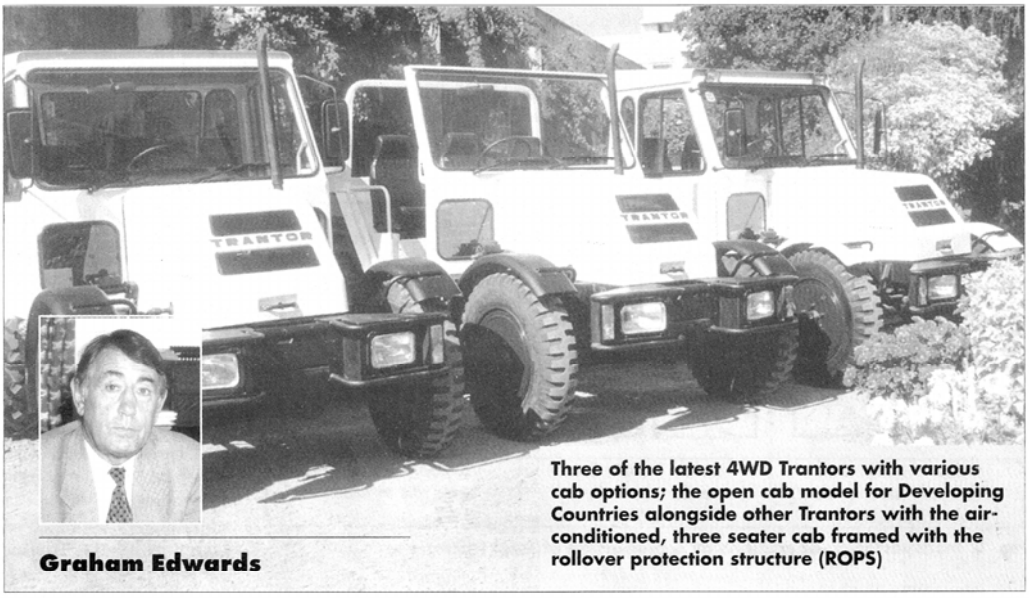

Three of the latest 4WD Trantors with various cab options; the open cab model for Developing Countries alongside other Trantors with the air-conditioned, three seater cab framed with the rollover protection structure (ROPS)

Graham Edwards

From conventional 'ploughing-first' tractors to 'transport-first' Trantors – two decades of radical design

Graham Edwards MSc was the Director of the Cell Manufacturing System Research Group at UMIST, Manchester, and visiting Professor of Manufacturing Systems at INSEAD, France, when he and one of his research students set up their company to create, design and develop a new kind of tractor. Stuart Taylor's SERC funded statistical study of the use of tractors on large UK farms indicated the need for a tractor that placed transport above ploughing in its design. Twenty seven years later, the development continues and Graham explains the reasoning that follows from 'statistics' to 'trailers, speed, linkage and p.t.o. work' - not from 'ploughing first' with its heavy, slow, drawbar pull connotations.

In recent years, the company has moved its focus from the relatively small UK tractor market to the large markets of India, Turkey, USA and Eastern Europe and have adopted an approach which accentuates transfer of technology and manufacturing under licence in countries with great potential.

A new model range is being shown to Trantor's loyal band of 350 plus UK customers this summer and the company is making a gift of shares (one for each year of Trantor ownership) to commemorate 25 years of British tractor development at a time when most British-owned tractor firms have folded, merged or been taken over.

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Introduction

At Manchester, UK, in 1972, some research indicated that farm tractors designed for ploughing at up to 10 km/h were mainly used for transport at up to 32 km/h. Some years later, statistics from Madras, India and Yemen (Middle East) seemed to show that the Manchester findings were more significant when viewed from a worldwide perspective.

The amount of transportation differs from country to country, region to region and farm to farm as the chart (*Fig. 1*) shows. Of course, companies, such as John Deere and New Holland cannot easily accept such radical findings because they make massive R&D investments in the status quo. It is, however, a fact that the sale of 'ploughing tractors' for transport work has been part of the sales pitch of the majors for many years.

