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MODERN CONVENTIONAL FARM TRACTOR AND AG-IMPLEMENT DESIGN IS CAUSING FOSSIL-FUEL WASTAGE, LOW PRODUCTIVITY OF LABOUR, LOW EFFICIENCY OF THE TRACTOR-FARM-IMPLEMENT COMBINATION AND DESTROYING SOILS, DUE TO COMPACTION.

Paper to the CIOSTA & CIGR Section V Conference, September, 2007 at Nitra University (Slovakia) by G.A.B. Edwards, M.Sc. F.I.Ag.Eng. F.I.Ag.Mgt. Trantor International Ltd.

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Attitudes in the Farm Machinery Industry

32 million drivers use their tractors every day and they are a significant polluter of the world's atmosphere, partly because of their average age (averaging 10-35 years) and partly because of their basic design. What is perhaps worse, however, is that modern tractor design (post 1970) has moved towards more pollution of the atmosphere, whilst also wasting massive quantities of fossil fuel. The design and market research teams at John Deere, Agco-Ferguson, Fiat-New Holland-Case, Landini-McCormick etc., are the main organisations to be blamed, as they have failed, over a period of a quarter of a century, to recognise, consider and use many of the facts available to their organisations, contained within magazines associated with farming and from the journals of professional institutions in agricultural engineering. (A list of references is available from TIL).

It is not that the world's main tractor manufacturers have not been fed the statistical data of farm tractor usage nor is it the absence of innovative tractor prototypes that, in principle. demonstrate excess diesel wastage and low driver productivity. It is rather that John Deere's tractor designers, along with most others have been stuck in a time-warp of tradition and conservatism with designers following their competitors, rather than leading with innovative ideas **(1).** Such lack of thought and depth of analysis partly results from the bureaucratic nature of Agco, Deere, Fiat and most of the "majors". They have operated centre-periphery systems where communications between the tractor users and the board of the tractor company is "disturbed" by organisational systems that diffuse innovation and demonstrate dynamic conservatism. These are not new patterns of big-company behaviour for they were well-explained in the 1970 Reith lectures for the BBC in U.K. **(2)**

The practices of conventional tractor managers, designers, market research managers, owners of distribution chains and many customers are now under fundamental re-examination because of the worldwide importance of energy conservation, the need for a much higher level of productivity of operators of tractor and implement combinations, and because of soil damage by compaction. The principal motivation comes from the need to preserve oil reserves but it needs to be understood that re-designing diesel engines for low-emission levels does not bring with it a reduction in diesel-fuel consumption – quite the reverse! At least as bad, is the absence of new

farm tractors that are fit for purpose! The modern tractor has many purposes and most of them are in transport, in p.t.o. work and in lower draft tasks. Customers, a journalist or two, as well as ManuFuture, EurAgEng and the Agricultural Engineering Industry Vision 2020 and Strategic Research Agenda (see www.manufuture.org and www.cordis.europa.eu) **(3)** have begun to express concern about the 'far too heavy' gas-guzzling tractors used widely across Europe and elsewhere.

On Farm-Fuel Consumption

Some in the Farming World have noticed that John Deere (the world's tractor leaders) have 6810 and 6910 tractor models that perform at 4 miles per gallon, (one litre per kilometer approximately) carrying implements and pulling empty trailers to and from the fields. The recorded experience **(4)** of a U.K. company using 200 h.p. tractors to haul a 14 ton, partially filled trailer showed a 3.17 to 3.96 miles per gallon performance. Not only this, the time taken for the journey of 10.8 miles was 30 minutes, about twice as long as is necessary for genuine efficiency.

These 2006 findings can perhaps be best compared by the much earlier work study investigations of STWA (Severn Trent Water Authority) of U.K. that operated a carefully-selected number of farm tractors for the task of carrying and spreading cow-muck to sweeten the grass. The STWA work study (see the detailed calculations in the pdf brochure K from TIL) showed that the miles per gallon was greater than 8mpg when an unusual new concept of 80 hp, 2 WDrive Trantor tractor was used for pulling a 1200 gallon slurry tanker. The comparison was concerned with a conventional 80hp x 2 WDrive plougher of the conventional kind pulling a similar loaded tanker and with the same Perkins 4.236 engine in both tractors!

The conventional Perkins-driven ploughing tractor used for the comparison showed mpg figures comparable to those recorded by Farmers Weekly in 2007. In the STWA case, the load of 1200 gallons of slurry was followed by the returning empty load. In addition, over an 8 hour day (not like the farmer's 12-14 hour days!) the number of trips of 20 miles could be doubled using the unusual TRANsport-tracTOR (TRANTOR) concept. See Big Farm Management **(5)**

It can be seen that the progress of selecting tractors for the many time-consuming work tasks, **[6]** such as transportation of crops, implements, seeds, fertiliser etc., involves thought and careful analysis. The work could indeed take twice as much or half as much driver, tractor and implement/trailer time. It is clear too that using fuel at around one kilometre per litre (4 miles per gallon) is wasteful and expensive if the tractor user has the possibility of buying a different kind of tractor that can deliver over 8 miles per gallon and provide twice the speed over a 20 mile round trip!!

