Agricultural engineering in development: guidelines for mechanization systems and machinery rehabilitation programmes
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The need for mechanization systems and machinery rehabilitation programmes is common to nearly all developing countries, in many of which, as little as 30 per cent of the machinery park is in operating condition. Such countries can ill afford the waste in capital investment and reduced production potential that are implicit in this situation.

The purpose of this publication is to provide guidance which, within the context of a mechanization strategy, will help governments to reach decisions regarding rehabilitation programmes, and to implement them when appropriate. Unfortunately, it is not possible to establish precise criteria that can be universally applied to planning and operating such programmes; there are too many variables from one situation to another. Nevertheless, there are a number of overall considerations and procedures that should be taken into account when analysing the local situation and when planning and launching rehabilitation programmes. This publication describes these considerations and procedures. It also provides information, of a case study nature, on some past and ongoing machinery rehabilitation programmes.

It should be emphasized however, that rehabilitation programmes are relatively new, and still somewhat rare. Thus, the body of actual experience remains slim, despite quite advanced conceptual thinking on the subject. This publication, therefore, is a guide rather than a manual. It aims to highlight issues and provide suggestions for governments to consider; it cannot, unfortunately, provide recipes.

The first draft of this publication was prepared by the Overseas Division of AFRC Engineering, Silsoe (UK), and staff of AFRC Engineering subsequently assisted with revisions and editing. A paper based on this draft was discussed in detail during the Ninth Session of the FAO Panel of Experts on Agricultural Mechanization, held in Beijing, Peoples' Republic of China, in September, 1989.

The final version, based on earlier drafts, and on the recommendations emanating from the FAO Panel of Experts, was prepared by Agrisystems (Overseas) Ltd, a consultancy group.

A number of machinery manufacturers have taken an interest in this initiative from the start and have provided information and made useful comments as the work progressed. This support has been invaluable.

The services of all those who contributed to the preparation of this publication are gratefully acknowledged.

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INTRODUCTION AND BACKGROUND

Controversy continues to surround the issue of mechanization, especially with regard to the level of mechanization appropriate to developing countries. However, few would deny that increasing agricultural productivity is the cornerstone of rural development, and that, according to estimates, growing populations in developing countries will require a doubling of food production in the next 20 years. Against this background, it is widely acknowledged that the low level of power available to agriculture is a key factor in retarding growth in agricultural production and productivity.

The best mix of human, animal, and mechanical power is a complex issue, and it varies according to the specific circumstances. However, without a major expansion in availability of mechanical power, and a widespread adoption of advanced mechanization, it will not be possible to bring about the sustainable development of agriculture required by mankind. Land currently under cultivation must be made more productive through intensified cropping, and new land, often in areas considered marginal hitherto, will need to be brought into production using resource conservation techniques.

The strong urbanization trend in developing countries is also part of this scenario. The Report of the World Commission on Environment and Development, often known as the 'Brundtland Report' after the Norwegian Prime Minister who led the Commission, forecast that by the year 2000, more than half of the world population would be living in urban agglomerations, with a commensurate reduction of labour availability on the land. This urbanization trend in developing countries may also lead to situations similar to that now seen in a few industrialized countries, where appropriate mechanization enables farmers to cultivate their land in addition to holding a job in commerce or industry. Such part-time farming, when off-farm employment is available nearby, is becoming increasingly popular and is generally seen as a positive factor in reducing urban drift, and in making rational use of land and labour resources. Part of the earnings from off-farm activities usually go into on-farm investment, particularly for the mechanization which frees the time necessary for additional off-farm activities. China is a prime example of one developing country where diversification out of agriculture and into rural industries has sparked rapid growth in family part-time farming coupled with increased mechanization.

It is evident, therefore, that machinery will play a key role in the endeavour to improve agricultural production and productivity. In fact, it was estimated by FAO in 1986 that 30 per cent of all the investment required in agriculture in the developing countries by the end of the century will be for agricultural machinery, equivalent to an expenditure of US$40,000 million per annum.

Much of the past experience in advanced mechanization in developing countries has been disappointing. This, in part, has been due to the high risks which attend annual food and cash crop farming in the tropics. These risks, coupled with the low market prices that have prevailed for agricultural produce, militate against the successful use of sophisticated and expensive machinery.

Typical patterns of ownership and servicing of agricultural machinery in the developing world are also an important part of the scenario. The following broad categories of machinery users can be identified:

- Estates, plantations, and large agri-businesses that purchase their machinery outright or with credit from commercial banks, and have their own maintenance and repair facilities;

- State farms or parastatal crop production schemes that have their own resources
for equipment purchases but which, in addition, often benefit from international loans and usually have their own maintenance and repair facilities;

- Large private farms that have access to commercial bank credit for purchases and usually have their own maintenance and repair facilities;

- Medium-size farmers/contractors who have access to commercial bank credit and are dependent upon local repair shops;

- Individual contractors, who do not own land, but have access to commercial bank credit and who depend upon local repair shops;

- Government, regional, or co-operative machinery hire schemes, often financed under aid projects, with some maintenance and repair facilities;

- Small, individual farmers, mainly in Asia, who purchase their own equipment, often with credit, and additional to their own use, hire it to neighbours.

These groups are all, in the final analysis, dependent upon the returns and profits from farming enterprises to meet the costs of their machinery operations. Given the prevailing erratic trends in market prices, and the fact that farming enterprises are often in remote areas where service support is weak or non-existent, the deterioration in the machinery park is often evident at an early stage.

The estate and plantation sector, concerned with cash crops such as sugar, oil palm, coffee, and tea, usually have processing factories as an integral part of the enterprise, and therefore, engineering and support services are readily available.

State or parastatal enterprises usually establish their own mechanization support services, and examples of these are the numerous irrigated and rainfed schemes in the Sudan.

Private farmers producing food and cash crops, such as those in Kenya, Tanzania, Zimbabwe, and Zambia rely mainly on the machinery importers for their support services, which sometimes includes credit in conjunction with commercial banks. In Pakistan and India, many medium sized farmers growing staple crops of wheat, rice, cotton, groundnuts, and sugar under irrigation have been classified as "emerging farmers" by credit agencies and given special treatment and encouragement. An excellent example is the work of the Asian Development Bank in Pakistan, which, with support from the World Bank, financed tractors and machinery on a large scale for many years. Given their personal involvement, individual contractors are flexible and self-reliant in their operations, and with support from local repair agencies, they can offer low-cost services over a wide terrain. This is in contrast to governmental and co-operative hire services that are more centralized and offer no incentives to the machinery operator.

In effect, success in mechanization requires the highest level of management and operational efficiency, readily available fuel and lubricants, and efficient, low-cost repair services. In practice, these prerequisites for success have seldom been met, and only the best organized large estates, and the most enterprising individual farmers and contractors succeed. Hence, a large number of tractors and machines purchased with public, commercial, and private funds have suffered premature breakdown and degradation; and this breakdown has often taken place very early in the machinery's anticipated working life. Surveys indicate that, in many developing countries, up to 30 per cent of tractors are lying idle through want of replacement parts and that the reliability index is less than 50 per cent. This means that over half the time a tractor is needed it is unserviceable.

Idle machinery and equipment equates to the loss of a costly resource, and its non-availability for agricultural production has widespread damaging consequences. It affects farmers, employed labour, local entrepreneurs, agricultural support services, and above all the national economy, and thus, governments themselves.
It could be supposed that animal draught can easily substitute for failed and idle tractors, but such substitution is not as straightforward as it might appear. In addition, draught animals have yet to prove a viable alternative to tractor power under all circumstances, nor have they even been fully exploited as a complementary form of power.

When a tractor becomes inoperative and is not repaired or replaced, the area under cultivation attributed to that tractor will decline, at least in the short term. The farmer facing the need to adopt an alternative source of draught power, such as oxen, will be confronted by a number of constraints. For example, trained oxen, implements, and supporting inputs (such as veterinary and extension services, and ox dips) may not be available; and unless the farmer had previous experience of oxen, it is unlikely that he could become a proficient animal handler without extensive training and support services. Furthermore, in some cases, cultural and social values may hamper a switch from tractors to oxen, for this may be seen as a backward step. And finally, it must be remembered that draft animals require fodder; to produce it may mean that a farmer has to reduce the land area he devotes to vital food crops for human consumption.

Some Definitions for the Purpose of this Publication

Before going into the substance of rehabilitation programmes, and the issues that surround them, an explanation is required concerning the meaning of some key words and phrases as they are used in this publication.

Rehabilitation Programmes – This phrase is used to cover a wide range of interventions, in particular:

a) Rehabilitating support services for mechanization in such areas as planning, management of operations, replacement parts, servicing, and training, with the overall aim of obtaining optimum use of machinery, the highest possible level of reliability, and the longest possible economic life.

b) The process of repairing, and renovating defective machinery to return it to operational status.

c) The process of creating local capacity to manufacture and/or recondition components required in b) above.

Further definitions are required for the words 'repair' and 'renovate' as they are used here:

- **Repair** – the correction of a defect, or defects, through the replacement of the defective component(s) or through workshop procedures such as welding, soldering, machining, etc. 'Repair' implies an intervention only on the component(s) that are actually unserviceable.

- **Renovation** – the rebuilding of machinery to return it to guaranteed and near-new condition, using high-quality components fitted by skilled and conscientious workmen. Implicit in the renovation process is that, in addition to replacing unserviceable parts, some parts that are still serviceable will also be replaced.

Rehabilitation programmes may be applied to a wide range of equipment and structures,
including tractors and power units and their related implements, animal-operated equipment, and hand tools. In this publication, however, the accent is on tractors and their associated equipment, since they provide the greatest scope for rehabilitation programmes. The accent will also be on the renovation aspect of rehabilitation in this publication. However, before examining renovation programmes, the question of machinery that has failed prematurely must be examined, for premature failure lies at the core of all considerations concerning rehabilitation and renovation programmes.
THE PROBLEM OF PREMATURE FAILURE

The term 'premature failure' is used here to mean the breakdown and unserviceability of machinery before the end of its anticipated economic lifespan. Proper maintenance and operation, in all respects, are assumed and the conditions in which the machinery is to work are also taken into account. Thus, the anticipated lifespan of a tractor working in the harsh conditions of the tropics, particularly in Africa, might be shorter than that of the same tractor, operated and maintained at the same level, but working in temperate conditions, with well prepared fields and good roads.

Premature failure is a crucial issue when considering renovation programmes, for if the root causes of premature failure cannot be identified and corrected, the renovated machinery will again fail prematurely – in effect a vicious circle.

The Causes of Premature Failure

These can be divided into those of an indirect nature, on the one hand, and of a direct nature, on the other. The indirect causes result mainly from institutional and economic factors, while the direct causes are those linked to physical factors concerning the operation and maintenance of the machinery itself. Clearly, however, there is a strong relationship between them.

The indirect causes of premature failure are as follows:

- The policies and strategies of governments – or perhaps more accurately, lack of them in many cases – towards agricultural mechanization has had a profound effect on the ability of the agricultural sector to adopt and sustain tractor-based technology. Tractors and implements may be provided from government and donor funds, but their operation is often unsustainable because of poor support services.

- Technical training has been neglected in many countries, and almost universally, there have been under-estimations of the time and resources required to balance the skills imparted by training institutions with the needs of modern agricultural equipment.

- In the majority of developing countries, networks of machinery distributors and service centres tend to be few in number and located in urban rather than rural areas. Service centres that do exist often lack capital equipment, skilled and semi-skilled personnel with diagnostic abilities, service vehicles, and reliable communication links to the main distributor. (It has been argued that these services are underdeveloped because there is insufficient advanced mechanization in rural areas of low income countries to warrant, economically speaking, a network of maintenance workshops).

- Agricultural machinery mechanics are often poorly trained and inadequately managed. And in comparison with other trades, mechanics are not well treated; the job is considered to be very lowly and it attracts salaries that seldom match those of other, less skilled trades. It is hardly surprising that the limited number of skilled mechanics in many developing countries often show a preference for employment in the urban, private sector, where wages, status, and the perception of a better quality of life are generally higher than in remote rural areas.

- Low profit margins in agriculture, often resulting from government pricing policies for agricultural commodities, coupled with high fixed costs, caused
mainly by low annual tractor-utilization rates, make it difficult for farmers to pay the costs of services provided by workshops established in remote areas.

- International aid for agricultural development often includes support for mechanization, in part because many donors favour the inclusion of hardware. However, such support is often short-term in outlook, aiming at rapid development with little thought to longer term considerations of sustainability.

- Donors may make their aid conditional to purchases in a specific country, so called "tied aid", or they may stipulate procurement through international competitive bidding. In either case this can lead – and has led in the past – to unsuitable equipment being purchased and disbursed. If the equipment is unsuitable in the first place, its early demise is likely to follow. The tying of aid to products from donor countries has also been cited as a main reason for the multiplicity of makes often found in developing countries, leading to problems of stocking of replacement parts, specialized training of mechanics, and so on.

- Reliance on a source of power coming from outside the country, with items required for routine maintenance and repairs, (and often fuel too) paid for in foreign currency, carries an inherently high risk. If the equipment is imported under a bulk tender, a low initial purchase price is usually negated by such pressure on the profit margin for the importer that he is totally unable to finance after-sales service over a wide geographic area, especially since there is seldom any guarantee that he would be paid for it. Another consideration is that the farm machinery park may be so small that servicing and repair operations are uneconomic unless parallel work is done on vehicles and items of a general engineering nature. This reduces the specialization that is essential for servicing complex machinery such as the modern farm tractor. Yet another problem faced by reputable machinery distributors who try to provide quality service is that they are in unfair competition with repair shops that lack the skills for quality work and charge lower prices.

- In many cases of international procurement, even when the most appropriate, high-quality equipment was supplied, lip service only has been paid to back up and after-sale service. The inclusion of a replacement parts percentage with new equipment has proved notoriously difficult to implement in practice, since funds have seldom been earmarked for emergency supplies in later years.

- The procurement regulations of aid agencies usually stipulate purchase directly from the manufacturer, thus by-passing the manufacturer’s importer and distributor in the recipient country. This may not have negative consequences where a state or parastatal organization assumes the responsibility for technical support services for the machinery, but where such services are expected from the distributor, the situation is quite different. Under conditions of normal commercial purchase, the distributor receives a commission in which there is an element to allow him – or rather to oblige him – to provide warranty services and replacement parts back-up for the equipment. A direct purchase from a manufacturer may create a situation that is ripe for premature failure. It can be averted only by a clear understanding among all concerned, and by special arrangements to compensate the distributor for providing warranty services and replacement parts back-up, and also granting him foreign exchange allocations for the necessary imports.

- All farm tractor and implement manufacturers understand the desirability of after-sale service and back-up support. Unfortunately, however, of the dozen or so major manufacturers selling their products in developing countries, very few show total commitment to the idea. From the other side, government policies do not always recognize the point of view of the manufacturers that back-up services must be profitable, or at least break even.
Government or state-run farms, schemes, or machinery hire services, frequently in remote areas, are often expected to run independently of the commercial importers and distributors of the equipment they use. This effectively restricts and discourages efforts by distributors to establish countrywide service networks, although in some cases they have to service private contractors working in the same area, or even in the same scheme.

The remote locations in which machinery often operates in developing countries is itself a factor in premature failure. Long distances to central servicing facilities increases the difficulty in obtaining replacement parts, and the high costs of transport are passed on to the customer.

State-operated machinery rarely proves efficient and often suffers premature failure. This is because there is little or no incentive for optimum performance, and most operators, paid a salary through the year, are not motivated to use and maintain the equipment with care. In addition, management is often weak.

In the 1960's and early 1970's, foreign currency for the purchase of replacement parts was often available to farmers and importers through the commercial banks, drawing on government sectoral allocations. Today, huge external debt problems in many developing countries have cut off that source. In any case, foreign exchange for new equipment has too often been given priority over that for the importation of replacement parts, allegedly to encourage local manufacture. However, this has often been done with little reference to the capacity of local industry, and it has created such constraints for importers and distributors that sometimes even the most reputable have been forced to curtail their after-sale services.

Rates of import duty levied on replacement parts are often very much higher than on new machinery; 50 per cent on parts as opposed to 10 per cent on new equipment is not uncommon. This encourages the premature abandoning of older machinery, even if it could still be repaired, in favour of the purchase of new.

The organization, management, and distribution of replacement parts is weak in many developing countries. All too often, parts availability has been insufficient to keep up routine maintenance, let alone repairs. It is not unusual in agricultural projects to see new machines that have never worked because they have been robbed of parts to repair others.

Implementing manufacturers' recommendations for maintaining agricultural machinery and equipment is a universal problem, and not one confined to developing countries. However, it is more acute in developing countries for a number of inter-related reasons mentioned in this section.

