key characteristics of planning and building in rural and urban Kenya are:
1. It is a process involving many stakeholders, principally regulators, developers, professionals and contractors.
2. Stakeholders are clustered and regulated by different legal and regulatory regimes.
3. It employs many labourers, especially in urban areas where it is the leading employer.

Planning and building process

Step 1 The developer (a household or corporation) identifies the project and the land on which the building will be constructed.

Step 2 The developer identifies a team of consultants (architects, quantity surveyors, surveyors, planners, environmental impact assessment experts, etc.) who manage the planning and building process. In rural areas, the master builder or 'fundi' is mostly responsible for management of the process.

Step 3 The design team carries out site investigations to determine the suitability of the site and the feasibility of the project.

Step 4 If the project is judged feasible, the design team applies to a local authority for planning approval.

Step 5 If planning approval is obtained, the design team prepares the design and submits it to a local authority for development approval.

Step 6 Upon approval, the design team appoints a contractor to build the project.

Step 7 Upon successful completion, the developer applies to a local authority for an occupancy certificate and registers the property with the Ministry of Lands.

These steps describe a process that is lengthy and involves several professionals, especially in urban areas. In rural Kenya, not all these steps are undertaken.

AN APPROACH TO BUILDING PLANNING

Once the building requirements have been established in the economic planning, it will be the task of the farm-building engineer to work out the functional and structural designs and deal with the farmstead plan. While there are laws, regulations and guidelines enacted by the central or local governments that govern the building and construction industry, most are only applicable to areas that have been designated as urban (townships, municipalities and cities). (see box 2.1 for Kenya). Rural areas are governed by County, District or Rural Councils with limited capacity to enforce such laws and regulations.

The planning process always starts with a list of available resources and restrictions and other background material. The major outline for the design is then sketched. The final design is developed by working from rough sketches towards increasingly detailed plans of the different parts of the building. Often, however, when some internal units such as farrowing pens have been designed and the required number established, the dimensions of the final building will be influenced by the pen size and number. The farmer will often impose restrictions on the design before the planning process begins. These should be critically evaluated and their effectiveness examined before they are accepted as part of the final design. It will be useful to discuss the extent of the proposed building and enterprise with an agricultural economist if the plan has not been based on an overall economic plan.

Standard solutions, promoted using demonstration structures and extension campaigns, will be the most important means of introducing improved building designs to small-scale farmers in rural areas for the foreseeable future. However, improved standard designs will be widely accepted by farmers only if they are based on a thorough understanding of the agricultural practices and human value systems prevalent in the local farming community and are developed to utilize locally available building materials and skills.

New ideas, materials and construction methods should be developed and introduced to complement the strengths of indigenous methods. Local builders will be valuable sources of information regarding indigenous building methods and effective channels through which innovation can be introduced. Close cooperation between builders and farmers will help the local community to deal with its own problems and to evolve solutions from indigenous methods and local resources that will have a good chance of becoming accepted.

Background information

An economic plan for the farming operation will provide much of the background information required by the farm-building engineer. As this is often missing, such information will have to be obtained by interviewing farmers and by studying similar farms in the area. Where the design is developed for a specific farm or farming enterprise, priority should be given to gathering as much information as possible from that farm or about that enterprise. All information should be critically evaluated prior to its acceptance as background material for the design of the proposed building or for a standard drawing.

When developing an economic plan, the farm-building engineer should obtain as much of the above information as possible, in addition to data relating to the following factors:

1. A comprehensive master plan of the farmstead.
2. For storage structures, data concerning the expected acreage and yield of the crop to be dried and stored, the length of the storage period, i.e. the amount of produce to be sold or consumed at the time of harvest.
3. For animal housing, the quantity and quality of animals currently owned and the possibility and time scale for increasing and improving the herd through a breeding programme should be considered.
4. Availability of building materials and construction skills at the farm or in the rural area concerned.
5. Laws and regulations applicable to the proposed building and the enforcement agencies involved.

Calculations

The standardized economic calculations used to determine the gross margin in a farm operation are often limited in scope and therefore a more detailed examination of the enterprise housed in the building may be of use. Knowing the expected production volume, additional data are calculated using the background information.

In the case of a building to be used for storage, the expected volume of the crop to be stored is determined, as well as the required handling capacity. In a multipurpose store where several different commodities are held, a schedule of the volumes and storage periods will be useful to determine the maximum storage requirement.

Analysing the activities

Activity analysis is a tool used for planning production in large, complex plants such as factories, large-scale grain stores and animal-production buildings, but it can also be a useful instrument in smaller projects, particularly for the inexperienced farm-building engineer.

Most production operations can be carried out in several ways involving various degrees of mechanization. By listing all conceivable methods in a comparable way, the most feasible method from a technical and economic standpoint can be chosen. This will ensure good care of produce and animals, as well as effective use of labour and machinery. Uniformity in handling improves efficiency, e.g. produce delivered

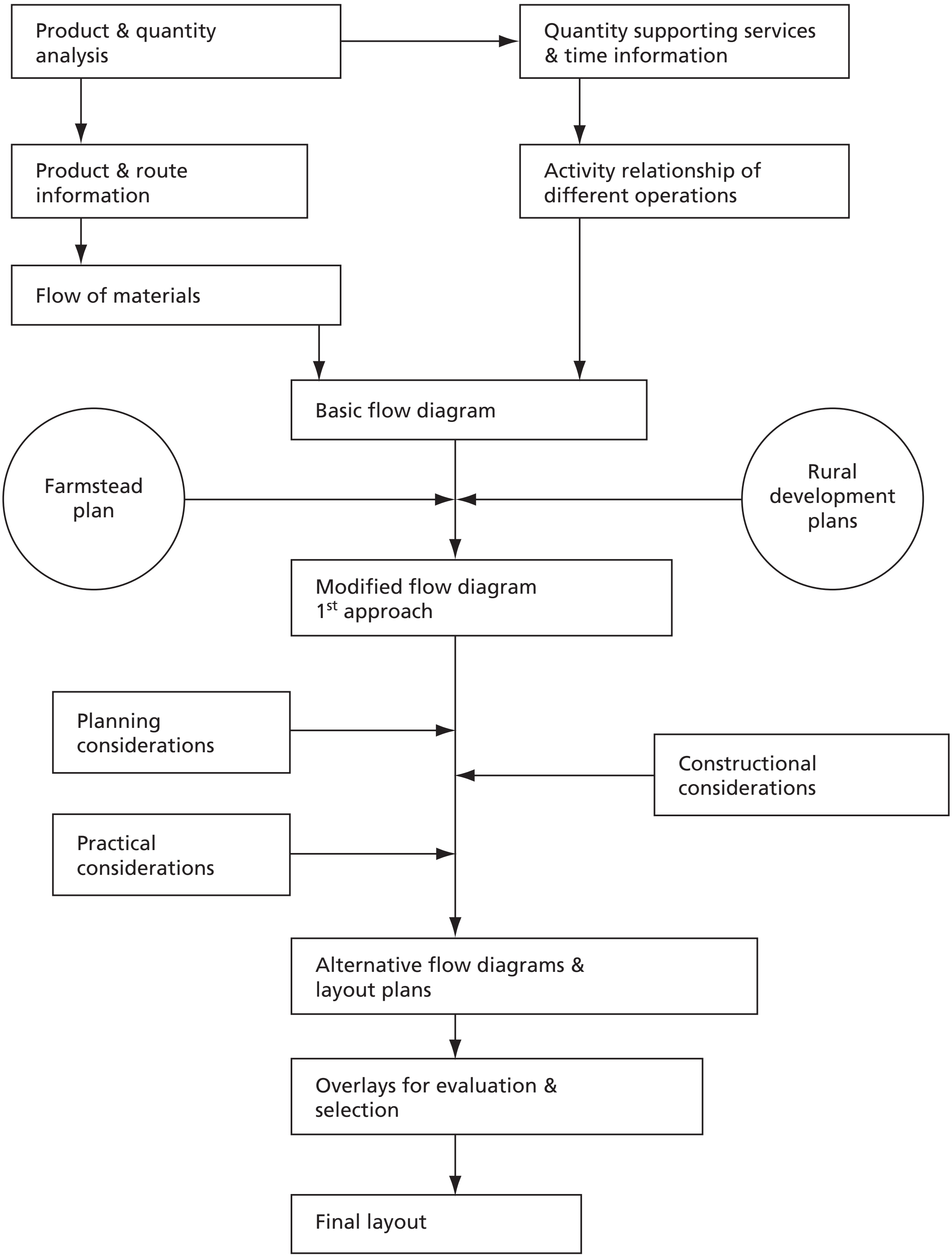


Figure 2.2 **Layout diagram of the planning procedure**

in bags to a store should be kept in bags within the store, particularly if it is to be delivered from the store in bags.

In animal housing projects, the handling operations for feed, animals, animal produce and manure are similarly analysed. Note that the analysis of handling operations for feed produced at the farm should include harvesting and transport from the field because these operations may determine the most appropriate storage and handling methods inside the building.

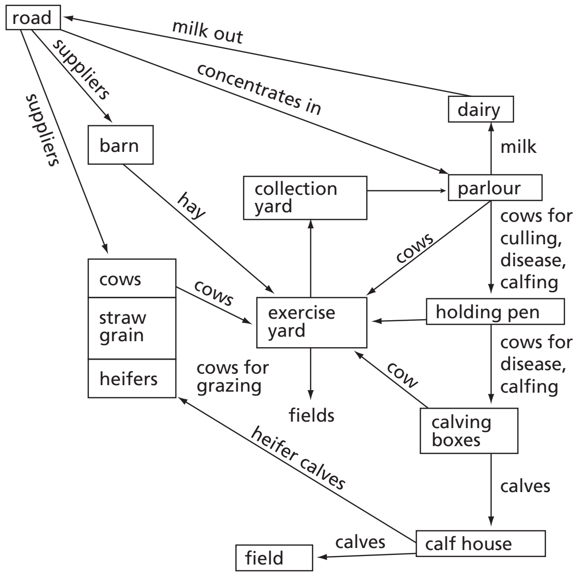


Figure 2.3 **Example of a material flow diagram for a dairy unit**

When all handling operations have been analysed, the result is summarized in a schedule of activities.

Labour efficiency is often an essential factor in small farm development. If farmers have a reasonable standard of living, cultural norms and social pressures may limit their willingness to invest in labour for a relatively low return, while labour-efficient methods allowing for a reasonable return on the labour invested may increase their willingness to produce a surplus.

Room schedule

This is a brief description of all rooms and spaces required for work, storage, communication, servicing of technical installations, etc. As variations in yield and other production factors are to be expected, an allowance is added to the spaces and the volumes. It would be uneconomical, however, to allow for the most extreme variations, particularly if a commodity to be stored is readily marketable and can be bought back at a reasonable price later.

The total space requirement is then obtained by simple addition. Also, partial sums indicate how the production operations can be divided into several houses.

Communication schedule

This describes the requirement and frequency of communication between the various rooms and spaces within the building and between the building and other structures at the farmstead. A schedule for movements between the farmstead, the fields and the market is also essential. It may also include quantities to be transported. Based on this information, the rooms between which there is frequent movement of goods and services can be placed close together for convenience and work efficiency when the building is being designed. The communication schedule is not always accounted for separately, but instead may be included in the schedule of activities.

Following the principle of working from the major outline of the project towards the details, the next step is to place the proposed building on the farmstead. Efficient communication within the farmstead is of great importance in creating functional and harmonious operations. The schedule of functions serves as a checklist when transportation is analysed. The room schedule provides information on the size of the building and the structural concept likely to be used.

A standard design can obviously not be shaped to fit a specific farmstead. Nevertheless, the group of farms for which the design is developed may have common features, which allows the designer to make recommendations concerning the location of the new building. Some structures have special requirements concerning where they can be constructed on the farmstead. A maize drying crib, for example, must be exposed to wind.

Where the plan includes the addition of a new building to an existing farmstead, alternative locations for the proposed building are sketched on the master plan or, better still, on transparent paper covering the master plan, and the communication routes are indicated by arrows between the buildings, the fields and the access road.

Considering all the planning factors and requirements, one of the proposed building locations is likely to have more advantages and fewer disadvantages than other alternatives. The transport routes to and from the building are then further studied and noted for use when the interior of the building is being planned.

Farmers will often have firm opinions about the location of the building from the start of the planning process. Their opinion should be critically analysed, but naturally it should be given considerable weight when the site is finally chosen.

Functional design of the building

Sketching alternative plan views of the building is mainly a matter of combining and coordinating the requirements that have been analysed in earlier steps. Some general guidelines are as follows:

1. Concentrate functions and spaces that are naturally connected to each other, but keep dirty activities separate from clean ones.
2. Communication lines should be as straight and simple as possible within the building and, to reduce the number of openings, they should be coordinated with those outside, as shown in the farmstead plan.
3. Avoid unused spaces and long communication corridors.
4. Provide for simple and efficient work. Imagine that you are working in the building.

5. Use as few handling methods as possible and choose methods that are known to be reliable, flexible and simple.
6. Provide a good environment for labourers and animals or produce.
7. Provide for future expansion.
8. Keep the plan as simple as possible within the limits of production requirements.

Finalization of sketching

After a number of sketches have been produced, they are carefully analysed to select the one that best reflects the farmer's objectives. However, because a farmer's objectives are usually complex and difficult to elicit, it is common to use more readily evaluated criteria such as total construction cost or cash expenditure. The selected building plan is then drawn to the correct scale, sections and elevations are sketched and, where applicable, the building is positioned on the master plan. In many cases, the results of earlier steps in the planning process, such as the activity schedule or room schedule, may have to be reviewed and adjusted as the work progresses.

Prior to being widely promoted, standard designs are often tested at a few typical farms. The construction phase and a period of use will often give rise to useful experience that may result in improvements to the design. Only if the designer is prepared to modify the design continuously as needed to adapt it to changing agricultural practices will it have a good chance of being successful in the long run.

A 'one of a kind design' intended for a specific farm can obviously not be tested in practice prior to its construction. Therefore the sketch, including a cost estimate, must be presented and carefully explained to farmers so that they understand the plan and feel confident that they can run an efficient and profitable production system in the building. Notwithstanding this, the farmer is likely to have objections and suggestions for alterations, which must be considered and worked into the final sketches. As an understanding of the operation and a positive attitude by all concerned are basic requirements for efficient production, farm labourers and members of the farmer's family who will be working in the building should also be given an opportunity to review the sketches.

Final design

When all sketches (farmstead plan, functional plan and structural concept) have been corrected, coordinated and approved by the farmer, the final building documents are prepared.

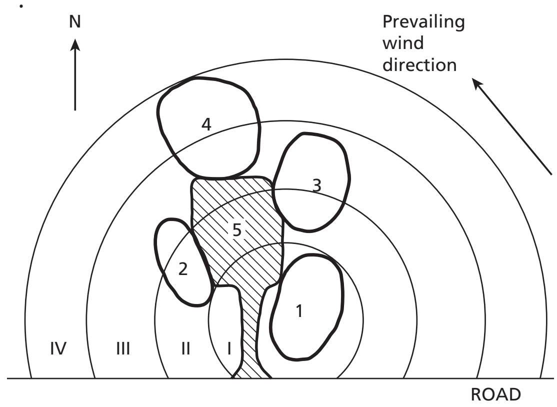
FARMSTEAD PLANNING

The farmstead forms the nucleus of the farm operation where a wide range of farming activities are undertaken. It normally includes the dwelling, animal shelters, storage structures, equipment shed, workshop and other structures. A carefully developed plan should provide a location for buildings and facilities that allows adequate space for convenient and efficient operation of all activities, while at the same time protecting the environment from such undesirable effects as odours, dust, noise, flies and heavy traffic. A wide range of factors, described in the 'Communication Schedule' section, should be considered when planning the location of buildings and services at the farmstead.

