

**THE ROLE OF SMALL FOUR WHEEL TRACTORS
IN AGRICULTURAL AND INDUSTRIAL DEVELOPMENT
IN THE TROPICS**

by

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INTRODUCTION

In less than a century, the "motorized soil-tillage implement referred to as a tractor" has become the most important piece of mechanical equipment in the entire field-work inventory of modern farms in industrialized countries. Tractors are also credited with playing a similarly crucial role in the mechanization of farms in tropical and subtropical countries - primarily developing nations. Site and infrastructural circumstances allowing, 35-50 kW tractors have emerged as the "standard". For most ranges of farming activity, particularly soil tillage and transportation, such tractors provide adequate tractive and propulsive power. However, the economically justifiable mechanization of most small-to-mid-size farms (defined as having up to 2 - 10 or more hectares, depending on the country in question) cannot be achieved with such "standard tractors".

While production-enhancing agricultural inputs like seed, fertilizers and pesticides can be increased in arbitrarily small increments, most technical expedients are either not divisible at all (from a techno-economic standpoint) or only in a few big steps. In South and South-East Asia, single-axle tractors and power tillers have achieved widespread acceptance for use in irrigated rice production. Indeed, single-axle tractors are subject to certain limitations with regard to soil tillage in rain-fed agriculture: they have limited performance capabilities; the level of physical exertion required of the user can be higher than when draught animals are used; under adverse conditions, the tractor turns out to be either under-powered or very hard to control.

The usual mechanization sequence, i.e. manual labour - animal power - (single-axle tractor) - standard tractor, has a technological flaw: a gap that could be bridged by a small four-wheel tractor. In Europe, 9-22 kW tractors played a key role in the mechanization of individual family farms. At first, tractors were regarded as little more than a substitute for a team of draught animals. Later on, though, the Little Grey Fergies (Ferguson) saved the way for a thorough going

accommodation of all agricultural production methods to the key piece of equipment "tractor", with its now customary (and still expanding) capabilities. During the 1960s, the demand for small tractors declined so rapidly in Western Europe, that the major manufacturers discontinued their respective models. Several countries in South and East Asia are presently undergoing a course of development similar to that experienced by postwar Europe. Increasing numbers of small 4-wheel tractors of Japanese or indigenous origin (particularly in India and the People's Republic of China) are emerging as the nuclei of mechanization for individual farms - either as the next higher level of technical progress following single-axle tractors, or as the result of direct transition from animal traction.

For Africa in particular, a major potential demand derives from the availability of inexpensive small tractor with an engine output of up to about 26 kW which could be acquired by numerous small farms. At the same time, such small tractors would be required to stand up to the difficult tropical and subtropical service conditions. They would have to be equally robust and easy to operate, service and repair. Additionally, the developing countries naturally are interested in manufacturing their own tractors in order to help build up and expand their local industry and crafts & trades sector while avoiding complete dependence on imports. Such "felt needs" are discussed in detail in publications by Boshoff and Joy (1960), Kilgour (1976), Crossley (1977), Catterick (1978), GTZ (1980), Wills (1980, 1985).

In connection with the development cooperation projects of practically all industrial nations, there has always been a large number of programs devoted to the "design, testing and dissemination of small/basic tractors in developing countries". Some such programs have been implemented on modest budgets, while others have enjoyed massive funding. Examples include: Bouyer, Tinkabi, Multitrac, Centaur, Self Help, NIAE Monowheel and Snail. Up to now, none of those programs has met with lasting success.

The experiences related above are interpreted heterogeneously:

- Judging by the technical and economic superiority of standard tractors, small tractors are assumed to have lost their *raison d'être*.
- On the other hand, despite past experience and the tractors already available in some countries, there appears to be no end to people's attempt to achieve the "fourfold goal; durability, low cost, simplicity and local manufacture."

The importance of small tractors in the mechanization of agricultural production in developing countries differs from country to country. That subject is

investigated in detail in order to clarify its ramifications with regard to at least the following: individual farms, rural crafts & trades sector, the industry in developing and industrialized countries and the public authorities at all levels in the agricultural and industrial sectors.

REASONS FOR MECHANIZATION

Mechanization has been a major factor in the development of agriculture in industrialized countries, and it enjoys a high place value in connection with the intensification of agricultural production in developing countries. Indeed, the number of tractors and combines in service often serves as a measure of the "modernity" or "progressiveness" of a country's agriculture (Sievers (1983), Binswanger (1984), and Farington (1984)). One of the main reasons for increasing a farm's degree of mechanization has always been and still is to raise its labour productivity, i.e. to achieve a higher output (expanded acreage or higher yield per worker) and/or better income per man-hour of work (ha/h, t/h). In doing so, the farmer substitutes capital in place of scarce/expensive manual labour. Increasing the degree of mechanization, e.g. by buying a tractor, substitutes capital for labour. Numerous pertinent studies (e.g. Abercrombie (1973), McNerny and Donaldson (1973), Binswanger (1978), Bergmann and Mai (1984)), have documented this effect - familiar in industrialized countries - for developing countries, too.

In his analysis of publications dealing with the effects of tractor utilization in South Asia, Binswanger (1978) differentiates two universally applicable categories:

Category 1: Higher degree of mechanization as a result of the desire to achieve higher yields. Insufficient (pulling) power is presumed to be a constraint to agricultural production, regardless of factor prices and endowments. Deeper tillage and more accurate work (sowing, distribution of pesticides, threshing and cleaning) are supposed to have the effect of directly increasing the size of the standing crop and/or net yield. Better efficacy allows better timing and, as the case may be, more intensive cultivation (multiple cropping) the main objective being maximum yield, as opposed to optimal intensity of a particular production method or farm unit. Macroeconomic cost factors are given too little consideration. The protagonists of this thesis frequently cite a 1967 diagram by Giles (1967) in which a correlation between power available per hectare (hp/ha) and main-crop yields (kg/ha) is offered for some 40 industrialized and developing countries. That diagram gave rise to the call for a "minimum power requirement" of 0.5 hp/ha. Giles (1975) however, modified that interpretation in 1975 and later on called it a "misunderstanding" (Giles

(1984)). Nonetheless, emphasis is still placed on the important complementary contribution of mechanization along with other intensification measures, especially: irrigation; use of high-yielding varieties (HYV); use of fertilizers and pesticides; as well as better farm management.

Category 2: Higher degree of mechanization as a result of factoral exchange (substitution effect). According to this view, any work done by the tractor, combine harvester or the like could also be taken care of by a combination of manual labour, draught animals and appropriate implements. The transition to a stage of mechanization marked by higher efficiency and higher capital input is determined by the cost and availability of other production factors (Binswanger (1978)).

DIFFUSION AND PRODUCTION OF TRACTORS

In 1985, nearly 25 million tractors were in service around the world, more than 20 million of them (81.5%) in industrialized countries and nearly 5 million (18.5%) in developing countries. Japan has the highest specific tractor population density (390 tractors per 1,000 ha. arable land plus permanent crops). On a regional basis, Western Europe has the most tractors per unit area of land (85 per 1,000 ha.), while developing countries in Africa have the least (1.5 per 1,000 ha.). Global tractor production (excluding single-axle types) for use in agriculture amounted to approximately 1,600,000 in 1985 down roughly by 250,000 from 1980. This included some 316,000 small tractors with engine power ratings of 26 kW or less. Thus, small tractors accounted for barely 20% of total production. Only four countries produce an extraordinarily large percentage of small tractors: over 80% in India and Japan and over 50% in China and Korea (estimated), in addition to 100% of Thailand's admittedly quite modest domestic production. All other tractor-producing countries turn out about 10% (Italy) or significantly less small tractors.

Nearly 95% of all small tractors built in 1985, (i.e. 296,000 out of 316,000 Table 54), were produced in India, China and Japan. Accordingly, products from these three countries represent the lion's share of small tractors now in use in developing countries. Seven developing countries have their own small-tractor production facilities: India, China, Korea, Turkey, Brazil, Thailand and Swaziland ("special case" Tinkabi). All but the last two of these countries count as "threshold countries" producing in 1985 more than 97% of all small tractors of non-Japanese origin.