Farmers commonly consider preventative maintenance only in terms of its immediate cost, rather than of its long term benefit, and they therefore neglect it.

Many governments with foreign exchange difficulties draw up official lists of approved items for import. There have been cases in which lubricants for certain types of machinery were not on the approved list, forcing the use of other lubricants, with resultant premature failure.
Direct Causes of Premature Failure

The direct causes of premature failure are often linked to the indirect ones just cited. The most common direct causes are the following:

- Equipment that has been ill-chosen for the tasks required of it, and for the conditions in which it is to work, will usually fail prematurely. Firstly, incorrect specification of equipment may cause mechanical problems. For example, there are combine harvesters that suffer breakage when harvesting extremely dry maize in Africa, and agricultural trailers that are not heavy-duty enough to withstand the rigours of transporting sugar cane day after day under certain conditions. And incorrect specification of rear wheels and tires can also lead to early failure. A second and quite common result of incorrect specification is equipment that is unable to perform the tasks required of it. In consequence, and since there is almost never any possibility of exchanging it, the equipment is set aside. It has not failed in the mechanical sense, for it is still serviceable – at least until lack of use and exposure to the elements degrade it.

- Linked to the above consideration of faulty specification of equipment is the mis-matching of implements to tractors, causing failures in one or the other, or even in both.

- Operators who have not been properly informed and trained, or who are not machinery-oriented, can commit numerous mistakes that gravely affect the reliability of machinery, and also its lifespan. Incorrect handling and setting of machinery can subject it to stresses for which it was not designed, and even lead to accidents. Then, there is a whole gamut of potential errors and omissions concerned with routine maintenance. These include everything from neglecting filter changes to using incorrect oils and lubricants, or attempting to carry out repairs for which the operator has neither the equipment nor skills.

- Poor land clearing that has left rocks and tree stumps in the ground can seriously damage equipment. And working over hard and rough ground increases the fatigue failure of components.

- The use of spurious replacement parts that do not measure up to the manufacturer's original specification. These may fail and in doing so cause damage to other components, thus aggravating the situation.

Prevention and Reduction of Premature Failure

It will be clear from the causes of premature failure just cited that some of them are more easily tackled than others. Low international prices for agricultural commodities, for example, are beyond the control of any single government, but within the framework set by those international prices, governments can create their own policies to ensure the maximum possible profit to farmers, thus improving the economic environment in which farm machinery operates, in turn making proper maintenance and repair more affordable.

The key to reducing premature failure, however, lies in correcting the first cause mentioned above, that related to the frequent deficiencies in government policies and strategies in respect
of mechanization.1 Sound policy and well-formulated strategies provide an umbrella under which almost all of the above-mentioned causes of premature failure can be eliminated, or at least mitigated. Even those causes which might appear to be external to the situation, such as tied aid that could lead to the provision of unsuitable machinery, can be tackled by a government that has set clear parameters in its mechanization strategy.

The experience with State or parastatal organizations running tractor hire schemes has been so generally negative that few funding agencies would consider supporting such a scheme today. The ideological umbrella that gave rise to such schemes is being blown away in most parts of the world at the time of writing. Agricultural mechanization strategies should reflect this tendency and seek arrangements for ensuring that those using and looking after machinery have a personal commitment to its optimum use and economic lifespan.

A sound mechanization strategy will also take the vital foreign exchange issue into account, identifying not only the foreign exchange requirements for importing new machinery from abroad, but also allocating foreign exchange to cover the necessary support services for the machinery throughout its economic life, especially with regard to replacement parts. There are established criteria for planning of this sort. For example, experience and analysis show that throughout a tractor's economic life, between 120 and 150 per cent of the original purchase price must be spent on repair and maintenance, and that of this figure from 60–80 per cent will be needed for replacement parts, most of which will probably have to be imported from the manufacturer.

However, replacement parts require more than foreign exchange allocations. Their organization and management is a specialized field. In any country, parts are subject to mysterious probabilities in demand which makes their management difficult; and the problems are compounded when, as in the case of a developing country, parts have to be brought in from far away sources. Training of all staff concerned with replacement parts is an essential element in preventing premature failure.2

Routine maintenance, if correctly carried out, will often prevent and sometimes reduce, the effect of catastrophic failure. (For example, the early detection of a faulty oil seal). The elements required for correct maintenance include the following:

- Knowledge of what is required;
- Practice in translating knowledge into procedures and the clearcut division of responsibilities;
- Replacement parts, including filters and other consumables;
- Purchasing power for correct fuel, oils, and parts;
- Tools and accessories.

The absence of any of these elements or portions of them will mean that maintenance is skimmed; and eventually it may not be done at all, because if the means are lacking, those responsible will become discouraged and not bother about it.

1. This publication does not go into depth on the subject of formulation of mechanization strategies. Readers are referred to Agricultural Mechanization in Development: Guidelines for Strategy Formulation FAO Agricultural Services Bulletin No. 45 (FAO 1988).

2. For detailed information concerning replacement parts, the reader is referred to Agricultural Engineering in Development: The Organization and Management of Replacement Parts for Agricultural Machinery, FAO Agricultural Services Bulletins Nos. 72/1 & 72/2 (FAO/GTZ 1988)
A major factor in premature failure is that of human omission and error. Technical training, therefore, assumes a position of prime importance among the measures that need to be taken to prevent or reduce premature failure. Good training is time consuming and expensive; for instance, in the industrialized countries, it takes four years to fully train a tractor mechanic. But training leads to fuller and more productive employment, and to a more equitable distribution of income, particularly to the poorer and less privileged members of society. Even more germane to our argument here, training appropriately directed to agricultural mechanization, and backed by other essential resources such as replacement parts, is the key to ensuring sustainable machinery operation.

Current aid donor policies show increasing concern for training and the needs of low income members of society, while in developing countries there is a growing awareness of the need for selected reform in technical education. However, relatively few developing countries are willing, as yet, to accept that radical change is necessary.

There is an understandable dilemma over the funding of technical training when, as is invariably the case, this has to be paid for from scarce government resources, and bearing in mind also that a government has responsibility for providing technical training in numerous other disciplines that are involved in its overall development strategy. A further commonplace problem is the migration of trained personnel to the private sector or to lucrative assignments overseas, which is seen as a direct drain on the economy in general and on the training budget in particular. (However, it may be argued that repatriated earnings do compensate to some extent).

Technical training, particularly that directed at the operation and maintenance of agricultural equipment, is expensive for a number of reasons. Among them are: the time and resources required to reach an acceptable standard of competence when the seasonal limitations of field activities are taken into account; the training aids that are required for the effective teaching of practical skills; and the amount of technical and educational literature required to keep up to date with engineering and teaching methods.

In promoting the development of human resources in the traditional and transitional sectors of the economy – and agricultural mechanization belongs very much to the latter – the training must be directed not only at the technical content (i.e. the requirements of the equipment in that particular environment) but it must also be adapted to the needs of the people studying to become proficient in their chosen subjects.

It may be argued that in some developing countries there is a surplus of engineers, usually at the graduate level, while at the same time, there is a shortage of technicians and service mechanics. Excessive emphasis on theoretical studies, divorced from practical applications, is a primary cause of this. Others are the low prestige attached to vocational training, a lack of understanding of its methodology, and a shortage of facilities and of staff with experience in the design and application of techniques of practical training.

Training resources in many developing countries could be better utilized, qualitative training objectives better achieved, and the wastefulness of high rates of student drop-out reduced, through a clearer definition of training objectives.

Training syllabuses should address the true needs, and not the needs assumed by political or academic planners, and curricula must be carefully developed to meet them. An implicit objective should be the creation of problem-solving abilities, rather than the accumulation of knowledge or the memorizing of information. In effect, learning by rote has little value in this training context, and the emphasis should instead be on the development of analytical and manual skills through repeated practice in problem solving. The numerous practical skills required by mechanics, involving coordination of hand and eye, can only be achieved at a satisfactory level of competence through sufficient practice spaced over time. However, these practical skills must be integrated with the intellectual skills required to decide on the appropriate courses of action. The training of service personnel must address both aspects. And service engineers need to understand that their training is not concerned with the pursuit of
knowledge for its own sake, but rather a discipline in which diverse knowledge is used to solve problems of the physical world.

Training of agricultural machinery technicians may be absorbed into automotive engineering courses run by some vocational training schools. There are, of course, many similarities in the two fields, but there are also differences, and the particular needs of the two disciplines are seldom given enough attention. For example, it is not uncommon for tractor mechanics to be taught the theory of independent suspension systems, whereas the hydraulic systems so common in agricultural engineering receive little, if any, attention.

Correcting these anomalies in training for agricultural mechanization would be a first step that governments could take without serious cost implications, although they need to be aware that the higher the capital investment in farm machinery, the greater and more sophisticated is the technical training required for its sustainable operation.

If maximum performance and life is to be obtained from machinery, training must begin with operators. They need sound knowledge of optimum methods of operation, adjustment, maintenance, and care. (They should also have, but rarely get, suitable recompense for their labours!) Economic viability of machinery depends greatly on the skill and competence of its operator, but unfortunately, the training that he receives is too often limited to a brief explanation of the various controls from the manufacturer's salesman. The numerous scrap heaps of broken and mis-used equipment, poor crop performance, and soil erosion are related to the inadequacy of this approach.

The existence of numerous government and private sector training courses for equipment operators in industrialized countries should give governments of developing countries some indication of the complexity involved, as well as food for thought when considering the training requirements in their own contexts. Furthermore, many industrialized countries legally require that operators of certain types of machinery, for example field crop sprayers, hold a formal Certificate of Competence, yet another indication of the importance attached to training machinery operators.

In many industrialized countries, training also exists for mechanics and machinery workshop technicians, and standards of competence are set on a national basis. However, training alone will not ensure the availability of competent and conscientious mechanics and workshop technicians. In most countries, there is social pressure to gain educational qualifications as a means of gaining access to properly remunerated employment. But poor salaries for mechanics and engineering technicians have minimized the effects of this when applied to agricultural machinery.

Considering the high capital cost, and economic value to the country, of the agricultural machinery being used and looked after by operators and mechanics, investment in more and better training would be fully warranted. A simple form of training involves watching and copying, and this was the basis for long apprenticeships in many craft industries. It still has a place for training of service personnel, but it needs to be complemented with periods of formal education. Furthermore, methods of teaching practical skills have evolved that are less time-consuming and more easily permit the acquisition of associated knowledge. The more sophisticated the machinery or technology, the more thought based on technical knowledge is required to keep it in working order. A higher standard of general education is therefore needed to facilitate adequate assimilation of the complex processes involved.

Technical training can no longer be considered as a tiresome offshoot of a particular discipline. If farm machinery is to be sustainably used in developing countries, technical training must be addressed as a discipline in its own right, and the starting point for this lies with the government authorities concerned. And the notion that "People who can, do, and those who cannot, teach!" must be eliminated for ever, as must also the idea that the only good jobs in society are those that involve clean hands and only the occasional foray away from the office.

It will be realized from statements above that the problem of reducing and preventing premature
failure has many facets, and resolving it will be more or less complex according to the particular circumstances of a country. However, until such time as a government steels itself to tackle the issues head on, thereby creating the conditions for the sustainable use of farm machinery, any decision to import new machinery or renovate unserviceable machinery already in the country will lead to the same result: more resources poured down the same drain!
THE CONSIDERATIONS SURROUNDING MACHINERY RENOVATION PROGRAMMES

The Objectives of Renovation Programmes

Governments that have decided to support agricultural production by making available additional mechanical power to farmers have to decide how to proceed. They will have several options, but an overriding consideration is almost certain to be how to make optimum use of the limited foreign exchange available.

The first option, appropriate only in a few cases, is local production under license from an international manufacturer; another is import of new machinery from an industrialized country; and finally, there is the option of renovating machinery already in the country.

Renovation programmes, from a government's viewpoint, are a way of making optimum use of a fixed allocation of foreign exchange, taking into account that most tractors are imported into developing countries and that manufacturers require payment in hard currency for replacement parts and for new equipment.

All the major renovation schemes so far undertaken have been funded, at least in part, by donor agencies. They have not, therefore, been justified by any of the interested parties on purely commercial grounds. The donor agencies, the manufacturers, (and their franchised agents) who implement the programmes stress that the aim of a renovation scheme is not just to create cheap 'new' tractors.

The aims and perceived benefits of renovation programmes are:

- Renovating tractors is cheaper than purchasing new;
- Foreign exchange requirements are reduced compared to buying comparable new tractors;
- The process provides training for technicians;
- It revitalizes tractor support infrastructure, especially workshops and part stores;
- It capitalizes the unused stock of immobilized tractors;
- It may promote local reconditioning or production of replacement parts, with associated benefits for the national economy.

Most of these benefits are cited in manufacturer's literature and in donors' justification of programmes. They have thus become the conventional wisdom on the subject. However, although some evaluation of the technical success of a renovation programme is normally conducted, the infrastructural and training benefits too often take a back seat once a programme is under way.

It should be borne in mind that, while aid-funded machinery renovation schemes alleviate the short-term problems of inoperative machinery, the longer-term, and far more important, objective is to create the environment in which mechanization can be sustained within the country's own resources.
Renovation Experiences to Date

To date, the only large-scale machinery renovation programmes that have been undertaken in developing countries have concerned tractors. (See the Case Studies in Chapter III of this publication). There are two main reasons for this: firstly, the four-wheeled tractor is a ubiquitous, costly, and complex piece of agricultural equipment, which because of its numbers and central role in mechanization, offers greater scope for renovation than other types of agricultural machinery; and secondly, manufacturers have recognized that the market for new tractors, which has been depressed in recent years, is unlikely to recover in the short term, and that renovation programmes allow them to make modest profits in these difficult circumstances.

From the technical viewpoint, two basic approaches to renovating machinery have been used:

- **The Repair-as-Necessary Approach.** Under this approach, the degraded machinery is examined and its actual specifications and tolerances are compared with those stated in the manufacturer's technical data for new equipment. Only those parts required to restore the working life of the machinery are replaced. In the case of tractors, each is rebuilt according to its individual needs to restore it to its original specifications.

- **The Kit Approach.** This is based on the replacement of whole sub-assemblies of the machinery, whether or not all the components in the sub-assembly are actually defective.

The kit approach was pioneered for tractors by Massey-Ferguson under the trade name 'ROC' (which stands for Rehabilitation, Overhaul, and Certification). A ROC tractor is rebuilt to conform to the technical specification of a new tractor, including any updates such as a gearbox with ten speeds instead of eight.

The ROC programme consists of an 'A Kit' and a 'B Kit'. The A Kit, which is mandatory, usually comprises a new full engine, clutch, gearbox, and hydraulic system. The B Kit is not mandatory and is made up of those parts that are desirable for the specific conditions, based on an assessment of the models, specifications, and the degree of degeneration.

In addition to the two Kits described above, a large number of other parts may be purchased as required.

**The Attitude and Involvement of Machinery Manufacturers with Respect to Rehabilitation Programmes**

Renovation programmes for tractors have been mainly limited to two manufacturers, Massey-Ferguson and Ford New Holland. Both of these undertook renovation programmes to counteract decreasing sales of new equipment in specific territories and when a donor was willing to finance the foreign exchange component of the scheme.

Had there been no problems of availability of foreign exchange, there would probably have been little demand for renovation programmes. And it is certainly easier for a manufacturer to sell a new unit than to renovate a damaged one. However, in recent years, manufacturers have begun to realize that there are considerable benefits inherent in renovating their products that are already in a country. Business from replacement parts has traditionally been profitable, but in markets where sales of new units are declining, renovation programmes are a way for a manufacturer to maintain a market share.

It must also be remembered that the proliferation of makes in many countries, partly resulting
from tied aid and partly from the availability of subsidised products, has often led to situations in which so little business is being done by a single manufacturer that the viability of maintaining a franchized distributor in a country is put in jeopardy, without going into the issue of whether he can afford proper back-up services such as the stocking of sufficient replacement parts. In these conditions, renovation programmes can maintain a distributors business activity. In addition, when a distributor has become run down, a renovation programme is often seen by the manufacturer as a way of restoring the physical and manpower resources to required standards. For a manufacturer, these factors are the key to maintaining long-term operation presence of their products in a country.

This said, however, it should be made clear that very few manufacturers have so far allocated much in the way of their own resources to exploring what is, in fact, a new form of business. The few that have done so have been rewarded over the past few years with substantial business in the form of parts sales, much of which is aid–donor funded.

The greater proportion of tractor manufacturers, many of which are part of multinational corporations, have done nothing, having preferred to wait and learn from their competitors. Others have paid scant attention to any proposals, while on the other hand and to be fair, some of the smaller, and perhaps less financially secure manufacturers, have committed resources which they could not afford.