The problem is currently not yet one that can be solved by any tractor user going out to buy one of these unusual new kinds of tractor. That is a solution that will eventually materialise when the Research and Development of farm tractor and rural farm work vehicle manufacturers become orientated towards:-

(a) fossil-fuel minimisation, as measured by Kilometres/miles per litre/gallon.
(b) improving the productivity of the lighter farm work tasks that do NOT require (unlike ploughing and sub-soiling) massive tractor weight and massively heavy farm implements.

Irrational Focus-Group Based Market Research

When John Deere, Agco and Fiat-New-Holland-Case & others are working to understand what trends exist in the worldwide market place, it is insufficient to consider only "Focus Groups". Most farmer-focused opinion studies are well-structured to indicate some short term trends but they are notoriously poor when trying to determine long-term, worldwide trends. JCB Ltd., used focus-groups in 1985-6 with market research consultants when Mike Butler of JCB Ltd., was deciding what the Fastrac specification should be like. **(7)** The presence of a platform, like M.B. Trac, equal-wheels like County & the Ag.Unimog, all-round suspension like Trantor tractors, became the features that were in-built on the first dozen or so Fastrac prototypes. (see Case Study Annexure 1).

Focus groups can only record the views and opinions of those interviewed. If the focus-group member is informed and knowledgeable and if he has kept up to date by reading published R&D reports or knows of some new and valuable research data being collected, he becomes a most valuable member of his group. All too often the focus groups are composed of followers not leaders, of traditionalists not forward-thinkers and few have the access to facts collected in other countries on other farms with different crops, on different soil structures and where the farms are managed in a different way. Not only this, the farm systems models available for Europe consider in-field work only and have yet to be developed to embrace the "whole-time tractor and implement system". **(8)**

It is for these and other reasons that the Italian tractor market researchers at Fiat, the US-design engineers at John Deere and the distributors of Agco tractors in Turkey or the newly-emerging Indian tractor makers at PTL and Mahindra do not have (in their market research departments) what should be their basic 'bread and butter' that is - Tractor and Implement Work Task User Statistics illustrated in chart form in appendix 1 and comprehensively explained in the pdf brochures E and A from TIL on request.

These facts of daily farming life need to be conducted across the farming world and are ;-

- about the work of tractor and implement combinations, e.g. when, how long and the influence of new technology, e.g. Direct Drilling, on these combinations
- about regions where they hold market leadership
- about regions opening up to modern agriculture-systems such as China, Ukraine and Russia, to name just 3.

Without data collection related to tractor work task usage in country after country how can John Deere, Agco, Fiat or Claas know what the tractor and implement combinations the user needs most? Anything less than complete and detailed studies for key crops is surely not an option for thinking men responsible for designing tractor and implement combinations for the world's farmers.

Work Tasks, Tractors and Agricultural Implements.

In many regions of the world today tractor users rely upon the plough as their principal farm implement for primary cultivation. In consequence, farm tractor design has slavishly followed the needs of high drawbar pull and lots of draught. In about 65% of the world arid and dryland-agriculture is the norm. The plough has become a user-habit, because many dryland – based emerging countries follow wet-field (temperate) practices, without understanding their implication. Professional agricultural engineering is too often at a primitive level, in the knowledge base of farmers in food-producing countries and therefore, the plough (which removes the valuable moisture in the soil) is still used as if there was some "divine western ploughing law" for the universe. Ploughing in drylands clearly needs to cease.

The EC is largely a temperate zone and one of the innovations to improve the efficiency of Tillage-based cultivations results from the use of power-take-off (p.t.o) implements. Transmitting the engine power of tractors through the p.t.o (rather than through the tyres, which are prone to slippage in the wet fields) has been widely accepted by those tractor users that use the combination of tractor and p.t.o-driven implements of the Rotovator, Rototiller and power-harrow kind. The take up of these implements has fortunately been slow in countries like India. At the Central Institute of Agricultural Engineers (CIAE) India Gyanendra Singh, **(9 & 10)** states that less than 10% of p.t.o. usage is found in India. Currently there is a revolution taking place in Agriculture, due to the progressive realization that entering the soil deeply with ploughs, rotovators, power-harrows etc., is exactly what NOT to do. (see FAO publications on Conservation Agriculture). Trying to influence the vast Indian farming community (650 million farmers) to use, relevant to India, modern tractor and implement combinations has been a part of the work of CIAE. More recently, Zero-Tillage is being supported by the Indian government, through CASA, CSSRI and the Ministry of Agriculture.