Table 54: Global production of four-wheel tractors with engine power ratings of up to 26 kW (1985)

Country	Quantity	% of total production
India	72,250	22.9
China	50,000 ¹	15.9
Thailand	500 ¹	0.2
Korea (D.R.)	2,500 ¹	0.8
Brazil ²	2,790	0.9
Turkey	1,000 ¹	0.3
Developing countries	129,040	40.9
Japan ³	173,852	55.0
Germany (Fed.Rep.of) ⁴	2,468	0.8
Italy	8,550 ¹	2.7
Great Britain ⁵	1,900 ¹	0.6
Total	315,810	100.0

Excluding countries producing less than approx. 500 ea./a

- 1) estimate 2) ≤ 27 kW/37 hp 3) ≥ 22 kW/30 hp
 4) \leq kW/34 hp 5) ≤ 30 kW/41 hp

Degree of indigenization: The term "local content" is used to denote the share of components originating in the same country in which final assembly occurs. The information can be stated either as a weight percentage or, better, as a share of net value added, in which case the local labour costs would be included. Rough classification according to local content would rank the tractor-production figures as follows:

- 100% : India, China, Brazil
- 25-60%: Argentina, Mexico, Algeria, Turkey, Pakistan, Korea, Thailand
- 15-25%: Tunisia
- $\leq 10\%$: Egypt, Tanzania, Iraq, Syria

Tractors are/were assembled from ckd and/or skd parts in Colombia, Morocco, Nigeria, Republic of South Africa, Thailand and Korea, in addition to some makes and/or models in Mexico, Pakistan and Turkey. In order to protect their own industries, Brazil, India, China and Japan do not allow large-volume importation of tractors.

HISTORY AND PRESENT STATUS OF SMALL-TRACTOR PRODUCTION AND USE IN SELECTED COUNTRIES

India

In terms of domestic production and sales, India is the developing world's leading tractor manufacturer. Indigenous production began in 1961, and the country's 1985 tractor output amounted to 85,000 ea., with small tractors (26 kW or less) constituting the largest group by far units (about 80%). Together, the country's seven leading tractor makers (accounting for about 95% of all indigenous tractors) marketed in 1986 twenty-one different tractor models with power ratings ranging from 10-44 kW. Tractors with power ratings of between 18 and 20 kW (25-27 hp) account for some 30% of the total market, i.e. all types up to 20kW/27 hp make up one-third of the market. The next-higher power range consists solely of tractors rated at exactly 26 kW/35 hp - which commanded half of the entire Indian market in 1986! Tractors with more than 26 kW accounted for about 17% of the 1986 sales volume.

The primary cultivating requirements for small-area rain-fed conditions, i.e. for tillage implements with drawn tools, are decisive for the tractor's technical complement:

- maximum tractive power, meaning high weight per unit of power in combination with adequately dimensioned driven wheels,
- a maneuverable tractor-implement unit, meaning quick and easy lifting of implements with the aid of a hydraulic system.

Additionally, many tractors are also used for powering threshers and pumps, usually by means of a belt and pulley (possibly coupled onto the p.t.o. shaft). Rain-fed soil cultivation (even without roots) involves much higher dynamic peak loads than those encountered in a wet rice paddy. The chassis and drive gear must be sized accordingly.

People's Republic of China

The production and use of small four-wheel tractors in the the People's Republic of China is closely linked to the country's overall agricultural and economic policies. In the past, this has led to a number of complete and radical changes in agricultural production systems - with corresponding effects on mechanization. Recent developments in the production of tractors in the People's Republic of China must be viewed in connection with changes in the land tenure system that have taken place since 1980. The functional scope of the people's communes was reduced to such an extent that they no longer constitute a major source of demand

for "large" tractors with power outputs exceeding 21 kW. The production of "large" tractors (> 20 kW) decreased from 125,600 in 1979 to 28,600 in 1986 (cf Table 55). At the same time, the sale of small tractors was booming, up from 217,000 in 1980 to 822,000 in 1985. Unfortunately, no differentiation is made between two-wheel and four-wheel tractors, but the 10% share listed by Kong *et.al.* in 1983 for small four-wheel tractors is probably still roughly correct. Accordingly, more than 700,000 single-axle tractors and over 70,000 four-wheel tractors with power ratings of 26 kW or less can be assumed as the 1985 production figures. Hence, China's 1985 single-axle tractor output was already higher than any tractor production level ever achieved in Japan.

TABLE 55: Production of single-axle and four-wheel tractors in the People's Republic of China (1976-1986)

Year	Four-wheel	Single-axle*
1976	73,700	240,000
1979	125,600	317,500
1980	97,700	217,900
1981	52,800	198,900
1982	40,300	298,300
1983	37,000	497,700
1984	39,700	688,600
1985	45,000	822,500
1986	28,600	774,500

* = incl. small 4-wheel tractors up to about 15 kW/20 hp

Source: State Statistical Yearbook: China (1987)

The 1980 transfer of responsibility for production from the people's communes to smaller units (mostly family farms) has resulted in a gradual shift towards single-farm forms of mechanization in which single-axle tractors and, to the extent available and economically feasible, four-wheel tractors of up to 16 kW are viewed as the central pieces. Their potential is being successively implemented and expanded. The product array, i.e. the available line of tractors and agricultural machines and implements, will eventually be brought more in line with such specialized demand:

- Light, simple tractors that could hardly deny their single-axle heritage. Engine ratings range from 9 to 12 kW (Taishan 12, Dong Fang Hong)
- Light, more sophisticated tractors, some with four-wheel drive, designed for use in rice paddies (Feng Shou), similar to Japanese

- products.
Heavy, simple tractors with high power-to-weight ratios for tillage with drawn implements under rain-fed conditions. Similar to Indian products in the same size category.

All three include a high percentage of transportation work.

Thailand

The production and use of small four-wheel tractors in Thailand has attracted lots of attention and is often cited as a model for other countries in Southeast Asia and elsewhere. The two main factors governing agricultural production in Thailand have engendered two very disparate forms of mechanization: first, the traditional working of rice paddies, particularly in the central plains to the north of Bangkok, where single-axle tractors and small, lightweight four-wheel versions predominate; then the highlands, mostly in the north and northeast, where increasing mechanization has led to substantial expansion of farm acreage, almost all of it now being worked with imported 44-60 kW tractors.

Work on the design of lightweight four-wheel tractors began in the 1950's, a prototype called the "Iron Buffalo" made its debut in 1958. In the subsequent years that name became much more popular than the tractor itself. A domestic single-axle tractor "industry" began to emerge in the early 1960's. By the late 1970's annual production had reached a level of about 40,000 units, with 25 manufacturers covering 95% of the market. The country's first indigenous four-wheel tractors appeared in 1969. Depending on the source quoted, the production figures ranged from 4,000 to 7,000 per year between 1978 and 1982.

Some manufacturers of single-axle tractors first began with four-wheel tractors referred to as Ayudhayas (after the town in which they are manufactured). In addition to single-cylinder engines, two-cylinder types with a side flywheel are also used; power outputs range from 9-15 kW. Power transmission to the gearbox is effected with V-belts. Up to now all indigenous tractors have been built with chain-and-sprocket gearboxes with up to three gears. The differentials are taken from old trucks or passenger vehicles and then overhauled and modified as necessary for installation in the tractors. The steering gears and some front axles are also taken from used vehicles.

The very simple design, coupled with the use of second-hand parts, makes the finished product very inexpensive, with prices ranging around US\$4,000. Admittedly, though, the utility value is limited to main tasks like rice puddling and transportation (the latter only with rubber tyres). Except for some very gradual changes, the practice of using new and used parts together remains to this

very day the main feature of such tractors. Since the early 1980's the domestic market has been in a process of radical change - with no end in sight. Even before that, considerable numbers of used tractors (as many as 2,000 per year) with engine power ratings of about 44kW, most of them Fords and Massey Fergusons, were being imported from Great Britain. Suddenly, in 1981, three times as many tractors (both single-axle and four-wheelers) were imported as in the previous year. Large numbers of new Chinese single-axle tractors and several thousand used small tractors of Japanese origin have also appeared. Their selling price often amounted to only a third to one-half of that being asked for corresponding local products.