Competition between manufacturers, which is normally very much to the forefront when new tractor sales are concerned, hardly arises between manufacturers in respect of renovation. This is because manufacturers can only renovate their own products, since they have neither the technical expertise nor the access to parts to rehabilitate a competitors' products – even assuming they had the will.

There are, however, multi–make parts manufacturers who will step in where a tractor manufacturer declines to become involved. Such schemes have been carried out in the past, and where all other aspects of a project are equal similar benefits accrue. Questions regarding the quality of manufacture of these non–branded components are justified, since investigations suggest that the quality varies enormously. Professional advice regarding the possible use of such non–branded parts is therefore essential.

Certain manufacturers have advantages over others in renovation in that their products have greater commonality of parts. Unless there is a preponderance of one specific model, this is advantageous in that relatively fewer items are required to renovate a range of models. For example, a manufacturer might have produced four models of tractor ranging in power from 60–90 hp, all of which share common components. In some cases this extends even to engines which would have been originally produced with different rated power outputs. This commonality of parts increases the scope from economies of scale within one make, and also gives the end–user a choice of power outputs for their rebuilt tractors.

Criteria and Supporting Conditions for Rehabilitation Programmes

Decisions by governments and farmers concerning agricultural mechanization and rural development may appear simple, but in reality they are notoriously difficult. The difficulty arises from the complex inter–relationship of social, economic, and technical factors in any given situation, and the political implications they involve. Decisions concerning renovation programmes, and the factors that surround them, are equally difficult. What follows are some main criteria and conditions to be taken into account in reaching decisions.

It has already been stated, but it bears repetition ad nauseam, that no decision to renovate machinery should be taken without a concomitant resolve to address the causes of premature failure, through attention to the factors described earlier in this publication.
Towards this end, renovation programmes should be seen as part of a wider rehabilitation process that will improve infrastructural support services for agricultural mechanization, rather than as an end in themselves. In fact, renovation programmes per se may not always be economically viable, but if one takes into account the long-term benefits that can accrue in terms of training, replacement parts supply and other support services, they often become economically justifiable.

Clearly, decisions on rehabilitation programmes will normally be taken by national governments, but their implementation will need to involve some or all of the following: various government departments and operating units, the original manufacturers of the equipment and components and their local representatives and agents, international aid donors, and other private sector organizations and cooperatives.

Rehabilitation programmes should be closely related to, and be a component of, an agricultural mechanization strategy. In the planning process, governments will need to establish data collection facilities and have access to information on available machinery and equipment worldwide.

It is usually assumed that the renovated machinery and equipment will be returned to its original owner, whether it be an individual farmer, government department, or cooperative. In such cases, a contract should be established between the owner and the renovating organization. Alternatively, the renovating organization may purchase the degraded machinery and re-sell it when renovated, under conditions agreed with the government.

Although major rehabilitation programmes to date have dealt only with tractors, all types of defunct machinery and equipment should be considered eligible, and programmes should be undertaken when it is economically viable to do so. Examples of types of machinery that would warrant rehabilitation programmes under certain conditions are:

**Self–Powered Machinery**

- Tractors, Combines and other Harvesters, Irrigation Pumps, Crop Processing Machinery

**Auxiliary–Powered Machinery**

- Rotary Tillage Equipment, Trailed Harvesters, Balers, Crop Protection Machinery

**Implements**

- All types, whether Mounted, Semi-Mounted, or Trailed

Prior to deciding in favour of a rehabilitation programme, its financial and economic viability must be carefully assessed. Detailed information will be required as a basis for this assessment. (See Chapter V on Research and Planning for Rehabilitation and Renovation Programmes for more details).

Rehabilitation programmes provide the best returns when the macro–economic environment is conducive to continued repair and rehabilitation work beyond the immediate horizon of the programme. The most important macro–economic factors that encourage machinery repair and rehabilitation are fiscal policies related to exchange rates and interest rates.

Real interest rates in developing countries are often negative, i.e. the rate of inflation is greater than the interest rate offered by banks which, in neo–classical economic theory, reflects the opportunity cost of capital. In such cases, farmers may still want to purchase tractors if the investment is likely to give a greater return than investment in, for example, a bank deposit account. For this reason, the purchase may well reflect speculative investment rather than investment in equipment to be used productively. If this is the case, it is unlikely that the machinery would be utilised to its maximum productive potential, and it would thereby represent a financial gain to its owner but, on the contrary, a cost to society as a whole.
If the macro-economic environment is favourable, then the machinery repair industry should have sufficient incentive to facilitate repairs in a routine manner, without need to resort to aid-funded projects for rehabilitation schemes. 'Routine' in this case can be defined as having the resources to repair a machine when it breaks down.

The main elements of a favourable macro-economic environment are:

- An exchange rate which is not far from a free market equilibrium;
- Private sector access to foreign exchange;
- Low real interest rates;
- An expectation of economic stability.

Improvements to the macro-economic environment would be preferable to a machinery rehabilitation programme in the following circumstances:

- If no special need has been identified for the rehabilitation of a given set of machinery;
- If infrastructure and communications in the country or region are sufficiently good to allow businesses to grow where real demand for machinery repairs exists;
- If a special need for a demonstration project has not been identified.
- If there are one or more engineering companies in the country (or willing to move into the country) who have the drive and capability to expand their repair business to meet consumer demand and to undertake machinery renovation work. However, this will also depend upon their being granted access to the necessary resources.
- If the government is willing or able to take the necessary steps involved.

If the above criteria are met, routine repair, and renovation facilities where they are economically justified, can be expected to grow. This situation has the advantage of being less susceptible to 'project cut-off', i.e. the development of facilities with international aid that cannot be sustained once the aid terminates. However, this desirable situation is unlikely to come about in the majority of circumstances, because hitherto, rehabilitation schemes have been on a relatively small scale, and this is likely to continue. It is also likely that future schemes will be perceived by local decision makers as insufficiently important to warrant changes of policy extending beyond the sphere of influence of machinery rehabilitation per se.

As has already been noted, a central factor impinging on agricultural mechanization in developing countries in general, and routine repair or rehabilitation programmes in particular, is fiscal policy and the availability of foreign exchange for the purchase of replacement parts. In certain cases, fiscal policies will hold the key to encouraging successful rehabilitation programmes. The most important are those concerning rates of import duty. Agricultural machinery rehabilitation schemes have not in the past had to address the question of import duty policy in detail. This has been because they have been aid funded, and parts kits have been imported tax free. However, the question of policy towards import duty becomes critical if either the rehabilitation programme is run on a normal commercial basis, and not exempted from duties, or if it is to be sustainable.

In financial terms, whether or not rehabilitation is cheaper than purchasing new will often depend on import duty policy. Agricultural machinery parts often attract import duty at a much higher rate than new tractors, and duty rates are usually different for different types of components. As already mentioned, rates of 50 per cent for replacement parts are not uncommon
and compare with a typical rate of 10 per cent or less for the importation of new tractors and other agricultural machinery.

The rationale behind this is that rates for new machinery are low because its purchase should be encouraged in order to increase production. High duties on replacement parts are justified primarily on revenue earning grounds: it is (mistakenly) assumed that price has little importance in the demand for parts, or put differently, that there is a captive market for parts and people have to purchase at any cost.

This policy often has the effect of preventing the necessary repair or renovation of expensive agricultural machinery, rather than of providing revenue for government. Moreover, it encourages the premature scrapping of agricultural machinery and replacement with new.

From the renovation viewpoint, the best import duty policy would be to have a standard rate for all new machines and parts, and were this so, parts kits for renovation programmes would pay duty at a rate no higher than that applied to new machinery. This would be a logical policy since the components which go to make up the kits will only be used to recreate essentially 'new' machines, and the alternative to parts kits would be the purchase of whole new machines.

Determining import duty rates is a matter of government policy, but there are at least two sound economic reasons to encourage renovation schemes through appropriate duty rates. The first is that a renovated tractor costs less in terms of foreign exchange; the second is that the purchase of locally-made items, and the use of local labour, assist the domestic economy.

The government should also establish appropriate fiscal measures and incentives, and provide encouragement, for the local reconditioning or manufacture of replacement parts to original specifications. Furthermore, governments should consider the advantages of making renovated machinery eligible for public sector purchase.

Yet another responsibility of government is to ensure that there is suitable follow-up to the renovation process. The issue of preventing or reducing premature failure has already been addressed, but another important consideration is the utilization of the renovation facilities. Can they, perhaps, be turned into a practical training centre for repair and maintenance technicians, and for operators, and can the skilled staff who carried out the renovation programme become the instructors? A priceless national asset could grow out of a renovation programme if the answer to these questions were positive and appropriate action taken.

A final, but important, point is that the renovating organization must be allowed sufficient profit margin on the operation to provide financial incentive and viability.
CASE STUDIES OF TRACTOR RENOVATION PROGRAMMES

Five significant tractor renovation programmes have been completed, or are in progress, at the time of writing — four in southern Africa (Mozambique, Zambia, Malawi, Zimbabwe) and one in Latin America (Nicaragua). Another in Africa (Tanzania) has just been launched. Each of these will be outlined in the following pages, and then some overall points and conclusions will be drawn from those experiences.

Mozambique

Mozambique is a one party state, and since independence from Portugal in 1975 has been governed by FRELIMO — the Frente de Libertacao de Mocambique.

The newly-independent country adopted socialist models for its development policies, but the amount of technical, infrastructural and financial help required later led the Government to a gradual rapprochement with Western governments and institutions, and with multi-national corporations.

Domestic production is estimated to have fallen 37 per cent between 1981 and 1985, while the foreign debt was estimated in 1985 to have reached $3.8 billion. The foreign trade account has been in persistent deficit for many years. Export earnings have fallen rapidly due to the security situation, bad weather, lack of fuel, deteriorating capital supplies and shortages of urgently needed imports.

Agriculture is the most important sector of the economy because it employs nearly 85 per cent of the labour force, and it accounts for around 50 per cent of domestic production and the bulk of exports.

The major crops grown are cashew nuts, maize, cassava, copra, sugar, cotton, tea, rice, fruit and vegetables. Production between 1981 and 1983 fell by an estimated 50 per cent, although performance picked up in 1984 when production of the major cash crops increased due to improved weather and increased incentives to farmers.

The poor overall economic performance of the country has increased its dependence on international aid and loans. Invariably, both have been provided with conditions attached, and the Mozambique Government has had to comply with them. Normally, these conditions are in line with IMF and World Bank policy recommendations, and the Government has revised many of its policies to provide the private sector with the means to accelerate and sustain productivity through a more market orientated economy. To this end the Government has changed its policy to the private sector by: shifting land from the state farms to private, commercial and family farmers; eliminating price controls on fruit and vegetables; and establishing higher prices on other agricultural products.

The agencies that have to date financed the import of tractors and parts are ODA, USAID, SIDA and the Government of the Netherlands. One manufacturing company (Massey-Ferguson), in cooperation with its franchised distributor in Mozambique (Entreposto), has, over several years, supplied about 70 per cent of the national tractor fleet. However, it was estimated in 1979 that 50 per cent of all tractors in the country were inoperative through premature failure.

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1. Source: USAID
A renovation scheme was introduced which is currently rebuilding about 700 Massey-Ferguson tractors per year, with funding assistance from ODA (UK). Table 1 indicates the proportion of repairs by category of severity.

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Units</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major overhauls/complete rebuilds</td>
<td>17</td>
<td>24</td>
</tr>
<tr>
<td>Medium scale repairs</td>
<td>25</td>
<td>36</td>
</tr>
<tr>
<td>Small scale repairs</td>
<td>28</td>
<td>40</td>
</tr>
<tr>
<td><strong>Monthly Total</strong></td>
<td><strong>70</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Entreposto, Mozambique

A survey of Ford tractors in Mozambique indicated that a high proportion of them were inoperative, and following a major workshop reorganisation in 1986, the local agent (Technica, Maputo) is currently renovating about 250 tractors per month.

The monthly throughput of renovated Ford tractors was analysed according to the degree of damage and the repairs required, and is given in Table 2.

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Units</th>
<th>Percent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Overhauls/complete rebuilds</td>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td>Medium scale repairs</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>Small scale repairs</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Engine only overhauls</td>
<td>18</td>
<td>48</td>
</tr>
<tr>
<td><strong>Monthly Total</strong></td>
<td><strong>38</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Note: These figures are for Maputo only. It is thought that figures for the main centres of the associate companies are similar.
Zambia

In 1984, Zambia was suffering a severe shortage of foreign exchange. This was due primarily to its deteriorating trade position related, in particular, to the low price of copper—which accounted for over 90 per cent of foreign exchange earnings—and the increasing price of essential imports, such as oil and heavy engineering equipment. This shortage of foreign exchange limited the import of new tractors and of replacement parts for existing tractors. As a consequence, the country's aging tractor fleet was falling into disrepair with serious consequences for commercial agriculture in the country.

Given the extensive land area and relatively small population, tractors are an appropriate source of farm power, and crucial to the operation of the large-scale commercial farms in Zambia which supply most of the food to the urban areas. Over 13,000 tractors were estimated to be operating in the country at that time, although as in many African countries, the exact number was not known.

Table 3 shows the number of tractors imported into the country in the period 1971 to 1976. It was believed that many of these 8 to 13-year-old tractors could be economically rebuilt using imported replacement parts and local expertise. Many of the tractors were on commercial farms, although substantial numbers were also in para-statal organizations and within the government network, notably in the land development units and on research stations.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>1971/75</th>
<th>1977/83</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massey-Ferguson</td>
<td>1,396</td>
<td>1,374</td>
</tr>
<tr>
<td>Honda</td>
<td>1,000</td>
<td>n/a</td>
</tr>
<tr>
<td>Leyland</td>
<td>775</td>
<td>111</td>
</tr>
<tr>
<td>John Deere</td>
<td>754</td>
<td>n/a</td>
</tr>
<tr>
<td>Universal</td>
<td>700</td>
<td>n/a</td>
</tr>
<tr>
<td>International Harvester</td>
<td>600</td>
<td>n/a</td>
</tr>
<tr>
<td>Ford</td>
<td>585</td>
<td>420</td>
</tr>
<tr>
<td>Volvo</td>
<td>111</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5,920</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: 1971/76 Report of Committee Investigating Tractor and Farm Machinery Rationalisation - National Government

It was decided to concentrate initially on the renovation of Massey–Ferguson tractors because there were significantly more of these than any other single make in the country, and because the manufacturer was interested in developing a renovation programme. Furthermore, the franchised agents in the country were active in providing support services and had relatively good facilities and manpower resources.

With the help of Massey–Ferguson, the agents carried out a survey of numbers of units available for renovation. The conclusion was that a viable project existed if foreign exchange could be obtained for the importation of the necessary parts.

On the basis of this conclusion, and the results of a feasibility study carried out by ODA technical and regional advisers, it was decided to establish a project to rebuild 60 tractors in the first year and 60 in the subsequent year. If the project proved successful, wider application to
other makes of tractor would be considered. On the basis of estimated costs supplied by the manufacturer, it was expected that renovating older tractors could provide a replenished tractor fleet at a lower cost than the purchase of new equivalent units.

An independent assessment was made of the manufacturer's agent's suitability to carry out the renovation programme with aid–donor funding. This assessment showed that the company had been incorporated in Britain in 1909 and had a history of commercial activity in Zambia since 1964. Substantial local share holding existed and, in line with many African farm machinery distributors, the company also held franchised agencies with other major European and North American vehicle and earth-moving equipment manufacturers. The company showed every sign of being well–established and reasonably profitable. It was providing good services to agriculture and other industries in the country and had the necessary financial security to handle such a project under programme aid.

Estimated sales potential for new Massey–ferguson tractors in Zambia at the time was in the region of 400 units per year, but the agents were only able to obtain sufficient foreign exchange to cover very limited quantities of replacement parts. This reduction in business had resulted in a surplus of workshop capacity in terms of space and skilled labour. Local labour laws prevented staff redundancy, and indeed the company was anxious to keep its staff both in the hope of an improvement in the foreign exchange situation, and to maintain their long–standing good labour relations.

Fifty–seven people were employed in the workshop. Of these, 70 per cent were mechanics or other workers whose time would be directly chargeable. Utilization efficiency of the workshop staff was in the order of 82 per cent, a low level caused by the downturn in business resulting from the shortage of foreign exchange, rather than from internal inefficiency.

Skills and specialist product knowledge were good because many of the mechanics and technicians had been trained by the manufacturer. Standards of shop floor discipline appeared to be good, with work being undertaken in a practical and orderly manner. Nevertheless, to ensure quality control and a smooth start to the programme, it was decided that the manufacturer would provide the services of a senior product specialist.