Although the immediate objective of these plans may be the inclusion of a new building in an existing farmstead, provision should be made for future expansion and the replacement of buildings. In this way a poorly laid out farmstead can be improved over the long term.

Zone planning

Zone planning can be a useful tool, but it is most effective when planning a new farmstead. The farmstead is divided into zones 10 metres to 30 metres wide by concentric circles, as shown in Figure 2.4.



1 Family living area including the dwelling
2 Implement and machinery storage, farm workshop
3 Grain and feed storage
4 Livestock buildings

Figure 2.4 **Zone planning in four zones**

Zone 1 at the centre of the farmstead is for family living, and should be protected from odour, dust, flies, etc. Clean, dry and quiet activities, such as implement sheds and small storage structures, can be placed in *Zone 2*. Larger grain stores, feed stores and small animal units are placed in *Zone 3*, whereas large-scale animal production is placed in *Zone 4* and beyond.

The advantage of zone planning is that it provides space for present farm operations, future expansion and a good living environment. However, in many African cultures the livestock has traditionally been placed at the centre of the farmstead. Thus the zone concept runs counter to tradition and may not be desirable.

Farmstead planning factors

Good *drainage*, both surface and subsurface, provides a dry farm courtyard and a stable foundation for buildings. A gentle slope across the site facilitates drainage, but a pronounced *slope* may make it difficult to site larger structures without undertaking extensive earthmoving work. *Adequate space* should be provided to allow for manoeuvring vehicles around the buildings and for the future expansion of farm operations.

Air movement is essential for cross-ventilation, but excessive wind can damage buildings. As wind will carry odours and noise, livestock buildings should be placed downwind from the family living area and neighbouring homes. Undesirable winds can be diverted and reduced by hedges and trees or fences with open construction. *Solar radiation* may adversely affect the environment within buildings. An orientation close to an east-west axis is generally recommended in the tropics.

An adequate supply of *clean water* is essential on any farm. When planning buildings for expanded livestock production, the volume of the water supply must be assessed. Where applicable, the supply pipe in a good building layout will be as short as possible. Similarly, the length of utility supply lines (e.g. *electric, gas)* should be kept to a minimum.

The *safety* of people and animals from fire and accident hazards should form part of the planning considerations. Children, especially, must be protected from the many dangers at a farmstead. It is often desirable to arrange for some *privacy* in the family living area by screening off the garden, outdoor meeting/resting places, veranda and play area.

Measures should be taken for *security* against theft and vandalism. This includes an arrangement of buildings where the farmyard and the access driveway can be observed at all times, especially from the house. A neat and attractive farmstead is desirable and much can be achieved toward this end, at low cost, if the *appearance* is considered in the planning, and effective landscaping is utilized.

SAFETY AND FIRE PROTECTION

Measures to prevent fire outbreaks and to limit their effect must be included in the design of buildings. Fire prevention measures include the separation of buildings to prevent fire from spreading and to permit firefighting, and a farm or community pond as a source of water for extinguishing fires.

Fire resistance in materials and construction

The ability of a building to resist fire varies widely depending upon the construction materials and the manner in which they are used. Fire resistance is graded according to the period of time that a construction element is able to withstand standardized test conditions of temperature and loading.

Bare metal frameworks and light timber framing exhibit a low order of fire resistance and both types of construction fail to qualify for a grading of *one-hour fire resistance*, which in many countries is the lowest grade recognized. In contrast, most masonry walls have good fire-resistance ratings.

Timber framing can be improved with the use of fire-retardant treatments or fire-resistant coverings such as gypsum plaster or plasterboard. Steel columns can be protected with plaster or concrete coatings, while steel roof trusses are best protected with suspended ceilings of gypsum plaster or plasterboard.

Classification of fire hazards

Some types of activities and installations in farm buildings constitute special fire hazards. Wherever practical they should be isolated in a room of fireproof construction or in a separate building away from other buildings. A list of special fire hazards includes:

1. Flammable, highly combustible or explosive materials in excess of very small quantities, e.g. liquid and gas fuel, ammonium nitrate fertilizer, hay and bedding.
2. Hot-air grain drying and dust from grain handling may be explosive in high concentrations.
3. Furnaces and heating equipment; poultry brooder; fireplaces.
4. Farm workshop (especially welding) and garage for vehicles.
5. Electrical installations; continuously running mechanical equipment.

In addition, lightning, children playing with fire, smoking and lanterns are potential sources of fire outbreaks. Thatched roofs are highly combustible and prone to violent fires.

Fire separation

Fire spreads mainly by windborne embers and by radiation. Buildings can be designed to resist these conditions by observing the following recommendations:

1. Adequate separation of buildings by a minimum of 6 metres to 8 metres, but preferably 15 metres to 20 metres, particularly where buildings are large or contain special fire hazards. A minimum distance may be specified in the building code.
2. Construction using fire-resistant facing and roofing materials.
3. Avoidance of roof openings and low roof slopes, which can be more easily ignited by embers.
4. Use of fire-resistant walls that divide a large building into smaller fire compartments. To be effective, such walls must go all the way up through the building to the roof and any openings in the walls must be sealed by a fireproof door.

Evacuation and fire extinguishers

In the event of a fire outbreak, all personnel should be able to evacuate a building within a few minutes, and animals within 10 to 15 minutes. Equipment, alleys and doors should be designed to facilitate evacuation. Smoke and panic will delay evacuation during a real fire, so evacuation during a fire drill must be much faster.

In animal buildings, exit doors leading to a clear passage, preferably a collecting yard, should have a minimum width of 1.5 metres for cattle and 1 metre for small animals so that two animals can pass at the same time. Buildings with a floor area exceeding 200 m^2 should have at least two exit doors as widely separated as possible. The travel distance to the nearest exit door should not exceed 15 metres in any part of the building.

Fire extinguishers of the correct type should be available in all buildings, in particular where there are fire-hazardous activities or materials. Water is commonly used for firefighting, but sand or sandy soils are effective for some types of fire. Dry powder or foam extinguishers are best for petrol, diesel, oil and electrical fires. Regardless of type, fire extinguishers require periodic inspection to ensure that they operate properly in an emergency.

Bushfire

The dry season or any period of prolonged drought brings with it a constant fire hazard. Fanned by strong winds and intensified by heatwave conditions, a large bushfire is generally uncontrollable.

Firebreaks are an essential feature of rural fire protection and should be completed before the fire season starts. It is desirable to completely surround the homestead with major firebreaks at least 10 metres wide. Breaks can be prepared by ploughing, mowing, grazing, green cropping or, with great caution, by burning, and may include any watercourse, road or other normal break that can be extended in width or length.

Shelter belts or even large trees are useful in deflecting wind-borne burning debris. For further protection, all flammable rubbish and long, dry grass should be removed from the surroundings of the buildings and any openings, such as windows, doors and ventilators, covered with insect screens to prevent wind-borne embers from entering the building and starting a fire

PROJECT PLANNING AND EVALUATION TECHNIQUES

Project planning

Project planning is customarily defined as strategic, tactical, or operational. Strategic planning is generally for five years or more; tactical can be for one to five years and operational normally covers six months to one year.

Project planning means determining what needs to be done, by whom, and by when, in order to fulfil assigned responsibilities. There are nine major components of the project planning phase:

- *Objective:* a goal, target, or quota to be achieved by a certain time.
- *Programme:* the strategy to be followed and major actions to be taken in order to achieve or exceed objectives.
- *Schedule:* a plan showing when individual or group activities or tasks will be started and/or completed.
- *Budget:* planned expenditures required to achieve or exceed objectives.
- *Forecast:* a projection of what will happen by a certain time.
- *Organization:* design of the number and kinds of positions, along with corresponding duties and responsibilities, required to achieve or exceed objectives.
- *Procedure:* a detailed method for carrying out a policy.
- *Standard:* a level of individual or group performance defined as adequate or acceptable.

Project evaluation and techniques

Project evaluation is a management tool. It is a time-bound exercise that attempts to assess systematically and objectively the relevance, performance and success of ongoing and completed projects. Evaluation is undertaken selectively to answer specific questions to guide decision-makers and/or project managers and to provide information on whether underlying theories and assumptions used in project development were valid, what worked and what did not work, and why. Evaluation commonly aims to determine the relevance, efficiency, effectiveness, impact and sustainability of a project.

The main objectives of project evaluation are:

(i) To inform decisions on operations, policy, or strategy related to ongoing or future project interventions.
(ii) To demonstrate accountability to decision-makers.
(iii) Improved decision-making and accountability are expected to lead to better results and more efficient use of resources.

Other objectives of project evaluation include:

(i) To enable corporate learning and contribute to the body of knowledge on what works and what does not work, and why.
(ii) To verify/improve project quality and management.
(iii) To identify successful strategies for extension/expansion/replication.
(iv) To modify unsuccessful strategies.
(v) To measure effects/benefits of projects and project interventions.
(vi) To give stakeholders the opportunity to have a say in project output and quality.
(vii) To justify/validate projects to donors, partners and other constituencies.

Evaluation is often construed as part of a larger managerial or administrative process. Sometimes this is referred to as the *planning-evaluation cycle*. The distinctions between planning and evaluation are not always clear; this cycle is described in many different ways, with various phases claimed by both planners and evaluators. Usually, the first stage of such a cycle is the planning phase.

Project evaluation involves a needs assessment, which entails assessing the use of methodologies that help in conceptualization and detailing and the application of skills to help assess alternatives and make the best choice.

Methodology

The evaluation phase also involves a sequence of stages that typically includes: the *formulation* of the major objectives, goals and hypotheses of the programme or technology; the *conceptualization* and operationalization of the major components of the evaluation – the programme, participants, setting and measures; the *design* of the evaluation, *detailing* how these components will be coordinated; the *analysis* of the information, both qualitative and quantitative; and the *utilization* of the evaluation results. Different means of evaluation include:

- *Self-evaluation:* This involves an organization or project holding up a mirror to itself and assessing how it is doing, as a way of learning and improving practices.
- *Participatory evaluation:* Participatory evaluation provides for active involvement in the evaluation process of those with a stake in the programme: providers, partners, customers (beneficiaries) and any other interested parties.

  Participation typically takes place throughout all phases of the evaluation: planning and design; gathering and analysing the data; identifying the evaluation findings, conclusions, and recommendations; disseminating results; and preparing an action plan to improve programme performance.
- *Rapid participatory appraisal/assessment:* Originally used in rural areas, the same methodology can, in fact, be applied in most communities. It is semistructured and carried out by an interdisciplinary team over a short time.
- *External evaluation:* This is an evaluation conducted by a carefully chosen outsider or outside team.

Project evaluation involves:

(i) Looking at what the project or the organization intended to achieve. What difference did it want to make? What impact did it want to make?

(ii) Assessing its progress towards what it wanted to achieve and its impact targets.

(iii) Looking at the strategy of the project.

(iv) Looking at how it worked.

The main questions in an evaluation should address:

(a) *Effectiveness: Is the project or programme achieving satisfactory progress toward its stated objectives?* The objectives describe specifically what the project is intended to accomplish. Accomplishments on this level are sometimes referred to as project outputs (what was done), and are assumed to be linked to provision of inputs (human, financial and material resources contributed to achieve the objectives).

(b) *Efficiency: Are the effects being achieved at an acceptable cost, compared with alternative approaches to accomplishing the same objectives?* The project may achieve its objectives at lower cost or achieve more at the same cost. This involves considering institutional, technical and other arrangements as well as financial management. What is the cost-effectiveness of the project?

(c) *Relevance: Are the project objectives still relevant? What is the value of the project in relation to other priority needs and efforts?* Is the problem addressed still a major problem? Are the project activities relevant to the national strategy and plausibly linked to attainment of the intended effects?

(d) *Impact: What are the results of the project? What are the social, economic, technical, environmental and other effects on individuals, communities, and institutions?* Impacts can be immediate or long-term, intended or unintended, positive or negative, macro (sector) or micro (household).

(e) *Sustainability: Is the activity likely to continue after donor funding, or after a special effort, such as a campaign, ends?* Two key aspects of sustainability for social development programmes are social-institutional and economic (for economic development projects, environmental sustainability is a third consideration). Do the beneficiaries accept the programme, and is the host institution developing the capacity and motivation to administer it? Do they ‘own’ the programme? Can the activity become partially self-sustaining financially?

ENVIRONMENTAL MANAGEMENT

The environment consists of the land, air and water on the planet Earth. It encompasses all living and non-living things occurring naturally on Earth or any region thereof. The built environment on Earth comprises the areas and components that are strongly influenced by humans. A geographical area is regarded as a natural environment if the human impact on it is kept below a certain limited level.

The construction and operation of rural structures and infrastructure have the potential to introduce pollution into the environment. Pollution is the introduction of contaminating substances into the environment that lead to its degradation.

Environmental management is management of the interaction of modern human societies with, and their impact upon, the environment. The aim of management is to limit environmental pollution and degradation. In line with all management functions, effective management tools, standards and systems are required. These include the environmental management standards, systems and protocols that that have been set up to reduce the environmental impact, measured against objective criteria.

There are various international and national standards for environmental management. The ISO 14001 standard is the most widely used standard for environmental risk management and is closely aligned to the European Eco-Management and Audit Scheme (EMAS). As a common auditing standard, the ISO 19011 standard explains how to combine this with quality management.

In the tropics, various statutory agencies exist to enforce environmental standards. These include the National Environment Management Council (NEMC) of Tanzania, the Bangladesh Environment Conservation Act (BECA), the Environmental Management Authority (EMA) of Trinidad and Tobago, the Environmental Protection Agency (EPA) of Guyana, the Philippines Department of Environment and Natural Resources, the Federal Environmental Protection Agency of Nigeria.

In most countries, there is a legal requirement to conduct an Environmental Impact Assessment (EIA) before any construction project is given a license to proceed. The EIA is an assessment of the possible impact – positive or negative – that a proposed project may have on the environment, together consisting of the natural, social and economic aspects. The purpose of the assessment is to ensure that decision-makers consider the ensuing environmental impacts to decide whether or not to proceed with the project. The International Association for Impact Assessment (IAIA) defines an environmental impact assessment as "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made."

For ongoing enterprises an annual Environmental Audit is a legal requirement in many countries. Environmental audits are intended to quantify environmental performance and environmental position. In this way they perform a function analogous to financial audits. An environmental audit report ideally contains a statement of environmental performance and environmental position, and may also aim to define what needs to be done to sustain or improve on these performance and position indicators.

WORKING PROJECT

You have visited a village in a rural part of your country. A wide range of farming activities take place in the village, including livestock keeping, chicken rearing and small-scale processing of products and animal feeds. There are also buildings scattered all over the homestead.