Indeed, it is the sugar estates that show best how New Holland-Ford (NH) and John Deere have been providing tractors of a very sub-optimal kind and causing sugar estates to use more fossil-fuels (about 10%-30% more) than necessary.

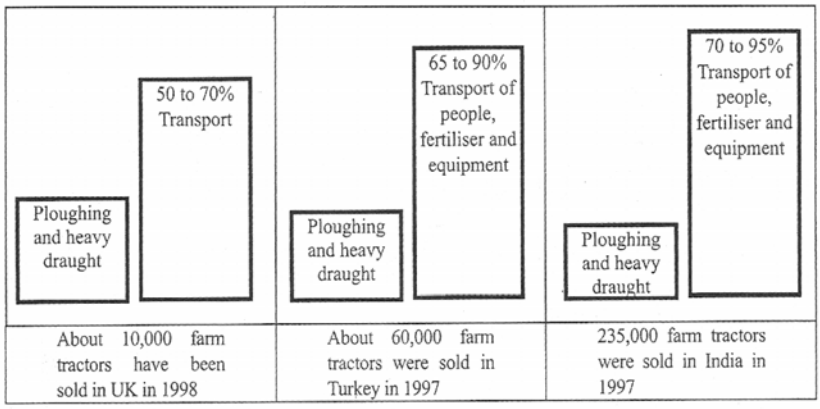

Fig. 1 Transportation operations as a proportion of total tractor use

Design specifications – the sugar industry

Tate and Lyle are well known in the sugar industry, in which India is the world's largest producer. Outside India, they invariably request that tractor manufacturers provide a special and different specification of tractors (designed on the 'ploughing-first' principle) for their transport work. Appendix I shows a typical specification for an 80 kW sugar cane transport tractor which requires that the manufacturer to take some things off and put some things on the conventional 'plougher'! (Note: p.t.o. blanked off; no brakes on front tractor wheels; hydraulics removed; and front weights requested to hold the front of the ploughing tractor down and to increase, not decrease, fuel consumption!)

Whilst the majors, such as John Deere, NH and Agco-MF, have moved on in recent years and added one higher gear to increase speed a little, they have not gone far enough and still not placed a braking system of truck standard (with front wheel brakes and compressor) on to their tractors and their trailers. Ford (NH) dealers in South Africa, however, have pointed the way to the manufacturer who has taken little notice. The publication, Sugar Cane Agriculture (1985) reports work conducted on the large C G Smith Sugar Estates: 'During the process of selecting a suitable haulage (transport) tractor, the inadequacies of the standard gearbox ratios became evident. They were overcome by fitting a 12 speed gearbox with improved ratios'. It is reported that the new gearbox gave a 7.9% improvement in fuel efficiency and a 20.9% improvement in tonnes moved per hour.

New and different tractors

Whilst the Intrac and the MB Trac are the two most well-known different kinds of farm tractor in Europe, neither of them can be properly defined as a transport tractor. The Bell Hauler, designed and made in South Africa, however, can be termed a transport tractor and has been extensively used as such on sugar estates and in mines. The South African Sugar Association Experimental Station stated in their report 'Comparison of Sugar Cane Haulage Tractors' (February 1984): 'The Bell 1756 Hauler with 118 kW engine power provides the cheapest way of hauling 24 t of sugar cane over 20 km if the crop can be handled by one unit'. The Bell Hauler is clearly a development from the 'ploughing tractor' and is rugged, tough and somewhat primitive, by European standards, from the driver's point of view. It has been widely accepted by sugar, timber, construction and mining companies in recent years in a transport role.

Another development, designed primarily for transport, is a British design called the Trantor - TRANsport TracTOR. This comparatively new development has a revolutionary approach to design as all the Trantor tractors have their own chassis, their own design of transmission, a unique three seater cab and three suspension systems for front axle, rear axle and hitch plus linkage. Braking on all wheels is standard, as is the fitment of a compressor to give air support to all wheels and to the trailer.