The physical facilities were also considered adequate. The main workshop was a clear–span building approximately 50 metres long and 12 metres wide, partially open on one side and equipped with two 3–tonne overhead gantry cranes. Tool stores, specialised work rooms and offices were annexed to the side and ends. The main parts store, offices and show room area were in a separate building, the two separated by a large, enclosed yard. Tooling was adequate, and the two overhead cranes were an important asset because they allowed easy handling of heavy components anywhere in the workshop.

The project was based on a formalised renovation scheme which the manufacturer was introducing at the time. It was intended that the renovated tractors would be considered as a separate product and distinct from the manufacturer's range of new machinery, but with each and every renovated tractor conforming to a minimum standard quality of specifications.

The manufacturer organised the scheme through a separate franchised agreement with its agents. This required them to renovate each tractor according to company instructions, and to provide a guarantee to the end user. In effect, the quality of the renovated tractors had to be guaranteed as equivalent to a new unit. Certain technical improvements were incorporated, although the tractors remained substantially original in specification. Reliability and longevity were to be much the same as a new unit, with all components, systems and sub–assemblies free from defects, and all wearing parts within the manufacturer's stated tolerances.

The replacement of certain major sub–assemblies was mandatory. This was to ensure that severely stressed items would in fact be completely replaced and – quite literally – as new, and to update certain detailed specifications of the tractors. As an aid to quality control, the project was supplied with a dynamometer to measure the power output of renovated tractors at the Power Take–Off Shaft.
The sub-assemblies where sold as a kit and formed the basis of each renovated unit coming out of the workshop. The kit comprised a new short engine, clutch, current specification transmission, and hydraulic system. In addition, other components considered at the time less critical could be replaced or reconditioned locally as required. For the warranty to be valid, all the parts had to come from the tractor manufacturer, or at least from an approved original equipment manufacturer, e.g. electrical components. This subsequently created considerable difficulty for the aid-donor's purchasing agent.

In common with most African countries there was no legislation in Zambia at the time concerning the fitting of safety cabs or Roll-Over Protective Structures (ROPS). In countries where legislation requires the retrospective fitting of ROPS, the incidence of death and serious injury to the driver in the event of an overturn has been markedly reduced. It was therefore decided that all tractors rebuilt by this project would be suitably equipped with a structure that conformed to the 1974 OECD standards.

It was recognized from the start that the standards of shop floor discipline and the skill and integrity of the technicians in charge of the work would be of paramount importance. Slovenly workmanship would result in faults, excessive warranty claims, and a short working life. Some form of quality incentive scheme might have been an appropriate way of maintaining high standards of workmanship, but since these are notoriously difficult to put into practice, none were included in the project.

The time required to complete the individual renovation tasks (Table 4) was estimated by the manufacturer and their agents, in consultation with the aid donor's agricultural engineering adviser. The hourly rates for the staff involved were identical to those used for normal commercial activity.

<table>
<thead>
<tr>
<th>Job Description</th>
<th>% of Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning and dismantling</td>
<td>7</td>
</tr>
<tr>
<td>Engine auxiliaries fitted</td>
<td>6</td>
</tr>
<tr>
<td>Front axle and support frame overhaul</td>
<td>6</td>
</tr>
<tr>
<td>Gearbox</td>
<td>4</td>
</tr>
<tr>
<td>Steering box</td>
<td>6</td>
</tr>
<tr>
<td>Hydraulics</td>
<td>6</td>
</tr>
<tr>
<td>Rear axle, brakes and differential</td>
<td>6</td>
</tr>
<tr>
<td>Rebuild into a skid unit</td>
<td>29</td>
</tr>
<tr>
<td>Drawbar and hydraulic linkage</td>
<td>2</td>
</tr>
<tr>
<td>Electrical wiring</td>
<td>6</td>
</tr>
<tr>
<td>Panel work, instruments and cosmetic parts</td>
<td>3</td>
</tr>
<tr>
<td>Run-up and pre-delivery inspection</td>
<td>3</td>
</tr>
<tr>
<td>Sub total</td>
<td>84</td>
</tr>
</tbody>
</table>

Contingency for unforeseen problems, e.g. removal of broken studs. 16

TOTAL 100

Table 4 Analysis of Typical Labour Inputs per Tractor Renovated

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From the labour input requirements to renovate a tractor (Table 4) it was estimated that the agents had the capacity to renovate about 12 tractors per month. To achieve this, six teams, or 15% of the direct labour force, would be engaged in renovation work at any one time. An initial batch of 60 units could thus, theoretically, be rebuilt in 20 days, or say one month. That was not however to be construed as a target, particularly as the company would initially be gaining experience. It did however suggest that the workshop would not be overstretched by the initial phase of the programme.

<table>
<thead>
<tr>
<th>Renovation Kit comprising:</th>
<th>UK Pounds Sterling (£)</th>
<th>Local Currency (£)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short engine</td>
<td>1,950</td>
<td></td>
</tr>
<tr>
<td>Clutch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission</td>
<td>1,950</td>
<td></td>
</tr>
<tr>
<td>Hydraulics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panelling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROPS (Safety Frame)</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td><strong>2,150</strong></td>
<td></td>
</tr>
<tr>
<td>Additional Parts Required:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinder head reconditioning</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>Fuel system</td>
<td>60</td>
<td>140</td>
</tr>
<tr>
<td>Cooling system</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>Front axle and support frame</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>Starter motor and generator</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Rear axle, brakes and differential</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Lighting kit</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>Wiring harness</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Tyres</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Instruments and switches</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Battery</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Paint and painting material</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous hardware</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Drawbar and hydraulic linkage</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td><strong>2,105</strong></td>
<td><strong>450</strong></td>
</tr>
<tr>
<td>Freight charges @ 15 units per container</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL COST</strong></td>
<td><strong>4,455</strong></td>
<td><strong>450</strong></td>
</tr>
</tbody>
</table>

* Local contribution includes goods and services, costed in local currency and converted to Sterling at 200 = £1.00
The unit parts cost (Table 5) was made up of, firstly the mandatory components and, secondly, the quantities of additional parts estimated as necessary. The local contribution included services and goods with proprietary items being returned to local agents for reconditioning. The fuel and electrical system components were the main items in this category, with a warranty provided by the reconditioning organisation. In order to support local industry, some items such as batteries, paint and tyres were to be purchased locally, although it was recognised at the time that supplies might be unreliable.

As can be seen from Table 5, the components provided in the kit made up about half of the total parts cost of renovating a tractor. It could be argued that this is a high proportion, but one advantage was that no detailed inspection or quality control was required for those factory-produced sub-assemblies. In any case, attempts to cut costs by refitting worn or defective components would have given a product that would have been unreliable and short-lived.

On completion of the work, each and every tractor was examined by an inspector nominated by the manufacturer. This was carried out against a detailed inspection sheet which later formed the basis for the guarantee and future machine records. On satisfactory completion of this inspection, which covered details down to the standard of paint finish, the tractor was issued with a special decal and a new identification number. (The old serial number was also maintained for future parts reference). It was then covered by the scheme warranty.

However, it was also recognized that final proof of the quality of the rebuilt tractors would lie with the farmers. The field performance of as many tractors as possible particularly in the early stages, was carefully monitored with the assistance of the end-user. A tractor weekly record sheet and quarterly summary were prepared for the purpose. Each customer was requested to participate in the monitoring process by keeping a record of performance which would be followed up with visits from the aid-donor advisers to determine the level of satisfaction with the tractor, and to resolve any problems which might arise.

The renovation service was publicized by the agents and was open to private, government and parastatal organisations, although it was expected initially that participation by the private sector would predominate.

Originally it was thought that the tractors would be renovated in one of two ways:

- Agents would purchase tractors as time expired units after inspecting them in the field and negotiating a price with the owner. New imported components would be used to renovate the tractors which would subsequently be offered for resale at a fixed retail price agreed with the aid donor.

- Alternatively, tractor owners who wished to retain the unit after renovation could ask the agents to do the work on a contract basis. In this case, a fixed contract sum would be agreed with the aid donor.

As it turned out, the second option was the only one which proved to be acceptable to the farmers. A full 12-month warranty and free servicing was to be provided on the renovated units which would be identical to that of a new Massey-Ferguson tractor. The price to the farmer was to be considerably less than a new tractor. Aid funds were to be used to finance the foreign exchange costs of the work with the agents providing the full local currency equivalent to the government. A normal profit element was built in to the project costing.
Zimbabwe

In 1982, Zimbabwe was in an economic decline due to increasing prices of essential imports and depressed prices for its exports. In addition, a severe drought was seriously affecting the agricultural sector of the economy. One result was that the shortage of foreign exchange limited the import of new tractors and of replacement parts for the existing tractors. As a consequence, the country's tractor fleet was aging and falling into disrepair, and this put further constraints on commercial agriculture.

The prolonged drought ended in 1984/85, and conditions favourable to an increase in agricultural production returned. However, this potential could not overcome problems in other sectors of the economy, with a result that the agricultural infrastructure of the country was further starved of essential foreign exchange allocations.

With its extensive land area and relatively small population, tractors are an appropriate source of farm power in Zimbabwe, and they are crucial to the commercial farming sector, upon which the country depends largely for its food production and export commodities.

An estimated 20,000 tractors existed in the country in the mid-1980's, of which the predominant make was Massey-Ferguson with about 38 per cent of the total, i.e. 7-8,000 units. Table 6 shows the distribution of the main makes and models.

Despite extensive entrepreneurial activity and expertise within the country, it was estimated that about 4,000 of these tractors were either out of action or in need of major overhaul, and so many could be available for renovation.

<table>
<thead>
<tr>
<th>Make</th>
<th>Number</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massey-Ferguson</td>
<td>7,600</td>
<td>38</td>
</tr>
<tr>
<td>Ford</td>
<td>3,500</td>
<td>17.5</td>
</tr>
<tr>
<td>Fiat</td>
<td>2,500</td>
<td>12.5</td>
</tr>
<tr>
<td>Deutz</td>
<td>2,200</td>
<td>11</td>
</tr>
<tr>
<td>Others (9 Makes)</td>
<td>4,200</td>
<td>21</td>
</tr>
<tr>
<td>TOTAL</td>
<td>20,000</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Agricultural Dealers and Manufacturers Association

The Government of Zimbabwe was anxious to limit the number of tractors imported into the country and had asked the Agricultural Dealers and Manufacturers Association (ADMA) to develop a policy for rationalising imports and parts supply. The Massey-Ferguson distributor, as

1. Other makes were mainly John Deere, International Harvester, Leyland, Landini, Marshall, David Brown, Case, Fendt, Kubota. Import restrictions, currency allocations, and customer preferences have reduced to six the number of makes currently imported into the country. They are: Case/International, Deutz, Fiat, Ford, John Deere, Massey-Ferguson.

2. These figures are impossible to verify.
a member of that organisation, was involved in developing this rationalisation policy and was naturally anxious to maintain its share of the market. Tractors from western industrialized countries have a high capital cost and, although competitive with products from other parts of the world when costed out over a life time, are at a disadvantage when competing for initial purchase against lower quality or lower cost, or subsidised machines.

ADMA was unable to convince the Zimbabwe government that it should limit tractor imports to those makes and models that had proved themselves sufficiently robust to stand up to the harsh conditions in the country. Aid–subsidised tractors of well–known makes were arriving from a number of countries, and at the time of allocating funds for these, some 10–15 percent extra was allowed for the purchase of replacement parts to be shipped with the tractors. Problems began to arise when the parts purchased with the tractors were exhausted and no further funds were made available to replenish the supply. Tractors of other, and less–known makes were donated by governments, without replacement parts, and no funds were made available to purchase them, thus compounding the problems.

The more far–reaching and damaging effects of those years on tractor mechanisation in the country have yet to be felt.

The Massey–Ferguson agent, Farmec, was of the opinion that a renovation programme would offer the farmer a viable alternative, provided the finished product was of good quality and financially attractive. Drawing on the experience of their colleagues in the region, and from their knowledge of conditions in Zimbabwe, they believed that there was scope for a major tractor rebuilding programme. And they had the necessary resources to carry it out.

A study was carried out by ODA advisers, with assistance from Farmec to examine the technical and economic feasibility of rebuilding Massey–Ferguson tractors in Zimbabwe. The proposed scheme differed from previous schemes in that the tractors were to be rebuilt to contemporary rather than original specifications, i.e. they were to be upgraded from the previous to the current series of tractors. This would allow the programme to benefit from:

- On–going technical improvements;
- Economies of scale in component manufacture;
- Continued long term availability of parts for the rebuilt tractors;
- The psychological effect on the operator of receiving a rebuilt tractor which would be indistinguishable from new.

On the basis of cost estimates supplied by Massey–Ferguson, it was expected that tractors could be renovated to provide a replenished fleet at a lower cost than the purchase of new units. It was therefore decided by ODA and the Zimbabwe Government to establish a project under Programme Aid to renovate 140 tractors over a two–year period.

A wider application to other makes of tractors was also considered, and manufacturers were invited to submit proposals where they thought they could offer appropriate services.

The renovation programme was advertised and was open to both private and public sector users. The tractors would be rebuilt on a contract basis at a fixed contract price. An inflation factor was built in to allow the price to be revised as the cost of local labour and raw materials increased. The contract provided a full 12–month warranty and free servicing, identical to that for a new tractor. In addition, the contract set criteria for the condition of the old unit being returned for rebuilding. These covered aspects such as the completeness of the tractor and the condition of certain components. Such criteria were considered necessary to avoid being offered tractor skeletons for renovation.

The tractors would be renovated to a strict standard of quality and specification. All current modifications and improvements would be incorporated, and it was expected that, apart from the
decals, the tractors would look and perform exactly as new units. ROPS were to be fitted to each tractor.

Estimates of the costs of the programme suggested savings to the end user of around 20 per cent on the retail price of a new tractor. Part of this saving would arise from a differential sales tax which classes a rebuilt tractor as a "replacement parts sale". This is subject to a lower rate of tax than that on a new tractor.

A survey of the facilities of the agents confirmed their ability to carry out the work and noted the good resources and high-quality staff available. There were no apparent shortages in tooling, apart from a Power-Take-Off dynamometer, which was included in the first shipment of parts to allow each renovated tractor to be tested under load prior to delivery to the farm.

The renovation work was to be carried out in an area set aside exclusively for the purpose. High-quality, local reconditioning services were available, but such were the economies of scale that local currency prices were frequently higher than the alternative of imported parts. The programme aimed to complete 5-6 tractors per month, with numbers gradually increasing as further experience was acquired.

Under the agreement, the agent had to lodge the local currency equivalent of the hard currency component with the Zimbabwe Government. This, together with the opportunity cost of the buildings set aside for the work and the extra labour employed, represented a considerable investment in the programme. Although some interest charges were included in the financial analysis, delays in the arrival of parts placed an unplanned financial burden on the agent. This delay was caused by the Zimbabwe customs authorities. They could not understand how the project would work, nor how it was costed, and hence delayed clearing the parts into the country.

By late 1987, 26 tractors had been rebuilt to prescribed standards and current production was running at 6 - 8 per month, using two teams of two men each, supported by other specialised workshop staff, clerical staff, and stores personnel. Records showed that the time involved per tractor amounted to 80 team-hours, i.e. 160 man-hours, with a further 55 hours of other staff time, giving a total of 215 man hours. This was somewhat less than the estimate of time for other, but similar, projects in the region and indicated that the operation was efficient.

The quality of the renovated tractors was proving to be very good, and the programme was understandably popular amongst commercial farmers. There were no warranty claims on the first 26 tractors.

The comparative costs of new and renovated tractors in Zimbabwe is shown in Table 7.

The contract stipulated that old components removed from the tractors would remain the property of the agent. Gradually, with selected items (at ratio of about 1 to 5), some use was made of these parts to start a service exchange scheme. This was absorbed into the company's normal commercial activity.

To reduce the risk factor, the company preferred to keep most of the work under its own roof, although where practical, some parts were manufactured locally. Particular examples were exhaust pipes, foot plates and similar hardware, batteries and a proportion of the tyres used for the programme.

Unfortunately, the economies of scale of manufacture meant that, as predicted, many of the components could be imported at substantially lower cost than they could be overhauled or manufactured in the country. In addition, the reliability of supply was better and the risk of receiving unusable products was lower. Nevertheless, national economic benefits did accrue from local manufacture, and the agent was anxious to balance this with the provision of good service to the farmer. At the time of writing, local manufacture accounts for about 7 per cent of the total parts value.

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Support for the programme from farmers has been excellent, and the demand for renovated tractors far exceeds the current capacity of 6 – 8 per month.
Malawi

The rate of economic growth in Malawi has slowed considerably since 1980, and in common with other countries in the region, it is facing economic difficulties that have resulted in a shortage of foreign exchange. Agriculture, which is dominant in the economy and supports over 85 per cent of the population, can be divided into two main sectors:

- Small holder production which concentrates on food crops and accounts for 85 per cent of total agricultural output;
- Estate and commercial production of three main crops; tobacco, sugar and tea. These account for only 15 per cent of agricultural output, but provide nearly 75 per cent of total exports.

