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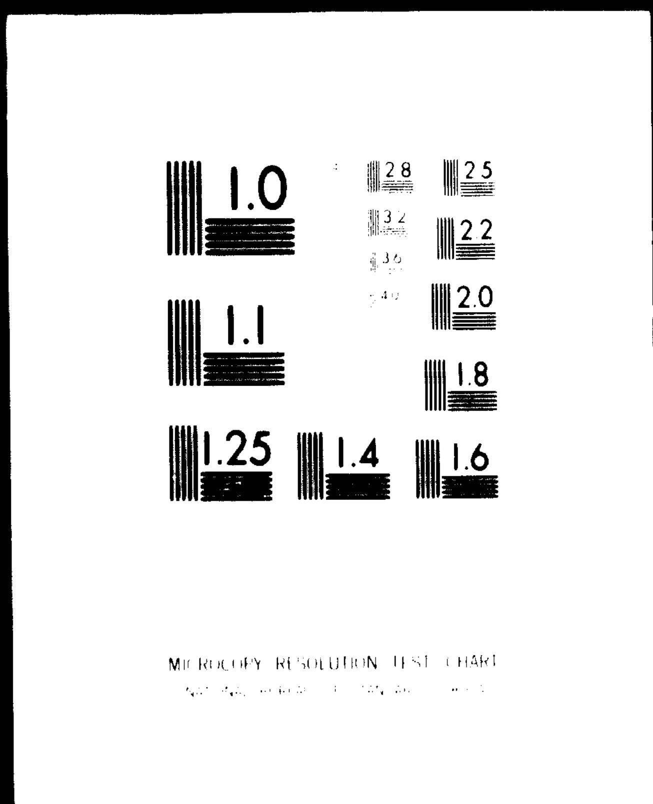

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A NEW APPROACH TO THE MANUFACTURE OF LOW COST VEHICLES IN DEVELOPING COUNTRIES

THE TRANTOR PROJECT 1/.

Prepared by

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I. INTRODUCTION

INDUSTRIAL DEVELOPMENT IN THE THIRD WORLD AND/OR INDUSTRIALIZATION OF THE DEVELOPING NATIONS

The industrialization of Europe and particularly Britain was tied to the many inventions and discoveries of industrial processes and products coupled to the development of skilled workers. In U.S.A., on the other hand, there was a recognition that without the basic skilled population, which Europe had at that time, its inventiveness had to be directed towards a different kind of industrialization which has often been called 'mass production'. Inventors such as Eli Whitney where no less inventive than their predecessors but they were originally inventing and developing new means of production by the adoption of different ideas in production as well as new methods, tools and processes.

Third World Industrialization

It should not be either presupposed or generally accepted that the basis for the industrialization of Africa or the Middle East, for example, will necessary follow that of the United States. It should not either be supposed that the basis of third world industrialization will necessarily follow that of Europe. We should not either believe that the presence of great natural resources such as oil, uranium, copper will have the effect of substantially retarding the process of industrialization for despite its wealth per head even Kuwait is actively pursuing a process of industrialization which has the major task of providing work for its population.

At the recent World Bank conference (1975) much discussion centred on the way in which Third World or developing (underdeveloped) countries could be assisted more adequstely in future. This short document is an attempt to comment upon the problems posed at the World Bank conference but it also is a proposal for action in a particular kind of way with a specific project in mind. The project has been the subject of substantial research and development at Manchester University, Bradford Univeraity and it has been conducted alongside industrial work at firms in Britain, Canada, Australia, France and Germany.

Some of the Baaic Elements of Industrialization for Third World Countries (excluding politics) in 1975.

1. The Industrialization programme should be relatively inexpenaive (North America's for example was 'quick and expensive')

2) The induatrial akills of production tasks (turning, milling, drilling, woodworking, welding, painting) have to be taught and learnt as do the tasks of management (accounting, storekeeping, progreasing, buying) in respect of "controlling" the production processa and "controlling" the teaching proceaa.

3) In a wide variety of different countries it is essential to take industrialization and production to the people (regional policy) and not create massive migration to overcrowded citiea.

4) The technology of production should be relatively simple since the problems of technological complexity are usually found at the maintenance or after-sales service point e.g. the recent report on the large percentage of broken-down tractors in Tanzania.