The Trantor Series 2 tractor pulling the 4 t Trukspec trailer loaded with 14 t of topsoil. The whole combination travels at 65 km/h

'Transport-first' tractor developments in the UK

In the UK, the Trantor transport tractor developments began with the belief that the Land Rover and farm tractor could be combined into one vehicle. Two early prototypes were driven at over 100 km/h for suspension, tyre and braking 'trials'. (The April 1978 Power Farming article

by Norman Lucas introduced readers to these early developments). The Trantor was thought by some to be an attempt to produce a British Unimog for British farmers. This was not the case, because the Unimog, like the MB Trac, was not designed for unbalanced trailers, as anyone placing a heavy, laden, unbalanced trailer, with lots of weight on the drawbar, on a Unimog will know. The most significant difference between the Trantor and the Unimog, as far as transport is concerned, is the unique suspended Trantor hitch and the position of the hook on the tractor *i.e.* near to the driver and under the rear axle!

The Trantor has been developed over 20 years: it has become slower and more like a conventional tractor with an excellent p.t.o.; and it has retained its low weight, all round suspension and air assisted brakes. It is a 'transport-first' tractor and not a 'ploughing-first' tractor. Whereas Henry Ford found '1700 other than ploughing duties', for farm tractors, the Trantor design team searched for '1700 other than transport jobs' for their tractor and steadily developed the Trantor product range to encompass more of them and so conduct more farming work.

The design approach to the Trantor 'transport-first' tractor development, was launched from a different starting point. Whilst Mercedes Benz has moved from a 'short 4WD truck' (Unimog) to a 'systems tractor' (MB Trac), MF, John Deere and New Holland have hardly moved from the basic 'plougher' but have added some minor haulage improvements. The Trantor was developed from the prototype (1973), which looked like a Land Rover with big rear wheels, through Series 1 Trantors (1980) as a 'road haulage tractor' with limited field work capability, to the series 2 'high speed, light fieldwork tractor' with excellent p.t.o. and 4WD!

The prototype 41 kW Trantor at harvest time in 1973; designed to pull a bigger trailer than a Land Rover but travel at Land Rover road speeds

Future possibilities for ploughing tractor development

Whilst the developments of ploughing tractors for transport work continue, they are now close to the limit of their possibilities. Future improvements are likely to be associated with three different developments *i.e.* transmission, brakes and suspension.

Transmission

The German based tractor companies have transmission options which increase the road speed of their farm tractors (at the maximum engine speed of about 2,000 rev/min) from 32 km/h to 40 km/h. Fendt, Deutz and MB Trac publicity and 'informed comment' indicates that each company is conscious of the need for higher road speeds and of each other. Transport is considered sufficiently important in Germany for each manufacturer to observe: 'Our road performance, if you choose our options carefully, is much the same as other German farm tractors'. The transmission work in South Africa by MF (Fedmech) and Armstrong Motors (Natal) with Ford transmissions and Perkins Engines, indicated that the speed was increased from about 32 km/h maximum speed to about 37 km/h. All the German tractor firms offer an option giving 40 km/h and legislation may soon be introduced in Europe to create 50 km/h and 80 km/h tractor speeds.

Brakes

The braking systems on tractors seem to be on the point of some kind of change. In France and Germany, 'air over hydraulic' is becoming more and more common as trailer loads on big farms have increased. The 'Natal Fords' are similar to this but the air seems only to be added for the braking of the rear tractor wheels and all those of the trailer. Whilst the Scottish Institute of Agricultural Engineering (SIAE) produced a considerable amount of work dealing with tractor stability of hills, they were unable or unwilling (!) to consider the significance of front wheel braking and trailer braking on hills; whereas in South African studies, greater emphasis was given to tractor and trailer braking on hills.