This, of course, has had a devastating effect on Thailand's tractor industry. Within a single year, the production of single-axle tractors dropped by 10,000 units, and the four-wheel tractor market showed a similar reaction a year later: annual production dropped to about half of what it had been and continued to fall to about one-tenth of the original level (roughly 500) by 1985. While the production capacity and output figures for single-axle tractors eventually balanced out at about 40,000 units per annum, the number of four-wheel tractor producers dropped from 12 to 3 by 1985. There was no notable increase in demand prior to 1986, and there has been little, if any, further development of the products since 1981. Probably no other country with a fairly extensively mechanized agricultural sector has reached that stage with so little government interference, at least not in the form of furtherance.

Even more so than in the People's Republic of China single-axle tractors and small four-wheel tractors belong to one and the same technical and functional category in Thailand, while large tractors constitute a class of their own. Single-axle tractors have taken over the work that used to be done by draught animals - and do it according to the same principles: rice paddies are tilled right after the summer's monsoon rains; plows and rakes have remained essentially unchanged. Now, though, instead of the hooves of animals doing the stamping and mixing, the puddling is done by cage wheels.

The new and used Japanese-built tractors that have been imported in substantial numbers since 1980 have power outputs (9-15 kW) similar to those of their Thai counterparts, but that is about all they have in common. The Japanese products have numerous functions like multi-speed p.t.o.'s, hydraulic attachments, etc., and some have front-wheel drive and/or transmissions with anywhere from 8 to 16 gears. Moreover, they are much more comfortable, convenient and quiet-running. Another conspicuous difference between Japanese and Thai tractors is that most of the former are equipped with power tillers for rotary cultivation. That reduces by 50% or more the necessary number of tillage passes; the basic cultivation process is changed from drawn tools to power-driven ones. In a

nutshell; tractors imported from Japan were technically superior in every respect to Thai products with comparable power ratings; and at second-hand-tractor prices, they also had a cost advantage. Even the fact that prior use had detracted from their original life expectancy was hardly a problem, because it was still longer than that of the local products.

Other developing countries

With regard to agricultural mechanization, the Democratic Republic of (South) Korea is following the same course as Japan, but with a roughly 20-years lag. The country's industrial achievements has put the government in a position where it can provide massive assistance to the agricultural sector, with emphasis on capital-intensive production techniques. Four companies make and market four-wheel tractors with engine power ratings of between 10 and 35 kW. Local manufacture accounts for 63-100% (average: 86%). The tractors are built on license in a joint-venture basis using parts made by foreign manufacturers:

- Daedong, with Kubota and Ford
- Tong Yang, with Iseki
- Gold Start (ex Hyundai), with Mitsubishi and Fiat
- Kotje, with Hinomoto
- Korea Heavy Industries (KHIC), with Fiat

The number of four-wheel tractors produced each year (4,800 in 1986) is supposed to be increased by 1,000 annually until 1991. It has been estimated that at least two-thirds of them will have engine ratings of less than 26 kW. Four-wheel tractors are supplanting single-axle tractors on South Korean farms.

In some countries, particularly within Africa, there have been and still are various government and private initiatives aimed at promoting the use and production of small tractors. In Zambia, for example, nine small tractors were subjected to detailed testing between 1979 and 1981 (Aked (1981), Aked and Cullen (1981)). Each tractor accumulated between 300 and 500 hours of service. Then, the tractor's serviceability under Zambian conditions was evaluated with the following results:

- suitable: Agrale 4100 (Brazil), Tinkabi (Swaziland), Swaraj 720 and 724 (India), Yanmar (Japan);
- unsuitable: MF 210, Belarus T 25, Bouyer TE ("in need of further development").

Unfortunately, such clear-cut statements are rare.

Both Cameroon (Balo (1982), Schulz (1983)) and Tanzania (Hartmann (1986)) reportedly have been working on the design and comparative testing of small tractors, but no follow-up measures (dissemination) have, to our knowledge, been taken to date. In Cameroon and Tunisia simplified standard tractors with an engine power rating of 31 kW were tested in 1978 (Zaske, (1978)). Several times already, Egypt has negotiated the signing of an agreement covering the production of an approximately 30 hp tractor. Discussions were held with Deutz in 1977 subsequent to negotiations with Hefty (USA) (Krause and Gego (1977)) and prior to dealing with Renault. In 1986 Deutz returned with a type-DE 3607 tractor, a modified version of its D 3607. It was intended that a two-cylinder 22 kW engine already being built in Egypt would be installed in that model. Some 800 tractors with 18 kW/24 hp were imported in 1988 from the People's Republic of China.

Japan

Judging by the total number of units produced, Japan is second only to the Soviet Union as the global leader in tractor manufacturing. Fifty-five percent of all small four-wheel tractors produced in 1985 (173,000 of 316,000) were made in Japan. The first single-axle tractors were mass-produced in 1925. Between 1960 and 1970 the number of single-axle tractors (power tillers) in service in Japan rose from about 500,000 to over 3.2 million. Within a single decade, draught animals were almost totally replaced by tractors. More than 500,000 single-axle tractors were produced in Japan in 1968.

The first four-wheel tractors with engine power ratings of 7-15 kW appeared in early 1960's. They were copies of imported products and, as such, hardly suitable for working in rice paddies, because they were excessively heavy and lacked waterproof bearings. The breakthrough came after 1972 as a result of important innovations like compact construction, high-lug tires and four-wheel drive for Japanese-built tractors. By way of analogy to the Japanese products, such tractors are now referred to the world over as "compact tractors". The production figures practically exploded - from 33,757 in 1971 to 286,349 in 1976, and the in-service inventory passed the one-million mark in 1978. The number of tractors with power ratings of 22 kW and below, as a percentage of overall four-wheel tractor production, declined from 97% in 1976 to 80-85% about a decade later. Roughly half of the tractors produced are exported, with more than half of the exports going to the U.S.A.

The technical characteristics of Japanese-built compact tractors include a number of peculiarities. One of the most important criteria was the desire to have a tool with which to work (mainly till) rice paddies in an optimal fashion while putting enough power and convenience at the farmer's/driver's disposal. At the same time, the tractor had to be suitable for working in small fields and

negotiating narrow paths and crossings. Thus, the following characteristics apply in general:

- low total weight and power-to-weight ratio
- compact construction with correspondingly short dimensions
- several P.T.O.-shaft speeds
- large number of gears, including creeper gear
- dis-engageable front-wheel drive
- multi-cylinder diesel engine.

The p.t.o., transmission and front-wheel drive functions are intended for service with a power tiller in rice paddies. The weight and compact construction reflect the size of the field and the given working conditions.

Over-capacities began appearing in the Japanese tractor industry in or about 1976. A large percentage of all tractors produced are thus now exported. With the exception of those sold directly under manufacturers' names, the exported tractors are marketed in the colors of the importing country's manufacturers, e.g. Mitsubishi through Case/IH, Yanmar producing for John Deere, Shibaura for Ford, etc. Most Japanese-made four-wheel tractors are not used for field work in industrialized countries. Instead, they are used mostly for municipal tasks like mowing lawns and playing fields and in combination with small construction machines. The standards set by such user groups (in industrialized countries) are similar to those of Japanese farmers with regard to versatility, maneuverability and convenience of operation.

It is important to note that single-axle tractors had already taken the place of draught animals in all accessible rice-growing areas before four-wheel tractors came on the scene. The latter amounted to a kind of "upward mobility" in the sense of substantially easier work, more power available, and the chance to use implements with higher power requirements, e.g. multi-row rice transplanters. In contrast to, say India or Western Europe, Japanese farmers did not start motorizing with small - compact - four-wheel tractors. In fact, the process of motorization (as part of or resulting from intensification in general) had already taken place, i.e. the farmers were already experienced in the use of machines. Despite the larger number of components and functions, the manufacturing costs remained relatively low thanks to mass production and lightweight construction. The tractors were sized to accommodate the load cases normally encountered in rice cultivation, the peak dynamic loads of which are substantially lower than those encountered in rain-fed farming. Moreover, the average tractor accumulates a meager 67.5 operating hours per year indicating the level of subsidization of agriculture in Japan!