5) Whereas simplicity is a more rational approach to production tasks it should be borne in mind that the managerial problems can be more easily solved by proposing that relatively small factories be built.

6) The combination of small size of factory and simplification of product, assembly and manufacturing process mean that our inventiveness in future should be directed towards the adjustment of technology (intermediate technology and appropriate technology) to fit into "small" and "simple" systems of organization and production.

7) The design of products should centre on need rather than fashion and durability rather than the "throw away" replacement concept of the economically strong nations.

8) The needs to be satisfied by early industrialization approaches should centre on the need for self-sufficiency in respect of the basic human needs with food, agriculture and transportation as some of the early projects.

9) The industrialization process should be aimed toward competitiveness since it is pointless producing tractors for twice the cost of buying them with the foreign exchange gained from exports.

These are some of the fundamentals of the newly emerging process of industrialization which seems to fit the needs of Third World countries in 1976. Although they have been written as points in an approach to an analysis of the needs it is far too early in time in respect of their acceptance to properly weigh these factors in isolation. It is as much as we can do to examine various projects if they fit or do not fit the needs of particular nations at this point in time. It is largely because I believe that the TRANTOR project may have "accidently" but positively approached a sufficient number of these factors that I have tried to explain our approach so that others may examine it and comment, adopt alternative and improved approaches and possibly build an improved "theory of real practice" which may prove useful to students of world industrial development. I believe that Stuart Taylor and my research group, now my colleagues in the business of TRANTOR LTD., were conducting some very unusual research which concerned the interrelationships of product design, production system design, production control and a new kind of management style necessary when involved in the other three. I believe also that the work was conducted just as the 'big is better' movement had realised that small[1] is also useful. I believe that the notions of intermediate and appropriate technology were just beginning to be observed[2] and group technology was so new as to be almost entirely misunderstood[3]. I believe also that 'growth for its own sake'[1] was beginning to be seriously questioned and since the time was the seventies it was not difficult to question - it was indeed more difficult to accept the well-accepted[4,5]. I consider myself fortunate to have been able to work at something I believe I could see as a new way forward, despite much objection and difficulty from my senior colleagues at my University workplace, and see in the work of others such as those mentioned, but also in the words of Rolf Lindholm in Sweden's SAF and in the action of my colleague and close friend Jean Pierre Schmitt, a gleam of light which, although obscure, in some way reflected much of that which we were working towards.

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1 E.F. Schumacher, Small is Beautiful. Blond and Briggs

2 C de Beer, University of Eindhoven, Research work in Holland and in the Third World

3 Sir Walter Puckey. Various letters to the British Production Engineering Institution

4 D Schon. Loss of the Stable State. Temple Smith

5 I. Illich. De-Schooling Society

The work that follows begins as it so often does, at the end, where we state that we have something interesting to offer - the product, the factory for making it in and the way in which industrialization follows from the need to have an agricultural vehicle made by the nation itself and the way that this process leads on to a new kind of industrialization for the people of the region.

It is hoped that the reader will find it useful to follow that we thought were our thought processes. We have tried to keep money out of our presentation but we can assure the reader that our calculations are much longer even than our explanatory texts. We hope you will enjoy reading it half as much as we have trying to do it and then write it.

II THE TRANTOR PROJECT - Technical, Business and Marketing Considerations

General Strategy

The TRANTOR is a general purpose vehicle NOT a special-purpose one and it has been designed and built by this Company. It enters a market which is currently satisfied by the makers of tractors, Land Rover - type vehicles and lorries and trucks up to about 8 tons. The combined WORLD population and future market for all the vehicles in these categories produced by Massey-Ferguson, Toyota, General Motors, Fiat, Ford and others is so large that by obtaining 1% of the market would bring great success to the TRANTOR project.

The product is particularly noteworthy because of its wide range of general uses and the policy of this Company is to ensure that an appropriate TRANTOR is seen, tested and thoroughly examined in each of the countries and regions of the World where production may be established or the vehicle used. If a country is beginning to establish its own motor vehicle industry then TRANTOR manufacturing and assembly ought to be included in the most basic needs of the nation concerned because of its use as a car, tractor, truck and lorry. TRANTORS plough and take the full range of farming equipment, and military TRANTORS pull army equipment and carrying 7-10 passengers and load. The trailing capacity of 10 tons with unbalanced trailers is common to each as is the integral safety cab and cruising speed of 50 mph (80 Kph).