These revenue-earning commodities are heavily influenced by both world market prices and high transport costs. The latter are mainly a result of Malawi's land-locked situation.

Tractor use in Malawi is confined almost entirely to the estate and commercial farming sectors, and hence, any shortages in tractor power have a detrimental effect on export earnings. The market for tractors in the country is small and does not generally attract large numbers of subsidised products. Massey-Ferguson and Ford are the dominant makes with typical total sales of 100 new units each per year. Taking into account Malawi's growing foreign exchange problems, both companies have looked into the feasibility of renovating existing tractors, although to date only Massey-Ferguson have actually put this into practice.

By the end of 1987, the Massey-Ferguson franchised distributor, Farm & Engineering Services Ltd. (FES), had renovated a total of about 80 tractors, mostly to MF-prescribed standards. All these had been funded through normal commercial channels. Output averaged about one tractor per week.

FES investigated and put into practice, on a limited scale, the renovating of 'specials' to individual customers' specifications. A typical example was tractors rebuilt solely for sugar cane haulage. These were equipped with strengthened towing hitches and extra driver protection, but the hydraulic system and power-take-off components were removed.

Unfortunately to date it has not proved possible to use aid funds to exploit any training and regional cooperation.

One major fleet user, the Malawi Government, is currently considering using aid funds to renovate its own fleet of Massey-Ferguson tractors. This would be carried out as a normal commercial activity with the total cost borne by an aid donor. A modest programme to renovate 40 tractors per year is planned, and this could be easily absorbed into the current renovation activities.
Nicaragua

To date, Nicaragua provides the only example of a tractor renovation programme in Latin America. It occurred in the period directly following the civil war, which severely damaged much of the agricultural and industrial infrastructure. The retreating forces ransacked numerous tractors, both new and used, removing valuable components from them and leaving them unserviceable. However, their associated implements were hardly touched.

After the war, the Government introduced emergency measures to meet the immediate needs of the people. Its development programme was divided into two parts: an immediate programme for rehabilitation, and a longer-term development programme.

In view of acute and widespread malnutrition, especially among the rural poor, an immediate priority was agricultural production. Tractor mechanisation was seen as a means of addressing the immediate problems, and so, a special department was set up with the task of developing agricultural mechanisation on a national scale. Its professional staff decided that the following services should be provided:

- A contract hire service for the small and medium farmers (up to about 30 hectares) with priority given to helping the poorest.
- A mechanisation extension service. This was to include farm planning and incorporate an advisory function, not only to the poor farmers, but also to the managers of large state-owned enterprises.

The organisation was also responsible for developing the agricultural engineering industry in the country. This included the rationalisation of imports and a limited amount of farm machinery manufacture. An agricultural engineering section was quickly established and began attempting to rehabilitate tractors.

Some 600 tractors were originally involved, and within the first year, 400 of them had been put back into service using parts and resources that existed within the country. Further progress was not possible without international aid and the direct import of parts.

The newer tractors were relatively straightforward to bring back into service, although careful attention to cataloguing serial numbers was necessary to ensure correct parts provisioning. In addition to the missing components, a great deal of hardware and slow moving items, such as brackets and mud-guards which had either been lost or damaged during the looting, were also required. These were difficult to identify.

Two different makes of tractor were involved, with two or three models of each make. For this reason, a relatively small number of a large variety of different parts were required.

The 170 older tractors remaining after the initial restoration activities all required what amounted to a major overhaul, particularly of the engine, although other systems, such as the steering, brakes, and hydraulics, also required attention. A multiplicity of makes and models was involved among these older tractors, and some of them were 20–25 years old. It was therefore necessary to prepare a comprehensive list of requirements for each tractor, and to include quite large quantities of general workshop consumables such as gasket material and fasteners. General hand tools and special service equipment were also required. Lubricating oils were scarce, and until normal commercial lines of supply could be established, barrels of universal tractor oil and quantities of gear lubricants, hydraulic fluids and greases were included with the parts consignment. The quantities supplied reflected not only the immediate requirements but also included the lubricants and parts required for servicing over the medium term. The supply of parts, which was put out to tender, had a total cost, in 1980, of about £200 000 or an average of about £1 000 per tractor.

No economic analysis was carried out because the project was funded from the ODA Disaster
Relief Fund. However, from the observations of the technical adviser, there can be no doubt that renovation was by far the preferred option for alleviating the tractor power shortage. The project was seen mainly as a short term solution to an immediate and acute problem, but nevertheless, long-term benefits would accrue from improvement to mechanization support services and from the exposure of Ministry staff to the renovation process.

Moreover, without immediate mechanisation, food production targets for the year could probably not have been achieved, and thus the project could be justified on humanitarian grounds alone. Other forms of draught power, such as oxen or mules, would not have been able to provide a viable alternative within the time available. The renovation targets set were realistic because there was high quality technical expertise to hand. Fuel, competent operators, and other resources for utilising the renovated tractors were available, so there was little risk that they would remain idle.

There were so many tractor makes and models involved in the renovation that no single manufacturer was sufficiently well represented to justify specialised technical assistance. Parts supply had to be from a multi-make manufacturer. A British manufacturer was awarded the contract, and the quality of the replacement parts supplied was closely monitored.
Tanzania

At the time of writing, a renovation programme for Ford tractors in Tanzania had been recently launched, following a study carried out in 1988.

It was difficult to assess the tractor population in Tanzania in 1988. An FAO estimate of 1983 put the total at just over 18,700 units. In the intervening years, and with limited new inputs, the total tractor fleet was likely to be of the order of 15,000 units, but with many less actually operational.

Lonrho, the conglomerate corporation which owns Riddoch Motors, the franchised Ford agent in Tanzania, made an assessment of the number of Ford tractors in the country, based on available data and backed up by a customer survey. They estimated the number at about 2,000. About half of the farmers thought to possess Ford tractors, however, were not known to Lonrho and were not contacted during the survey. Thus, it was possible that the figure of 2,000 represented a 50 per cent underestimate, suggesting a Ford tractor population of about 4,000.

This figure of 4,000 Ford tractors seemed to be confirmed by work done by the Tanzanian Motor Services Corporation (TMSC) to verify another manufacturer's estimate, made in 1985, which put the total tractor population at 16,000. There appeared to have been little change between 1985 and 1988, and since Ford tractors occupy about 25 per cent of the market, the figure of 4,000 appeared more or less correct. Massey-Ferguson, with a market penetration estimated at 38 per cent, would have had of about 6,000 tractors in the country.

The Government of Tanzania, in conjunction with its agent GOPA Consult Plc, had been negotiating with the EEC to obtain its financial support for a renovation programme. GOPA Consult believed that funds to renovate 600 tractors would be made available, but there was no indication at that stage of how this figure had been calculated. It was intended to renovate both Ford and Massey-Ferguson tractors, as detailed in Table 8.

There was no evidence that any other manufacturers were interested in a renovation programme, though the door was left open for them to become involved should they so desire.

Most of the tractors were owned by large estates and by individual farmers-cum-businessmen. The latter usually carried out their own work and in addition worked on contract, including rural transport, for others.

<table>
<thead>
<tr>
<th>Estimated Total Units</th>
<th>Ford</th>
<th>Massey-Ferguson</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>To be renovated</td>
<td>240</td>
<td>360</td>
<td>-</td>
<td>600</td>
</tr>
</tbody>
</table>

Farmers were keenly interested in the likely cost of renovating tractors, particularly in terms of value for money. They appeared willing to accept renovation costs of 80 per cent of new price,

provided that they knew exactly what replacement parts would go into the renovation work.

Their ability to pay for renovation did not seem to be in doubt; most farmers had other interests such as road transport, garages, shops, etc. and their tractors were used partly for these other interests. None of the farmers interviewed expressed concern about expenditure of local funds, but they were acutely aware of the foreign exchange problem and its influence on the availability of replacement parts. Many stated that they would buy more tractors, or replacement parts, or renovation services if they could pay for them in local currency.

Throughout most of the 1980s, there had been an almost complete lack of investment in replacement parts and new units. Hence, both the Ford and Massey-Ferguson fleets were aging and well worn. However, there were no discernible differences in the condition of the tractors from region to region, and no regional variations in the pattern of wear.

In Tanzania, compared to Europe, there was a completely different level of expectation regarding tractor life and serviceability; at 10–years old, a tractor was still relatively new in the eyes of its owner. On the other hand, tractor owners expected to have to carry out major repairs every 1–2 years from new. Engine overhauls predominated, at intervals of every 1 500 – 2 000 working hours. This was due largely to a combination of poor operation, high sulphur content in the fuel, lubricating oils of dubious quality, and lack of regular maintenance. The desirability of preventative maintenance was understood by owners, but the resources to put it into practice were sadly lacking.

There was also a wide gap between the viewpoint of farmer and the engineer on what constituted 'good condition'. Farmers did not appear to hold the concept of 'wear' or 'finite design life'. Tractors that were 15–20 years old were considered to be in perfect working order, despite audible indications to the contrary.

Prior to the study concerning a tractor renovation programme in Tanzania, a similar programme for trucks had been in operation for some time, and most farmers knew about this programme. GOPA Consult was involved with the truck programme, and the differences between tractor and truck renovation were not immediately apparent to them. Truck renovation is more labour intensive and there is more scope for repair to non-wearing components such as the body and chassis.

GOPA Consult expected that the renovation programme could cover tractors that only required a minimum of attention. In fact, however, most of the tractors inspected had done 15 000 – 20 000 hours, some over a 20–year lifespan or more, in conditions as harsh as anywhere in Africa. The 'minimum of attention' in such circumstances was nothing short of a complete rebuild, apart from some non–wearing items. Even major castings and housings needed attention in many cases.

GOPA Consult were initially reluctant to accept the supply of replacement parts in kit form. Presumably, they believed that kits would contain parts that might not be necessary, and not everyone is informed regarding the economics of replacement parts provisioning.

In particular, there is a vital economic fact of importance about replacement components: when they are taken from a manufacturer's production line – in so-called PKD (Partial Knock Down) state – they usually bear a completely different, and lower, price structure to individual parts sold through the normal replacement parts distribution network.

Ultimately, it was decided to import the replacement parts in kit form, but the kits could be broken down into sub-assemblies so that the tractor owner would have the option of selecting the items required. At the same time GOPA Consult would be satisfied that only essential work was carried out, thereby maximizing the number of tractors put through the renovation process.

The EEC agreed to finance a test batch of 20 Ford tractor renovations, and the work began in the last months of 1989. The total value of the replacement parts financed by the EEC for the first 20 tractors was just under £115 000, CIF Dar es Salam, or about £5 350 per tractor. The EEC
assistance also provided two kits of special tools and the services of an expatriate technician to oversee the work and ensure training for local staff.

At the time of writing, batches of three tractors at once are being brought in for renovation, and they are being worked on by three technicians. The tractors remain the property of the original owners, who are expected to make a down payment when the tractor is brought in. The work and parts required are then agreed, the cost calculated, and a contract drawn up. Assemblies that are completely replaced, for example the engine, are covered by a 1-year warranty, whereas individual parts that are replaced are covered for 6 months.
SOME CONCLUSIONS FROM THE IN–COUNTRY EXPERIENCES DESCRIBED

The four completed or well-advanced schemes in Africa had the following characteristics:

- Each had an established large-scale mechanized farming sector and consequently a large tractor park.
- Each market was dominated by one or two makes of tractor.
- Many tractors had become immobilised due to a lack of foreign exchange for the import of replacement parts and to a reduction in the purchasing power of agricultural producers.
- There was no reason to expect a radical reversal in the falling trend in new tractor sales.

As is indicated in Table 9, most of the tractors (40%) were inoperative because of relatively small faults. Only a quarter required major overhauls.

<table>
<thead>
<tr>
<th>Table 9 Type of Repairs Required</th>
<th>(Africa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Repairs</td>
<td>40%</td>
</tr>
<tr>
<td>Medium Repairs</td>
<td>35%</td>
</tr>
<tr>
<td>Large Repairs/Overhauls</td>
<td>25%</td>
</tr>
</tbody>
</table>

With regard to costs and benefits, a primary justification for tractor renovation schemes is that it is cheaper to renovate a tractor than to purchase one new. Certainly, this appears to be true for medium and large tractors of Western European manufacture, using the kit approach.

The question of kits versus repair–as–necessary using individual parts was touched on in the Tanzanian Case Study. It requires a brief further examination. According to the information prepared for the Tanzanian renovation programme, based on experience elsewhere, renovation of seriously degraded tractors is only economical if the replacement parts are provided in kit form. More specifically, if it is assumed that the fitted cost of a basic kit amounts to about 80 per cent of the cost of a new tractor, using individual parts and fitting them to the same level of replacement as that of the kit, would cost more than a new tractor.

Clearly, it is the degree of degradation, and the quantity of replacement parts required, that will determine the benefit or otherwise of procuring parts in kit form, not forgetting either that the kit approach provides guarantees in respect of quality of the renovated unit that can never be equalled in a unit that has been repaired–as–necessary.

Cost comparisons for renovating tractors in Southern Africa have been made by the manufacturing companies themselves and by various donor agencies. Table 10, below, seems to show that a tractor can be renovated for between 70 per cent and 80 per cent of the cost of purchasing a new machine.
Table 10

<table>
<thead>
<tr>
<th>Country</th>
<th>New Tractor</th>
<th>Renovated Tractor</th>
<th>Renovated as % of New Tractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zambia</td>
<td>37 826</td>
<td>28 028</td>
<td>74</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>36 655</td>
<td>26 087</td>
<td>71</td>
</tr>
<tr>
<td>Malawi</td>
<td>28 001</td>
<td>19 602</td>
<td>70</td>
</tr>
<tr>
<td>Mozambique</td>
<td>28 234</td>
<td>23 513</td>
<td>83</td>
</tr>
</tbody>
</table>

Notes:
1. Costs include all offshore charges, insurance and handling, interest on capital, assembly costs, warranty shortfall and dealers profit, but not import duties and taxes.
2. Due to rapid devaluation occurring in some of the above countries, the rehabilitated tractor costs are not necessarily the actual prices that were being charged to farmers at the time. They have been adjusted, where appropriate, to the price that would have to be charged if the tractor renovation kits were imported at the same exchange rate as the tractors.

Table 11 provides a breakdown of sample costs of a new versus a renovated tractor in a country of Southern Africa. It is expressed in a local currency and refers to late 1987.

The point must be made, however, that these apparently straightforward tables of comparative costs mask several complicating factors, notably in respect of the price of a new tractor. The price to the consumer of the same tractor varies by over 35 per cent from US$ 28 000 in Malawi to US$ 37 800 in Zambia. In part, these prices reflect differences in the costs associated with each market (shipping costs, sales, marketing and warranty costs). However, it is interesting to strip out these costs and compare the FOB costs for tractors destined for these markets. The figures in Table 12 relate to one make of tractor, and show a 28 per cent variation in price.

It becomes clear, therefore, that the calculated cost saving on a renovated tractor is dependent on the manufacturer's pricing policy for new equipment, and also for parts kits, for that particular country. If a manufacturer's price for a given parts kit is the same, irrespective of the country in which it is to be used, the FOB prices for a new tractor largely determines the cost saving. For example, if the FOB price for Mozambique were the same as that of Zambia, a renovated tractor would cost 70 per cent of the cost of a new one, rather than the 81 per cent actually calculated. Conversely, if the FOB price for Zambia was set at the Mozambique level, a renovated tractor would work out at 87 per cent of the cost of a new one, rather than the 74 per cent actually calculated.

The conclusion must be that, given the wide price range of new tractors of the same make and model in different markets, a manufacturer's pricing policy for a country is of extreme importance.

1. Further cost analysis carried out in 1990 in Zimbabwe seems to show that this figure for renovated price as percentage of new tractor was optimistic. 77 per cent would be more accurate. (See Table 7)
Table 11 Sample Cost Analysis and Comparison of New and Renovated 84hp Tractors in a Southern African Country.