Whilst some Euro Agricultural Engineers know that a mainly-p.t.o-using tractor is probably different in design to a ploughing and sub-soiling-only tractor, there are many multi-tractor users that use their different tractors either as “a main plougher” or as a “main secondary cultivation and p.t.o tractor”. Whereas self-propelled sprayers have begun to be built as specialist spraying machines the p.t.o-tractor has yet to materialise. In the case of tractors used with front loaders, the presence of telescopic handlers and rough-terrain fork-lift trucks demonstrate the same kind of specialisation as the self-propelled sprayer but so far, the pto-tractor or the mainly-pto tractor has not materialised. (Howard Rotovator of U.K. were thinking about this when taken over in the 70’s).

Innovation

In general, innovative tractor design in EC has been thought about and engineered in Germany (M.B. Trac, Intrac, Schluter, Xylon) and U.K. (Fastrac and Trantor **(11)** but in all cases, except one, the move toward “specialisation” (telehandlers and self-propelled-sprayers) has been rejected. In the six examples cited above, five of these companies have made the firm design-decision that their tractors must plough and sub-soil as well as conduct all of the 1200 other-than ploughing duties identified by Henry Ford so long ago. All six however have recognised the great importance and popularisation of the power-take-off (p.t.o.) and have included all of the significant p.t.o-applications within their design specification.

Direct Drilling and Zero-Tillage.

Whilst p.t.o. implements began to be accepted in earnest in the 70’s, it was in the 90’s that Direct Drilling and Conservation Agriculture (Direct-Seeding and Zero-Tillage +) became a topic of serious interest and practical case-proving.

Dragging the implements and using the p.t.o, are two options which separately and together should impinge upon and potentially begin to change tractor design, either in the direction of:-

(i) the p.t.o-focused new kinds of tractor
(ii) the old-fashioned do-it-all, heavy ploughing-first, wheeled tractors or the
(iii) low-ground pressure rubber-tracked crawler.
(iv) The Zero-Tillage, p.t.o and transport-focused, high-speed tractor.

This author believes, for example, that the modern farm tractor has become a special-purpose ploughing and heavy cultivation tractor and definitely not a general-purpose farm machine!

Whilst the design and development of new kinds of implements such as a small, light weight Shakerator and the forward-motion-based, higher speed soil engagement Low Draught Direct Drills (of Dale Drills in U.K) or the cross-slot drills from Baker in New Zealand, for example should clearly be a part of new tractor and implement combinations in the new Ecological Paradigm of Conservation Agriculture. Currently, however, it is more important to determine, in each country of the world, under each crop type, in each region and on each farm – what is it that absorbs most tractor, operator, implement time and for how long do these seasonal tasks take? (pdf Brochure E Work Task Analysis (WTA) outlines this approach).

Appendix 1 is a composite example from the reality in Europe and shows the importance of the implements and tractor work-task-timing and the season in which the task is normally done. These figures have been collected from 1971 onwards and provide a general guide to actual practices. The wide agricultural implement range of the Kverneland Group, which markets Taarup, Vicon, Accord and other leading brand names, shows, from the work of George Randles, its U.K director, (now Ag. Tech, at Helsby), that this analytical concept makes sense to all farm machinery manufacturers.

It was, however, the late David Crolla **(12)** in his Hokaido paper, that viewed the world farmer’s future by recommending the need for ONLY 2 different tractor concepts. His ride and vibration work **(13)** explains the background to his views in respect of higher speed transport work.

Whilst change is clearly implied, when Appendix 1 is used with Crolla's papers, this WTA seems to have escaped the notice of the leaders of the farm machinery industry worldwide and farmers in general.

Today's Reality – Too Heavy and Too Slow.

In India, as many as 250,000 tractors have been bought and used in one year. Nearly all tractors are below 65 hp and all are 2 WDrive and have no cabs. Whilst fuel consumption is a very important consideration to the industry and to the customers, the labour productivity of drivers and their tractors and equipment is not at all generally significant. Because the Indian farm-implement sector was restricted, (by government decree), to the small-scale-village sector, and was only recently de-regulated, the quality and design of farm implements is very poor and unrelated to modern practices of the outside world. This is currently changing quite quickly, however.

Contrast this market and design engineering situation with that of EC where most tractors sold are 4 WDrive, all have ROPS cabin availability and, unlike the old-fashioned Indian tractors have a power to weight ratio that is certainly deliberate but actually increases the volume of fuel used. Whereas in India the tractor fuel cost is roughly equivalent to that in EC, the labour cost of drivers in India is very low indeed and hardly a consideration in respect of productivity. In EC, it is the labour cost that dominates the thinking process and labour productivity is seen as important alongside heavy tractor weight and lots of big engines of a low emission, high fuel-consumption kind! This results in the perception that bigger and wider implements are very important. Primary cultivation dominates the thinking process in most countries of the EC and fuel consumption and soil-compaction have, along with between-field transportation and in-field low draught work, **(14)** been given a very low priority by all tractor design teams.