The primary aim of the TRANTOR project is to provide all countries of the World with a motor industry which they will largely own and operate and which will satisfy the home market and provide an export potential. Because TRANTORS can act as passenger cars, trucks and tractors, the project helps the developing country conserve its scarce capital resources. It allows such nations to use their limited resources in other more productive investments elsewhere - for example, the vast range of agricultural equipment needed for efficient food production.

The attractions of the TRANTOR project to developing nations also extend to the minimisation of use of foreign currency reserves because TRANTORS are designed to be manufactured, not just assembled in the country concerned. A further basic principle of the project is the way in which the TRANTOR project can be utilised to extend the range and increase the rate of industrialization by teaching in a specially designed training school the wide range of skills required, which include painting, welding, drilling, milling, turning, grinding and boring.

A Policy for a Collaborative Association with TRANTOR

When entering negotiations in a 'new' country collaboration with this country is likely to come from government agencies, private manufacturing and selling businesses, business consultants, development authorities, agricultural and transport specialists and those currently working in motor and agricultural engineering.

In all cases we think it is important to:-

(i) make arrangements for a vehicle or vehicles to be hired or sold for demonstration and test under local conditions.

(ii) conduct feasibility studies concerning the potential in home and neighbouring export markets; the skills available to build TRANTORS and to assess the rate and the stage by stage process of factory building (i.e. assembly, manufacturing of chassis, simple skill working, complex skill working). It is necessary also to assess the various details of the product design which would best satisfy the market. Various alternative component supply sources, with costs delivered to site need to be considered. Factory location, land availability and plans for after-sales service all need to be examined as part of the feasibility studies.

This Company offers this whole service from its technical staff led by Stuart Taylor, TRANTOR's Designer, through to its work organisation (Group Technology) consultants led by Dr.Ahmed Fatheldin and Professor Jean Pierre Schmitt (France). The work of these consultants, whose languages range from German, French, Arabic and English, is well known in the field of work organisation. Our consultants have been pioneers in this new field of work groups and have advised Platt (Saco-Lowell), Dunlop, Sovirel, British Oxygen (BOC), Whittaker-Hall, Knorr-Bremse, Ferranti, Rank Xerox and Tube Investments (Matrix). Our advisory work has always concerned the way in which these large and labour-intensive firms should develop in future to increase their productivity, improve their delivery, reduce their work-in-progress and develop their management and labour relations style to meet the needs and changes of the day.

Our whole policy is to offer a complete turn-key operation for any country wishing to have its own motor vehicle industry based partly or wholly or even firstly on TRANTORS,

The following information is available for perusal:-

1) A 12 minute colour film of the TRANTOR project (Agricultural and Military)

2) A sixteen page colour brochure in English, French and Arabic

3) A TRANTOR product specification in colour

4) An outline proposal for setting-up TRANTOR factories.

5) A list of bought-out components with detailed part specification. (Many alternative engines, electrical equipment and general bought-out parts are available from many different countries).

6) A minimum building specification

7) The fixed capital equipment needed to make TRANTORS at about 20 per week.

8) The training school equipment needed for full and complete training in TRANTOR manufacturing and assembly.

9) A draft legal contract/letter of intent in respect of the factory proposal.

10) A suggested stage by stage process leading from TRANTOR assembly and chassis manufacture to complete manufacture over a range of different periods from 1 to 5 years.

In addition there is a scale model of the plant, designed for Nigeria, which can be seen at our Stockport (U.K.) offices. All drawings, jig and tool designs and special fixture drawings can be seen at Stockport as well as the TRANTOR assembly work groups, the rear axle sub-assembly group and the transmission work group. Chassis manufacture and panel assembly can be seen in Northern England.

'OECD REPORT' - Alternative Transport Technologies - an extract relating to the TRANTOR project.

The TRANTOR project conducted firstly at Manchester University and then at Bradford University Management Centre concerns a new type of agricultural transport and work vehicle, which is designed in a new way to embrace the new kind of small group production system of manufacture and assembly. An unusually practice-centred University research team led by G.A.B.Edwards originated the project with W.S.H.Taylor, TRANTOR's designer, at UMIST Manchester, England. The work concerned with the design of the organisation of work was conducted by Edwards and Taylor with the assistance of the former's research team which received its financial support from the Science Research Council.