1. Illustrate how you would go about reorganizing the existing farmstead in preparation for future expansion.
2. With the aid of sketches, present a plan and elevations of a simple rural farm building

FURTHER READING

Davidoff, P. & Reiner, T.A. 1962. A choice theory of planning. *Journal of American Institute of Planners* (AIP), pp. 103-115.

FAO. 1980. *Farm management research for small farmer development*, by J.I. Dillon & B.J. Hardaker. FAO Agricultural Services Bulletin No 41. Rome.

FAO. 1984. *Agricultural extension systems in some African and Asian countries*, by P. Von Blanckenburg. FAO Economic and Social Development Paper No 46. Rome.

FAO. 1984. *Agricultural extension: a reference manual*, by B.E. Swanson (ed.). 2nd edition. Rome.

Government of Guyana. 2010. Environmental Protection Agency (EPA) (available at http://epaguyana.org).

Government of Nigeria. 1992. Federal Environmental Protection Agency (available at http://www.nigeria-law.org).

Government of Philippines. 2010. Department of Environmental and Natural Resources (available at http://www.denr.gov.ph).

Government of Trinidad and Tobago. 2011. Environmental Management Authority (EMA) (available at http://www.ema.co.tt/cms).

Hall, P. 1974. The containment of urban England. *The Geographical Journal*. Vol. 140. No 3, October, pp. 386–408. Blackwell Publishers.

Harwood, R.R. 1979. *Small farm development: understanding and improving farming systems in the humid tropics*. Boulder, Westview Press Inc.

Midwest Plan Service. 1974. *Farmstead planning handbook*, Ames, Iowa, Midwest Plan Services.

MidWest Plan Service (MWPS-2). 2005. *Farmstead Planning Handbook: Guidelines for Planning and Expanding Agricultural Facilities and Operations*. USA, Ames.

Miller, G.A., Galanter, E. & Pribran, K. H. 1960. *Plans and the structure of behaviour*. New York. Holt, Rinehart and Winston.

Noton, N.H. 1982. *Farm Buildings.* Reading, College of Estate Management.

Ruthernberg, H. 1980. *Farming Systems in the Tropics*. 3rd edition. Oxford University Press.

Wildavsky, Aaron B. 1973. If planning is everything, maybe it's nothing. *Policy Sciences.* Vol. 4. Summer, pp 127–153.

Chapter 3
Graphical techniques

INTRODUCTION

Graphics are essential for planning buildings, completing engineering designs, estimating quantities of materials and relative costs and, lastly, communicating to the builder all the information that the designer has formulated.

Computing, drafting, typing and printing technologies have changed dramatically since the early 1980s. Slide rules have been replaced by calculators and computers. Drawing tables, pencils, pens, T-squares and erasers have been replaced by computers. Various computer hardware systems have been developed to process high-quality graphics at very high speeds and to keep project costs to a minimum. These technologies are known as computer-aided design and drafting (CADD).

Computer-aided design and drafting (CADD)

CADD is an electronic tool for preparing quick and accurate drawings with the aid of a computer instead of the traditional tools (pencils, ink, rulers and paper). Unlike the traditional methods of preparing drawings on a drawing board, CADD enables high-precision drawings to be created on a computer.

CADD software has generally replaced the traditional drawing board in drafting offices. In the 1990s, CADD was used only for specific high-precision engineering applications. This was a result of the high price of CADD software, which made it accessible to only a few professionals. However, as prices have fallen there has been a significant increase in the use of CADD software and it is now widely used by most professionals.

CADD software can be used to produce two-dimensional (2D) drawings directly or to build a three-dimensional (3D) model of a project, from which the software can extract 2D drawings that will be printed on paper. Some CADD software also includes modules for rendering realistic images.

Much more can be achieved using CADD than with the traditional drawing board. Some of the major capabilities are: presentations, flexibility in editing, units and accuracy levels, storage and access for drawings, sharing CADD drawings, project reporting, engineering analysis, computer-aided manufacturing (CAM), design and add-on programmes.

Using CADD to produce a building drawing has the following advantages:

- The drawings are clean, neat and highly presentable.
- The drawings can be subdivided into smaller parts that can be reused or worked on by several people.
- Updating drawings is much faster than with hand-drawn plans that would have to be redrawn.
- Drawings can be presented in different formats, thereby facilitating transfer from one system to another.
- Several integrated tools are used to check drawings for errors.
- It is possible to work with real world units – the CADD system performs scaling automatically to fit any size of paper.

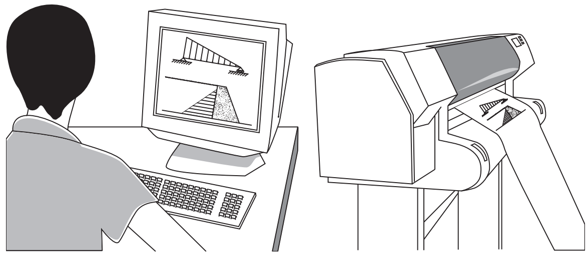


Figure 3.1 **A modern drafting office**

It should also be noted that current CADD systems are moving away from traditional drawing-oriented solutions towards fully featured architectural solutions (i.e. building information processing), which can be used not only to design a project, but also to manage the enormous quantities of information (such as materials, prices or utilization) that go into an architectural project.

CADD hardware and software

The main components of a CADD system are the hardware and the software. The CADD hardware refers to the electronic and electromechanical parts of the system. The hardware include: system unit, central processing unit, memory, hard disk, floppy disk, CD-ROM, external storage devices, monitor, printers and plotters, keyboard, digitizer and mouse.

The CADD software refers to the instructions that tell the hardware via the operating system how to perform specific tasks. A CADD programme contains hundreds of functions to perform specific drawing tasks such as drawing objects, editing objects, data management, data storage and data output.

The CADD programme usually implements a user interface to enable the user and the computer to communicate efficiently. Most CADD applications provide a graphical user interface (GUI) for this purpose. Using the GUI, the user may communicate with the computer via menu bar, command line, tool buttons, dialogue boxes and the model space. These can be used to directly or indirectly call functions implemented in the drawing module, which supplies the user with tools to:

- draw lines
- select line types;
- draw flexible curves;
- draw arcs and circles;
- draw ellipses and elliptical arcs;
- add text to drawings;
- manipulate text styles;
- add dimensions to drawings;
- set dimension styles;
- add hatch patterns to drawings;
- draw symbols;
- draw arrows.

For a given single task, several functions are executed behind the scenes that then results into the final drawing, which is basically a grouping of individual components (lines, arcs, circles, ellipses, polylines, text, dimensions, pointers, symbols, borders and patterns). Performing the same tasks with the traditional drawing board would involve use of several instruments, which is time consuming and inaccurate. With a CADD system, all these are automated and can be performed efficiently.

The edit module in CADD programmes provides great flexibility in changing drawings. If the editing functions of CADD were not available, then it would probably take the same time to complete a drawing as it would on a drawing board. However, with editing capabilities inbuilt, CADD becomes a dynamic tool that results in significant time savings. Changes that may look extremely difficult on a drawing board can be easily accomplished with CADD. For example, even for major changes redrawing is not necessary because diagrams can be manipulated in a number of ways to rearrange existing pieces of the drawing to fit the new shape. The basic editing capabilities include erasing, moving, rotating, mirroring, scaling, copying and changing the appearance of drawing objects.

Drawings created in CADD can be stored in the computer hard drive as memory blocks called files. The user can name the files as desired, though the operating system may impose some restrictions on the use of specific characters and symbols. This is important as it enables the files to be accessed when required in the future. For example, if some work on a specific file is to be postponed to another time. Also, modifications can be made to the files for use in another project. Such a file can be renamed leaving the original file intact.

The files dealt with in a given drawing office can run into hundreds. Thus, it is important that proper file management be put in place. This is made easy by the computer as it allow files to be stored in directories and subdirectories. Files organized in this manner are easier to trace when required.

CADD design applications

The CADD system, as the acronym suggests, should have a design component inbuild. But this is not the case most of the times. Many CADD programmes have only the drafting component even if they bare the name CADD. However, mild design can be carried out with these systems. A CADD programme can only be called a design programme, if it has capabilites to solve problems and perform analyses.

Where a CADD system has design capabilities, the programme is usually based on a number of principles that will vary from product to product. The product can be based on performing calculations; it may employ comparison and logic; use a database or another form of artificial intelligence or combination of everything.

The following are some examples of design programmes:

1. *Calculation programmes:* These are extremely effective in solving complex mathematical problems.
2. *Intelligent CAD systems:* These are based on logic and comparison and have a number of applications in product design, mechanical design, spatial planning, etc.
3. *Knowledge-based CAD systems*: These are also known as expert systems. They make use of information gathered from previous projects (or parameters defined by the programmer) and use it for new design proposals.

PROJECTIONS

Projections are often useful in presenting a proposed building to someone who is not familiar with a presentation in the form of plans, sections and elevation drawings. Isometric or oblique projections are useful for presenting a pictorial, although slightly distorted, view of a structure. The axonometric projection is best suited to showing the interior of rooms with their furniture, equipment or machinery. The two-point perspective, which is a little more complicated to construct on a drawing board, can be generated easily using CADD and gives a true pictorial view of a building as it will appear when standing at about the same level as the building and at some distance.

All types of projection can be constructed to scale, but they become really useful to the building designer once the technique is so familiar that most of the details in the drawing, and eventually even the major contours of the picture, can be drawn freehand.

Isometric projection

With isometric projection, horizontal lines of both the front view and the side view of the building are drawn 30° from the horizontal using dimensions to scale. Vertical lines remain vertical and the same scale is used. Simple 2D functions can be used and lines drawn at specific angles to complete an isometric drawing. Polar coordinates are particularly helpful for measuring distances along an angle.

Oblique projection

An oblique projection starts with a front view of the building. The horizontal lines in the adjacent side are then drawn at an angle, usually 30° or 45°, from the horizontal. The dimensions on the adjacent side are made equal to 0.8 of the full size if 30° is used, or 0.5 if 45° is used.

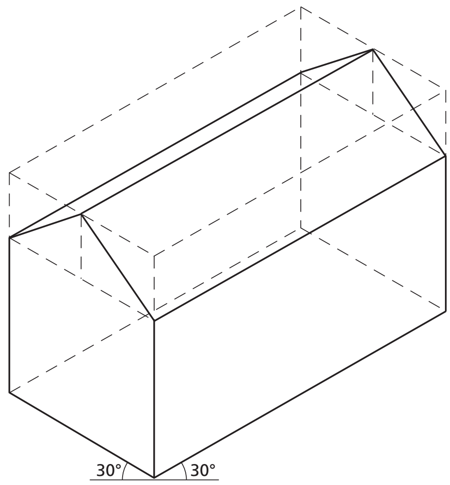


Figure 3.2a **Isometric**

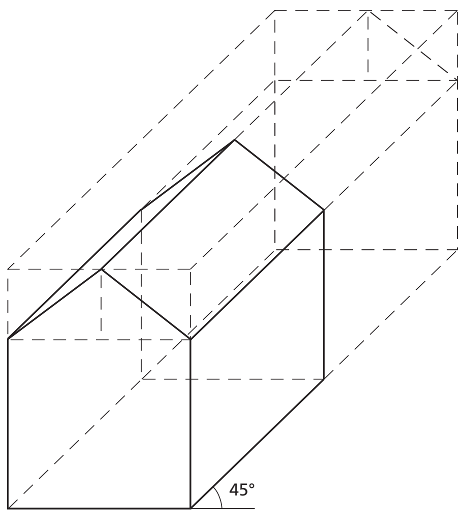


Figure 3.2b **Oblique projections**

Axonometric projection

In an axonometric projection, the plan view of the building is drawn with its side inclined from the horizontal at any angle. Usually 30°, 45° or 60° is chosen because these are the angles of a set square. All vertical lines of the building remain vertical and are drawn to the scale of the plan view.

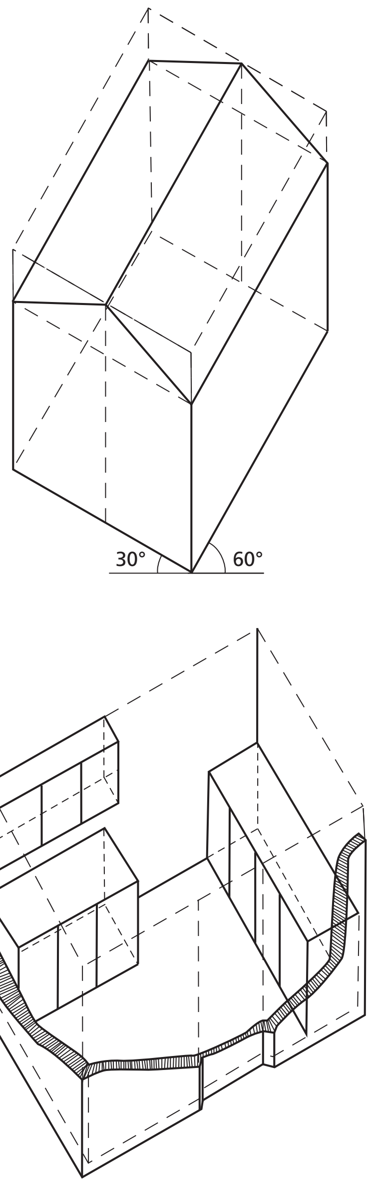


Figure 3.3 **Axonometric projection**

PERSPECTIVE

The different technical terms used in perspective drawing can be explained by imagining that you are standing in front of a window looking out at a building from an angle where the two sides of the building are visible. If you then trace on the window pane what is seen through the glass, this gives the outline of the building. This results in a perspective drawing of the building and, if the glass could be removed and laid on the drafting table, the drawing would look like a perspective drawing made on paper.

The station point is the viewing point, supposedly occupied by the eye of the observer. The viewing point is also determined by the eye level, usually assumed to be 1.7 metres above ground level. Looking across a large body of water or a plain, the sky and water/ground appear to meet in the distance, on the horizon line. This must always be considered to be present, even when hidden by intervening objects. The horizon line is at eye level.

When standing and looking down a straight road, the edges of the road appear to meet at a point called the vanishing point, which is on the horizon line and therefore also at eye level. Similarly, the parallel horizontal lines of a building appear to meet at vanishing points, one for each visual side.

The outline of the building is brought to the window by your vision of the building, along the vision rays. The picture is traced on the window pane, which is called the picture plane.

As the technique with a window pane obviously cannot be used for a proposed, but still non-existent building, the perspective has to be constructed from available documentation. A perspective drawing of a building can be constructed using the plan view or, if several buildings are to be included, the site plan may be more suitable. In addition you need elevations of all visual sides of the building(s), i.e. in the case of one building the front elevation and one end elevation.

THREE-DIMENSION DRAWING AND MODELLING IN CADD

The isometric, oblique and perspective views of objects can be easily, accurately and efficiently drawn in CADD. CADD also provides a great deal of flexibility in terms of editing and display compared to the drawing board.

Two methods can be used to draw 3D object. The drawings can be done using 2D functions or 3D functions. The 2D approach enables the designer to draw 3D objects in the traditional drawing board style in which drawing tools such as lines, arcs and ready to use 2D objects can be joined together to come up with the desired drawing. The 2D approach is quick way to draw simple isometric and oblique views. However, 3D objects drawn in this manner are static just as they are in traditional drawing board.