Federal Republic of Germany

Within the brief span of 15 years (1950-1965) practically all draught animals were replaced by so-called "Bauernschlepper" (farmer's tractor). For a while, tractors with engine power ratings of 26 kW or less accounted for about 90% of all tractors sold. By 1960, though, their market share had dropped to 80%, and it took only 10 more years for the situation to be totally reversed: more than three out of every four new tractors registered in 1970 already had more than 26 kW, and that category rose to about 90% in 1976 and has remained there ever since. Very few makes now include models with 26 kW or less in the Federal Republic of Germany, and most of them are either smallest member of a "family of tractors" with higher engine outputs (meaning that the "baby of the family" has a throttled engine and small tires) or one of several types that have remained essentially unmodified for 20 or 30 years.

It was not until the early 1980s that some new efforts were invested in (re)designing small tractors. In February 1988 the Institute for Agricultural Machinery, Munich Technical University, introduced the prototype of a "small research tractor" (Kirste (1984)). The purpose of such work has been to achieve:

- lightweight construction, with advantages in connection with price, fuel consumption and ground pressure; lightweight passenger-vehicle-type engines and transmissions and appropriate material (plastics)
- the option of shutting off unneeded features to lower the tractor's energy consumption and increase its longevity
- convenient operation (well-arranged levers, noise abatement)
- compliance with legal restrictions on noise emission and exhaust-gas pollution.

From that point on, though, Germany's case differs from others by reason of its characteristic dovetailing of crop farming and animal husbandry, which has had a substantial influence on the development and dissemination of small tractors in that country.

Large agricultural estates were able to employ several stages of technology at once, but small and medium-size farms, many of which were encumbered by a high location-dependent share of meadows and pastures, could not. Such farms, especially those using teams of horses or oxen, had to change from one source of traction to the other as quickly as possible. The power requirement was decided by analogy to the farm's previous draught-animal inventory; "single-furrow" or "double-furrow" tractors with 8-13 kW hp were chosen accordingly. With hardly an exception, the small-to-midsized farms in the Federal Republic of Germany proceeded from the use of draught animals (horses, oxen, cows) to small tractors

(Bauernschlepper) and then on to more powerful agricultural tractors. Hardly any tractors with engine power ratings of 26 kW or less are still used alone on a farm.

Table 56: Small tractors as percentage shares of total exports and first registrations in Great Britain

Year	Exports		First registrations			
	Total	<25 kW = %	Total	<30 kW = %		
1975	134,440	5,245	3.9			
1980	100,961	297	0.3	20,750	166	0.8
1981	87,282	76	0.1	21,315	405	1.9
1982	74,296	62	0.1	25,568	614	2.4
1983	68,040	1,067	1.6	28,485	997	3.5
1984	83,705	4,521	5.4	25,548	1,073	4.2
1985	76,798	1,197	1.6	24,623	1,211	4.9
1986	60,491	1,663	2.7	18,775	1,164	6.2

Source: AEA & VIC (1987)

Great Britain

The share of newly registered tractors belonging to the less than 30 kW category has been on the rise since 1980, gradually increasing from 0.8% to 6.2% of total tractor stock in the country. While that does not suffice as a basis for long-term trend analysis, it does show that Great Britain is the only (or just the first?) country in Europe in which the trend has been reversed after nearly 20 years. The situation in the USA is similar. At present (1989) Great Britain has more sales agencies for Japanese-built tractors than any other country in Europe. Five of them operate under their own names, and three other makes carry the trade names John Deere, Ford and Massey Ferguson. About 2,500 Japanese tractors were imported in 1985, nearly all of them with power ratings of 26 kW and below. Some 60% are used for tending municipal grounds, sports facilities and recreation areas, 20% in the construction sector, and the remaining 20% in agriculture. The latter 500 tractors account for about 40% of new registrations in their size category (cf. Table 56).

United States of America (USA)

After accounting for only about 10% of new sales in 1976, tractors with less than

28 kW engines bounced back to account for roughly 50% share of the market in 1985. The large demand (upwards of 50,000 annually) is covered almost exclusively by imports, especially from Japan. Most imports are transacted under the name of one or the other old-established North American manufacturer. Many tractors with engine power ratings of less than 30 kW are put to one or the other non-agricultural use. Crucial areas include horticultural farms and the grooming of lawns and sports grounds, in addition to municipal work like street cleaning and snow plowing. Many "weekend farmers" use such tractors, as do some large farms to complement their large-tractor fleets. High tractive power is just as unimportant as sustained maximum output. Convenience of operation (incl. low noise and vibration levels), hydraulic versatility, multiple P.T.O. speeds, compact design and maneuverability are the criteria cited most often by both American and Japanese buyers.

SMALL TRACTORS FOR DEVELOPING COUNTRIES

The preceding section dealt with the production and use of tractors in various countries, with special attention paid to small tractors. In addition to the makes and models discussed in that context, there is also a wide variety of "small tractors specifically developed for or adapted to tropical and subtropical conditions" (cf. Table 57). Three types require special mention: the Bouyer (France) and the Tinkabi (Swaziland), being the only two tractors in platform-tractor category ever to be produced in significant numbers, and the Multitrac (F.R.G.), which is still at the development stage. According to the available information, it must be assumed that none of the other types will ever rise above their present status (prototype or pilot production). What all of them have in common is the widespread assumption that the lack of appropriate technology ("gap below the standard tractor") has a limiting effect on the extent to which the productivity of rural areas can be increased. Technical progress in the design of small tractors is seen as the best remedy. The significance and expense of the next steps (production and marketing) are often underestimated. Consequently, very few such tractors have ever got past the prototype stage.

BOUER/CFDT

This small tractor with a front platform was developed as a joint effort of the French cotton company CFDT (*Compagnie Francaise pour le Developpement des Fibres Textiles*) in Paris, the tropical farm machinery center CEEMAT (*Centre d'Etudes et d'Experimentation du Machinisme Agricole Tropicale*) in Antony near Paris, and the Bouyer Company in eastern France. The BOUYER TE was designed for use by CFDT's contract farmers. Apart from the usual characteristics of a small tractor (simplicity, robustness, etc.), this one features exceptionally high ground clearance (580 mm) in combination with a wider-than-average track of 1400-1600 mm,

TABLE 57: Survey of type-specific case studies

Make/Model	No.in Table 58	Design Origin (country)	Period of design/prod.	Prod. Qty
<u>Platform tractors</u>				
Bouyer, takeover	26	France	1972-1984	1261
by CFDT	27	France	1984-	320
Tinkabi	29	Swaziland	1968-1985	800*
Prod. resumed	-	(with 31 kW)	1987-	
Multitrac	30	FR of Germany	1977-	25
<u>Others</u>				
Lister Pico	31	Great Britain	1980-	P
Centau	32	Great Britain	1980-	P
AGRITOM PO26	28	France	1986-	P
AFCOM	35	Cote d'Ivoire	1977	P
<u>Universal tractors</u>				
Self Help	17	U.S.A.	1962-	250*
Agro Util	18	U.S.A.	1970-	50*
Kabanyolo	23	Uganda (EAU)	1960-1972	P
Goldoni	20	Italy	1978	P
Renault Afrique	24	France	1976	P
Gutbrod SSFT	21	F.R.G.	1978-1980*	P
Howard	22	Australia	1972-1978*	P
Buffalo	19	U.S.A.	1960-1978	P
Economy	-	U.S.A.	1962-1980*	P
Farmking	15	Great Britain	1985-	50
Br. Leyland 184	14	Great Britain	1960-1985	s.t.
<u>Basic tractors >35 hp</u>				
Desophisticated tr.	-	F.R.G.	1976-1980	P
Farewell/Tugwell	-	GB/Zambia	1986-	
Zambezi	-	Zimbabwe/India	1983-	
<u>Three-wheel tractors</u>				
NIAE Monowheel	39	Great Britain	1962-1967	P
Farmboy	38	GB/Switzerland	1971-1974	P
Poynter Triple	40	Australia	1972	P
Combiculteur	36	France	1976-1979	15*
Agrostar	37	CH/ Australia	1975-1983	P
Motorcycle tractor	40	Netherlands	1964-1976	P
<u>Tool-carriers</u>				
Tuff-Bilt	34	U.S.A.	1965-	s.t.
ENTI	33	Netherlands	1983-	500*
Normandia	-	France	1979	P

Table 57 continued

<u>Special designs</u>				
Amex	25	Great Britain	1978	P
Snail/Spider	45	Great Britain	1972-	P
Pangolin	43	Cote d'Ivoire	1974-1977	P
Quadractor	-	U.S.A.	1978-1982	400
JAC Prod. resumed	44	Australia	1986-	P
Rokon	42	U.S.A.	?-1985*	s.t.