There are two real problems which prevent developing countries from successfully producing their own vehicles and, in general, they have, up to date, only assembled such products. These products which have been assembled have usually been fundamentally designed for the requirements of the Western world. The requirement of the developing countries home market invariably, however, is for a more functional, harder wearing more durable product than that designed for the West. Top speed and acceleration may be important to the market of the United States but it is the ease with which a leaf spring can be replaced or the strength of the front bumper which are often more important to a developing country. A product which is designed for the environment of the western world is also designed so that it can easily be produced within relatively advanced western production systems. Vehicle products are usually made on a mass production basis in large batches (manufacture) and on flow-lines in assembly. They are invariably built in large plants employing several thousand people and they are situated in heavily populated areas. These factories require enormous amounts of capital investment before the first production machine flows from the line and they usually demand large home markets and well-established servicing networks to be economically successful. Developing countries are generally short of capital and have a wide range of more basic products in food and agriculture, for example, which compete for the limited amount of available capital. Developing countries usually have smaller centres of population and insufficient skilled and semi-skilled labour in one centre to support a large plant.

Any regional development planning, which is such a vital feature of planned industrialization, requires that small pockets of industrial factory practice be made available in region after region.

The TRANTOR project is a serious attempt to design a new product and to design a new kind of factory unit which considers regional planning, minimum capital, durable products etc. as its fundamental constraints. We have tried to begin here at a new kind of beginning for the developing nations.

The product is a versatile and functional transport vehicle. Its fundamental specification was drawn up following a two-year study by W.S.H.Taylor of the transport requirements in agriculture and where tractors are used in rural areas, for forestry and in other general work tasks. The TRANTOR has been designed to carry out virtually all the tasks and operate with the same attachments as the conventional agriculture tractor. It can, however, be driven light at speeds of up to 60 m.p.h. and it can also haul trailer loads of up to 8 tons safely at speeds of 35 m.p.h. It spans three markets, each of which is conventionally supplied by a different product and it therefore competes against the agricultural tractor, general purposes vehicles (such as the Land Rover) and small commercial lorries. The home market in some developing countries may be small for any one of these three products but for the TRANTOR that market size would be considerably increased. The multi-purpose nature of the vehicle can significantly reduce the capital cost to owners (individual or collective) who would need only a TRANTOR instead of a car, a lorry, a Land Rover and a tractor. TRANTORS are competitively priced and cost much the same as a tractor of similar horse-power.

The product design has been carefully considered from the point of view of the economics of low quantity production (smallness) and the factory design was a second but vital step in this same direction. There are, for example, no high quantity machining requirements for any of these parts which are designed specially for the TRANTOR and which would be manufactured in the factory. All such parts can be produced with simple, inexpensive capital equipment in the form of easily available simple machine-tools and specially designed jigs and tools. When designing the production system for the TRANTOR, it was clear that it would have to be produced economically in low quantities and that each TRANTOR factory would need to prove its economic viability where the number of employees would be about 100-150. At such a size the output of each plant is about 1000 units per year and if the market demand in a particular country, or region, becomes greater than this number it needs to be sufficiently viable in its usage of capital and give sufficient returns for it to be possible to duplicate the plant in another region of the country.

The basic idea is that the plant must be small and efficient but clearly the restriction of 100 to 150 persons could be adjusted to suit prevailing circumstances. The designers of the factory, which was part of a comprehensive research programme at two British Universities are fimrly of the view that the cost and ease with which the factory can be managed and controlled are vital to the success of the venture and hence the increase in employees has connotations other than those of more production. The idea of the small plant offers other advantages such as the coupling of after-sales service directly to the factory.

As a result of the decision to produce a small factory with the technology designed to suit the economics of smallness the capital required (fixed and working capital) before the first production machine comes out of the door is proportionately reduced. The capital requirement is further reduced by using only 'standard', 'off the shelf', machine-tools throughout the whole plant and not relying on any expensive special-purpose machinery.