These perceptions are very significant to the future of world farming and are influential factors in the design and selling of agricultural implements and farm tractors. John Deere have become the market leaders by following the focus-group approach, whilst hesitating to acknowledge intellectual thought, and scientific work task analysis. Contrast this with the Manufuture **(13)** and the FP7 'farm of tomorrow' notes of the EC's Agricultural Engineering perceptions of the future Working Programme (the Plan). Some of the issues raised in this paper are part of the innovation plan for Agricultural Engineering in the EC. In this document, tractor and implement efficiency (for 2020) may come from a wholly different approach, where energy-efficient tractor and implement combinations and labour and machinery productivity are key tasks. It is, however, also vital that such matters are considered, at the earliest time in the process of new tractor design and revised agricultural implement design.

This author believes that the new energy-efficient, highly productive farm tractors need to start with a clean sheet of paper, but to do so by a recognition of the significance of high horse power, rubber-tracked crawlers **(12)** and lower-weight transport-first tractors. **(14)**

Such a view and the EC plans for the future, require explanation. Professional agricultural engineers in particular want to influence the way forward by the holistic thinking processes that includes global-warming, fossil-fuel minimisation, higher productivity of labour, machinery and soil conservation by reducing soil compaction and total material and equipment flow analysis on existing and new types of farms where waste to energy and the growth of crops for fuel are introduced.

Weight

Wheeled tractors weighing 7 – 11 TONS and having 4 WDrive and good p.t.o's are much-used along with Crawler (rubber-tracked) tractors. They are reasonably efficient for ploughing and sub-soiling and the speed of operations of these tractors (which ought to be called specialised ploughing, sub-soiling and heavy draught tractors) is much the same as it always has been, since the speed involved with deep cultivation is between 1 and 12 kph (1 and 8mph). The logic of this kind of tractor for the slow task of plough-pulling etc. is very well established and is clearly sensible, practical and efficient, providing soil compaction is considered insignificant, in the case of

wheeled tractors and provided also that the farmer believes in and uses the ploughing system rather than Zero-Tillage/Conservation Agriculture.

The problem with these wheeled, low power-to-weight ratio ploughers is that they are designed for the specialised high-draught tasks but, as Appendix 1 shows, the main, time-consuming farm tractor and implement tasks are often not high-draught or need not be high-draught. Here, the task is to complete the work as quickly as possible and use as little fossil-fuel as possible.

Since conventional wheeled tractors are far too slow for most of the time-consuming tasks (because they are designed for these heavy and slow tasks), they are all about twice as heavy as they should be for the lower draught, transportation, spreading etc. tasks (shown in Appendix 1). Because tractors are too heavy and because the implements are also heavy they (out of the field!) use vast amounts of fuel at 3-4 miles per gallon, (1 to 1.5 kms per litre) whereas if they were designed differently and were more transport-p.t.o-low draught tasks-oriented they could save up to 40% of the energy/fossil fuel/diesel, depending on the tasks, as Appendix 1 shows.

A New Tractor Concept

Currently, there is no market awareness that a new kind or new concept of farm tractor **(15)** (lower-draught and lighter, faster duties) is at all required. The same is true for the p.t.o tractor. The majors have not looked at, or they have looked at and misunderstood (as the JCB Fastrac case study at Annexure 1 illustrates), or they have understood but decided that their future is elsewhere, (e.g. Xerion case study – as Annexure 2 illustrates).

It is, however, clear that the only pioneers of a new and different concept of farm tractor comes from Britain. **[16]** The concept has found many interesting customers to date and is called Trantor (TRANsport-tracTOR). Some of the 175 or so prototype photographs are illustrated later in this paper.

The origins of the Trantor tractor are in transportation and low-draught work tasks **(17)** and in recent years, the designers have made the decision to up-grade the product and "adjusted" the definition of their concept **(11).** Whilst some consider this concept now to be the general-purpose tractor of the new millennium, others prefer to call it either a transport-first tractor or a transport and p.t.o tractor **(18)** or a high-speed transport and low-draught tractor eminently suitable for ALL – Zero-Tillage Conservation Agriculture Work Tasks.

The company behind the project is a modest one but has invested about £200,000 per annum for over 25 years and created the designs, passed some OECD cab tests and produced a modular collection of designs and drawings that now form the complete supply-chain.

The current design and development focus is in widening the range **[19]** to encompass the higher average h.p. of tractors in use across the EC.

The project team have won innovation awards from the U.K. government (SMART 1 and 2) for their ideas and concepts and, with U.K. government assistance have begun to extend their R&D towards the changing face of worldwide farming.