Interpretation: No. in Table 57 = the line in Table 58, showing the respective technical data
 s.t. = several thousand, exact quantity unknown
 * = estimated
 P = only a few prototypes

corresponding to two rows of cotton (Wieneke and Friedrich (1982)). A total of 1,261 BOUYER TE tractors were delivered by 1984, 853 of them were still in service and another 315 on order by 1985. The manufacturer - Bouyer - went bankrupt in July 1984, at which time CFDT assumed responsibility for supplying spare parts under its own name and has since continued to make addition TE's in small lots (beginning at about 20 each) from external parts.

TINKABI

The first prototype, which was introduced in October 1969, had rudder steering and chain-driven wheels. A pilot lot of nine prototypes was finished in 1973 and distributed for intensive testing. One prototype went to Silsoe, England, for tractor testing according to the OECD testing code at the former NIAE (National Institute of Agricultural Engineering, now AFRC Engineering).

After having been "declared dead" several times in as many years, production of the TINKABI stopped in 1985. The total number of tractors produced until then most likely amounts to somewhere between 500 and 800. Then, in early 1987, the TINKABI reappeared as the AG 3124 packing 31 kW engine, with substantially larger tractor tires of the driven wheels (11.2/10x24) and equipped with a category-1 three-point linkage. The new version still had a front platform and a hydrostatic drive, but came with a new top speed of 20 km/h.

Most TINKABIs in Swaziland are used on farms ranging in size from 10 to 15 ha, with main crops consisting of corn (maize), cotton, peanuts (groundnuts) and beans. All of the farmers had long years of experience with draught animals. The fields are therefore free of major obstacles. Primary and secondary tillage and hauling are reported to be the main tasks for tractors. Quite a few TINKABIs have been equipped with flywheel-driven hammer mills and put out for hire. However

as Agrippa and Lukhele have reported in this volume (Chapter 8) the Tinkabi appears to have performed better in stationary jobs rather than in tillage.

Multitrac

In 1977, the Federal Ministry of Economic Cooperation (BMZ) in Bonn provided public funding via the "Deutsche Gesellschaft fuer Technische Zusammenarbeit" (GTZ) in Eschborn for designing, testing and disseminating of a "universal farm implement" (UAG). With a single exception, the tractor attributes envisioned for the "UAG" were about the same as those listed above for the "Bouyer" and "Tinkabi" tractors: simple, robust, inexpensive, platform-type, etc. However, in contrast to those other approaches, it was not a product, i.e. a platform tractor with a certain set of technical data, that was to be introduced and propagated, but rather the know-how for its manufacture.

A Y-shaped universal frame made of ordinary structural steel carries the components (engine, transmission, axles, etc.) that are available at the respective place of manufacture and/or use. Consequently, tractor production can be based on existing indigenous facilities, structures and capabilities. Theoretically, the frame-construction principle allows the use of myriad different combinations of engines, transmissions and axles, depending on local availability and prices. Worldwide response to the new MULTITRAC exceeded all expectations. This tractor, it seems, was the answer to many people's problems. The elaborated information (production documentation, etc.) was supposed to give potential buyers from developing (and industrialized) countries the know-how they would need for manufacturing their own technically, constructionally and financially made-to-measure MULTITRACs in compliance with their own domestic situation. However, that development-political approach proved impracticable in the presented form. Namely the four prototypes were not being understood as mere examples of how to implement the basic idea, but rather as a complete take-it-or-leave-it line of tractors from a new West German specialist manufacturer. Only about 25 MULTITRACs have been produced to date, so little on-the-job experience has been gathered. In 1988 some tractors were exported to Nigeria and Cameroon

Comparative Profile

Types of construction

All small tractors mentioned in the study were arranged according to their respective types of construction. At first glance, the diversity may seem somewhat bewildering, but it actually breaks down to only three basic types: universal tractors, platform tractors and single-axle tractors - plus a "potpourri" of special designs.

- Universal tractors: front engine, driver's seat at rear, most implements attaching at rear;
- Platform tractors and vehicles: front or rear platform (the latter configuration showing close resemblance to a pickup truck), with hauling as the main task;
- Special designs: e.g. tool carriers, hillside tractors, three-wheel versions, motorcycle tractors, prime movers with winches;
- Single-axle tractors, power tillers and rotary motor hoes.

Practically every conceivable kind of small tractor has already been tried out in connection with agricultural mechanization in the tropics and subtropics.

Technical data

The technical data of forty-five small tractors were analyzed for the purpose of defining the range of technical characteristics (cf. Table 58). Differentiation is made between series products and prototypes/discontinued series products. The comparative summary yields the following situation (cf. Holtkamp (1988, 1989) for details):

Weight (static weight of tractor)

The weights of the 45 chosen types of tractors range between 400 kg and 2,000 kg. On the average, standard tractors weighed a good 200 kg more than prototypes/erstwhile series products. In the 25-30 kW power range, the new European small tractor has a static weight of about 1,800 kg, with considerable tolerance in both directions. While the difference has diminished in recent years, Japanese tractors in the 1,050-1,700 kg range tend to weigh between 300 kg and 400 kg less for a given engine output.

Power-to-weight ratio

Like the reference variable, the static weight, these values also tend to be considerably higher for series-built tractors. The less than 20 kW range shows an enormous amount of scatter (12-145 kg/kW), while the range above 20 kW is within the limits 45-80 kg/kW. The latter is true of small tractors built in Western Europe. There is also a conspicuous "gap" extending from 13 to 16 kW (18-22 hp). Tractors situated to the left of the gap are hardly suitable for rain-fed tillage operations. The power-to-weight ratios of Japanese-built tractors are concentrated within the 50-70 kg/kW interval. This is attributable to their compact, lightweight construction in combination with multiple cylinder, high-speed, lightweight diesel engines.

Wheelbase

The wheelbase range starts at about 1300 mm for 8 kW and extends to nearly 2,000 mm at 25 kW. On the average, standard products from developing countries and Europe have wheelbases that are about 200 mm shorter than those of prototypes. The wheelbase of the average Japanese tractor is shorter by another 150 mm or so. Surprisingly, the wheelbases of tractors in all four groups converge closely at about 25 kW (interval: 1,800-1,900 mm).

Hydraulic lifting power

Of the 45 tractors in Table 58, 28 are equipped with a rear hydraulic, but lifting-power data is only available for 16 of them. The values range from 250 daN to 1,900 daN (1daN = approx. 1 kg). The factory data may be assumed to list the maximum lifting power, as opposed to the continuous lifting power, which may be as much as one-third lower than the maximum lifting power.

Performance, functions

Apart from the customary technical data, additional information concerning the following items was gathered:

- performance (in particular the area worked per unit of time)
- the resultant working time requirement (reciprocal of above)
- specific fuel consumption.

All of these quantities depend on the implements in use, i.e. their kind, size, effective width, speed and depth -in addition to local conditions. Here, too, only the general range of published information can be recounted. Consequently, no significant differences between small tractors with comparable engine output ratings can be inferred from them.