Suspension

Whilst there can be no doubt that suspension is an important element in farm haulage systems, any suspension that has been adopted has usually been placed on the trailer and not upon conventional 'ploughing tractors'. Renault tractors of France (1996) announced the placing of suspension under their cabs and spent £1.8m on it! Mercedes Benz, set the pace in 1975, by introducing a front suspension on to all of their MB Trac models and Fendt has followed this on some more conventional tractor models. MB Trac users in the UK have reported that this product is worth the extra cost, over conventional non-suspended ploughers, because of its comfort. Most German tractor trailer photographs show balanced trailers rather than the unbalanced ones used in France, Britain and other EEC countries. The balanced trailer is much less manoeuvrable but does not suffer from the 'drawbar bounce problem', associated with the British type of unbalanced trailer. Ploughing centred tractor designs suffer badly from 'drawbar bounce' and front end weights, which should be unnecessary for transport work (to keep fuel costs lower) are often added to compensate!

Table 1 Examples of transport activities

Task	*Operation*
1	'Ploughing tractor' carries plough to field and ploughs the furrow
2	'Ploughing tractor' carries sub-soiler to field and soil engages
3	'Ploughing tractor' carries power harrows to field and prepares seedbed
4	'Ploughing tractor' carries Dynadrive to field and works in ground;
5	'Ploughing tractor' carries seed to field and carefully drills
6	'Ploughing tractor' carries spray tank from farm to field and sprays
7	'Ploughing tractor' pulls slurry tanker to field and spreads
8	'Ploughing tractor' transports fertiliser to field and carefully spreads
9	(A) 'Ploughing tractor' bales hay; (B) another 'plougher' tows the flat-bed trailer
10	(A) 'Ploughing tractor' cuts grass; (B) another 'plougher' tows the silage trailers

The roles of transport tractors on European farms

The designers of 'transport-first' tractors needed to adopt a careful, studious approach and had to recognise the important differences of user (type of farm, different crops, size of unit, *etc.*), different tractor use profiles (how much time is spent on which tasks), as well as the technical features required (and not required) for each farm task.

In the case of a sugar transport specification (Appendix I), the transport tractor is clearly 'nothing but a transport tractor'. In Britain, the large Holbeach Farm Potato Co-operative (14 farms) and the Shrewsbury-based potato growing and merchant organisation, Scott-Newman, both have work profiles sufficient to find lots of work for transport tractors and both have used 'transport-first' tractors with at least two trailers per tractor. These organisations also use 'ploughing-first' tractors and, like the South African sugar estates, choose a 'horses for courses' buying and using strategy.

How is the 'transport' role defined?

The essential problem is: What actually constitutes transport? Since the reader must judge, it seems reasonable to take a few examples (Table 1).

In the first case of ploughing in task (1) of Table 1, depending on the size of farm (distance between plough store and field to be ploughed), the 12 hour working day of the farmer is probably 90% concerned with ploughing and 10% with transporting himself, to and from refreshment, and his plough to field and store. The ploughing job is slow and so are the tasks for sub-soiling and deep Shakerating in task (2), power harrowing in task (3), and Dynadrive work in task (4); and in all cases, the transport work is substantially less than the slower field work.

Sub-soiling and other heavy soil-engaging tasks have much the same transport to fieldwork time relationship. For drilling in task (5), the work in the field can be conducted at higher speeds (compared to ploughing) and is a precision task. The hoppers have the nasty habit of emptying; and hence the drill has to return to the seed storage point to be re-filled. Rich farmers might have another 'ploughing tractor', or fork lift truck at the ready with a seed hopper or trailer to fill the seed drill.

For spraying in task (6), slurry spreading in task (7), and fertiliser spreading in task (8), the work profile, as to the relationship between transport and fieldwork, moves more and more towards transport. The 'ploughing tractor' driver may ask himself if he is spending as much time in the field as he is out.

In tasks (9) and (10), the need is for the tractors on the transport duty to keep up with the harvester. As the technology improves, the combine, grass cutter and baler produce more output per hour. The 'ploughing tractors' on transportation, have to keep up with the increased performance. They cannot go quickly. They are not safe enough, nor can the driver hold the unsuspended tractor on field or track at speed. There is only one conclusion on most farms. Use another, slow, 'ploughing-first' tractor in the transport role! This means another person, and another tractor and *none* of the tractors are designed for efficient transportation!

Spraying - is this fieldwork or transportation?