<table>
<thead>
<tr>
<th>Description</th>
<th>New</th>
<th>Renovated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic cost FOB</td>
<td>37,612</td>
<td>30,654</td>
</tr>
<tr>
<td>ROPS</td>
<td>663</td>
<td>n/a</td>
</tr>
<tr>
<td>Shipping @ 4 Tractors/or 8 kits per container 2</td>
<td>4,290</td>
<td>1,755</td>
</tr>
<tr>
<td>Sub Total</td>
<td>42,565</td>
<td>32,409</td>
</tr>
<tr>
<td>Insurance, Clearing, Handling and Delivery charges</td>
<td>4,358</td>
<td>1,060</td>
</tr>
<tr>
<td>Sub Total, Capital Outlay</td>
<td>46,923</td>
<td>33,469</td>
</tr>
<tr>
<td>Interest on Capital Outlay</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Sub Total, landed cost</td>
<td>46,923</td>
<td>33,469</td>
</tr>
<tr>
<td>Assembly and PDI</td>
<td>850</td>
<td>n/a</td>
</tr>
<tr>
<td>Labour to strip and rebuilt</td>
<td>n/a</td>
<td>1,625</td>
</tr>
<tr>
<td>Overhaul front and rear axle castings and linkage</td>
<td>n/a</td>
<td>1,800</td>
</tr>
<tr>
<td>Spray painting</td>
<td>n/a</td>
<td>550</td>
</tr>
<tr>
<td>Oil and Lubricants</td>
<td>n/a</td>
<td>420</td>
</tr>
<tr>
<td>Number plates and Sundries</td>
<td>n/a</td>
<td>185</td>
</tr>
<tr>
<td>Sub Total, Cost Price</td>
<td>47,773</td>
<td>38,049</td>
</tr>
<tr>
<td>Warranty Shortfall and Allowance for free service@ 25%</td>
<td>995</td>
<td>617</td>
</tr>
<tr>
<td>Mark up @ 25% (new)10% (renovated)</td>
<td>11,943</td>
<td>7,610</td>
</tr>
<tr>
<td>TOTAL RETAIL PRICE</td>
<td>60,671</td>
<td>46,276</td>
</tr>
</tbody>
</table>

Renovated Tractor Price as % of New = 76%

1. Figures in local currency
2. Shipping cost based on CIF value and converted from US$
3. New tractors are paid for on delivery, hence no interest charge
4. Pre-Delivery Inspection
5. A mark up of 18–20% on renovation kits is usually agreed between the manufacturer and the distributor. In addition, all workshop charges for stripping and rebuilding, overhauling components, painting, etc. carry their own mark up.
importance in determining the cost savings resulting from a rehabilitation programme. Only if the manufacturer's pricing policy for parts kits for a certain country is a reflection of the prices set for new tractors in that same country, will the cost savings brought about by rehabilitation programmes be more or less the same everywhere.

<table>
<thead>
<tr>
<th>Country</th>
<th>Price (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zambia</td>
<td>20 120</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>18 040</td>
</tr>
<tr>
<td>Malawi</td>
<td>17 360</td>
</tr>
<tr>
<td>Mozambique</td>
<td>15 770</td>
</tr>
</tbody>
</table>

Table 12 1987 FOB Price of a New 84hp Tractor

Three reasons are usually quoted for differential pricing by manufacturers:

- Differences in tractor specifications for particular markets;
- Differences in marketing and servicing costs borne by the manufacturer;
- Differences in manufacturer commitment to particular markets, and the price of competitors' tractors.

In effect, tractor manufacturers, like manufacturers of many other goods, often set their prices according to what they think a particular market will stand, or because of a strategy decision they have made for that market. Quite frequently, manufacturers' pricing may appear irrational; for example, countries in which it is difficult to operate and which have high costs may not be those in which tractor prices are the highest.

The final selling price of both new and renovated tractors is also affected by the profit margins of local agents. In several cases, agents have – at least initially – operated on a lower profit margin for renovated tractors than for new ones.

One undisputable benefit of renovating tractors rather than buying new is that it saves on shipping costs. Typically, it is possible to ship four 75hp tractors or twelve complete kits in a single 20-foot container. Of course, the actual amount saved on shipping costs will depend on how comprehensive the tractor kits are – the more comprehensive the less the saving – as well as on the size of the tractors involved. Actual shipping costs per tractor from Europe to Africa are given in Table 13. As can be seen, the shipping costs for the renovation kits are always less than half those for a new tractor.

<table>
<thead>
<tr>
<th>Country</th>
<th>New Tractor</th>
<th>Parts Kit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zambia</td>
<td>1 980</td>
<td>495</td>
</tr>
<tr>
<td>Mozambique</td>
<td>1 044</td>
<td>540</td>
</tr>
<tr>
<td>Malawi</td>
<td>1 980</td>
<td>810</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>2 160</td>
<td>1 080</td>
</tr>
</tbody>
</table>

Table 13 Per-Tractor Shipping Costs 1987 (US$)
Price distortions also occur in centrally planned economies and these can affect the viability of a renovation programme. For example, in Mozambique, due to a fixed-price allocation system of tractors to farmers, a secondhand tractor can be sold on the open market for up to 150 per cent of the price of a new tractor. Such distortions make it very difficult to assess the real cost effectiveness of renovation schemes.

The quality of a renovated tractor also has to be considered when assessing the cost effectiveness of renovation versus buying new. A comparison of new prices is only adequate in cases where the specification, lifespan and operating costs of a renovated tractor are similar to those of a new tractor. This assumption can only be made for ROC-type renovated tractors. Tractors which are brought back into operation by schemes which repair-as-necessary, or which replace some assemblies as a matter of course but still undertake some repair-as-necessary, should not be considered equivalent to 'new' for costing purposes.

Improvements in specifications brought about through renovation should, where possible, be accounted for by adjusting the price of the new or renovated tractor accordingly. For example, if all the tractors under renovation in a scheme are being fitted with ROPS, then the comparative new tractor price should also include a ROPS, even if this is not normally included in the specification for the market in question.

It is much more difficult to account for the different specifications of tractors of different ages. Often ten- or fifteen-year-old models under renovation are no longer being produced by the manufacturer. Sometimes, tractors are renovated up to present day specification, but when this is not done, one cannot compare prices of like with like. In such cases, one should compare the renovated tractors with the closest comparable new tractor of that make and horsepower.

Of more material importance than minor differences in specification are the differences in economic lifespan and in operating costs. These factors are so important that differences in initial capital cost are not necessarily a reliable guide to the cost effectiveness of any particular renovation programme. Renovated tractors with a cost of up to 80 per cent of the price of a new tractor are likely to prove cost effective. Thus, unless the price of new tractors was producing distortions, the programmes described in this publication were, or are, cost effective.

If the multiple factors that influence the cost–benefit ratio of renovation programmes are considered, it could be concluded that such programmes are less likely to be viable in Asia than they are in Africa. There are two main reasons for this conclusion:

- New tractor prices are very low in much of Southern and South Eastern Asia, because the traditional market leaders from Europe want to preserve their dominant position in the face of Japanese inroads;

- The relatively skilled labour force, and low wage rates in most countries of Southern and South Eastern Asia lead to a high salvage value for defunct and unserviceable tractors, and this further reduces the cost benefits of a formal renovation programme for tractors.

However, notwithstanding these general considerations concerning Asia, it should be noted that Ford New Holland supplied 60 tractor renovation kits to Thailand in 1989 and expected to increase this number in 1990.

Training benefits are listed as one of the major advantages of machinery rehabilitation schemes, and it is therefore important to examine what benefits have accrued in this field as a result of the renovation programmes described in the Case Studies.

In Mozambique, there has been an expanded training programme related to the renovation scheme. However, no significant training programmes have been undertaken as part of any of the other schemes. This may be due, in part, to the fact that they were, or are, all relatively
small schemes, but even so, it is a serious weakness. It is true, however, that any renovation programme which has to recruit technicians will provide an element of on-the-job training. But in the case of the smaller schemes undertaken in Southern Africa, this has involved perhaps half a dozen mechanics.

It is therefore concluded that, with the notable exception of Mozambique, the programmes have not undertaken significant training. Nor does there appear to have been any study which has attempted to assess the effectiveness of the training which has been undertaken. Two questions need to be addressed:

- First, is the quality of the training good enough, and are the potential motivational benefits of linking training with a practical work programme being realised?
- Second, are the people who have been, or are being, trained in a position to use their newly-acquired skills?

Any country embarking on rehabilitation and renovation programmes should give serious attention to an integral and carefully planned and executed training component.

As has already been stated in this publication, governments have an important role to play in tractor rehabilitation programmes, even when the foreign exchange component of the cost of the programme is provided by an external donor -- as is usually the case.

There must be a willingness on the part of government to support the programme. And Government departments must be informed so that they do not obstruct the programme, for example, by delaying the import and customs' clearance of replacement parts. Rehabilitation programmes must cater to the possibility of the role of government being passive rather than active, but that passive support, at least, is a prerequisite for embarking on them.
BROKEN DOWN AND CANNIBALIZED TRACTORS
BROKEN DOWN AND CANNIBALIZED TRACTORS
TRACTORS BEING REHABILITATED
TRACTORS BEING REHABILITATED
RESEARCHING, PLANNING, AND OPERATING RENOVATION PROGRAMMES

Farm Surveys

Much specific and localized information will be required when considering renovation programmes. Data needs to be collected at the pre-feasibility stage to assess whether or not a scheme is a viable proposition. This requires a systematic approach, and what follows is a suggested survey methodology and an outline of the information which needs to be gathered.

The survey methodology advocated here is much influenced by what is known as the Farming Systems Perspective (FSP). Taken from Burnage (1989), it adopts the FSP concept using a three-pronged approach, covering: technical factors, agricultural factors, and political and socio-economic factors. 1

FSP differs significantly from a systems model in that it does not require complete numerical data for all included variables. It is a style of thinking which encourages the concept of a farm as a system. It is particularly appropriate to understanding and handling the complexity of agricultural research in developing countries.

The style of thinking of FSP determines that actual or potential rehabilitation schemes cannot be properly assessed unless they are seen in the wider context of the systems within which they function, or are intended to function. A tractor is a part of an On-Farm System which, due to variations in agro-climatic conditions and cropping practices, is highly location-specific. And On-Farm Systems exist in the wider context of the nation's socio-economic sub-systems, which in turn are linked into the world economic and political systems. FSP explicitly examines the interrelationships that exist between systems.

FSP is not a replacement for discipline-centred research, but rather a complementary approach which encourages researchers to appreciate and consider the wider issues which may affect, or be affected by, a given technology. FSP permits identification and definition of the systems that impinge on the research in hand. Once identified, research can be carried out in sufficient detail to allow rational policy decisions to be made – provided, of course, that the political climate is conducive to the change. Research based on this approach is essentially "bottom-up" in nature.

The farmer's decision-making process is directly affected by his perception of the multiple constraints that he faces both on-farm (e.g. agro-climatic conditions) and off-farm (e.g. changes in the prices to producers fixed by the government). Farmers have the best perception of their own environment. They may not be economists or trained agronomists, but are still specialists in their own right. It is therefore necessary to carry out part of the research in the farmer's environment.

Crucial to assessing and establishing a rehabilitation scheme is to identify all the factors that relate to it, and the FSP approach is of value in this respect. For example, the location, type and demand for physical facilities will be affected by a number of socio-economic factors such as the spatial location and population densities of tractor owners.

The inter-relationships between the sub-systems which affect the operation of tractors should

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1. The technical factors will be identified and discussed later. The scope of this publication does not lend itself to detailed treatment of agricultural and political/socio-economic factors, although many of the essentials have been mentioned in earlier sections dealing with the reduction of premature failure and the criteria for rehabilitation programmes.
also be recognised. For example, in tractor management, the necessary break-even annual tractor utilization rates will be a function of the relative prices of the elements and quantities of production inputs and outputs.

Before beginning the field work for a survey, it will usually be possible to find existing and relevant information in available reports and census data. A desk search should therefore be carried out initially to minimize the time spent on primary data collection in the field.

Ideally, the survey should be carried out by persons with a multi-disciplinary perspective of agricultural development, but who also have technical knowledge of agricultural machinery. The task involves making judgments based on interviews with farmers and on a quick appraisal of the condition of their machinery.

Assistance from government departments, such as the local extension service, may be required to locate tractors. The survey should aim to:

- Identify the sources and limitations of secondary (i.e. existing) data;
- draw up a list of the outstanding data which are not available from secondary sources;
- collect the needed primary data from field surveys undertaken to establish farmers needs; and
- determine the main reasons for the demise of the tractors, e.g. premature failure due to poor maintenance or operator abuse, so that remedial action can be taken within the holistic rehabilitation programme once the tractor has been renovated.

It is important also to identify the characteristics of the farming enterprises where renovated machinery is expected to operate and to recognise its owners and their characteristics precisely. Without this information, research will not reflect the true circumstances of the client group, and policies to provide remedial action may be misguided. Answers are needed to questions such as:

- Why do some tractors last much longer than others?
- Why can some farmers gain access to credit to pay for a tractor to be renovated while others cannot?

A specific classification of farming enterprises must be drawn up, based on their characteristics. Ruthenberg (1980) points out that, 'No farm is organised exactly like any other, but farms producing under similar natural, economic and socio-institutional conditions tend to be similarly structured'. Therefore, farms with similar structural characteristics should be grouped into classes using relevant criteria. The classification should reflect the type of farming system, the scale of operation and the efficiency at which resources are used. Farmers should be classified using the following criteria:

- The power source;
- The size of the total farm enterprise (total cultivated area);
- The type of crops grown;
- The degree of commercialisation;
- The way in which resources are organised.

In countries where broad farmer classifications have already been drawn up for agricultural planning purposes, these may be a useful basis, but specific characteristics relevant to
agricultural mechanization will need to be highlighted.

The constraints faced by farmers should be determined to gain an understanding of the particular reasons for the premature degeneration of their tractors and other machinery. The general reasons for premature failure have already been covered in this publication, but it is instructive to see how they affect different types of farmers, as revealed by a recent survey (Burnage 1989) for a rehabilitation programme in Zambia.

For large-scale commercial farmers in Zambia – as would probably be the case in most developing countries – the constraints were found to be:

- The frequent non-availability of replacement parts and the rapid escalation in prices;
- Lack of skilled drivers;
- Lack of skilled mechanics willing to work on the farm;
- Declining gross profit margins due to large increases in input prices (especially non-regulated commodities) in relation to increases in prices paid to farmers for their produce.

The main constraints facing medium-scale commercial farmers were found to be:

- The frequent non-availability of replacement parts and the rapid escalation in prices;
- Lack of service support in rural areas and provincial capitals away from the line of rail (the main concentration of urban settlement);
- Long distances to Lusaka to obtain replacement parts. This problem was often compounded by poor diagnostic skills, poor communications, and frequent parts shortages. If the wrong part was ordered or was not in stock, more than one journey had to be made to obtain the correct part, increasing its real cost;
- High price of tractor dealer support services;
- Low prices for farm produce and high input costs;
- Low annual tractor utilization rates, resulting in high fixed costs and total costs per hectare, often compounded by erratic fuel supplies and the need to drive the tractor long distances to collect it;
- Limited ability to carry out preventive maintenance;
- Low crop yields;
- Inadequate service in respect of input supplies and crop collection.

It can be seen that in this case in Zambia very few of the constraints would be resolved by an agricultural machinery rehabilitation programme, and very few farmers within this group could be clients of such a programme.
Survey of the Technical Aspects

Still in the assessment phase prior to a rehabilitation programme, the tractor population and the available infrastructure must be surveyed. The survey of the tractor population follows a logical sequence of events. Data sources need to be identified so that the quantity of inoperative and performance-impaired tractors, the makes, models and the level of degeneration of each can be established. They can be ranked into three broad categories:

Type 1: completely worn out and in need of a major overhaul. This normally involves the replacement of all major sub-assemblies to restore performance and the working life of the asset. A degree of updating may also be desirable.

Type 2: requires major attention to some sub-assemblies to restore performance and working life.

Type 3: needs only modest attention to restore performance.

The spatial distribution of the tractors that are potential candidates for renovation must be established. If the country has more than one suitable workshop site to carry out renovation work, the best site will, of course, be that which is closest to the greatest number of tractors. Alternatively, in vast countries such as Nigeria or Mozambique, it may be necessary to establish workshops at a number of locations in order to overcome the logistical problems of transport over long distances. Such decentralization would also allow recipient farmers better access to on-going service support after the renovation of their machinery than would otherwise have been the case.

During the field survey, the likely demand for rehabilitated tractors should also be assessed. Criteria likely to affect the demand are:

- The market price of a renovated tractor versus a new, equivalent tractor of the same make and/or other make;
- Availability of a renovated tractor versus new tractors of the same make and/or other makes;
- The effectiveness of the local distributor's marketing policy towards the potential client group;
- The farmer's perception of the distributor's competence to carry out renovation to a high standard;
- The farmer's perception of the likely level of service support after the rebuild;
- The ability of the farmer to provide sufficient funds or gain access to sufficient credit to pay the renovation price.

Experience shows that in all of the African countries where surveys have been carried out, the level of the market price was the most important single criterion.