Tractors have been Designed with Insufficient Thought for Energy Conservation and Productivity

80% of the farm tractors (in 1979) sold in U.K. were 2 WDrive but in the period from 1979 to 1989 the picture changed so that 80% of all new tractors sold were 4 WDrive (Appendix 2). The average h.p. of tractors sold in U.K. in 1973 was 60 h.p. and this rose to 100 h.p by 1993 (Appendix 3) and 126 h.p. in 2006. It has risen to around 150 h.p. in 2012.

In the 50's cabin protection from the weather was perceived as relevant but it was not until 1970 (September) that it became legally essential to have a safety cabin on a tractor in U.K. It was in 1976 that noise control became a serious legal consideration.

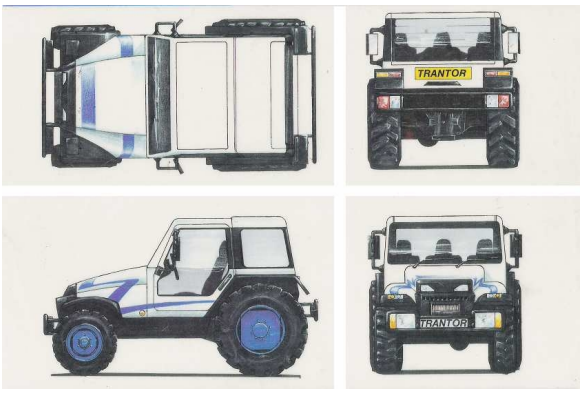
In September 1977, the safety and noise controlled cabins came into being. Whilst customers complained of the increase in price (sometimes doubling), the weight added by the ROPS cabin, the 4 WDrive and the increased h.p. was hardly, if ever, mentioned or, for that matter considered properly, due largely to the fact that diesel fuel was then low in cost.

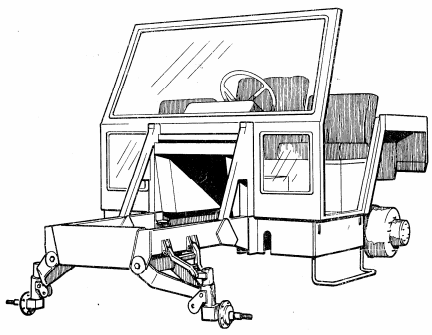
A more recent example relating to the stage by stage improvement of farm tractors has been the addition of more and more gears, more and more hydraulics, heavier and more powerful linkage, the presence and importance of front weights (due to 4 WDrive) and in some cases, like M.B. Trac, Fastrac and Xylon, the requirement to have a big platform to carry more weight. What has crept up on Agricultural Engineers is added weight and, in too many cases an ignorance of the fact that added weight is exactly the opposite of what is needed. It can be seen too, in the paper **(20)** that German innovators and researchers have been pre-occupied by carrying weight rather than hauling it. **(21)**

Conclusion

The professionals in the field of Agricultural Engineering have been working with many tractor and implement manufacturers and designing and developing equipment perceived by customers and market analysts as that which their customers need. All of a sudden global warming and the need for fossil-fuel reduction, and the future availability of alternative fuels has hit the hearts and minds of everyone. The Agricultural Engineering profession in Europe is the world's leader and, within this profession, the realisation of the importance of global warming and fossil-fuel usage has reached a point of understanding that "something must be done" and, unlike some other professions, we, the Agricultural Engineers require to lead, not follow. Also, the recent waterlogged fields of EC have emphasised the relevance of soil-compaction and the crop yield reduction it often causes. Too much weight is a vital matter in soil conservation and soil management and the reduction in compaction. After some years of pioneering a new farm tractor concept, more recent publications are now reporting on the wider significance of this new tractor concept for EC farms **(22)** but also the relevance to the changing and developing world **(23 & 24).**

This author (from Britain) has some experience of the Empire, Commonwealth and third-world farming and appreciates that EC leadership in science and technology is critical to our collective European future and particularly so as our European Community widens to embrace the vast land and farm regions of Russia, Ukraine and Turkey. This paper is principally concerned with trying to show that minimisation of weight is critical to fuel used in farming but productivity (of labour and machinery) is also vital along with soil compaction and the use of modern and relevant tractor and implement combinations. The writer believes there is no short cut to success. Our EC industry has been moving far too rapidly away from some basic farming practices. We should have been more aware of this in the period 1985-2007. This paper written in 2007 and up-dated in 2013, attempts to explain that the work of the big, powerful farm machinery manufacturers will have to change direction in future and do so quickly. As the world Business Council Report 2007 March – has indicated (in its press reports), there will be "No Business As Usual!" in the farm machinery and agricultural engineering world of food production and food security.





The New Trantor tractor concept is much more vehicle-like than farm tractor-like.

Annexure 1. - Case Study – JCB Ltd. – Fastrac.