It is the design of the tooling which is crucial to the success of smallness and our work group approach follows the principles of Group Technology which have been pioneered in U.K. by G.A.B.Edwards and his co-workers. It is necessary to begin to manufacture with a low skill requirement and in our TRANTOR factory each man needs only to be trained to operate one machine before the plant commences production. Our special tooling, jigs and fixtures has reduced the depth of skill required to handle each machine and so the initial 'start-up' training time is minimised. This does not prevent each operator acquiring a broader knowledge of several different machine-tools because he is able, as production gets under way, to move from machine to machine and widen his abilities and skill.

The inevitable question must be asked 'how can a small plant produce a vehicular product competitive in price to similar products mass-produced at over twenty times the rate?' It is clear that to machine components in batches of 400 a week is usually accepted as being cheaper per component than machining in batches of 20 a week.

TRANTOR manufacture is organised on a group technology (G.T.) basis (this firm has the most comprehensive series of papers on G.T. and they can be bought on request to us) which considers all the machined components in the plant and groups them into families which have similar machining requirements It i then possible, because one is dealing with groups of similar components, to set up groups of machine-tools with associated jigs , tools and fixtures so that the time taken to change from one family member to another is virtually the same as if they were the same components. As each family can contain anything up to fifty similar components, it is soon possible to substantially increase the effective batch size and reduce the cost per component Because the TRANTOR has been designed specifically for this type of manufacture it has been possible, at the component design stage, to consider the component family and to standardise on features common in the family, such as hole diameters, tolerances and material.

The TRANTOR project may thus be said to offer an unconventional alternative technology whose many aspects would prove useful in coping with the needs of countries in the third world. It does so by combining the most advanced practices in production with a belief in "scaling-down" for ease of access and control, and providing a product that can meet the special need characteristics of those who work and live in rural towns and villages.

CONCLUSIONS

The TRANTOR product has been designed to suit the needs of users in developed and developing countries alike. The TRANTOR factory embraces the precise needs, policies, facilities, and abilities of each country concerned and our design of the work organization is a particularly significant factor. The accompanying notes explain one of the ways in which we have staged the factory building programme to suit one particular region of one particular nation.

III ESTABLISHING MANUFACTURING AND ASSEMBLY FACILITIES FOR TRANTORS

In many developing nations it is necessary to establish a series of small factories in various regions but particularly in those where people are seeking useful work. The way in which work is organised in small factories depends largely on those people and particularly on their existing skills and the time needed to extend or develop them under TRANTOR manufacturing and assembly conditions.
A feature of the TRANTOR project is to offer MANUFACTURE, where most of the skills lie, AND assembly and the whole project is geared to the idea of assisting a developing country in widening and extending its skill base by offering simple fitting skills and simple machining skills like drilling but also offering skilled boring and precision turning. In order to satisfy this dual requirement, factories for TRANTORS come in a series of 'staged packages' with a 'tailor made' training school to suit the needs of each stage. The whole factory consists of 16 self-contained work groups each of which employs about 8 people. Each work-group has its own particular skills, jigs, inspection facilities, raw materials and machines. Each work-group requires different training school equipment and needs a different time duration for training. A developing country may decide to build the whole factory at once, i.e. four stages, or to stagger them over a few years. A brief description of the various stages is as follows:-

		Work Groups	Approx. number of workers
STAGE 1	Assembly of TRANTORS chassis assembly and servicing of TRANTORS	16.15.14.13. 12.11.10.9.	65
STAGE 11	Chassis member welding assembly, accurate welding assembly, panel manufacture	6.7.8.	25
STAGE 111	Simple turning and drilling, profile, cutting of plate, sawing, drilling, stamping and bending	3.2.1.	20
STAGE IV	Gear-cutting and hardening. Precision machining	4.5.	15

IV THE TRAINING SCHOOL WHICH SUPPORTS TRANTOR MANUFACTURE AND ASSEMBLY

The tailor-made training school includes the capital equipment for Stages 1 to IV inclusive and the specific school for a particular factory will be assessed at the appropriate time. It, too, can be in a series of stages.
The staff of this training school will all be carefully selected so as to take account of language and the various skills required in TRANTOR factories. Our staff will all be familar with the TRANTOR project and have had considerable experiece of training and of TRANTOR production in U.K. Particular attention will be devoted to, training in TRANTOR driving, servicing and repair and modern equipment will be utilised with service vans properly equipped and working from the training school which, in all cases, will be adjacent to the factory.

In order to build such a factory of 16 work groups the land required is 90,000 sq.ft. with buildings covering about 45,000 sq.ft.