It would be pointless to consider renovating a fleet of tractors without paying attention to their associated implements. A survey, similar in nature to the tractor survey and made at the same time, can assess the available implements. In the event that many different makes and types of implement are found, a renovation project for all implements becomes virtually impossible to organise and manage. The survey should try, therefore, to establish any commonality which exists between component parts of implements of different manufacture in order to identify those which can be easily renovated.

The survey of the infrastructure for a rehabilitation scheme should assess both private and
public sector institutions. The purpose should be to identify organizations that would be capable of carrying out a renovation programme, and of prime importance, also have the facilities needed for subsequent support of the renovated machinery. It is usually found that the most suitable organization is a manufacturer’s distributor.

Assessments should be made of the facilities under the headings listed below. At the same time, any improvements necessary to bring them up to an acceptable standard should be specified, allocating responsibility for carrying out the improvements, and estimating the costs so that they can be included in the financing package for the project. The areas for assessment are as follows:

**Workshop facilities**
- location
- size and condition of buildings
- special tools
- general tools
- machine tools
- mechanics available – quantity and quality
- supervisory staff
- reception area
- secure outside storage yard

**Warehouse facilities**
- location
- size and condition of buildings
- storage space
- security
- management systems
- microfiche/replacement parts catalogues
- store personnel

**Service support**
- vehicles
- location and standard of rural workshops

An objective should be to ascertain the additional overheads that will be involved for a rehabilitation scheme. From this additional overhead, it will be possible to calculate the minimum number of tractors that have to be rehabilitated for the organization to cover these additional costs, and make a profit.

There are some logistical and practical points that require attention when assessing a suitable workshop for a tractor rehabilitation scheme. Ideally, the workshop should be located so that it is close to the tractors to be renovated, thereby reducing transportation distances and costs, but at the same time, it should, ideally, be close enough to the port of entry for replacement parts to minimize the complication and expense of moving those parts to the workshop. This ideal location will have an electricity supply, and moreover, it will have enough amenities to attract and keep skilled labour in the area.

These requirements are somewhat theoretical because, in practice, suitable workshop facilities usually exist, are owned by the local distributor of the manufacturer’s product, and are located in an urban area. It is also likely that the limited scale of operation of a typical rehabilitation scheme could not justify, economically speaking, the construction of a workshop with the optimum logistical location. And even if a new workshop could be justified on economic grounds, in an ideal rural location, the practical considerations of the proximity of support
facilities, such as engineering workshops, cannot be ignored.

The buildings should be of a solid and secure construction in order to safeguard against theft of parts and equipment. If a kit-type renovation approach is being adopted, enough area should be made available to set up a flow-line assembly system. In addition, this area should be out of direct sunlight in order to ensure a favourable working environment.

A full set of the special service tools recommended by the manufacturer should be available and in a condition which allows their safe and efficient used by mechanics. The same requirements apply to any general hand tools. Machine tools may also be required. The number and type will depend on the renovation approach to be adopted. Required equipment may include a Power Take-Off dynamometer to run-up and test engines, a lathe, and a radial arm drill.

The level of competence of supervisory staff and mechanics should also be assessed, taking into account both general mechanical skills and specialised knowledge of the type and make of machinery to be renovated. This assessment will enable the training requirements of staff to be identified. Training inputs may range from setting up on-the-job training, with mechanics periodically attending a technical college to learn about the theoretical aspects of engineering, to sending supervisory staff on short courses at the manufacturer's premises. In most cases, it will also be necessary to arrange for a product specialist from the manufacturer to spend some time with the mechanics and supervisory staff. Although initially his main function may be to oversee the launch of the renovation, his primary longer-term function will be to impart knowledge about the technical and managerial aspects of the renovation work.

No renovation programme can proceed without a well-organized supply and storage of replacement parts, whether in the form of kits or individual items. The parts warehouse should be located next to the workshop. The building should be in a safe and secure condition, with sufficient space to store parts in an organised way and at the scale of operation that is planned for the scheme. Sufficient storage bins should be available, and a microfiche system, or a range of parts catalogues, will be required for the correct ordering and provisioning of parts.

The level of competence of stores personnel should also be assessed to ensure they have sufficient ability and skills to manage the stores efficiently. Any training needs should be planned on the basis of this assessment.

The service activities in the field, especially for continued on-going repair and maintenance, will call for reliable transport. Suitable vehicles, in good condition, should be provided to move both parts and personnel over rugged terrain. Tractors should not be driven over long distances, and therefore trucks may be required to bring the tractors in to the renovation workshop and to deliver them back to their owners. These trucks must be purposely designed for tractor transport, and the drivers appropriately trained, because tractors are potentially hazardous freight.

After an assessment of the infrastructure and the location and condition of the tractors for renovation, a decision can be taken as to where a project could be set up, and whether a kit approach or a repair-as-necessary approach would be most appropriate. This decision will also be influenced by the price and availability of comparable tractors from competing manufacturers. In fact, the market for renovated tractors and their price tag have to be seen in the context of alternative choices available to the farmer.

Typically, renovation programmes are most successfully carried out using a comprehensive kit approach, even if some parts may be replaced that theoretically still have some remaining service life. With the kit approach, it is easier to ensure 100 per cent availability of replacement components for each and every machine to be renovated. Midway through a rebuild is no time to discover that certain essential parts are out of stock and need to be ordered from the manufacturer — especially when lead times in ordering, and delay in delivery, are increased by the need to apply for foreign currency allocations and other bureaucratic procedures.

In addition, a kit approach requires less investment in sophisticated machining equipment, since
the need for reconditioning of individual components decreases. Furthermore, as many sub-assemblies are replaced as a matter of course, a comprehensive kit approach calls for less diagnostic skills from the mechanics, skills that are often lacking in developing countries.

The planning of programmes following the repair-as-necessary approach will depend largely on the existing production facilities, and quality of work, in the organisations to which reconditioning of components could be sub-contracted. Any proposed investment in new machine tools should be evaluated using a discounted cash-flow analysis, based on an assessment of the type of reconditioning tasks that could be carried out, and the likely number of components that could be handled over the project life.

With both the kit and repair-as-necessary approach, certain further other modifications may also be needed to make the tractor more suitable for operation under local conditions. For example, NIAE (1984) recommended that Roll-Over Protective Structures (ROPS), incorporating a sun canopy, should be included in Massey-Ferguson ROC kits for the Zambian market in order to increase operator safety and also to improve productivity. In other examples, the existing electrical starting system and ancillary components could be replaced with a spring starter system in order to improve the medium-long term starting reliability of the tractor engine.

If the renovation scheme is to be based on a kit approach, it is essential to test the proposed kit for comprehensiveness and compatibility against a typical tractor. This is especially important when the kit includes components to update the tractor specifications, for example a ten-speed transmission instead of the original eight. Without this pre-test, the chances of there being shortages in the kits, and incompatibility of replacement parts, increases considerably. The most suitable way to carry out the test is to strip a typical tractor and rebuild it using the trial kit. This should be carried out under the manufacturer's supervision and before kits are consigned to the project in operational quantities.

In most cases, renovation schemes are run in conjunction with the original manufacturer of the machinery, who supply kits and/or individual parts, and who is also expected to guarantee the final product. It is unreasonable to expect a manufacturer to sanction the use of non-branded parts in such circumstances. In other cases, however — and the Nicaragua experience described earlier is an example — there is such a variety of makes and models of machinery involved, with such small numbers of each, that it is unlikely that all of the individual manufacturers will become directly involved; and even if they did, for the scheme to deal with them separately for procurement of inputs would be difficult and costly.

In such cases, a procurement agency may be contracted for purchasing and supplying inputs. They will normally work through multi-make parts suppliers for most of the components required. In this type of procurement, a number of factors can influence the initial cost advantage of renovation versus new equipment. As Wrighton (1988) argues, cost savings of 10-40 per cent can be achieved by: avoiding over specification, choosing the best source of parts, obtaining the best price, paying attention to contract conditions, and choosing the best transport opportunities. However, when parts are procured from a number of sources, initial costs should not become the ultimate selection criterion. Quality of the components should be taken very much into account. As in most aspects of life, a trade off between quality and price will have to be made. The option which offers the lowest cost over the projected life of the renovated equipment should be chosen.

A range of second-hand components may be used in the renovation of a tractor, although this is not desirable on a large scale. Using parts from other broken-down tractors is merely another act of cannibalization. An exception to this is where parts removed from a tractor which is undergoing a comprehensive kit-approach renovation are used. Some parts, although still serviceable, are mandatorily replaced as part of a kit. Using these parts for keeping other tractors operative is an effective use of existing resources, saving the country foreign exchange.

Before implementing a renovation programme based on a kit approach, a series of phased management procedures must be drawn up to ensure that the work is implemented effectively
and efficiently. A realistic renovation schedule needs to be established, based on the resources available at the outset. The throughput of tractors in a given time period must also be established. The supply of parts can then be phased into the operation in a timely manner, avoiding bottlenecks, while still keeping the costs of holding stocks of components to a reasonable level. Speed of production should not be the ultimate criterion for the renovation programme. As has already been mentioned, the objectives of a renovation programme should include improving the existing infrastructure and levels of competence of technical and managerial personnel, and to improve the longer-term institutional support for the technology. A training function should, therefore, take a high priority in project design.

At the outset of the rehabilitation programme, it should be clear whether the farmer or the renovating concern is to be responsible for transporting the old unit to the workshop. The latter provides more control, but the costs have to be incorporated into the financial analysis.

A tractor renovation programme should be run as a separate function and in isolation from other activities in the workshop. Ideally, a separate building should be allocated to the programme, incorporating the workshop and stores. If this is not possible, it is essential to allocate a section of the existing workshop to the programme, to be supplied by a stores system that caters solely for the renovation work. For if stores facilities are shared with those used by routine workshop operations and parts sales, shortages of essential items for the rebuild programme will occur. Parts that were imported solely for use in renovation will be 'borrowed', with the best intentions of replacing them from the next stock order. However, experience has shown that this rarely happens, resulting in hold ups in the renovation work due to the absence of essential parts at critical times. An interface between the mechanics and the parts 'pickers' is also required.

The renovation of the tractor is broken down into a series of stages, (see below) each comprising a further series of operations. This procedure has proved to be effective, and it is possible to maintain close supervision over quality control. Each mechanic in the team has identified tasks, and the parts supply flow from stores to workshop can be set up to supply all the parts for each operation with minimum delay.

A new serial number should be allocated to the renovated tractor. The reasons for this are twofold. Firstly, the serial number provides identification for possible warranty claims; secondly, the number may be essential for ordering replacement parts in the future, especially when specifications have been updated.

The Operational Stages in Tractor Renovation

It is easier and more efficient to follow a sequence of operations during a renovation programme than to proceed on an ad hoc basis. A sequence along the lines of the following is recommended. It is based on the management procedure adopted by Farmec of Zimbabwe.

Stage 1

Fit engine flywheel and clutch assembly
Fit gearbox to engine

Stage 2

Fit final-drive components and brakes to rear axle housing
Fit internal hydraulic components
Fit engine and gearbox to rear axle housing

Stage 3

Fit top covers
Fit steering box
Stage 4

Fit front axle housing
Fit front axle, steering, and road wheel components
Fit cooling fan
Fit radiator
Fit brake and clutch pedals and operating rods/lines

Stage 5

Fit external hydraulic components and three-point linkage
Fit PTO shaft
Fit drawbar support frame

At this point in the procedure, the assembled unit should be painted.

Stage 6

Fit electric wiring harness, alternator, and starter motor
Fit fuel tank
Fit fuel lines and filters
Fit dashboard assembly and steering wheel
Fit engine throttle and stop controls
Fit air cleaner
Fit ROPS
Fit footsteps/platforms
Fit front grill, fenders, and sheet metal
Fit lights
Fit seat
Fit wheels
Fit exhaust system
Affix emblems/decals
Fit miscellaneous items

At the planning stage, a system of parts management should be adopted under which parts are given a number that is specific only to the renovation programme, and therefore, different from the manufacturer's part numbers. On the cardex or computer system, a record can be made of both numbers, so avoiding confusion if parts are being procured from alternative sources, or if manufacturers change their part numbers.

Parts should be stored in sections which correspond with the stages of the renovation work outlined above. For example, in Stage 1, following the drawing of the engine from the stores, the next items to be delivered by the storeman would be the flywheel and the clutch assembly.

All parts drawn should be entered on the job card and be signed for by the mechanic and the storeman as a way of making both parties accountable for their use. Further parts should not be drawn from the stores until the foreman has checked that the earlier ones have been properly fitted, and he has signed the job card to that effect. Only with the job card signed to certify correct fitting, and on presentation of the card to the storeman, should he release the parts the mechanic needs for the next operation.

When a number of mechanics are working on the same tractor, each mechanic should be issued with paint of a specific colour which he/she should use to mark with a spot all the parts, nuts, and bolts that he/she is responsible for fitting. This makes mechanics more accountable and allows tighter quality control of the work. A bonus scheme should be considered in order to encourage productivity and quality workmanship.
Monitoring and Evaluation

The overall purpose of monitoring and evaluation is to learn from current experience so that the implementation of future rehabilitation schemes can be carried out in a more efficient and effective manner.

To be effective, continuous monitoring and evaluation should be pursued throughout the programme. They are necessary to generate data against which the initial stated objectives and expected results of the project can be measured. (For example, to assess whether the provision of replacement parts was sufficient or whether the tractors lasted as long as anticipated). In many countries, too little is known about what tractors are actually used for, or the costs incurred during operation. To be meaningful, an evaluation must be based on carefully collected data.

Ongoing monitoring will confirm that the project is being implemented as planned, and ensure that any problems that do arise are identified and can be dealt with before they cause too much damage. By chronologically recording events as they happen, it is possible, in a final evaluation of the programme carried out later, to indicate both internal and external factors and events that affected its implementation and overall impact. Once these factors and events have been identified and recorded, anybody implementing a similar project in the future can gain from the experience and avoid repeating mistakes.

During the renovation programme, the findings from the ongoing monitoring and evaluation, from a holistic perspective, should be fed into the institutional hierarchy, identifying any constraints so that the necessary resources can be directed to the project when required.

In practice, there will be two distinct aspects for the monitoring and evaluation of machinery rehabilitation: the first will cover the programme as a series of clearly identifiable activities connected to the rebuilding work, with expected results over a given timespan; the second will take place after the actual renovation work on the machinery to establish, from the end-user's viewpoint, what overall economic and technical benefits were achieved, and how these relate to the national economy.

To facilitate the evaluation from the end-user's viewpoint and from that of the national economy, each unit of renovated machinery should be returned to its owner with a logbook for the recording of information concerning performance, failures, cost of repair and the like. Such information will be crucial to the final evaluation, and it should lead to general conclusions concerning:

- Whether the tractors have performed in a satisfactory and reliable manner over their anticipated lifespan;
- Whether or not the tractors have lasted as long as anticipated at the onset of the programme, and whether they have been used for the purposes intended at the outset of the programme;
- Whether or not the farmer has been satisfied with the product.

Any problems the farmer has experienced with support services for the tractor should be noted, as should any modifications that can be incorporated into future renovations to make tractors more suitable for operation under local conditions. This information can be gathered by a combination of interviews with end users and a review of the tractor logbooks. Where possible, this information should be compared with the results of other surveys carried out of tractors under similar circumstances.
LOCAL MANUFACTURE OR RECONDITIONING OF COMPONENTS

The idea that existing or newly-established local industries could become involved in the manufacturing or reconditioning of components for machinery rehabilitation programmes is particularly attractive. Given the foreign exchange problems of so many developing countries, the need to create productive employment opportunities, and the quantities of machinery that are lying idle for want of replacement parts, the local manufacture or reconditioning of such parts appears, at least at first sight, to provide a golden opportunity for local entrepreneurs and for the national economy. However, first some background considerations.

The economies of all the industrialised countries have developed with an integral domestic farm machinery industry. In many cases, this has released labour from the land and so provided a workforce for urban industries. However, circumstances in much of the developing world are very different, and commonly, the reverse of historical economic development is now desirable, that is to say, rural labour should be retained and any development initiative should aim at increasing labour utilisation. Labour is relatively cheap in developing countries, while capital is scarce.

Modern manufacturing techniques for components which make up sophisticated agricultural machinery are capital-intensive rather than labour-intensive. In addition, such manufacture is almost certain to rely on sophisticated, imported machine tools. These are expensive and require lengthy production runs to be profitable.