The Fastrac tractor followed M.B. Trac, Ag-Unimog, Intrac & Schluter's Eurotrac but was initially also influenced by Trantor tractors who designed & developed the first 80KPH tractors with rear axle suspension, linkage suspension & hitch suspension (for transportation reasons & efficiency) & commercial truck standard braking, 3 seats & front suspension. When JCB Ltd., created its focus-groups they made certain that their members had conventional ploughing tractor experience as well as containing others with up to 10 years of Trantor, Unimog and M.B. Trac user-experience. The Fastrac began to take shape and the first dozen or so prototypes indicated that the following features would be present:-

(i) Equal Wheels – all-round, as in 4 WDrive configuration like M.B. Trac
(ii) Platform at rear – smaller but similar to the M.B. Trac, mainly because spraying & M.B. Trac had become synonymous in U.K.
(iii) All-wheel braking to C & U (Truck) regulations – like Unimog & Trantor tractors.
(iv) All-round suspension on front & rear axles like Trantor & not like Renault (Claas) only under the cabin.
(v) An appreciation that conventional tractors required heavy weight to have sufficient traction. - County 4WD equal-wheels was a much respected product in U.K. for ploughing & sub-soiling & may have influenced the marketing consultants & JCB managers.

By 1986, the die was cast, the focus-groups had caused JCB Ltd., to have a new, heavy ploughing tractor that was better than the M.B. Trac for haulage because it was faster.
The focus groups did not influence or persuade JCB Ltd., & their consultants that the worldwide market required something different from & complementary to the heavy, slow, gas-guzzling ploughing tractors of all kinds. Neither the focus groups, the market researchers or JCB Ltd., looked at the 32 million daily farm tractor users around the globe nor did they conduct the kind of global work task analysis similar to that shown for U.K. in Appendix 1.

The result for JCB Ltd., was that they thought they would be able to take on John Deere, Fiat-New Holland-Case in their own backyard & market & distribute a marginally different farm tractor in Europe. The focus-group had not thought much about heavy & low draft work being different or that the work of the p.t.o did not demand or require massive weights. The result for JCB Ltd., was that they were unable, because of weight, size, design & cost to enter some of the main growth market for tractors in 2007 onwards, such as India & China.

Annexure 2. - CASE STUDY – THE CLAAS XERION

Designed and Developed before the purchase of Renault Tractors by Claas. The Xerion was designed to be a ploughing tractor, a self-propelled harvester or a waste disposal tanker to work consistently throughout the year. Claas called it a multi-use Systems tractor.

Prototype 1977.

Xerion 2500 in production by 1996 but ended 1999 after 80 examples were built.
Second generation Xerion 3300 launched in 2004. With the realisation that Xerion has to be a capable conventional tractor, i.e. must be great at ploughing. Xerion, like Unimog, M.B. Trac, Trantor & Fastrac has a substantial chassis of its own & is designed to carry the load – on front or rear platform rather than carry the load on the rear (M.B. Trac, Fastrac & Unimog) or the front (Xylon) & certainly not designed as a transport machine for pulling loads (hauling) quickly or carrying work teams to the job (Trantor). The Xerion weight is certainly heavy. Xerion can however lift 11 tons at the rear & 7 tonnes at front so it is not fuel efficient for lighter duties or when returning to & from worksites. The Xerion is first & foremost interesting & like the Fastrac, Trantor, Xylon & M.B. Trac somewhat different.

Appendix. 1. - A Typical Farm Calendar – Tractor Work Task Analysis in a European Context. TRANTOR INTERNATIONAL LTD.