The inclusion 3D modules within a CADD system greatly enhances it 3D drawing capabilities including ability to perform 3D modelling and the ability to derive the 3D models from their 2D drawing views. The 3D capabilities enable the designer to create 3D models that are virtually realistic as the actual objects and can even be made better by rendering programmes. The models developed can be rotated on the screen, displaying views from different angles. This is advantageous when the designer need to view the model at different angles so as to make necessary adjustment and during presentations to the clients, who are then able to view the end product in a virtual world and suggest changes if desired. The 3D models developed can be wire-frame, surface or solid

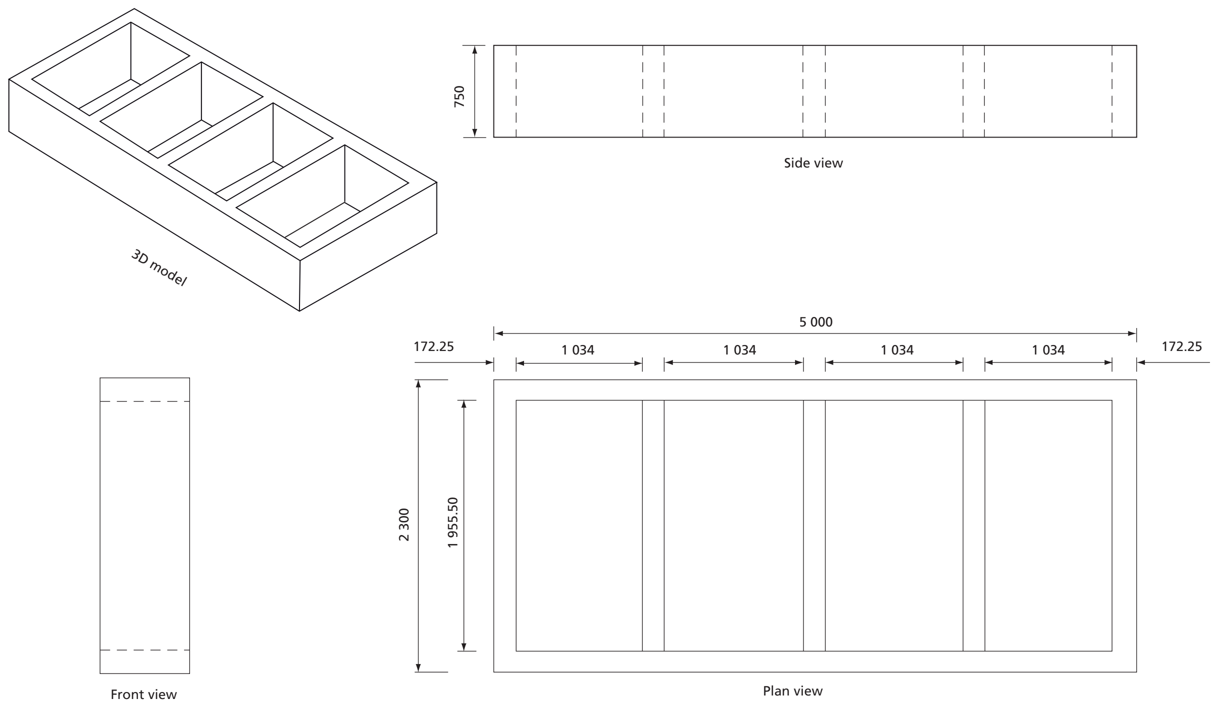


Figure 3.4 **Three-dimensional modelling**

models. Figure 3.4 shows a 2D drawing together with its 3D model developed within a CADD system.

PRINTING AND PLOTTING PROCESS

CADD drawings are printed using a printer or a plotter. The printing process is as simple as selecting the print or plot function from the menu. This action sends data from the computer to a printer or plotter, which produces the final drawing. The drawings are neat, clean and – depending on the quality of the printer – highly accurate.

Figure 3.5 **A plotter in use**

A number of parameters can be specified to control the size and quality of a plot. A drawing can be plotted to any size by applying an appropriate scale factor. Line thicknesses and colours can be specified for different drawing objects. A number of other adjustments can also be made, including rotating a plot, printing only selected areas of a drawing, or using specific fonts for text and dimensions.

The following are the most important considerations for plotting:

- selecting a scale for drawings;
- composing a drawing layout;
- selecting text and dimension heights;
- choosing pen colours and line weights.

Selecting a scale for drawings

When working on a drawing board, a specific scale can be used to draw diagrams. For example, when a plan of a building or a township has to be drawn, the size of the diagrams can be reduced to 1/100 or 1/1000 of the actual size, i.e. using a scale of 1:100 or 1:1000. When a diagram of a small machine part has to be made, it is drawn many times larger than its actual size. CADD uses the same principle to scale drawings but takes a different approach.

Standard paper sizes used for plotting

As building drawings include many details, they should be large enough to be accurately executed and easily read. The standard formats from the A-series should be used for all drawings for a building. However, several detailed drawings may be put on one sheet. The A-series includes the following sizes:

A0	841 × 1189 mm
A1	594 × 841 mm
A2	420 × 594 mm
A3	297 × 420 mm
A4	210 × 297 mm

If the building plans tend to be very long, one of the following alternative sizes may be useful:

A10	594 × 1189 mm
A20	420 × 1189 mm
A21	420 × 841 mm
A31	297 × 841 mm
A32	297 × 594 mm

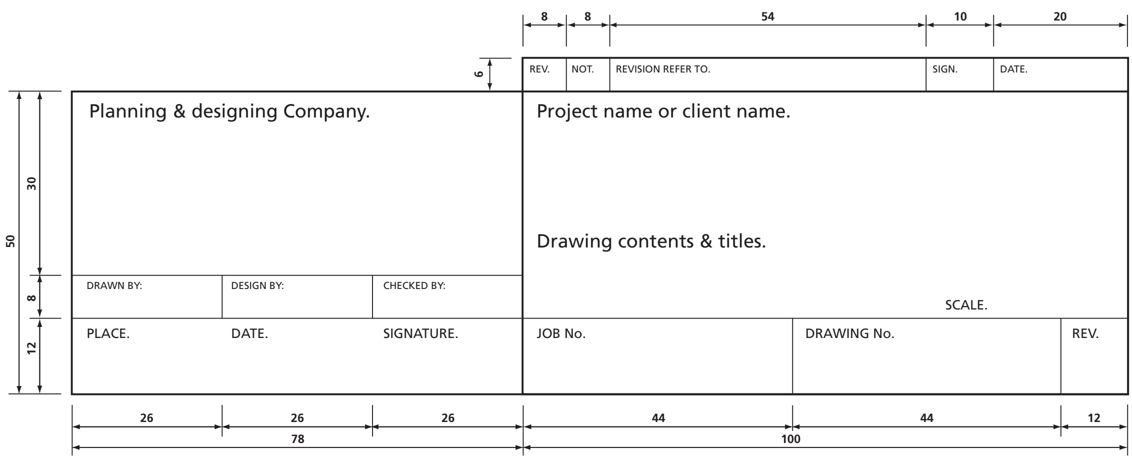


Figure 3.6 **Title box with revision table**

If possible, only one format should be used for all drawings in a project, or alternatively all drawings should be of equal height. The formats A0, A10 and A20 are difficult to handle and should therefore be avoided. It is better to use a smaller scale or divide the figure into more drawings.

CADD provides a number of special functions to compose a drawing layout. Diagrams can be arranged on a sheet as required and any scale factor can be applied. The drawing can then be plotted on the best fitting standard paper size.

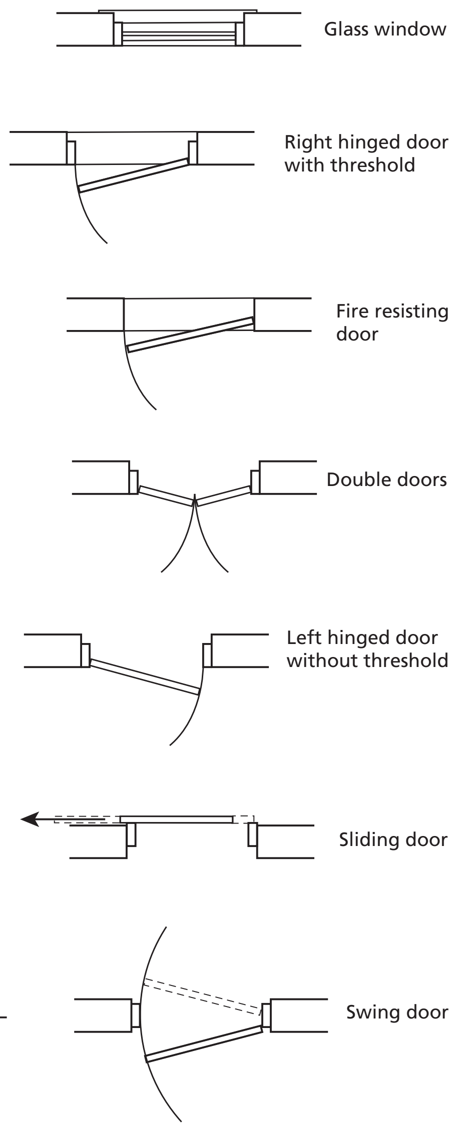
Title box

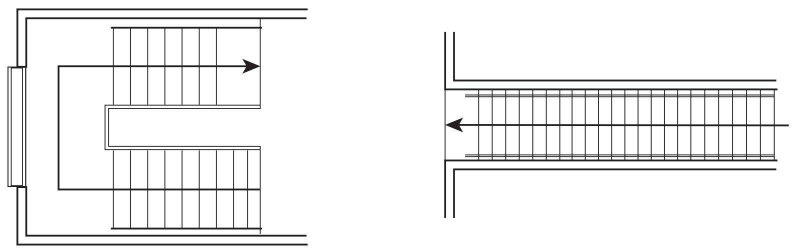
All drawings must have a title box, as shown in Figure 3.6.

Note that the lines indicating the dimension limits do not touch the figure.

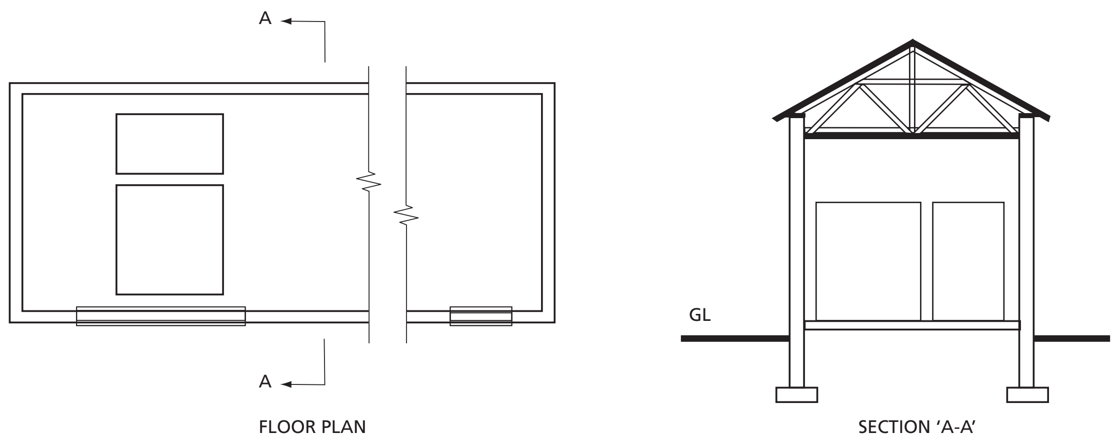
Architectural symbols

These are graphical representations of different features that appear on blueprint plans or elevation drawings of buildings. The graphics themselves can vary in appearance from one plan to another, but can usually be distinguished fairly easily by anyone with a basic understanding of their meaning.





Staircases - Arrows indicate movement up



Indication of section - Arrows show direction of view

Figure 3.7 **Architectural symbols**

Figure 3.8 **Symbols for installations in buildings**

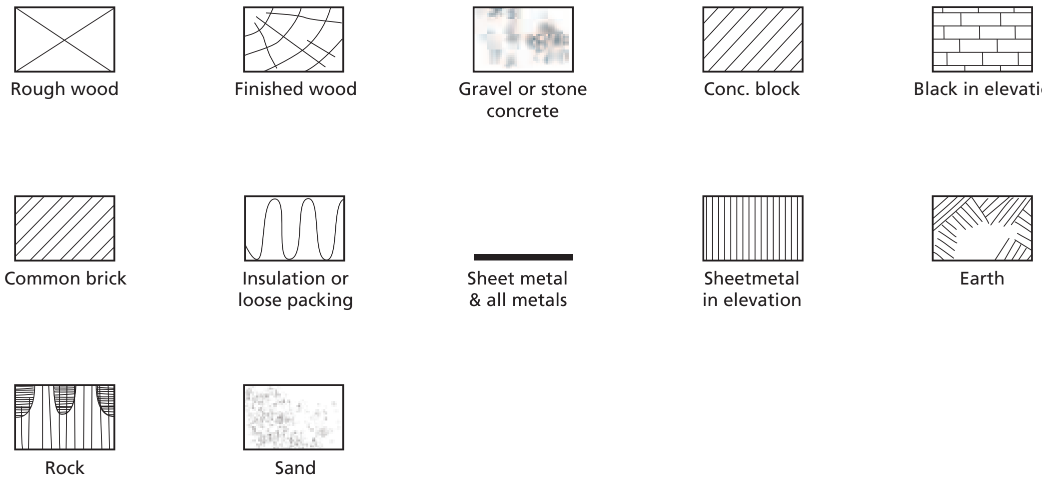


Figure 3.9 **Symbols for materials**

DOCUMENTATION FOR A BUILDING PROJECT

A building project normally requires several types of drawing that will be discussed in sequence in this section. In small- and medium-sized projects, two or three drawings may be combined into one, whereas in large projects each title listed may require several drawings. It is not advisable to include so much information in one drawing that interpretation becomes difficult.

Site plan

Scale 1:1000, 1:500 or 1:200

The location of the building in relation to its surroundings, including:

- existing buildings, roads, footpaths and gravelled or paved areas;
- the topography of the site with both existing and finished levels;
- plantings, fences, walls, gates, etc.;
- north point and prevailing wind direction;
- the extent of earthworks including cutting, filling and retaining walls.

Plan of external service runs

Scale 1:500, or 1:200

The layout of external service runs including:

- electricity and telephone;
- well or other source of water;
- drainage (run-off rainwater, groundwater);
- drainage (wastewater, urine, manure);
- sanitation (septic tank, infiltration).

External service runs are often included in the site plan or the foundation plan.

Foundation plan

Scale 1:200, 1:100 or 1:50

- Earthwork for foundation;
- drainage;
- footings and foundation.

Plan view

Scale 1:200, 1:100 or 1:50

- Outer walls;
- load-bearing walls;
- partitions;
- main openings in walls and partitions (doors and windows);
- door siting;
- stairs in outline;
- fixed equipment, cupboards and furniture;
- sanitary fittings;
- major dimensions and positions of rooms, openings and wall breaks;
- section and detail indications;
- room names;
- grid and column references (where applicable);
- in multistorey buildings a plan is required for each floor.