It is clear that spraying has become a highly specialised activity and there are few who will not have noticed that the MB Trac is often used for spraying and is very frequently used by contractors, the CSC of Scotland using over 30 such machines. Another trend in the UK has been for lower ground pressure (LGP) vehicles to be used for spraying, largely because the heavy 'ploughing-first' tractors damage the ground. In the USA, the farming pick-up truck is frequently used. Whilst these developments are modern, they do seem to demonstrate some kind of strange logic when considered together.

A 2WD Trantor Series 2, 72 kW, working with a Lely power harrow on a Yorkshire farm

Firstly, the MB Trac is quite a heavy tractor and has to be so, to be as good at ploughing as it undoubtedly is. It is used because it can be made heavier still by adding a massive 2000 litre spray tank. With tank and booms, the complete rig becomes even heavier than most conventional 'ploughing tractors' with their tanks. The soil is thus more easily damaged by compaction.

Pick-up trucks and LGP vehicles are light and fast. They are faster than tractors because they have road transport

transmissions and sometimes have some form of suspension on the axles, or between the tank and the vehicle. This allows them to cover more ground more quickly. The MB Trac has some suspension too, but it sprays at normal, slow, 'ploughing tractor' speeds and it is certainly a slow, heavyweight tractor.

The design characteristics of pick-up trucks (LGP vehicles) and MB Trac, both of which are very popular for spraying, could hardly be more different. Why are they both so popular? The MB Trac is used because it can carry more weight (on its platform) than conventional ploughing tractors, even though it is too slow and too heavy when compared to the LGP vehicles! The LGP vehicles are used because they are fast, suspended and light.

Some tractor design illogicalities

In Table 1, there are 10 examples of tractor and transport work. Ploughing and sub-soiling in tasks (1) and (2)) require characteristics from the tractor that are epitomised by traction theory. The requirement is for big wheels, lots of weight and pulling power at a range of different but closely connected, slow speeds in the range 4 and 8 km/h.

Power harrowing in task (3) is p.t.o. driven and can be conducted efficiently with either a 'ploughing tractor' or a 'transport-first' tractor with live p.t.o. Whilst the transport tractor, if it had suspension on both axles, is slightly faster, it is only marginally so. Any substantial advantage is largely one of comfort in the field and on the road.

The Dynadrive for task (4) is ground driven and requires less traction than for ploughing and sub-soiling in tasks (1) and (2), but greater field speed gives improved performance 'through the ground' and breaks up the soil more. Should a well-designed 'transport-first' tractor be used for this duty, the performance could be as much as 30% better. The transport tractor would need suspension on both axles to achieve such a marked improvement.

Drilling in task (5) is similar to that for the Dynadrive in task (4) in that substantial traction may be required but the task can be conducted much more quickly if a 'transport-first' tractor is used rather than a 'ploughing-first' tractor. There is a substantial re-filling role which is also a transport task. Whilst comfort is a benefit from suspension, improved fuel efficiency may also result from the transport-focused transmission. The major benefit from a well-designed and fully suspended 'transport-first' tractor should be the increase in the out-of-field re-filling speed and the in-field operational speed.

Spraying in task (6) demands characteristics which are quite the opposite to those for ploughing in task (1), as explained earlier in the Spraying Section. Higher speed from water to field, a vast increase in speed and comfort in the field (of 100%!) and improved fuel consumption of 40% can be achieved by a well-designed transport tractor, with suspension affecting linkage, p.t.o. and platform, and used with a mounted or trailed sprayer.

Slurry spreading in task (7) focuses upon the mixed or livestock farm where the task is similar to that of the transport tractor on spraying and the traction performance may also be critical due to the need to spread on wet grass or hillsides. Whereas the specification of the sugar cane transport tractor in hot countries usually focuses on harvesting sugar cane when it is not raining, the slurry spreading task is likely to be conducted during inclement weather. A four-wheel drive 'transport-first' tractor should be ideal for this work. For many farmers, more than 50% of the time on this task is not in spreading but in transportation and re-filling! Using a transport tractor for slurry spreading can increase the efficiency of tractor, driver and tanker by over 40% as the work study, conducted under Percy Moss of Severn Trent Water Authority, in UK, shows.