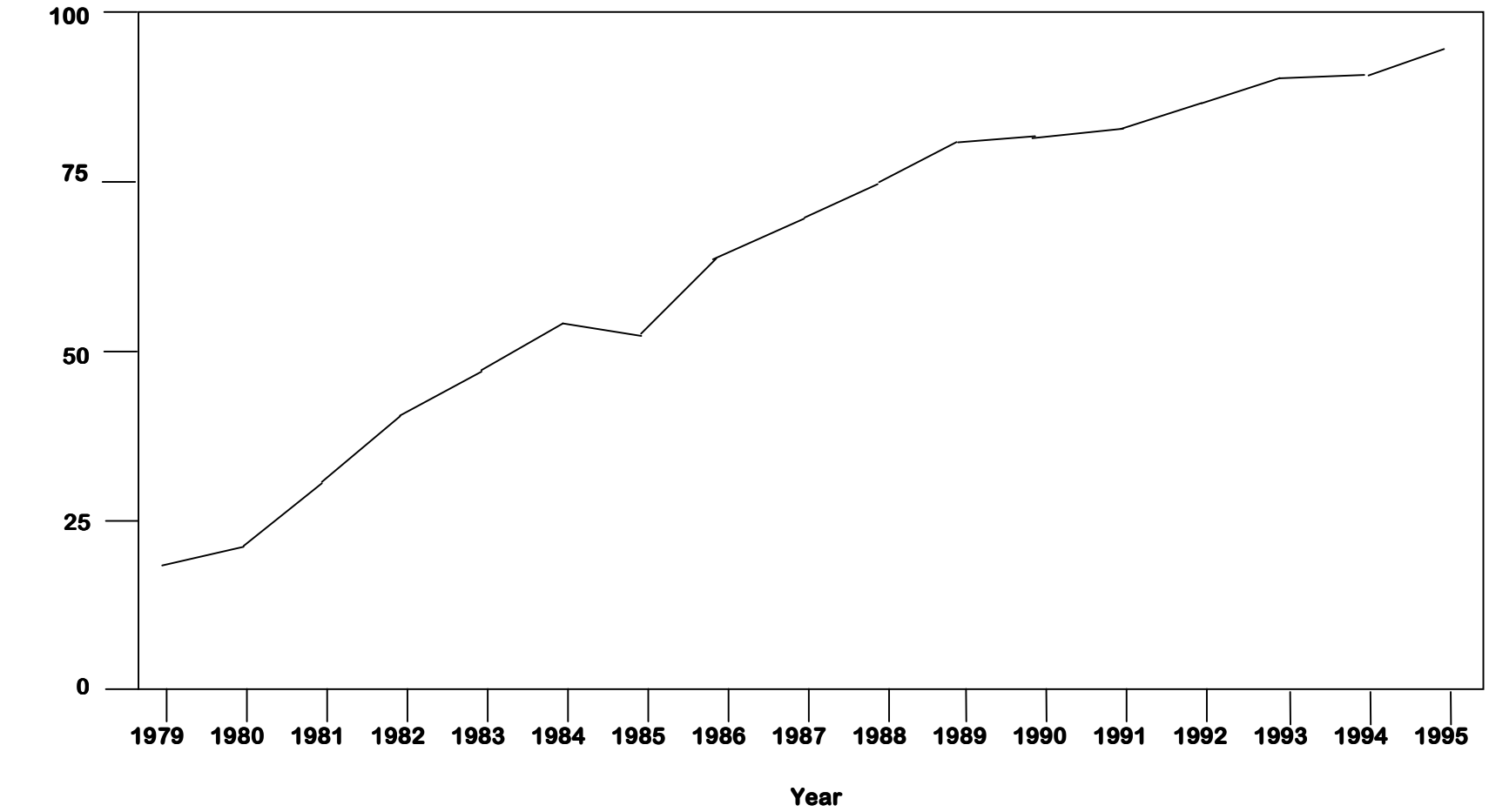
What kind of work are Trantor Tractors able to do more efficiently than conventional tractors where the benefits result from higher speed and lower weight (productivity due to speed, reduced fuel consumption due to weight reduction and transmission design) and where LGP tyres are essential for reduced soil compaction.

Farm calendar year.	1	2	3	4	5	6	7	8	9	10	11	12	BENEFITS		
													Speed	Fuel	Soil
General Haulage	■	■	■	■	■	■	■	■	■	■	■	■	***	40%	
Silage Haulage					■	■	■	■	■				***	40%	
Bale Haulage							■	■					***	40%	
Rape Haulage							■	■					***	40%	
Grain Haulage							■	■	■				***	40%	
Beet Haulage	■	■							■	■	■	■	***	40%	#
Potato Haulage						■	■	■	■	■	■		***	40%	#
Hedge Cutting	■	■				■	■	■	■	■	■	■	**	40%	
Spraying - LGP		■	■	■					■	■	■		***	20%	#
Spraying				■	■	■	■	■	■				**	20%	
Fertiliser Spreading		■	■	■	■	■	■	■	■				**	25%	#
Muck Spreading			■	■					■	■	■	■	*	25%	#
Slurry Spreading	■	■	■	■	■	■	■	■	■	■	■	■	***	40%	#
Cultivating			■	■	■			■	■	■	■		**	20%	#
Drilling		■	■						■	■	■		*	20%	#
Scratch Tillage								■	■	■			**	20%	#
Dressing	■	■	■										**	20%	#
Grass Mowing					■	■	■	■	■				***	20%	
Grass Seeding				■	■				■				**	20%	#
Hay Mowing							■	■					**	20%	
Hay Bobbing					■	■	■	■	■				***	25%	
Baling round/square							■	■	■				*	10%	
Discing							■	■	■				*	10%	#
Topping							■	■		■	■		*	20%	
Power Harrowing		■	■						■	■	■		*	10%	#
Harrowing			■	■									*	25%	#
Rolling		■	■	■					■	■	■		**	25%	#
Bale Wrapper			■	■	■	■	■	■	■	■	■		*	35%	
Grass Raking/Silage					■	■	■	■	■				***	25%	
Carrot Haulage	■	■	■			■	■	■	■	■	■	■	***	40%	#
VegetableHaulage	■	■	■	■	■	■	■	■	■	■	■	■	***	40%	#
Heavy Cultivation	2wk							2wk			2wk				
Potato bed forming			1 month												

*** a lot quicker and more productive than conventional tractors/faster
** quicker than conventional tractors/faster
* same as conventional tractors

the relevance of soil-compaction, particularly in Zero-Tillage and the need to fit LGP tyres on to the tractor, as well as on to the trailers, in order to protect the soil where that is essential, e.g in wet conditions.