Section

Scale 1:100 or 1:50

- Structural system for the building;
- major dimensions of heights, levels and roof slopes;
- annotations on materials for walls, ceiling, roof and floor;
- foundation (if not in a separate foundation plan).

Elevation

Scale 1:200, 1:100 or 1:50

- Doors;
- windows;
- miscellaneous external components;
- shading and hatching for the texture of facing surfaces (optional);
- dimensions of all projections from the building, including roof overhangs.

Details

Scale 1:20, 1:10, 1:5, 1:2 or 1:1

The information that builders need for each element of the building they are to construct may be classified as follows:

- What has to be installed or erected, including information about its nature and the physical dimensions.
- Where it is to be placed, requiring both graphical and dimensional information regarding its location.
- How it is to be placed or fixed in relation to adjacent elements.

The designer must include all details necessary for the builder to complete all elements of the building. When standard practice, general specifications or building codes are not followed, it is particularly important to include complete detail drawings, annotations and specifications.

Where prefabricated elements are used, for example windows, a specification rather than a detail drawing is adequate. This allows the builder to choose the least expensive alternative that meets the specification.

Where machinery and equipment require special foundations, supports, openings and cavities, the required detail drawings will, in most cases, be supplied by the manufacturer.

Often there is no need to produce detail drawings specifically for each project. An established drawing office will have detail drawings covering the most frequent requirements, which may be affixed to current projects.

Plan of electrical installations

Scale 1:200, 1:100 or 1:50

- Incoming power supply and all wire locations;
- main switch, fuses and meter;
- location of machinery and switches;
- location of lighting points and switches, both internal and external;
- sockets;
- annotations and dimensions.

Plan of water and sanitary installations

Scale 1:200, 1:100 or 1:50

- Pump, pressure tank, storage tank;
- water heater;
- water pipe locations;
- tapping points, valves and control equipment;
- wastewater pipe location;
- wastewater drains and sanitary installations;
- annotations, dimensions, levels and slopes.

List of drawings

Where there are several drawings for a building project, the loss or omission of a single drawing can be avoided by listing all of them on an A4 sheet. Information on the latest revisions ensures that all drawings are up to date.

Technical specifications

The technical specifications should set out quality standards for materials and workmanship for the building elements that have been described in the drawings. Where general specifications are available they are commonly referred to and only variations are specified in the technical specifications.

However, in drawings for small- and medium-sized farm building projects, there is a tendency to include directly on the drawings much of the information normally given in the specifications.

As a basic rule, information should be given only once, either in the specifications, or on the drawing. Otherwise there is a risk that one occurrence will be forgotten in a revision and thus cause confusion.

Functional and management instructions

Frequently information has to be transferred to the person using a structure to enable him or her to utilize it in the most efficient way, or the way intended by the designer. In a pig house, for example, different types of pen are intended for pigs of different ages. Alleys and door swings may have been designed to facilitate the handling of pigs during transfer between pens. In a grain store, the walls may have been designed to resist the pressure from grains stored in bulk to a specified depth.

Bill of quantities

The bill of quantities contains a list of all building materials required and is necessary to make a detailed cost estimate and a delivery plan. It cannot be produced, however, until the detailed working drawings and specifications have been completed. Bills of quantities are further discussed in Chapter 9 of this text.

Cost estimate

The client will require a cost estimate to determine whether or not the building should be constructed. Clients need to know whether the proposed design is within their financial means and/or whether the returns on the intended use of the building justify the investment.

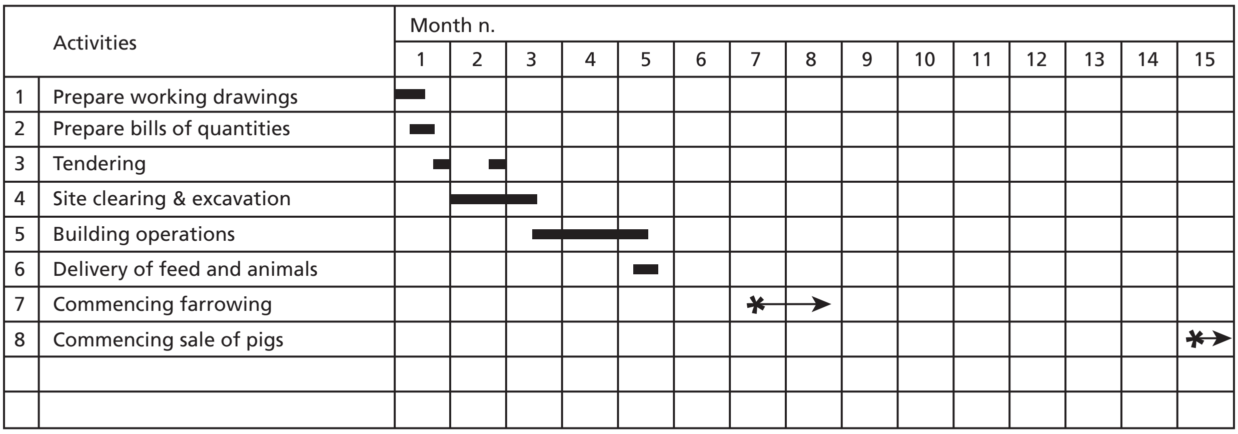


Figure 3.10 **Time schedule**

Time schedule

A simple progress chart, as shown in Figure 3.10, will considerably facilitate the planning of building operations and subsequent activities.

Farmers may obtain information concerning when they and any farm labourers will be involved in construction operations, when animals and feed should be delivered, when a breeding programme should be started, or the latest starting date for the construction of a grain store to be completed before harvest. This is the type of information needed to enable the returns on the investment to be realized as early as possible. A contractor will require a more detailed chart for the actual construction operations to ensure the economical use of labour, materials and equipment.

MODEL BUILDINGS

Even people with a good basic education will need considerable experience to be able to envisage fully a building from a set of drawings. The rural building engineer will therefore soon learn that the average rural dweller not only finds it very difficult to understand simple plan view and section drawings, but may even find it hard to interpret fully rendered perspectives. However, the fact that a model, unlike drawings, is three-dimensional and thus can be viewed from all sides brings more realism to the presentation and usually results in better communication and transfer of ideas.

There are three types of model in common use for the presentation of rural building projects:

- Three-dimensional maps or site plans are used to present development plans for large areas or the addition of a new building on an old site with existing structures. These models have contours to show the topography, while structures are rendered in simple block form with cardboard or solid wood, usually with no attempt to show detail.
- Basic study models are used to examine the relationships and forms of rooms and spaces in proposed buildings. They are often built of cardboard or are computer-generated using 3D graphics, and there is usually little attempt to show details, although furnishings and equipment may be indicated. Windows and door openings are shown with dark-coloured areas or left open. Contours are shown only if they are of importance for the building layout.
- Fully developed models may be used in extension campaigns, for public exhibition, etc. These models show details to scale and represent as accurately as possible the actual materials and colours. Part of the roof is left out or made removable in models aiming to show the interior of a building and, with current CADD software, it is even possible to make a virtual tour of the building.

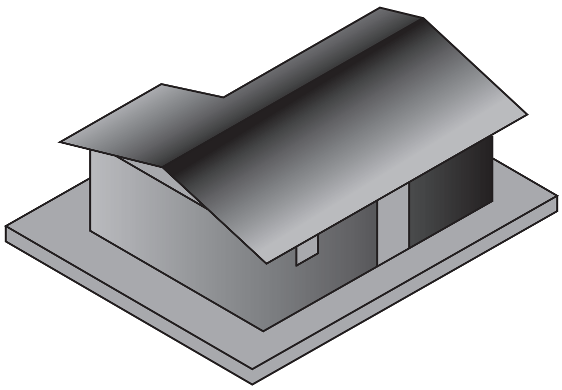


Figure 3.11 **Computer-generated 3D model**

Physical model

Where the model is to be physically built, a sturdy base for the model, made of either plywood or particle board, not only facilitates handling but also helps to protect the model. For models to be displayed in public, it is advisable to have well-finished borders, preferably in hardwood and, although expensive, an acrylic plastic (plexiglass) cover. During transport, a plywood box without a bottom, fixed to the base of the model with screws, will provide sufficient protection if handled with care. Otherwise, where appropriate, a full virtual tour of a building project can be shown to the public directly from a computer using an electronic projector.

The size of the model is determined by the scale to which it is made and the size of the actual project. While detail is easier to include in a model made to a large scale, too much detail may distract from the main outlines and essential features. If the model is too large it will be more costly and difficult to transport. Basic study models are often made to a scale of 1:50 or 1:100 to allow for coordination with the drawings, while fully developed models of small structures may be made to a scale of 1:20 or even larger. Whatever scale is used for the model, it is desirable to include some familiar objects, such as people or cars, to the same scale as the model to give the observer an idea of the size of the actual structure.

The construction of contours and elevations requires access to a map or a site plan with contour lines to the same scale as that used in the model. One way of showing contours is to build up a model with layers of cardboard or styrofoam sheets of a thickness equal to the scale of the real difference in height between contour lines. Employing one piece of cardboard for each contour line, trace the line onto the cardboard using carbon paper, cut out the contour, place it on the model and secure it with glue. The contours can either be left as they are, giving sharp, distinct lines, or be smoothed to a more natural slope using sandpaper or filler.

For more elaborate models the landscaping may be represented by painting. Trees and bushes can be made from pieces of sponge or steel wool on twigs or toothpicks. Coloured sawdust can be used for grass and fine sand for gravel. If available, model railroad supplies and other hobby materials can be useful.

Although the same materials employed in the actual building, or close simulations, are used for the most elaborate models, cardboard (or for models made to a large scale, plywood) is usually easier to work with and can be finished by painting to represent most types of material. Cardboard or plywood of the right scale thickness for use as walls is often unavailable, but it will make no difference as long as the overall scale and dimensions of the building are maintained.

Round wooden posts commonly used in farm buildings for post-and-beam or pole construction can be conveniently made from twigs or hardwood sticks. Any finish on the walls to represent openings or materials should be applied before the model is assembled. Neat, clean-cut lines are easier to achieve in this way. While a plain cardboard roof is adequate for most purposes, corrugated paper painted in a suitable colour may be used to represent corrugated roofing materials, and thin grass glued to the cardboard can be used to represent thatch.

The strength and rigidity of models can be increased by bracing the walls with square pieces of cardboard in positions where they will not be seen in the finished model. Bracing is particularly important in models that are going to be painted, as paint tends to warp cardboard and sheet wood if applied over large areas. Regardless of the material being represented, colours should be subdued and have a matt, not glossy, finish. Distemper or water colour is best for use on cardboard and unsealed wood, but care must be taken to remove excess glue, as this will seal the surface and cause the colour to peel off.

A photograph of the model may be used in cases where it is not feasible to transport the model, or when photos need to be included in information material but the actual building has not yet been completed. Models often appear more realistic when photographed, particularly in black and white because of the better contrast, but adequate lighting from a direction that produces a plausible pattern of sun and shade on the building should be used. Outdoor photography allows the sky or terrain to be incorporated as a background in the photograph of the model.

Computer-generated models

These models can be built directly using 3D CADD software or from the 2D drawings of the building. Once the model is complete, the addition of features to the model from the material library can achieve a realistic model picture. The quality of the model can be further improved by the use of rendering software. If the CADD software allows, the developed model can be used to simulate different conditions that may be experienced in the real building. For example, the building may be oriented in different directions and the effect of environmental factors such as wind and solar radiation can be studied to achieve the optimum design conditions.

REVIEW QUESTIONS

1. What are the advantages of CADD over manual drafting?
2. Outline some of the capabilities of a CADD system.
3. Describe the components of a CADD system.
4. How can a designer benefit from the 3D capabilities of a CADD system?
5. What are the advantages of developing a computer-generated model over a physical model of a building project?

FURTHER READING

Bellis, H.F. & Schmidt, W.A. 1971. *Architectural drafting.* New York, McGraw-Hill Book Co.

Duggal, V. 2000. *CADD primer: a general guide to computer-aided design and drafting*. Mailmax Pub (also available at http://www.caddprimer.com).

Giesecke F.E., Mitchell, A.T., Spencer, H.C., Hill, I.L., Dygdon, J.T. & Novak, J.E. 2008. *Technical Drawing*. 13th edition. Prenice Hall.

Jefferis, A., Medson, D.A., & Madsen, D.P. 2010. *Architectural drafting and design*. 6th edition.

Kicklighter, C.E. & Kicklighter, J.C. 2008. *Architectural: residential drawing and design.* 10th edition. Goodheart-Willcox.

McBean, G., Kaggwa, N. & Bugembe, J. 1980. *Illustrations for development.* Nairobi, Afrolit Society.

Osbourn, D. & Greeno, R. 2007. *Introduction to building.* 4th edition. London, Pearson Education, Prentice Hall.

Shumar, T.M. & Madsen, D.A. 2009. *Autocad and its applications – basics 2010*. 17th edition. Goodheart – Willcox.

Styles, K. 1982. *Working drawings handbook.* London, Architectural Press.

Taylor, R. 1971. *Model building for architects and engineers.* New York, McGraw-Hill Book Co.

Winden,V.J., de Keijzer, M., Pforte, W. & Hohnerlein, F. *Rural building - drawing book.* Maastricht, Netherlands, Stickting Kongregatie F.I.C.

Chapter 4
Geospatial techniques

INTRODUCTION

Geospatial technology is an integration of various technologies in the mapping, visualization and recording of phenomena in the Earth system and space. Down through history humankind has been attempting to fully understand and document the Earth, and this has driven innovation in geospatial science to the current state of the art.

Geospatial technology encompasses the following specialist areas:

1. *Engineering survey*: This involves the preparation of maps and plans for planning and designing structures, as well as ensuring that they are constructed in accordance with the required dimensions and tolerances.
2. *Geographic Information Systems*: This involves collecting and manipulating geographic information and presenting it in the required form.
3. *Cartography*: This is the accurate and precise production of maps or plans and the representation of the information in two or three dimensions.
4. *Photogrammetry*: This involves obtaining information from photographic images in order to produce a plan of an area.
5. *Hydrographic survey*: This involves measuring and mapping the Earth's surface that is covered by water.

In the development of rural structures, the engineering survey is most important because it allows:

1. Investigation of land using manual or computer-based measuring instruments and geographical knowledge to work out the best position for constructing buildings, bridges, tunnels, water channels, fences and roads.
2. Production of plans that form the basis for the design of rural structures.
3. Setting out a site so that a structure is built in the correct position and to the correct size.
4. Monitoring the construction process to make sure that the structure remains in the right position, and recording the final position of the structure.
5. Provision of control points by which the future movement of structures, such as roads, water dams, channels and bridges, can be monitored.

In large and complicated projects, it is necessary to engage the services of a geospatial expert, also known as a surveyor. In small buildings or infrastructure projects, and other professional, such as an engineer, may perform the geospatial tasks.

At different times in history, a variety of tools have been developed and used for land measurement, plan production and setting out buildings. These range from pacing methods to hand-held instruments. The various methods are discussed in the section 'Survey of a building site'.

SURVEY OF A BUILDING SITE

A simple survey of a building site provides accurate information needed to locate a building in relation to other structures or natural features. Data from the survey are then used for drawing a map of the site, including contours and drainage lines if needed. Once located, the building foundation must be squared and leveled. This section covers the various procedures involved.