In most developing countries, the industrial base is weak, with resulting deficiencies in terms of engineering skills. It is, therefore, unlikely that the more sophisticated items of machinery, such as tractors, would be wholly manufactured within a developing countries' resources. Of course, this is a generalization, and there is certainly a potential for sophisticated manufacturing in a number of countries that are still formally considered as "developing" but which have made astonishing industrial progress in very recent decades. Some countries in Asia and Latin America spring to mind in this context, but it should also be added that in countries where the engineering base has strengthened, the problem of premature failure of farm machinery has usually become less acute. In Africa, there are examples of agricultural machinery manufacture e.g. in Kenya and Zimbabwe, where a modest farm machinery industry has grown up, but the development of more sophisticated engineering production in the foreseeable future remains a matter of conjecture.

As tractor power and sophistication increase, the potential for component manufacture in a developing country decreases. In fact, for technical reasons, it would usually be difficult to use a wide range of locally-produced components in the place of imported ones.

In this connection, it is worth noting that manufacturers of tractors are locked into an eternal struggle to persuade owners of their machines to use only their own, so called 'genuine' or 'original', replacement parts, as opposed to those made by competitors and known variously as 'aftermarket', 'will-fit', 'non-branded', or more informally and critically, 'spurious', 'bogus' or 'pirate' parts. Replacement parts manufactured and marketed as non-branded are usually sold at a considerably lower price than original parts that come through the manufacturer's distribution network. Hence, these non-branded parts are a serious threat to the rather profitable replacement parts operation run by a manufacturer. And this explains much of their typical hostility towards 'aftermarket' parts, and the large sums they spend on advertizing the virtues of their 'genuine' parts.

However, to be fair, there is also the very serious matter of quality at stake, and even allowing for manufacturers' self-interest in being critical of 'aftermarket' replacement parts, there are some compelling arguments to the effect that these parts may lack the quality, and hence the durability, of the manufacturer's own parts.
For example, a spokesman for the Caterpillar Tractor Company, referring to engine cylinder liners and piston rings is on record with the following statement: "At Cat we engineer everything, and we know exactly how hard components have to be in the (cylinder) bore. But our tests show different hardness specifications among will-fit (e.g. spurious) liners and rings. If you have one outfit making the liners, and another making the rings, how much oil control and engine life can you expect?"

Furthermore, the same spokesman said, "Customers sometimes ask me why they should pay a premium for Caterpillar anti-friction bearings. Some of them seem to think that all we are doing is buying the part from someone else, putting it in a Caterpillar box and marking up the price. What these customers don't realize is that most Caterpillar bearings are made with special characteristics. We'll use a standard bearing if it will work. But if the application requires a special bearing – with more precise tolerances, special heat treating, or more strength – we work with the manufacturer to produce that unique part".

The point of including those quotations here is to illustrate an attitude, common among manufacturers, towards the quality of replacement parts not made by themselves or by one of their normal suppliers. It is also interesting to note that manufacturers work closely with their suppliers to obtain the characteristics required of a component. The costs of this research and development have to be recovered, whereas a spurious parts manufacturer does not have to bear such costs.

Hence, unless a tractor maker has a subsidiary manufacturing company in the developing country in question, the highly-engineered components required in a renovation programme will almost certainly have to be imported. Thus, the prospects for local manufacture or reconditioning of highly-engineered components for tractors do not appear good.

We must also bear in mind that the typical tractor manufacturer is unlikely to look with much favour upon a proposal for the local manufacture of components, for several reasons:

- Manufacturers have usually embarked on renovation programmes because the market for new machinery is slack, and they are unlikely to be willing to hand over production responsibility to another company or institution while their own facilities, and those of their regular component suppliers, are not running at full production levels. And, of course, each replacement part not provided by the manufacturer would reduce their gross profits on a renovation project.

- From a technical viewpoint, if manufacturers are expected to provide a warranty for the renovated product, it is a forgone conclusion that only replacement parts provided by them, or approved by them, will be acceptable. In theory, they could approve parts made locally, but the process of consultation and verification for specifications, and the quality control aspects, would probably be cumbersome beyond reason for the small production runs that would normally be involved. And the question remains, what could the incentive be for the manufacturer to become involved with a local supplier?

Not all the components of a tractor are highly-engineered, however. For example, radiators, electrical systems, water pumps, clutch assemblies, brake shoes, and fuel injection equipment are all items that could quite easily be reconditioned by local repair shops. However, the repair shops would need to be specialized, have appropriate inputs of technical data to ensure the required specifications, and pay careful attention to quality control.

In many industrialized countries, there are so-called service exchange schemes, under which items such as electrical components and fuel injection pumps that require overhaul are exchanged for a reconditioned unit. Rehabilitation schemes can be used to promote this concept by establishing the necessary resources of machine tools and trained staff.
In addition, there are replacement parts that are relatively simple to construct or have multi-product application, such as tyres, batteries, and fanbelts. These may be produced and available locally. Unfortunately, however, experience shows, that such local items may be more expensive to the farmer than the imported equivalent, and be of lower quality, but their use in a renovation programme will save foreign exchange, and this is usually an undeniable imperative.

Much of the above presupposes that the original manufacturer of the equipment is involved in the renovation programme, and that for the most part, a kit approach is to be adopted. This was the case in the experiences described earlier, with the exception of Nicaragua. And it is experiences such as that of Nicaragua that open up new areas of consideration in respect of the local manufacture or reconditioning of components. It will be remembered that the multiplicity of makes and models in Nicaragua was such that no one manufacturer was sufficiently well represented to justify specialized technical assistance, and a repair-as-necessary approach was adopted with replacement components being provided by a multi-make parts manufacturer in an industrialized country. The foreign exchange component to acquire these parts was provided by a bilateral donor.

The manufacturing and reconditioning capability vary both between countries and between organisations within a country. And there is a relationship between the availability of machine tools and the level of engineering of components to be reconditioned. However, in some developing countries, and in some cases, it should not be beyond the possibility of local industries to assume, at least in part, the role of multi-make parts manufacturers, if they were provided with appropriate incentives and support by the government. Manufactured or reconditioned components could be used in repair-as-necessary renovation schemes, as well as in more routine preventative maintenance and repair operations.

It may also be possible to recondition some components and sub-assemblies by using a combination of imported parts and local materials and resources. In Zambia, for instance, there is a large engine remanufacturing facility. Provided that parts, such as pistons, rings, and bearings, which cannot be manufactured locally, can be imported, then the constant reconditioning of engines in that plant is almost unlimited.

Future development of parts manufacturing industries will depend heavily upon the domestic market size and the prospects for export. And fundamental also will be the commitment by governments to industrialised expansion in general, and to the allocation of resources of raw materials, skilled labour, energy, and capital in particular.

However, if a government does decide to promote such a programme of multi-make parts manufacture or reconditioning by local industries and workshops, as a means of saving foreign exchange and improving parts availability for the national tractor fleet, the question of quality should remain of paramount importance. A realistic and rigorous analysis should be made of the components that could actually be manufactured or reconditioned locally to the correct specifications with existing facilities, and also with certain inputs of technical training and economically justifiable machine tools. Outside expertise should be called in to assist in this process if necessary. It should be clearly borne in mind that sub-standard replacement parts are a false economy in the long run. In addition, the failure of a sub-standard item, such as a gear pinion, can result in catastrophic failure of the whole gearbox, with very high cost implications for the owner. Therefore, where there is any reasonable doubt as to the quality levels that can be achieved locally for a given component, especially for one which, were it to fail, would have serious collateral consequences of cost or safety, the correct decision is to continue to import the original from the manufacturer.

It will be realized from what has gone before that the question of local manufacture or reconditioning of replacement parts for sophisticated machinery will, in most cases, be surrounded by numerous problematic factors. However, the same is less true for implements, for which modest parts manufacture is feasible in both urban and rural areas of many developing countries. It requires only limited tools and the skilled manpower to use them. In fact, this type of work is quite often suited to the infrastructure of blacksmiths and artisans in rural areas.
Some implement components require the use of sophisticated materials, for example, medium carbon steels for soil engaging parts. These materials can be imported economically provided that the subsequent manufacturing costs are kept low.

Transport equipment to move farm inputs and produce are a basic requirement for agriculture everywhere, and in developing countries in particular, farm tractors and trailers assume an enormously important role in rural transport generally. Hence, scope exists in many countries for the manufacture of trailers, and this is widely exploited already in many developing countries. Unfortunately, insufficient technology is invested in this useful aspect of local manufacture, with the result that trailers are often poorly designed and poorly made. Better designs, and the use of some imported components, e.g. wheels and axles, could offer a more valuable contribution to the economy. The renovation of trailers, whether imported or locally made, could also offer opportunities for local industries.

In general, a lack of formal skills is a major constraint to local manufacture and reconditioning. In addition, in few cases will there be a large enough demand for new implements to warrant setting up a proper manufacturing plant. For this reason, people with the necessary capital and the skills required are not being attracted into the venture.

It is usually more appropriate, therefore, for manufacture and reconditioning to start in an informal way. For instance, a local blacksmith or tractor dealer may allocate just one man to make or renovate one trailer a month.

An effective mechanism is needed to lift this type of ad hoc manufacture and reconditioning onto a sounder engineering and business basis. This could best be achieved by having trained agricultural engineers linked to small businesses; and mobile training workshops, or demonstration participatory research projects, could help to promote the initiative.
ANNEXE 1

FINANCIAL COMPARISON MODELS

Case Studies, with costs, have been presented, and some general conclusions have been drawn from them. This Annexe will provide some financial comparison models of tractor renovation versus purchasing new.

Financial Comparison Model

This model was developed for the financial analysis of aid-funded machinery renovation programmes. However, it is also applicable to commercial programmes, provided that the prices used include all the relevant duties and taxes. The data in the model are illustrative only and do not relate to any particular country.

The financial cost of a new machine is taken as the cost of a comparable aid-funded tractor procured directly from the manufacturer. As a rule of thumb, this will be 10–15 per cent below the normal retail price paid by the farmer (exclusive of any import duties). The capital costs of new and rebuilt tractors are compared according to the following factors:

- Capital cost (less salvage value of old tractor where appropriate);
- Anticipated economic life of the tractor;
- Salvage value at end of tractor's life.

The model is also based on the assumption that provision for a replacement tractor be treated as part of the annual cost. This replacement is taken as being a new tractor because it is assumed that a second renovation would not be possible.

The tables on the following pages have costs expressed in constant 1988 US Dollars and a Local Currency (US$1 = LC34). All the figures are approximate rather than absolute and are provided for comparative purposes. Furthermore, it is not possible to specify costs of every item because of local variations. Instead, total average costs are provided on the basis of experience to date, and the tables can serve as a matrix to help identify individual items and their cost when assessing the viability of a proposed renovation programme.
### Table 14  
**FINANCIAL COST OF LOCALLY MANUFACTURED OR PURCHASED REPLACEMENT PARTS**  
(Per tractor in 1988 constant US$)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>UNIT PRICE</th>
<th>QUANTITY</th>
<th>TOTAL PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front tyre</td>
<td>41</td>
<td>2</td>
<td>82</td>
</tr>
<tr>
<td>Front tube</td>
<td>7</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>Rear tyre</td>
<td>136</td>
<td>2</td>
<td>272</td>
</tr>
<tr>
<td>Rear tube</td>
<td>19</td>
<td>2</td>
<td>38</td>
</tr>
<tr>
<td>Battery</td>
<td>43</td>
<td>1</td>
<td>43</td>
</tr>
<tr>
<td>Filter</td>
<td>9</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Paint</td>
<td>68</td>
<td>-</td>
<td>68</td>
</tr>
<tr>
<td>Fuel/solvents</td>
<td>29</td>
<td>-</td>
<td>29</td>
</tr>
<tr>
<td>Consumables</td>
<td>60</td>
<td>-</td>
<td>60</td>
</tr>
</tbody>
</table>

Sub Total 615

Procurement Agent's Fees (3%) 19

**TOTAL COST (IN LOCAL CURRENCY) EQUIVALENT TO US$** 634

### Table 15  
**FINANCIAL COST OF RENOVATING ONE TRACTOR**  
(in constant 1988 US$ and Local Currency)

<table>
<thead>
<tr>
<th></th>
<th>US$</th>
<th>Local Currency Equivalent (LC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFFSHORE COSTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of spares kit</td>
<td>6 531</td>
<td></td>
</tr>
<tr>
<td>Freight</td>
<td>119</td>
<td></td>
</tr>
<tr>
<td>Insurance</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>Procurement agents fees</td>
<td>202</td>
<td></td>
</tr>
<tr>
<td>Cost CIF</td>
<td>6 917</td>
<td></td>
</tr>
<tr>
<td>Sub-Total Offshore Costs</td>
<td></td>
<td>235 178</td>
</tr>
</tbody>
</table>

| LOCAL COSTS               |         |                                |
| Local replacement parts/supplies (Table 14) | 21 556  |
| Import Duties at 30% offshore cost            | 70 553  |
| Clearing charges                           | 3 000   |
| Rebuilding charge                          |         |
| - 250 hours at LC 70/hr                     | 17 500  |
| Transport costs                            | 1 000   |
| Sub-Total Local Costs                      | 113 609 |

**TOTAL COST PER TRACTOR** 348 787

---

61
Table 16  FINANCIAL COST OF IMPORTING ONE TRACTORS  
(In constant 1988 US$ and Local Currency)  

<table>
<thead>
<tr>
<th></th>
<th>US$</th>
<th>LC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OFFSHORE COSTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOB</td>
<td>9,239</td>
<td></td>
</tr>
<tr>
<td>Freight</td>
<td>255</td>
<td></td>
</tr>
<tr>
<td>Insurance</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>Procurement agent's fees</td>
<td>287</td>
<td></td>
</tr>
<tr>
<td><strong>Cost CIF</strong></td>
<td>9,857</td>
<td></td>
</tr>
<tr>
<td><strong>Sub-Total Offshore Costs</strong> (in Local Currency Equivalent)</td>
<td>335</td>
<td>138</td>
</tr>
<tr>
<td><strong>LOCAL COSTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Import Duty (5% of offshore cost)</td>
<td>16,757</td>
<td></td>
</tr>
<tr>
<td>Clearing charge</td>
<td>3,000</td>
<td></td>
</tr>
<tr>
<td>Assembly charge</td>
<td>5,500</td>
<td></td>
</tr>
<tr>
<td>Clearing charges</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>Transport costs</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>Dealer commission (5% of offshore cost)</td>
<td>16,757</td>
<td></td>
</tr>
<tr>
<td><strong>Sub-Total Local Costs</strong></td>
<td>43,014</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL COST</strong></td>
<td>378,152</td>
<td></td>
</tr>
</tbody>
</table>

==========================================================================================================

62
Table 17  FINANCIAL COMPARISON OF RENOVATION VERSUS PURCHASING A NEW TRACTOR
(Constant 1988 Local Currency)

<table>
<thead>
<tr>
<th></th>
<th>NEW TRACTOR</th>
<th>RENOVATED TRACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Cost (Year 1)</td>
<td>378 152</td>
<td>348 787</td>
</tr>
<tr>
<td>Less salvage value of old unit</td>
<td>(50 000)</td>
<td></td>
</tr>
<tr>
<td>Net Cost (Year 1)</td>
<td>328 152</td>
<td>348 787</td>
</tr>
<tr>
<td>Depreciation Cost (Year 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New tractor - 10 year life (10%)</td>
<td>32 815</td>
<td>-</td>
</tr>
<tr>
<td>Renovated tractor - 8 year life (12%)</td>
<td>-</td>
<td>41 854</td>
</tr>
<tr>
<td>Comparative Cost (Year 1)</td>
<td>360 967</td>
<td>390 641</td>
</tr>
</tbody>
</table>

Alternative Comparisons

1. If import duties were the same for the new tractor as for the replacement parts to renovate the old, at say 5% for both instead of 5% and 30% respectively (See Tables 15,16), the comparative cost in Year one would be: 360 967 331 846

2. If, in addition, both tractors were assumed to have the same working life of 10 years, the comparative cost in Year 1 would be: 360 967 323 177

It becomes clear from an analysis of Tables 15, 16 and 17 that a main factor in determining the financial advantage of tractor renovation is government policy on import duties. If replacement parts were to carry the same rate of duty as new equipment, renovation programmes could bring considerable financial gains, in addition to the other benefits described in the body of this publication.
<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Year</th>
<th>Language(s)</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Farm planning in the early stages of development</td>
<td>1968</td>
<td>E'</td>
<td>Rep. 1982 - F' S'</td>
</tr>
<tr>
<td>2.</td>
<td>Planning for action in agricultural development</td>
<td>1969</td>
<td>E'</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Karakul processing</td>
<td>1970</td>
<td>E'</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Bread from composite flour</td>
<td>1970</td>
<td>E'</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Sun-drying of fruits and vegetables</td>
<td>1970</td>
<td>E'</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Cashew nut processing</td>
<td>1970</td>
<td>E'</td>
<td></td>
</tr>
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<td>7.</td>
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