Fertiliser spreading in task (8) calls for a fast, suspended, 'transport-first' tractor of light weight to skip over the soil, not to damage it, but capable of precision work and high accuracy. The transport tractor with light weight, suspended axles and live p.t.o. can do the trick at a greatly improved performance over slow, heavy 'ploughers'. The increased performance in the field can be as much as the 30% reported by the John Fleming Farms Company of Pagham, Sussex, UK. The out-of-field increased performance is close to 50% better.

Tasks (9B) and (10B) are support tasks to the harvesters. The tractors are used either to drive the harvester or to pull the trailers. With self-propelled harvesters, the tractor needs only to be a 'transport-first' tractor! When the tractor is operating the harvester, the power and efficiency of the p.t.o. is critical and so is the range of slow speeds on the tractor. Some 'ploughing tractors', such as Renault, are very good at the extremely slow speed necessary for particular carrot harvesters, as Tinsleys of Holbeach, UK know only too well! The technical requirements of slowness, heavy weight and p.t.o. power may be valuable characteristics when filling the trailer. They are not beneficial characteristics required to get from the field to the processing factory or the store!

The lighter weight 4WD Trantor 'transport-first' tractor just completing work in the field and returning to the water source at speeds far in excess of that possible with 'ploughing-first' tractors.

Summary

A marked distinction can be made between:

1. *heavy, slow,* unsuspended 'ploughing-first' tractors with

Table 2 Innovation in the farm tractor world

Tractor manufacturers	*World tractor market in power ranges, kW*						
	15-22	*23-30*	*31-50*	*51-70*	*71-100*	*101-120*	*121 +*
Main manufacturing countries India 260,000 per year, Germany 16,000 per year, Turkey 40,000 per year, Italy 45,000 per year, UK 50,000 per year, France 12,000 per year.	India China	India Turkey	India Turkey Serbia Russia Romania Belarus Japan	Italy UK France Germany Russia Serbia Romania Belarus	USA UK France Germany Finland Italy	USA UK Germany	USA
Main manufacturers of primitive tractors Little change or innovation is expected in these countries for 5 years (minimum innovation)	India China	India Turkey	India Turkey Serbia Russia	Russia Belarus Romania Serbia			
Main manufacturers of conventional 'ploughing-first' tractors with modern features (incremental innovation) Synchro, change on the move gearboxes, safety cabins, 40 km/h speeds, electronic draught control, Agco, NH, Deere, Same, Landini, Kubota, Renault		Japan Italy	Japan Italy	Italy UK France Germany	USA UK France Germany Finland Italy	USA UK Germany France	USA
Tractor manufacturers making unusual improvements to 'ploughing tractors' Cab suspension 40 km/h front axle suspension					Renault of France Fendt of Germany		
German designers Systems tractors considered to be future shape of farm tractors (1972-1999) (innovation and invention)				Intrac by Deutz Xylon by Fendt MB Trac by Mercedes Benz	Xerion by Claas		
The world's first fully suspended tractor British designer considers that the world of tractors needs a 'transport-first' tractor able to work more speedily on roads and in fields *e.g.* spreading, spraying (revolutionary invention)			Trantor prototype	Trantor Series 1 Trantor Series 2	Trantor Javelin		
Fully-suspended 'ploughing-first' tractors JCB Ltd picks up Trantor's fully suspended transport tractor ideas and develops the Fastrac range					Fastrac range of tractors produced in UK		

excellent independent p.t.o.'s and lots of low gears – the traditional 'ploughing tractor'; and

2. *lighter, faster*, suspended, 'transport-first' tractors with excellent independent p.t.o.'s, with some high road gears and some low field gears - new designs of 'transport-first' tractors.

No research and product development makes sense without determining who will buy new tractor types and where, in the market, these new product types will fit. In Table 2, taken from an unpublished article 'Innovation in The Farm Tractor World', the various new developments in farm tractors are placed in the context of the market segments in the world of tractors.

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