Appendix 2. U.K. FARM TRACTOR MARKET - THE GROWTH IN SALES OF 4 WHEEL DRIVE TRACTORS



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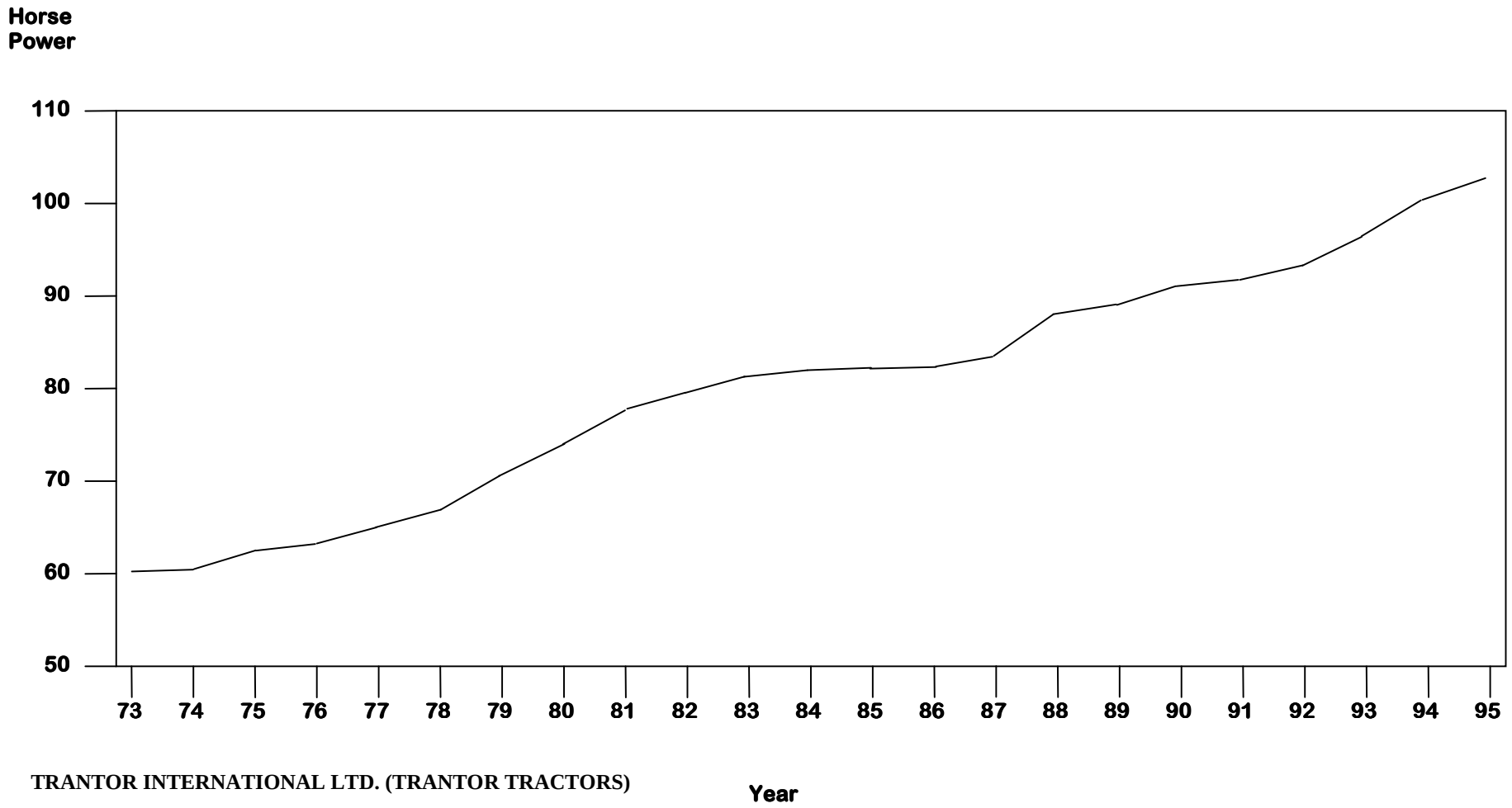
Appendix 3. THE U.K. FARM TRACTOR MARKET AVERAGE HORSE POWER – 1973 to 1995



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