Distances

Steel tapes or surveyor's chains are used for measuring distances when stations are far apart and the tape or chain must be dragged repeatedly. Linen or fiberglass tapes are more suitable for measuring shorter distances such as offsets when making a chain survey or laying out a foundation. To obtain accurate results, a chaining crew must first practice tensioning the chain or tape so that the tension will be equal for each measurement.

Range poles are 2 to 3 metres metal or wooden poles painted with red and white stripes, and are used for sighting along the line to be measured.

Land arrows come in sets of 10 and are set out by the lead person in a chaining crew and picked up by the following person. The number picked up provides a check on the number of lengths chained.

A field book is used for drawing sketches and recording measurements.

When measuring for maps or site plans, horizontal distances are required. Thus, when chaining on sloping land, stepping will be necessary. This procedure allows the tape or chain to be kept level, as checked with a hand or line level, while the point on the ground under the high end of the tape is located with a plumb-bob, as shown in Figure 4.1.

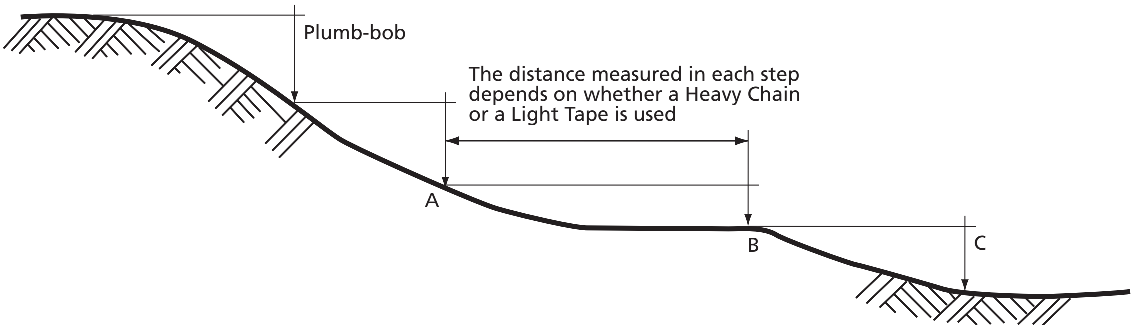


Figure 4.1 **Stepping on sloping ground**

Angles

There are several types of tripod-mounted levels available, some of which are equipped with horizontal rings allowing them to be used for measuring or setting out horizontal angles. Theodolites are designed to measure or set out both horizontal and vertical angles. Although these surveying instruments provide the most accurate means of measuring angles, they are expensive and rather delicate. Fortunately much of the surveying of rural building sites involves only distances, 90° angles and contours that can be measured or set out with fairly simple equipment.

One simple yet accurate means of setting out the 90° corners of a building foundation makes use of the Pythagorean Theorem, or the 3–4–5 Rule (or any multiple of the same).

Starting at the corner of the foundation site, a line is stretched representing one side of the foundation. A distance of 4 metres (m) along the line is marked. Then another line is stretched from the corner at approximately 90°, and 3 m is measured along this line. When using the tape between the 4-m and the 3-m marks, the second line is swung slightly until exactly 5 m is measured between the marks. The first two lines then form a 90° angle.

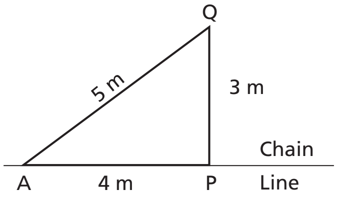


Figure 4.2a **The 3–4–5 Rule**

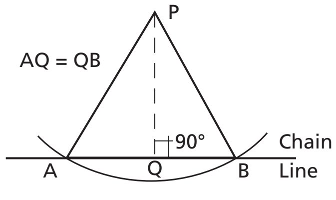


Figure 4.2b **Erecting a perpendicular**

Figure 4.2 illustrates this procedure, as well as the method of swinging an arc to erect a perpendicular.

Two simple instruments for setting out right angles are the cross-stave and the optical square (Figure 4.3). Either can be mounted at eye level on a range rod at the corner where the angle is to be set out. The instrument is then turned carefully until one line of the right angle can be sighted. The second line can then be swung slightly until it can also be sighted.

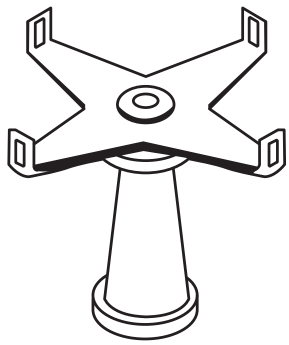


Figure 4.3a **Cross-stave**

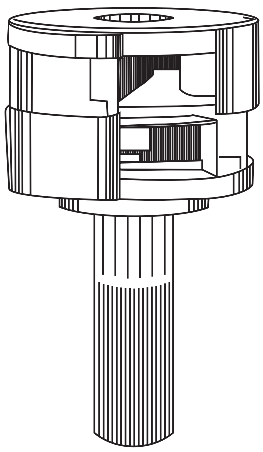


Figure 4.3b **Optical square**

Vertical alignment

A surveyor's plumbline consists of a sturdy cord, a distance bar and a conically shaped plumb-bob with a hardened steel point. It is used for positioning surveying instruments or when stepping with a tape or chain. It may also be used to check the vertical alignment of foundations, walls and posts. A simple plumbline for these jobs can be made from string and a stone (see Figure 4.4).

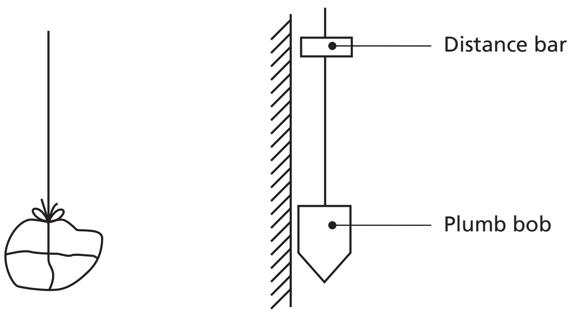


Figure 4.4 **Plumb bobs**

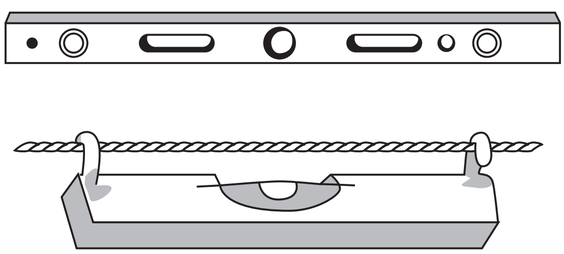
Leveling

Just as in the case of angle measurement, there is a wide variety of surveying instruments used for leveling. Most are designed for accuracy and are rather expensive. Although built for use in the field or on a building site, as with any precision instrument they require careful handling and regular attention to ensure good service.

Fortunately, there are several rather simple devices that may be used for leveling foundations, running contours or aiding in step-chaining.

Builder's levels are made of wood, plastic or aluminium and are available in several lengths, 1 metre being a convenient size. The bubble tubes are graded for sensitivity to suit the work. Most are now made of plastic and filled with fluorescent liquid – an aid in poor light. see Figure 4.5.

Line levels are designed to hang on a tightly stretched line. Both of these types are useful in foundation construction work.

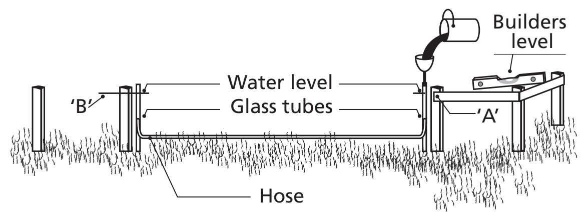


Alluminium line and surface level

Figure 4.5 **Builder's level and line level**

Hand levels and Abney levels are both hand-held instruments incorporating a spirit bubble tube and a split-image mirror. When they are held to the eye and the bubble centred, the viewer is looking at a point exactly at eye level. They are useful for keeping a chain or tape horizontal when stepping, and for doing simple contouring. The accuracy of work with either of these levels may be improved somewhat by placing the level on a rod of known length, still keeping the instrument approximately at eye level. As they have either a low-power scope or no telescope, they are only suitable for distances of up to approximately 30 metres.

For levelling the lines used in laying out a foundation, a builder's water level is a simple, inexpensive device that provides a satisfactory degree of accuracy. It consists of a length of rubber or plastic tubing, at each end of which there is a transparent sight-tube of glass or plastic. It works well over a distance of about 30 m and is particularly useful for transferring levels around corners, from outside a building to inside, or around obstacles where the two levelling points are not intervisible. It is also a useful tool for obtaining the slope in pipe runs. See Figure 4.6 for the method of use.



1 Set corner profiles at one corner as at right
2 Place hose as shown
3 Fill with water until water level is at top of corner profile A
4 Mark water level at opposite end B and set profile to mark

Figure 4.6 **Setting out corner profiles**

Chain surveying

In a chain survey, the area to be surveyed is enclosed by one or more triangles, the sides of which are measured and recorded. Then the perpendicular distance from the side of a triangle to each point of detail, such as trees, buildings or boundaries, is measured. From this information, a detailed plan of the site can be drawn to scale. A proposed structure may then be superimposed on the plan and its location transferred to the actual land site.

The following step-by-step procedure is used in a chain survey:

1. Make a preliminary survey by walking around the site, deciding where to put stations and where the main survey lines should be arranged. Stations should be selected so that they are intervisible and the lines laid out so that obstacles

are avoided. Make a sketch of the site in the fieldbook (Figure 4.7a).

2. Set the range poles, chain the triangle sides and record the distances.
3. Measure the perpendicular offsets from the chain lines to the details of the site. This will be easier to do if the chain lines have been arranged so that offsets can be kept as short as possible. Record the measurements in the field book (Figure 4.7b). Each page should record offsets along one chain line. Entries start from the bottom of the page and details are entered to the left or right of the centre column where distances along the chain line are noted. Not all details are measured by perpendicular offsets. Sometimes it is more accurate and convenient to use pairs of inclined offsets which, together with a portion of the chain, form acute-angled triangles. Note the top corner of the house in Figure 4.7b.
4. If contour lines need to be included on the map or site plan, the next step will be to measure levels with a levelling instrument and a staff.

   The grid method is most commonly used for construction projects, provided the ground does not slope too steeply. The grid is pegged out on the site in the position considered most suitable, and levels are taken at points where lines intersect. Sides of squares may be 5 m to 30 m, according to the degree of accuracy required. If the area is reasonably small, staff readings may be recorded near to each point on a sketch or drawing similar to that shown in Figure 4.7c. Alternatively, staff readings may be recorded in a field book. Each point has a reference letter and number.

   If all points on the site are within range of the levelling instrument and, providing the staff at each point can be seen through the telescope, the instrument should preferably be set up near the middle of the site so that all readings can be taken from one position. The first staff reading is made on an ordnance benchmark (OBM), if one is available in the near vicinity, or alternatively on a site datum, which may be assumed to be at a reduced level of 10 m, or any other convenient height.

   It is normal practice to leave a number of selected and carefully driven pegs in position on the site to assist in the work of setting out when development work commences.

   From the spot levels obtained by this grid method, the contours can be drawn, the volume of earth to be excavated can be calculated and the average level of the grid can be determined.
5. Make a map or site plan. Start by making a scale drawing showing the main surveying lines. Then plot the offsets to buildings and other features in the same order as they were recorded in the field book.

   If contour lines are to be included, start by drawing the grid to the scale of the drawing. The contour lines may then be indicated by interpolation. Contour points are plotted on each line between each pair of spot levels in the grid, assuming the ground has a fairly constant slope. A smooth curve is then drawn to link up points of the same height. Note that contour lines may not cross, but they may approach closely at points where the gradient of the ground surface is steep.

To produce the final map or site plan, cover the preliminary drawing with tracing paper and draw the final plan, omitting the survey lines, offset lines and grid.

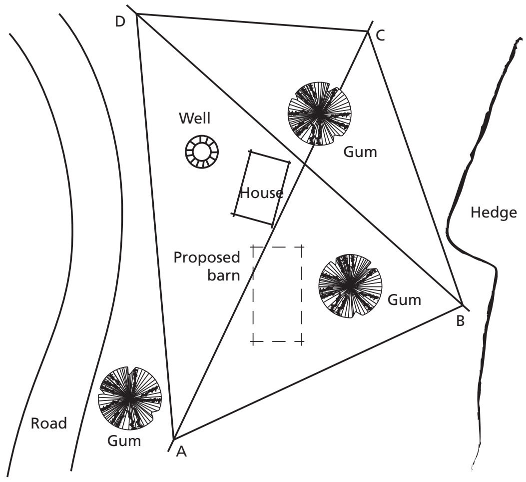


Figure 4.7a **Field book sketch of the site with stations and main survey lines**

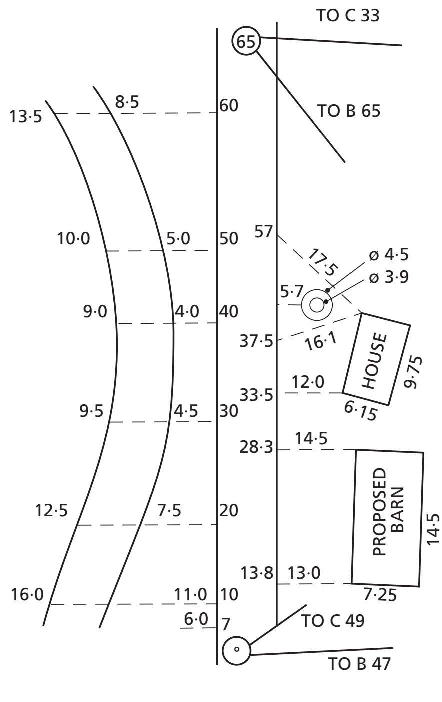


Figure 4.7b **Field book recordings of offsets along chain line A–D**

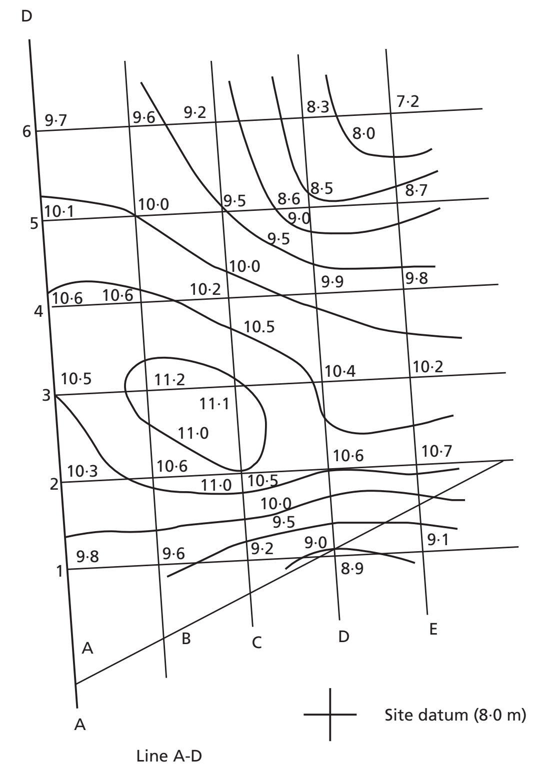


Figure 4.7c **Site plan made up to scale from field book recordings**

Setting out the building work

Before a decision about the final site of a building can be made, a number of factors need to be taken into account. Consideration must be given to local authority and planning regulations, to functional requirements, orientation, view, prevailing wind, noise, shelter, water supply, access, slope of ground, privacy and the type of soil on which to build.