V BACKGROUND

Arising from the publicity given to the cell system in 1973 by firms such as Volvo and Saab, in relation to changes from assembly lines to assembly cells, it was part of our work to examine what was being done at Volvo and Saab and to report upon the findings. Although this report is available elsewhere it briefly concludes 'that Volvo and Saab have made much propoganda but have done little that is new and are in roughly the same position as Philips were in 1963'. The Philips experiments were explained by Van Beek in 1966, in the journal 'Occupational Psychology'.

Because of the widespread confusion concerning the meaning of the group or cell system of production, which partly results from the publicity given to Volvo and Saab and later Fiat, it was thought sensible to look into the precise differences and similarities between manufacturing cells or groups and assembly cells or groups. This was mainly investigated in the period 1972 and 1973 and visits to firms using assembly lines, manufacturing lines, functional layout-based manufacture, group assembly, group technology, manufacturing cells and various plant dominated (process) systems were made, and an analytical framework was developed for comparisons of the different systems.

The research group was interested in the way things do happen as part of the process of determining the way in which they can be designed. Following from the comparative study a simple basic framework was constructed for comparison purposes. It is the intention to develop this comparative model by using it in a variety of different situations throughout the period of the research. A project approach was adopted where a new vehicular product called the Trantor was the focal point of study. This project began with the objective of designing group systems of production for the entire manufacturing and assembly of the product. From the design stage through to the manufacturing and assembly stages the factory design was focused on small groups so as to produce a factory which would be acceptable for human beings to work in, could be controlled by a simple system but was also acceptable in terms of its economic performance.

A motor vehicle product was selected because:-

1. It was the most well-known and most often referred to example of flow-line assembly.

2. In manufacturing (not assembly), vehicles are normally made in functional layout-based workshops although sometimes product (component) lines are used. It should be noted that the way this sector of industry has grown has tended to accentuate the division between 'manufacture' and 'assembly' because of the separation of 'the manufacturer' from 'the assembler'.

3. The manufacturer of parts for vehicles is, therefore, often seen by the firm assembling the product (the assembler) as a supplier. In that capacity 'the manufacturer' has become more of a specialist supplying the needs of car assemblers such as Ford, Vauxhall and Leyland.

4. The influences upon the component manufacturer are towards the supply of large batches of relatively similar components to assemblers. To the manufacturer they are the relatively special products of, for example, Girling, Ferodo and Hardy-Spicer. (Note the 'assembler recognises the goods as components but the 'manufacturer' as products.)

5. The assembler tends only to manufacture those components which are individual to his product. In many cases there is also a tendency to abdicate from manufacturing by sub-contracting.

VI WHY SELECT THE TRANTOR?

1. Because it was a new product which was at the design and prototype stage at a time convenient to this study.

2. Because it was a motor vehicle and permitted comparison with Saab, Volvo and Fiat.

3. Because it has assembly and manufacture and therefore was useful for comparison with Ferranti, Platt International (Bolton), Whittaker-Hall and Audco in manufacturing and Volvo, Philips and Friedland in assembly.

4. Because it had, like other such products, individual and special items made only for itself.

5. Because it had high volume potential as implied in a study of Tractors conducted by the Economist Intelligence Unit, Motor Business, July 1973.

6. Because most motor vehicle product design, in the last 50 years, has changed not so much only to suit developments in technology or improvements in design but mainly becasue of the needs of 'mass production' (Flow-line assembly and large quantity batch manufacture).

7. Because the trend to mechanisation and automation has had the effect of deskilling the tasks and making jobs boring for people. Motor vehicle production has been the focal point of much discussion in recent years.

8. Because these influences are also directed towards large scale (e.g. economics of scale), high capital intensive factories which have been encouraged by the belief in the cheapness of capital and the support of such notions by government, and some of these influences are beginning to be challenged.

9. In addition to these points the researchers had some 'beliefs' of their own:-

   (a) greater size does not necessarily equate to greater efficiency;

   (b) greater size does not necessarily equate to greater stability;

   (c) mechanisation and automation are not necessarily the right or only objectives for the future of manufacturing;

   (d) human beings have received insufficient fundamental consideration at the factory design stage - whatever the system used!