DISCUSSION AND CONCLUSIONS

Demand and agricultural uses for small tractors

It would appear that the increasing use of small four-wheel tractors in developing countries is concomitant to and a result of - as opposed to a precondition for - gradual intensification of agricultural production. The purchase of a farm's first small tractor reflects prior changes in that farm's factor endowments and their availability. The goal would seem to give the farm a new and better combination of production factors capable of optimizing production, minimizing risks and maximizing profits. Any investment in farm mechanization stands in direct

competition with potential investments in yield-increasing measures like irrigation, seed, fertilizer and pesticides. When intensification efforts are just getting under way, measures of the latter kind not only offer better cost-benefit ratios, but are also more feasible for small farms, thanks to their largely unlimited economic divisibility.

Many of the farms getting their first (small) tractor already have draught animals or a single-axle tractor. Most small four-wheel tractors purchased in developing countries are intended to serve as the farm's only tractor. Firstly, the tractor is supposed to supplement the work of draught animals (in rain-fed farming areas) and of single-axle tractors (in rice-growing areas, where they have already replaced draught animals). Later, though both are completely replaced by small four-wheel tractors. Nearly all small tractors (like draught animals and single-axle tractors) are privately owned - an indication of a family-farm structure. Unlike large tractors, the typical small tractor is operated by the owner himself or by a member of the family. While small tractors are frequently used to complement large ones in Western Europe and North America, that practice is still rare in developing countries.

Farms with limited acreage and capital (= the typical small farm) are equally limited in the amount that can be spent on motorization within a given time span. Options include making use of a farm-credit program (to the extent available) or buying a small or used tractor. Since it often makes little sense from an economic standpoint to mechanize a single small farm with a four-wheel tractor (even a small one might be too expensive!), only multi-farm cooperation can enable the farm to gain access to the production factor "agricultural tractor". Also, multi-farm use of machinery makes it possible to monitor, plan and adapt the farms' production operations and capital goods to the altered production techniques. Small tractors are and always have been most popular in Europe (particularly in the Federal Republic of Germany and Italy), India, China, Japan, and the USA.

Irrigated rice growing by reason of the given agrarian structure and topography, inherently involves very small areas. Small tractors, with their low power-to-weight ratios, are at an advantage over large ones. They are powerful enough to plow the soft soil or drive a power tiller. The process of motorization began with the introduction of single-axle tractors to replace draught animals for puddling work. Then, the single-axle tractors, most of which now have engine power ratings of 13 kW or less. While they at first result in only insignificant technical changes, i.e. even the hourly performance increases only slightly, the work is a lot easier, so that more hours can be put in, thus increasing the daily performance. Considering today's production techniques, small tractors therefore serve as an indicator of intensive production, the desire to achieve a lighter workload, a

shortage of labour and/or the farm's financial capabilities (including off-the-farm income).

Rain-fed farming poses a different situation: single-axle tractors are not powerful enough for large-area cultivation, because the soil resistance is two to eight times higher than in a wet rice paddy. Drawn implements like plows and cultivators require tractors with relatively high pulling capacity. Tractors with 30 kW, or even better 40 kW, are technically superior to smaller ones. If the family's combined on-the-farm and off-the-farm income does not allow the purchase of a new large tractor, and/or if no used tractor is available, a small one (if one can be found) will have to do at first. In northwestern India, northern and eastern China, as well as in parts of Turkey and Brazil, small tractors with a high power-to-weight ratio are quite common. Most of them have 20-26 kW engines and therefore belong to the "medium-size" class for their own particular range of application.

On a small farm, the first small tractor (new or used) constitutes a technical and financial step into a new kind of technology. It shows that the farm is taking part in economic progress. The second tractor after five to ten years can be expected to have at least 25 kW, probably more. In the meantime, new production methods will have been adopted, and the draught animals will have been reduced in number or abolished altogether. The initial excess capacities are successively reduced by off-the-farm contract work or area expansion, i.e. by taking back leased land and buying or leasing more land. Depending on the main crops, local conditions, producer prices, etc., at least 6 to 8, or better 10 to 15 hectares of cash crops with a corresponding arable-land area of at least 15 to 25 ha are regarded as minimum acreage for the cost-efficient use of small tractors under rain-fed farming conditions. In many developing countries, that would constitute a large-scale farm.

In most cases, the adequately cost-efficient use of a tractor (on the basis of annual operating hours) is not achievable by merely attending to scheduled work, even on other farms, too. The tractor would also have to be used for transport duties and other jobs that are not, or at least less, time-dependent. Farms with integrated crop and animal production require year-round supply and disposal operations that set up good working conditions for small tractors, which, with their compact dimensions, have advantages over large tractors in barns, stables and farmyards. On a typical farm, a small tractor may face "competition" from manual labour; draught animals; single-axle tractors; large four-wheel tractors; transport vehicles, e.g. pickups; stationary drive units.

Non-agricultural uses for small tractors

In industrialized countries, most new small tractors are put to non-agricultural

uses. The same trend also appears to be emerging in developing countries. Some uses for small four-wheel tractors include:

- upkeep and maintenance of sporting, recreational and touristic facilities
- community-level tasks (cleaning streets, plowing snow)
- construction
- transportation and
- military activities.

In the latter two areas, small tractors are used almost exclusively as truck tractors for shuttling work on paved grounds; in the other areas they are also used for powering mobile or stationary equipment.

Manufacturing

According to their type of construction and historical background, small tractors the world over can be divided up into four main groups:

Group 1: Developed from single-axle types, frame construction, engine power ratings up to 13 kW (southern and eastern China, Thailand).

Group 2: Four-wheel tractors originating in the same production facilities and on the basis of the same duty profiles as single-axle tractors, but with a high technical niveau from the very beginning, monocoque construction, high piece numbers, engine power range primarily from 10-20 kW with upward trend (Japan, market leaders in the U.S., just beginning in Korea).

Group 3 Independent or license-aided types of universal tractors, monocoque or half-frame construction, large series engines beginning at 20 kW. Extensively identical to larger tractors (India, eastern and northern China, Federal Republic of Germany, eastern European countries, various types in Turkey and Brazil).

Group 4: Same as group 3 but with narrow track, designed especially for use in orchards and vineyards as well as on plantations, often having four wheels of equal size, sometimes with articulated steering (Italy, Federal Republic of Germany, a few in Brazil, Turkey and the Soviet Union).

In the less than 26 kW power range, none of the tractors belonging to category 3 or 4 have undergone any nominal re-engineering in industrialized countries. Any tractors belonging to that category that are still (or again) on the market are therefore based on two-decades-old technology - with the exception of some Japanese products sold under the names of venerable old firms. Recently,

however, there have been signs of new activities among West European manufacturers that would affect, but not necessarily be limited to, the 26-37 kW power range. If so, international work-sharing in the production of small tractors could develop according to the following breakdown:

- a) Tractors for irrigated rice paddies, mostly less than 18 kW/25 hp, will be made in Japan and, with increasing frequency, under license in other Asian countries (China, Korea, Thailand). Some indigenous Chinese products will be offered, possibly also some from Thailand. Assuming certain changes in the existing agrarian structure and production techniques, larger tractors may also gain acceptance among rice growers.
- b) Tractors for rain-fed farming, higher than 20 kW with upward trend, made in India, in parts of southern and eastern Africa; some built in Brazil, Turkey and Pakistan.
- c) Tractors for complementary and/or non-agricultural uses in the U.S. and, increasingly, in Western Europe, made in Japan, some being marketed by old-established manufacturers.
- d) No more small less than 26 kW tractors built in Europe or North America that would appear suitable for use in developing countries. Conversely, the next power category, i.e. 30-40 kW, could regain new status in Europe as well as in developing countries. The narrow-gauge models can be expected to defend their position in this power category.

The importance of choosing suitable implements cannot be over-estimated. While the three-point linkage (four different categories: 0 through 3) has emerged internationally as standard equipment for the attachment of tools and implements, the mere fact that both the tractor and the implement belong to the same category is no guarantee that they will also fit together. Standardized linkages are more universal, but also more expensive than special-purpose designs.