Orientation can be important – perhaps the best position for comfort is an east–west alignment. This arrangement eliminates much glare by confining the sun's rays to the end walls. It also allows cross-ventilation – crucial when humidity is high.

To set out a building there needs to be a base line (one side of the building) and a fixed point on the line, usually one corner of the building. At this point, as at all other corners, a peg is first driven and then a nail is driven into the top of the peg to mark the exact position of the corner.

The distance from one peg to the next is carefully measured with a steel tape, and the peg and nail firmly driven. Depending on the size and nature of the building, the correct position of all other lines and pegs in relation to the base line and to each other may be obtained by means of:

- a levelling instrument fitted with a horizontal circle;
- a cross-stave or optical square;
- a flexible tape, using the 3–4–5 method;
- a builder's square (see Figure 4.8).

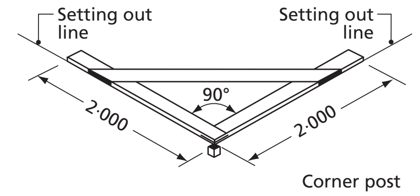


Figure 4.8 **Builder's square**

Having obtained the direction of all lines, measured all distances and driven pegs and nails at the points, the accuracy of the setting-out may be checked by measuring the overall horizontal distances in both directions. Pairs of lines should be exactly equal.

Check again the accuracy of the setting-out by measuring the diagonals of the rectangle. For buildings with sides between 5 m and 20 m long, the length of the diagonals *A* and *B* in Figure 4.9 should not differ by more than 0.5 percent. If adjustments are necessary subsequent to this check, it is advisable to keep the two longest parallel sides fixed and to make the required adjustments on the short sides.

Finally, check the drawing against the setting-out to ensure that lines and corners are in their correct positions and that dimensions are correct.

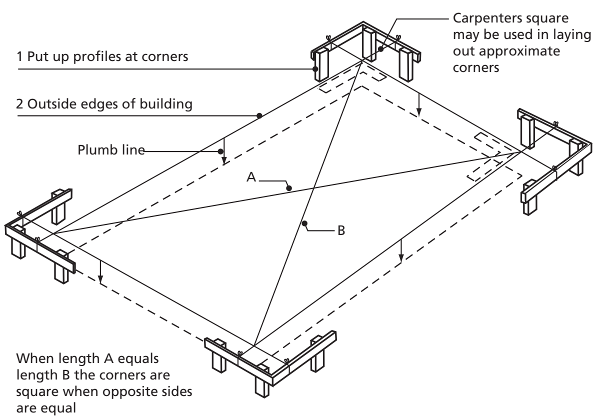


Figure 4.9 **Corner profiles and checking for accuracy**

When the setting-out and checking have been completed, timber profiles are erected. Profiles consist of horizontal rails supported by vertical pegs set up clear of the excavation. Inside and outside faces of the wall and the width of the foundation are marked on the horizontal rail by means of fine nails or saw cuts. Strings are later stretched between these nails or saw cuts on opposite rails to guide the workers during trench excavation and footing and foundation wall construction.

Ideally, profiles should be set up for all corners and internal walls. The profile shown at A in Figure 4.10 should be located at A1, if the foundation area is to be excavated.

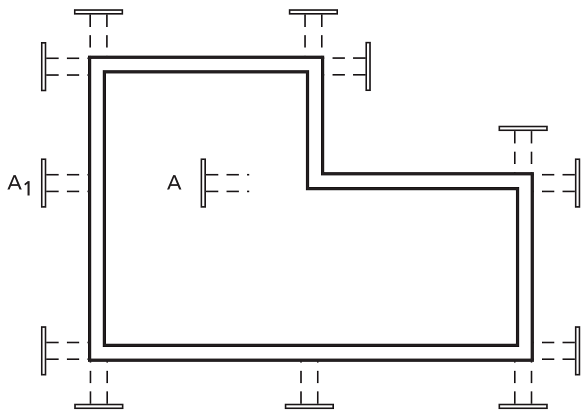


Figure 4.10 **Plan of walls and profiles**

Excavation depth control

When any building work is to be done, it is usually necessary to excavate at least a foundation trench. In many cases, if concrete is to be used, some excavation is required in order to make the floor finish at the level required. In addition, it may be necessary to finish a surface such as a roadway or ditch bottom to an even gradient. In all these cases it is necessary to control the depth of the excavation to ensure that the correct amount of soil is removed.

Sight rails

Sight rails are made either across the line of an excavation, such as a trench, as shown in Figure 4.11, or alongside an area such as a roadway or floor. If the

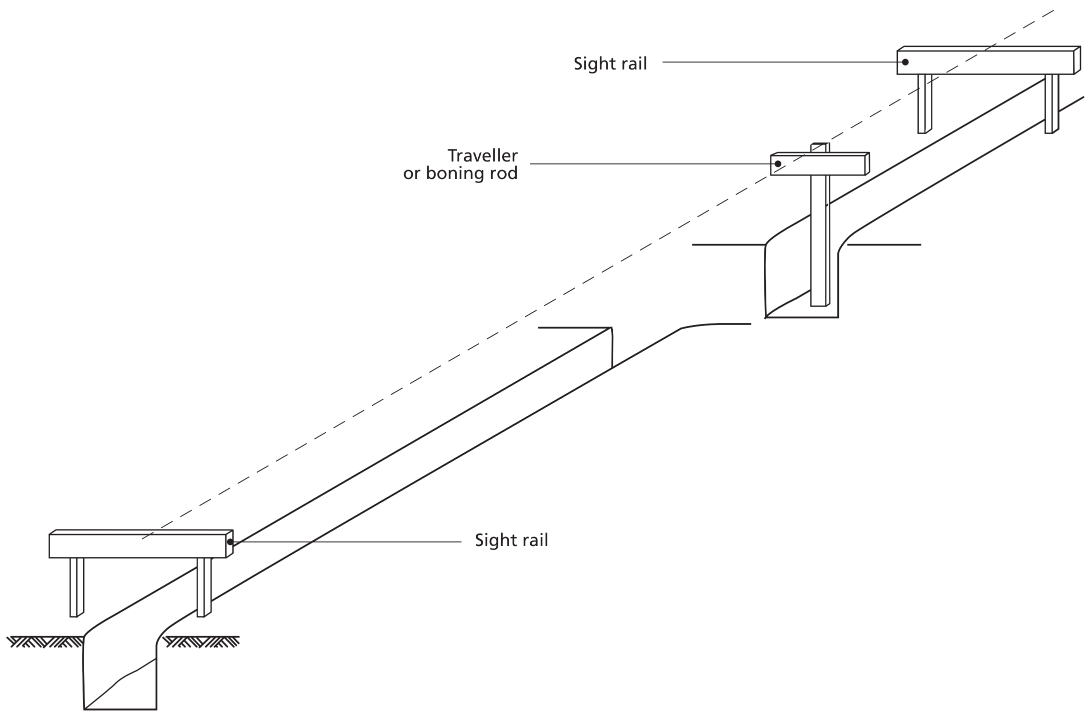


Figure 4.11 **Sight rails and traveller for boning**

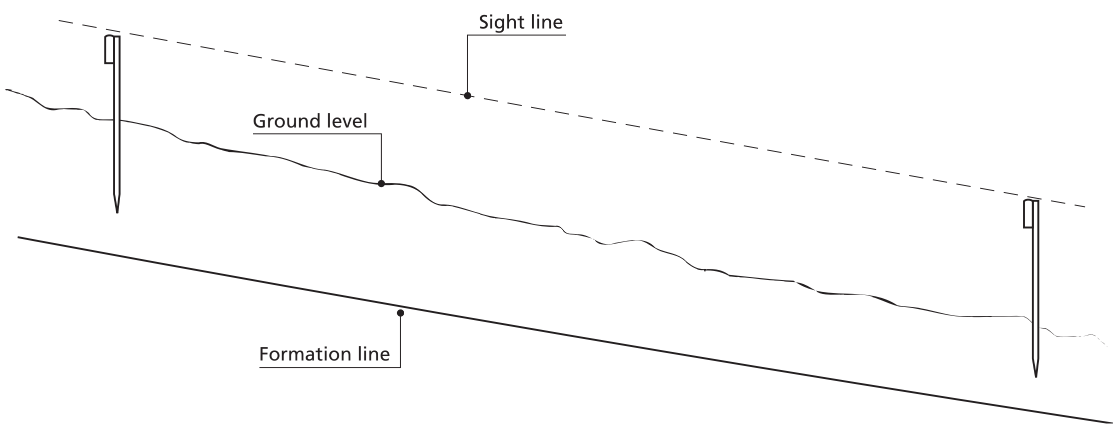


Figure 4.12 **Section between two sight rails on a gradient**

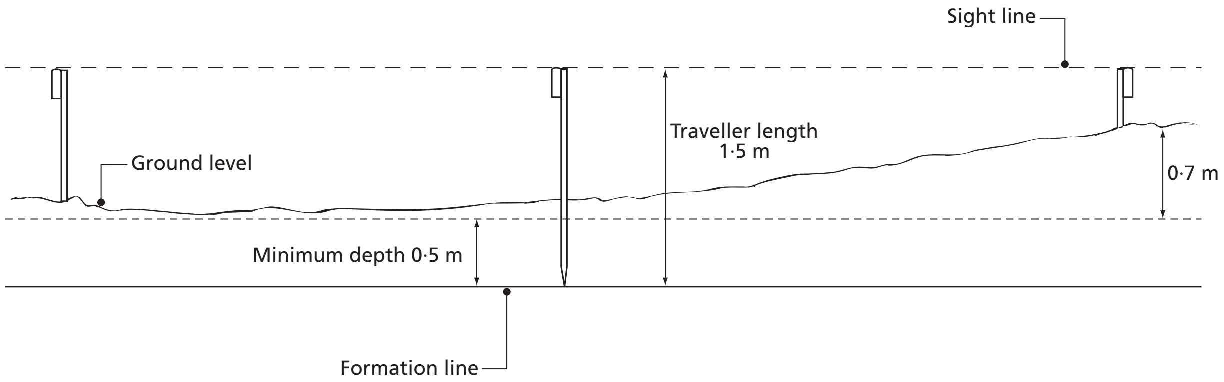


Figure 4.13 **Section showing level excavation**

excavation is to be level, then the tops of the crosspieces must all be at the same height. If there is a gradient to the excavation, however, the tops of the sight rails should be set at heights so that they fall on the same gradient (see Figure 4.12).

On a small building site it may be possible to use a long straight-edge with a spirit level to ensure that the sight rails are level. However, with longer excavations or where a gradient is required, it may be necessary to use a tape and level to achieve the appropriate fall from one sight rail to another.

Traveller

A traveller, also known as a 'boning rod', is T-shaped and normally wooden. The overall length is the same as the distance from the sight rail down to the excavation depth required, as shown in Figure 4.11. It can be an advantage, therefore, to set up the sight rails at a known height above the excavation. For example, a level excavation will normally be specified as having a minimum depth. If a trench is required with a minimum depth of, say, 0.5 m and the ground rises along the length of the trench by 0.7 m, then the first profile must be set high enough for the second to be above the ground, and a traveller of 1.5 m may be used. The first profile will then be 1 m above the ground. See Figure 4.13.

As the excavation progresses, the depth can be checked by looking across from the top of one profile to another. As long as the traveller crosspiece can be seen, the excavation is not deep enough and should be continued until the crosspiece is just invisible.

Volume of earth to be removed

The labour and expense involved in moving soil can be substantial. Careful planning and volume estimation will minimize the amount that needs to be moved.

When the land is essentially level, the volume to be removed from an excavation can be estimated by multiplying the cross-section area of the excavation by the length.

Often, however, the land has a considerable slope and must be levelled before construction can begin. Sometimes the soil will need to be removed from the site but, in many cases, soil removed from the building site can be used for fill in an adjacent area. It is rather more difficult to estimate how much to 'cut' to ensure that the soil removed just equals the 'fill' required to give a level site. Several approaches are explained in surveying books, but a graphical method using the information from the site contour map should be satisfactory for rural building construction.

A scale drawing of the building foundation is made and the contours superimposed on it (Figure 4.14a). A line is drawn through the centre of the building plan and a section constructed using the values obtained from the intersections of the contour lines and the section line (Figure 4.14b).

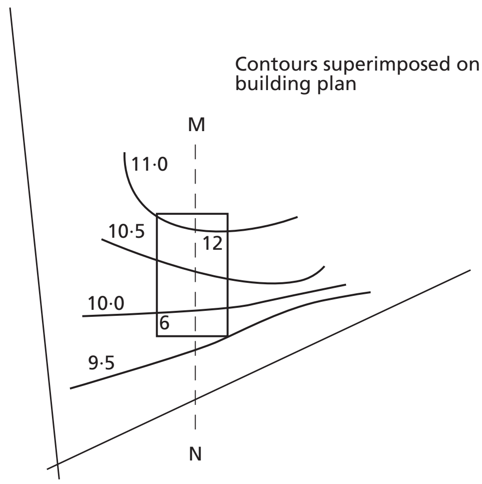


Figure 4.14a **Contours for establishing a cut and fill line**

A horizontal line is then drawn that is estimated to produce equal areas for cut and fill. The elevation of the line indicates an optimum elevation for the building. The approximate volume to be moved is given by the equation:

$V = ½\ hbw$
$= ½ \times 0.6 \times 6 \times 6$
$= 10.8\ m^3$

where
h= height above line
b = base of cut area
w = width of cut area

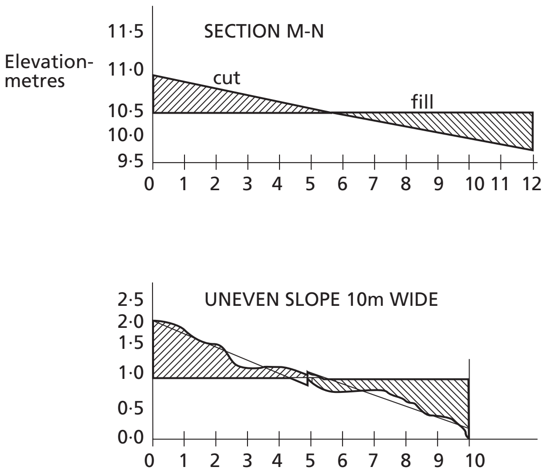


Figure 4.14b–c **Estimating cut and fill**

If the slope is not as uniform as illustrated in Figure 4.14b, the slope line must be averaged as shown in Figure 4.14c. In this example the volume to be moved is estimated to be 45.6 m^3.

$V = ½\ hbw$
$= ½ \times 1.9 \times 4.8 \times 10$
$= 45.6\ m^3$

When excavated, the volume of firm soil will increase by approximately 20 percent. If this soil is used for fill, it must either be allowed to settle for some time or be compacted to reduce it to the original volume before any construction work can begin. In addition, African soils are generally prone to settlement and erosion. Problems may be experienced in wet areas at the edge of the fill if it is not adequately stabilized with vegetation or a retaining wall. Therefore the 'cut and fill' technique should be avoided and, if used, a reinforced concrete footing may be required.