Small tractors are the result of attempts to satisfy a real or perceived need. The user's requirements should be the decisive criteria. In the course of the last 100 years, very few of the many technical solutions that have been tried out at different times in different parts of the world have actually gained lasting acceptance:

- Universal tractors in combination with a standardized implement linkage setup have gained by far the most widespread acceptance;

- Wherever they make sense both technically and financially, special-purpose tractors have gained relevance:
 - system tractors
 - narrow-gauge tractors and articulated-steering versions
 - tool carriers
 - hillside tractors
 - row-crop tractors
 - all-terrain transport vehicles
 - off-the-road motorcycles etc.

- Other approaches are found to lead in the wrong direction. This does not include only "dead-end designs" like most three-wheel versions. Tractors that have served well and gained acceptance in other places may turn out to be technically unsuitable or out-of-date, non-competitive or otherwise inadequate or out-moded when they are "transplanted".

Costs and Prices

Low manufacturing costs are necessary for producing a competitively priced tractor - assuming the absence of protectionist measures that shield it from competition. Renius (1985) mentions the following factors as points of departure for reducing the cost of tractor manufacture in industrialized countries:

- rationalization of production (low labour costs)
- large series (low fixed costs)
- modular design (minimum number of individual parts)
- value analysis (minimal technical input)
- lightweight construction (low material costs)

For small tractors built in developing countries, the importance of some factors varies, and there are additional possibilities of cost reduction:

- Labour-intensive production methods are preferable to capital-intensive methods and usually on par with them with regard to economic criteria;
- Lightweight construction could be an unsuitable approach due to the possibly questionable quality of the available primary raw materials and the probably tough duty requirements.

Design simplification, including omission of functions is a recommended means of reducing production costs, but only to the extent that basic functions are not impaired (cf. Table 58). Even for small tractors, such basic functions normally call

for a hydraulic three-point lift, a power takeoff shaft and a transmission with an adequate number of speeds. The cost-reducing effect of numerous attempts to do away with some major components by opting for a three-wheel design has consistently been over-estimated, while the resultant limitations on such tractors' utility value have been underestimated.

The use of used parts in "new" tractors has caused more than one product to be dubbed a "junk tractor". Be that as it may, that practice does yield substantial savings. Tractors from Ayudhaya, Thailand, stand out as a good example of products comprising both new and overhauled parts. Frequently, reconditioned parts are erroneously referred to as "robust". The lower purchase price approximately corresponds to the parts shorter service life.

The potential advantages of buying and selling used tractors on a broader scale, however, are seen in a more positive light. Especially if the tractor has had a general overhaul, its various components can be expected to have more or less equal life expectancies. For a farm in a technological transition phase, e.g. when it is in the process of converting from animal power to tractor power, the reduced longevity of a used tractor has little if any limiting effect, since the tractor will hardly be used to capacity during the first few years, anyway. An assured supply of spare parts is just as important as for new tractors. Small tractors tend to gain little acceptance in rain-fed farming regions where ample numbers of used large tractors are available.

The use of mass-produced parts from the motor vehicle and tractor industry is viewed by many as a magic formula for reducing the cost of production. Indeed, even old-established tractor manufacturers buy cogwheels, gaskets, filters, V-belts, fuel systems, electric systems and even complete engines, transmissions and axles from specialized suppliers. Since the cost-cutting effects of mass production are already being exploited, new products like small tractors can hardly be competitive unless they too utilize such parts. Wholesale prices are only available to wholesale buyers, of course. If components are bought singly or in small numbers, the buyer must expect to pay spare-parts prices.

Production in the developing country instead of in the industrialized country of origin should help reduce the cost of manufacturer thanks to lower wages. On the other hand, that has not always been the case in practice, at least not from an economist's standpoint, namely when the cost of labour was over-estimated in comparison to the cost of materials. Because of the "double assembly costs", locally assembled tractors consisting of ckd/skd imports can initially be expected to cost 3-6% more than cbu imports. The use of locally available parts does not always have the effect of cutting costs. Frequently, such parts are imported for no particular purpose and therefore sold exclusively at "spare-parts

prices". The breakthrough depends on indigenous production of essential components.

In 1985/86 the World Bank had 16 developing countries compared with regard to how they price and market agricultural tractors. Table 60 surveys the tractor prices being asked in those countries and states them both in absolute terms and as grain-equivalent units. The tractor in question was chosen as a typical representative of the 60-65 hp category, and the prices are based on the currency exchange rate applicable to the importing of tractors. In the autumn of 1985, the least expensive tractors, costing about US\$ 130 per hp, were to be found in Turkey and Pakistan, while those being offered in Equatorial Africa were the most expensive (more than US\$ 300 per hp).

The order or priority in the first column of Table 60 is totally different, if the selling price per horse power is related to the prices that the farmers get for their products. Measured in "grain-equivalent units", the cheapest tractors are found in Korea, where a 47 hp tractor goes for 16 tons of rice. By contrast, an Egyptian farmer would have to pay 89 tons of rice for a 65 hp tractor, which amounts to about four times the horsepower-specific price paid by the Korean farmer. The difference is chiefly attributable to state-controlled producer prices for rice and wheat, which are well above the world price in Korea, but well below it in Egypt. This makes no account of differences in the cost of producing rice (substantially higher in Korea).

In the course of its service life, the typical agricultural tractor in an industrialized country needs repairs and spare parts costing between 1 and 1.5 times as much as its original purchase price. In developing countries, the factor is more like 2.5. Though most tractors come with a package of spare parts and fast-moving parts corresponding to about 10% of their value, they are often inadequate with regard to type and extent. A relevant study conducted by the World Bank (Agrisystems (1986)) sharply criticizes the international tendering approach as the "worst possible solution for the end user". Tendering keeps manufacturers from building up a permanent spare-parts and repair services organization. Short-term advantages (cheapest offer) are soon eaten up by long-term drawbacks like inadequate spare-parts supply. In that connection, the bilateral and multilateral organizations concerned with international cooperation stand accused of short-sightedness: as soon as a project with a "tractor-supply component" has been completed, the supply of spare parts usually dries up.

Conclusions

- a) Practically all conceivable designs for mobile, fieldgoing prime movers with 2, 3 or more wheels and answering the description of a "small tractor" have

already been tried out. Investing more effort into new small-tractor designs would appear to make little sense.

- b) Small tractors have gained acceptance where they offer advantages in day-to-day use - not necessarily in manufacturing and marketing - in comparison with other sources of energy and/or traction. The production techniques, local working conditions and, above all, the price prove to be the decisive factors. Small tractors lose their price advantage wherever there is a "second-hand tractor market" and large tractors are technically suitable. The economic equivalence of large, second-hand tractors and new small tractors underlines the fact that the latter are not what is needed for effecting the economically appropriate mechanization of small-to-tiny individual farms. Small tractors and second-hand tractors can help small farms get tractorized (four-wheel type) more easily than they could with a new 40-50 kW "standard tractor". In rain-fed farming, small tractors supplement large ones and can have a quite useful farm development function.
- c) Any farmer buying his first small tractor should own or have access to enough suitable land and already have been practising in the intensive, "large-scale" production of cash crops. Small-tractor programs and other mechanization programs are usually quite similar, both in their objectives and their implementation.
- d) The production of agricultural tractors does not always start with "small ones", but depends on the size category with the demand. Consequently, domestic tractor producers certainly need not begin with a small tractor. Nor should any project be based on the assumption that demand could or should be stimulated merely by putting tractors within the buyers' reach. The planning that goes into the establishment of local manufacture should allow for, among other things, the fact that more foreign currency will be required during the first seven to ten years than would be necessary to merely pay for imports. That at first seemingly contradictory observation is rooted in the need to continue importing while still spending extra money on research, development and the requisite production facilities.
- e) Points of departure for economic cooperation projects include the establishment of the requisite marketing infrastructure, followed by establishment of the necessary production and engineering capacities. Unless the overriding objective is to increase the percentage of local manufacture, assembling tractors from imported parts would have very limited positive effects; the contribution toward cost reduction and the establishment of local capacities is usually over estimated.