MODERN GEOSPATIAL TECHNOLOGIES

Modern scientific advances in information technology have resulted in the development of the following areas of geospatial science:

1. Remote sensing
2. Global Positioning System (GPS)
3. Geographic Information Systems (GIS)
4. Digital mapping

These technologies are important in the positioning, mapping and design of rural structures and infrastructure.

Remote sensing

Remote sensing involves the detection and measurement of radiation/reflectance of different wavelengths reflected or transmitted from distant bodies. It is the science and art of identifying, observing and measuring objects without coming into direct contact with them.

Global Positioning System (GPS)

The GPS is a system of 24 satellites owned and managed by the United States Air Force. The satellites orbit the Earth continuously and transmit radio signals that are tracked by GPS receivers on the Earth's surface to compute their three-dimensional position in an Earth-fixed coordinate frame/system. With the three-dimensional coordinates computed, the position of the receiver is defined uniquely in the three-dimensional coordinate frame.

The GPS infrastructure is composed of three segments (see Figure 4.15):

1. **Space segment**: This comprises a constellation of 24 satellites that broadcast electromagnetic signals to the GPS receivers on Earth. They also receive commands from the ground control stations.
2. **Control segment**: This monitors the space segment and sends commands to the satellites. It computes the satellite orbit data and uploads them to satellites for transmission to receivers. It also monitors the satellite clocks for synchronization and general satellite health.
3. **User segment**: This comprises satellite receivers sited on the Earth surface, including the air and the sea. The receivers record and interpret the electromagnetic signals broadcast by the satellites and compute the position to varying degrees of accuracy depending on the type of the receiver and the physical conditions.

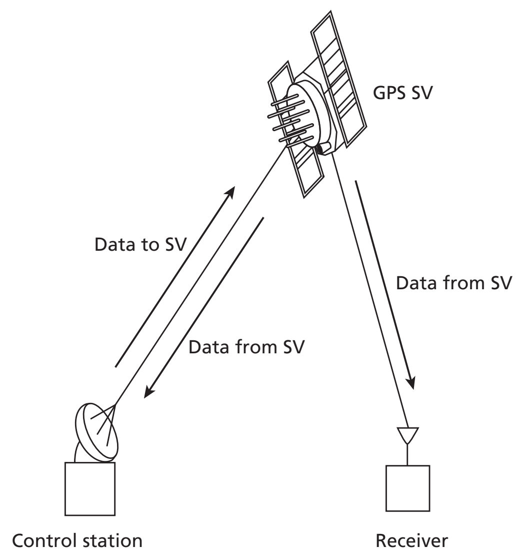


Figure 4.15 **GPS segments**

The computation of three-dimensional coordinates of points in the Earth space allows the mapping of features in a given reference system. The mapping accuracy varies according to the type of the GPS receiver used. Hand held receivers are less accurate as compared to geodetic receivers.

Principle of GPS positioning

The GPS can be explained by a simple resection process where ranges/distances/vectors are measured from a user's GPS receiver to the orbiting satellites 20 200 km above the Earth surface.

Consider a satellite S, at a single epoch (instant of GPS time system) being tracked by a GPS receiver *GR*, on the Earth surface (Figure 4.16a). The Geocentre, as shown, is the centre of the Earth with coordinates X,Y,Z (0,0,0).

The space co-ordinates of the satellite, relative to the earth centre can be determined from the ephemeris (orbit data) broadcast. The vector *r*, the geocentric co-ordinates of the satellite are therefore known. The vector/range *R*, from the receiver to satellite is normally measured by the receiver from the signals from the satellite. This is achieved by multiplying the GPS signal travel time from the satellite to the receiver and the velocity of the GPS signal.

The vector ρ, is the geocentric co-ordinate of the receiver at ground station whose values are unknown. The unknowns in this case are the three Cartesian coordinates (X, Y, Z). The solution of the three co-ordinates requires at least three equations. Given that every measured vector to a satellite produces one equation and there are three unknowns, observations to at least three satellites as shown in Figure 4.16b are required.

Using the three vector/ranges equations, the solution is computed as indicated by the following equation:

$$R_r^s = \sqrt{(X_s - X_r)^2 + (Y_s - Y_r)^2 + (Z_s - Z_r)^2}$$

where R_r^s is the range between the satellite and the receiver, (X_r, Y_r, Z_r) are the coordinates of the receiver and (X_s, Y_s, Z_s) are the coordinates of the satellite.

When the system is using code pseudo-ranges for range measurements, additional unknown, the GPS time exists, increasing the total number of unknowns to four. Thus measurements to at least four satellites are necessary (see Figure 4.16c). With carrier phase measurement, an additional unknown, the ambiguity number, is introduced. Here again, the solution will require at least four satellites. Whichever the case, any GPS measurements therefore requires observations to at least four satellites for observation positions to be determined. In this case the position of the receiver is obtained as X, Y, Z, t, where t is the time.

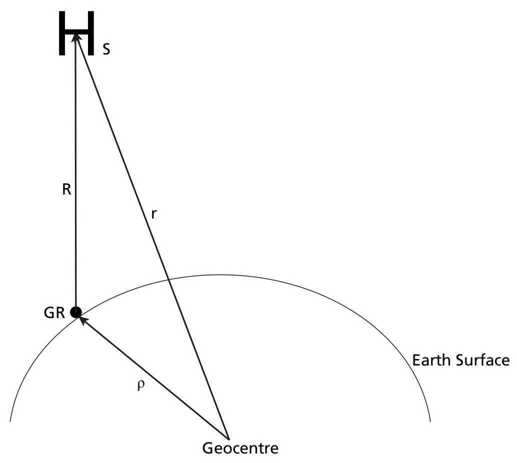


Figure 4.16a **One satellite tracking**

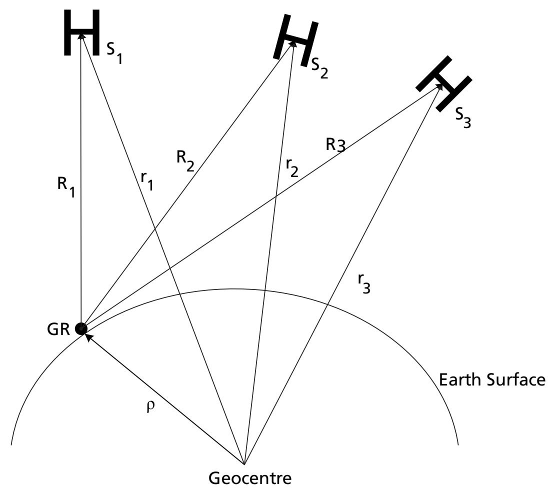


Figure 4.16b **Three satellite tracking**

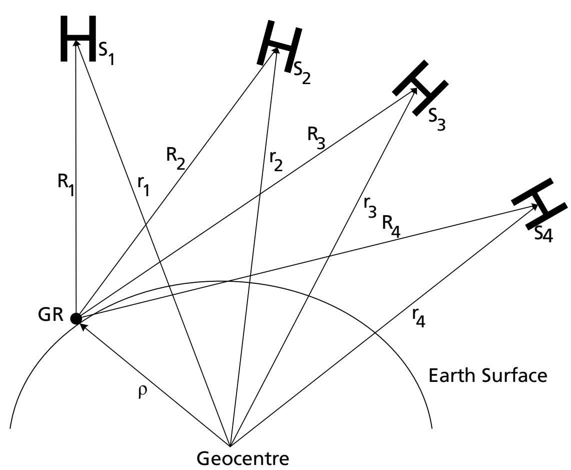


Figure 4.16c **Four satellite tracking**

Figure 4.16 **GPS positioning principles**

Geographic Information Systems (GIS)

This is the merging of cartography and database technology. It refers to a set of systems that captures, stores, analyses, manages and presents data that are linked to location. Technically, a GIS is a system that includes mapping software combined with an application for remote sensing, land surveying, aerial photography, mathematics, photogrammetry, geography and software tools. Apart from supporting map drawing on demand, GIS is able to support decision-making because of its ability to match the spatial characteristics of the data (such as position and the topology of lines and polygons, i.e. how points are connected to each other) with other textual data. This auxiliary data about points, lines and polygons on a map forms part of the attribute data (see Figure 4.17).

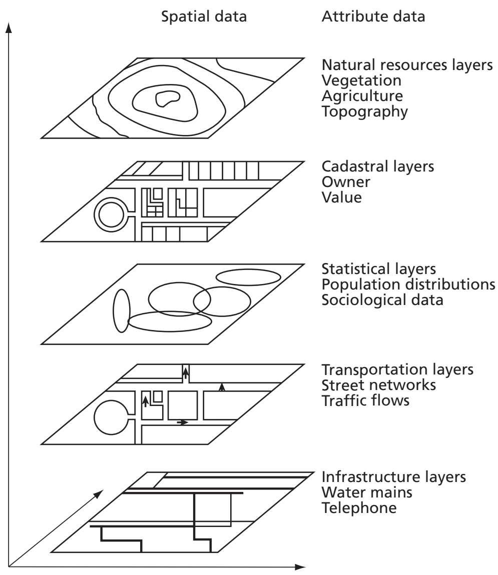


Figure 4.17 **The GIS concept incorporating spatial data layers and attribute data**

In a GIS database, each layer of a map may have a set of global attribute data specifying, for example, the origin of the data set, when it was last updated, the purported accuracy of the data and how it was captured. This is sometimes referred to as 'metadata'. However, attribute data for specific feature points in a map (or map layer) usually take the form of a text table. The definition of the text table normally differs for different features. For example, a tree may have attribute data linked to it concerning species, height, girth, etc., while the attribute data linked to a road segment will have different entries, such as width, date of construction or surface quality. The ability to access this additional data (hidden in attribute data tables) simply by pointing to the map feature on the computer screen makes GIS a powerful query tool.

Digital mapping

Digital mapping is the production of maps in electronic or computer-compatible formats. In digital mapping, the geographic location of terrain points in a given reference system is stored in an electronic medium in the form of letters or numbers (i.e. X, Y, Z or latitude, longitude and heights). Digital maps are compiled from aerial photographs and/or satellite imagery.

Photogrammetry is the art, science and technology of obtaining reliable information about physical objects and the environment through a process of recording, measuring and interpreting photographic images and patterns of recorded radiant energy and other phenomena.

Photographs are still the principal source of information, and included within the domain of photogrammetry are two distinct processes: (1) metric photogrammetry and (2) interpretive photogrammetry. Metric photogrammetry involves making precise measurements from photographs to determine the relative location of points. This enables angles, distances, areas, elevations, sizes and shapes to be determined. The most common application of metric photogrammetry is the preparation of planimetric or topographic maps from aerial photographs.

The principle of metric photogrammetry is to conduct measurements on a pair of photographs (stereo-pair) with an overlap area that appears in both photographs (see Figure 4.18). Through mechanical or computational means, the position and orientation of the two cameras are determined in a model, which includes the photographed terrain in its three-dimensional (scaled) visualization. The horizontal (planimetric) and vertical (height) coordinates can be scaled off this virtual model (viewed stereoscopically through special optics).

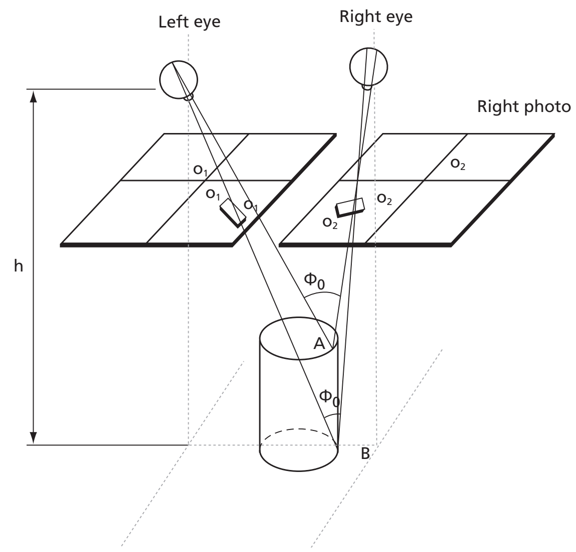


Figure 4.18 **Stereoscopic reconstruction of terrain objects using overlapping aerial photos**

Some of the most significant advances in photogrammetry have been to transform the process of making maps using labour-intensive, analogue photogrammetric techniques into modern, automatic digital photogrammetric procedures, where the photographic image is stored in a computer rather than in the form of a plate or negative. Although airborne cameras are still used to make the initial image, in the near future high resolution satellite images will be used increasingly for small-scale maps. These images have a resolution finer than 1 metre.

REVIEW QUESTIONS

1. Name five or more necessary types of surveying equipment that a rural farm or rural area surveyor must own or possess, preferably stating the importance of each alongside its name.
2. When setting out farm structures, which factors should be considered when deciding which equipment to acquire for use in the particular set-up?
3. In which instances in rural farm surveying does older equipment still prevail over modern surveying equipment?
4. Compare instances in rural surveying where modern surveying equipment would be preferred over older equipment?
5. Modern GPS technology has revolutionized the surveying industry. What positive changes has it brought to the process of managing rural farms?
6. What are the main challenges facing rural surveyors and field technicians with regard to adaptation of modern surveying technology?
7. Briefly describe three modern geospatial techniques.
8. Briefly discuss four uses of modern geospatial techniques.

FURTHER READING

Allan, A.L. 2007. *Principles of geospatial surveying*, London,Whittle Publishing.

Anderson, J.M. & Mikhail, E.M. 1998. *Surveying theory and practice.* Boston, WCB McGraw-Hill.

Chang, Kang-tsung. 2008. *Introduction to geospatial information systems*, 4th edition. Toronto, McGraw Hill Higher Education.

Clancy, J. 1991. *Site surveying and levelling.* 2nd edition. A butterworth – Heinemann title.

Collett, J. & Boyd, J. 1977. Eight simple surveying levels. *Agricultural equipment and tools for farmers designed for local construction*, No. 42. London, Intermediate Technology Publications Ltd.

Cooper, M.A.R. 1987. *Control surveying in civil engineering.* Collins, London.

Irvine, W. & Maclennan, F. 2005. *Surveying for construction*, 5th edition. McGraw Hill Higher Education.

Kaplan, E.D. 1996. *Understanding GPS principles and applications,* Artech house publishers.

Kavanagh, B.F. 2003. *Surveying principles and applications.* New Jersey, Prentice Hall.

Olliver, J.G. & Clendinning, J. 1979. *Principles of surveying.* Volume 1. *Plane Surveying*. 4th edition. New York, Van Nostrand Reinhold Co.

Schoffield, W. 2001. *Engineering surveying*. 5th edition. Oxford, Butterworth.

Scott, G.A. 1973. *Construction surveying.* London, Longman Group Ltd.

Wellenhof-Hofmann, B., Lichtenegger, H. & Collins, J. 2001. *GPS: Theory and Practice,* 5th edition, Springer Wien. New York

Wolf, P.R. & Ghilani, C.D. 2002. *Elementary surveying; an introduction to geomatics*. 10th edition. New Jersey, Prentice Hall.