- f) In the past, the actual agricultural users of small tractors - a farm-size category defined more by income than by acreage - have rarely been explicitly named as the target group of projects concerning either financial or technical cooperation. In some countries or regions, that group may account for a relatively small share of the total number of farms, but there are millions of them in the Third World per se, and they therefore possess a considerable developmental potential. What they are not is small farmers: Small farmers can only be reached by a combination of administrative and organizational measures, e.g. multi-farm use of agricultural machinery, in addition to such project approaches as those defined above - not by churning out new prototypes.

TABLE 58

Table 58: Technical Data for a Selection of Four Wheel Tractors up to 26 kW

No.	Make/Model	Cat.	Power kW	Gears f/r	Speeds max km/hr	Tyres front	Tyres rear	Track min mm	Track max mm	Wheel base mm	Static weight kg	Hydraulic lift daN	Power-to weight ratio kg/kW
1	AGRALE 4100	1	11	7/3	13.2	4.00x15	8.00x24	-	1100	1205	1100	330	100
2	AYUDHAYA UTAMCO	1	10	4/1	35	5.60x13	9.00x20	-	1400	800	500	500	80
3	AYUDHAYA AT 1800	1	11	2/1	28	5.50x13	9.00x20	-	1140	1495	1000	-	91
4	BASAK. 17	1	12	4/1	15.7	4.400x12	7.00x18	-	-	-	800	-	67
5	EICHER CHANDI	1	10	6/1	26	5.50x16	11.2/10x28	1275	1461	-	1445	h	145
6	EICHER GOODEARTH	1	18	8/2	23.6	5.50x16	11.2/10x28	1270	1420	1844	1650	h	92
7	EICHER GOLD	1	26	8/2	25.2	6.00x16	12.4/11x28	1278	1432	1946	1805	h	69
8	SWARAJ 720	1	11	6/2	25.5	5.50x16	11.2/10x28	1200	1470	-	1250	800	114
9	SWARAJ 724	1	16	6/2	-	5.50x16	11.2/10x28	1300	1900	-	1780	1000	111
10	SWARAJ 735	1	24	8/2	30	6.00x16	12.4/11x28	1300	1900	-	1925	1000	30
11	DONG FANG HONG	1	11	8/2	23.8	4.00x12	7/30x16	-	960	1400	950	420	86
12	FENG SHOU	1	13	8/2	23/7	4.00x14	8.3/8x20	-	1000	1400	880	h	68
13	SN 25	1	18	-	21.2	-	-	1000	1400	1550	1120	650	62
14	LEYLAND 184	1	22	9/3	-	5.50x16	11.00x24	1120	1830	1715	1360	1300	62
15	FARMKING	2	17	3/1	21.3	6.00x16	11.2x24	1220	1930	1780	1185	h	70
16	DEUTZ DE 3607	2	22	8/2	27.2	7.00x28	11.2/10x28	1130	1520	1800	1560	1900	71
17	SELF HELP	2	9	6/2	-	4.00x12	8.00x16	-	-	1370	517	-	57
18	AGRO UTIL	2	13	4/1	-	4.00x12	8.3x24	1016	1372	1575	693	-	53
19	BUFFALO	2	13	hydr	12	-	-	-	-	1676	715	h	55
20	GOLDINI	2	13	6/3	21.6	5.00x15	9.5x20	-	-	1500	820	-	63
21	GUTBROD	2	16	4/1	-	4.00x12	7.5x15	795	1120	-	610	h	38
22	HOWARD	2	5	4/2	9.1	-	-	700	900	-	480	-	96
23	KABANYOLO	2	10	6/2	29.2	4.00x12	7.00x16	-	1230	1410	525	-	53

cat. = category

TABLE 58 Continued

No.	Make/Model	Cat.	Power kW	Gears f/r	Speeds max km/hr	Tyres front	Tyres rear	Track min mm	Track max mm	Wheel base mm	Static weight kg	Hydraulic lift daN	Power-to weight ratio kg/kW
24	RENAULT	2	11	4/2	16	4.00x10	6.00x16	-	810	-	480	-	44
25	AMEX	2	16	4/1	20.1	4.00x15	7.50x16	-	1040	1520	454	250	28
26	BOUYER	2	18	6/3	22.2	5.00x15	9.50x24	1430	1600	-	1120	-	62
27	CFDT	1	23	6/3	10.9	5.00x15	9.50x24	1430	1600	-	1120	-	49
28	AGRITOM P.D.26	2	19	8/2	18	5.00x15	9.50x24	-	1350	1800	1160	h	61
29	TINKABI T. 172	2	12	hydr	12	5.00x15	6.00x14	-	1800	2100	1050	h	88
30	MULTITRAC 2502	2	24	4/1	13.2	4.50x16	9.50x25	-	1390	2100	1260	650	53
31	LISTER PICO	2	25	6/1	22.7	6.50x16	11.2/10x24	-	1524	2300	1740	1195	70
32	CENTAUR	2	9	3/1	16.1	6.00x16	9.50x24	-	1370	1830	1064	160	118
33	ENFI	1	19	hydr	16	7.00x12	9.50x24	1350	1650	-	1050	800	55
34	TUFFBILT	2	17	h+3	9.5	4.80x12	8.3/8x24	914	1830	1830	680	318	40
35	AFCOM	2	11	4/1	13	6.00x16	7.50x18	-	1600	1750	870	h	79
36	MOUZON SATEC	2	9	V+5	13.3	5.00x10	7.50x18	1300	1700	-	920	h	102
37	AGROSTAR	2	12	4/2	20	3.00x12	8.3/8x24	1180	1680	-	1000	h	83
38	FARMBOY	2	10	-	18	5.00x13	9.5/9x24	-	-	-	1040	-	104
39	NIAE MONOWHEEL	2	8	2/1	12	5.00x16	8.00x24	-	1520	1676	825	-	103
40	POYNTER TRIPLE	2	9	2/2	10.4	6.00x16	11x24	1524	1930	-	585	-	65
41	ZUGM. WAGEHIGEN	2	5	2/0	10	4.00x12	6.00x16	-	-	-	379	h	76
42	ROKON	2	7	V+3	65	6.70x15	6.70x15	-	-	-	84	-	12
43	PANGOLIN	2	11	4/1	14	7.00x16	7.00x16	-	1000	700	600	-	55
44	JAC/DUADRACTOR	2	6	3/1	-	6.50x15	6.50x15	1219	1524	-	408	-	53
45	SPIDER	2	5	-	24.7	5.00x15	7.50x16	-	1500	1800	710	-	142

Cat. = category 1 = series products 2 = prototype or discontinued series h = hydraulic syst. with unknown lifting power.

TABLE 59: Potential Means of Cutting Production Costs

<i>Omit</i>	<i>in favour of</i>
- electric system incl. battery and starter	starting by hand or spring-loaded starter
- hydraulic system	lifting the implements by hand or using only trailer-type (drawn) implements
- power takeoff shaft	belt pulley (very limited option, only possible in combination with a flywheel)
<i>Simplify</i>	<i>by</i>
- hydraulic system	opting for no hydraulic control
- transmission	making do with fewer speeds
- electric system	opting for lighting only
- power takeoff shaft	limiting it to a single stub/speed
- disc clutch	opting for a pulley clutch (also easier to install)

TABLE 60: Tractor Prices in Selected Developing Countries

Country	Retail Price US\$ per hp	Rice equivalent	Maize per tonne	Wheat hp
Turkey	130	0.45	1.21	1.03
Pakistan	136	0.85	-	1.30
Morocco	149	-	0.74	0.88
Brazil	176	0.91	1.71	0.93
India	177	0.76	1.41	0.98
Thailand	181	1.76	1.97	-
Malaysia	192	0.86	-	-
Indonesia	198	1.25	1.93	-
Sudan	200	-	-	-
Mexico	212	1.66	1.50	1.85
Egypt	212	1.37	1.92	2.65
Kenya	249	-	2.28	1.58
Korea	281	0.34	0.61	0.70
Nigeria	302	0.57	1.09	0.82
Cameroon	308	0.85	2.13	-
Tanzania	317	-	1.03	-

Source: IBRD (1987)

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