   (e) current production systems tend to create and then reinforce a kind of industrial apartheid between functions and a conceptual approach had not yet been properly developed to change that situation;

   (f) the process from original overall design does not necessarily always or even rarely, in practice, move effectively into the production stages. The introduction of specialists too early on in the process is, in our view, unhelpful when the entire product is being discussed as a whole. (The researchera believe that many such changes to the design process have happened as a result of the growth in size of firms and the advent of mass production thinking). We tend to believe that it is the absence of thought concerning the design and production interface that has caused many of today's problems;

(g) the structure of the process from design to manufacture in many firms is often inefficient and unhelpful. Because the normal structure tends to formalise communications the effect is that the product 'goes down' to manufacture from design. In our view, it would be better if the production engineering department, for example, were in 'direct contact' much earlier in the process;

(h) the commonly-held belief and behaviour pattern which 'naturally assumes' that the adopted system for assembly will be a flow-line is not necessarily correct. It may be entirely inappropriate for well-developed nations in future;

(i) It is not necessarily correct to 'naturally assume' that the manufacture of 'bits' should be done by the specialists who normally make those components;

(j) Insufficient fundamental re-examination is usually given, at the policy level, to factors such as the size of firm and the type of production system which is best for people. The researchers also believe that the world is changing in social, technical and economic terms at a faster rate than at any time in our history and this certainly affects the way in which factories of the future 'should' be designed;

(k) the importance of greater capital investment is over-played and this results from a basic belief in mass and high quantity production. The use of the flow-line immediately implies expensive specialist machines. Whereas high capital investment in machinery may be a good way to increase efficiency in certain kinds of production system, it is by no means the only way and certainly not necessarily the best way in other types of production system. Other ways should not be forgotten at a time when mass production and advanced technology have been the cornerstones of our society's beliefs - particularly when such notions appear to be breaking down as a result of pressure from a variety of directions;

(l) the rate of increase in the cost of capital and labour has not been equal and consequently it is important to consider alternatives. A production system which uses human resources (in an acceptable way to those people) and small amounts of capital may be more successful in future than one which merely accepts the 'law of today's situation' where high capital intensiveness with minimum labour is the aim.

Because of the opportunity presented by the new product, allied to the reservations of the research workers, the research group began to build a model of a new kind of factory which tried to consider people as a major resource! The product had been designed and the prototype had been built and partly tested at the commencement of the research programme. It is necessary, therefore, when trying to explain our reasoning, to explain the way the product itself was conceived before explaining the approach to factory design.

VII THE PRODUCT DESIGN PROJECT 'A TRANTOR'

It must be a fairly rare opportunity which allows one person to conduct a technical market survey, design and build a prototype motor vehicle, lead the jig and tool design team and also participate, at the strategy and policy level, in financial, marketing and production decisions. Our introductory remarks have emphasised that the research team considered that each different discipline (product design, jig and tool design, production engineering, etc.) should follow a concurrent decision-making process as a matter of paramount importance. Close inter-communications between each discipline was considered absolutely essential at each stage in the movement from the basic outline to the final detail. The product design was conducted in such a milieu, largely because the designer participated and took a leading part at each stage from product design to factory design. At some stages different disciplines and influences such as finance and marketing were expected to dominate but in all cases the designer was present to lead or follow as he thought fit. The greatest constraints on product design, at the outset, were those influences of the market survey and the availability of finance to support development work. At the secondary stage, when such problems were resolved and the project progressed into greater detail, engineering disciplines became the main constraining force.

Product Design Sequence

The lateral steps in decision-making within product design, moving from the outline stage to the final detail stages, seemed, to the writers, to follow a five-stage process. These stages were observed by the designer and observing researchers as:-

1. The Conceptual Design Stage

2. The Technology Design Stage

3. The Assembly Design Stage

4. The Sub-Assembly Design Stage

5. The Component Design Stage

1. The Conceptual Design Stage

"The outline stages have the greatest 'decision flexibility' at cheapest cost". The result of the technical market survey is best summarised from a paragraph of the conclusions taken from the research thesis which summarised the field work.

"The specification of the type C transport tractor (the Trantor) is not such a straightforward specification on which to build up a design because transport work on the large farm involves a wide range of loads and speeds. The vehicle must be capable not only of carrying personnel quickly from A to B, ideally handling like a land rover, but also be capable of hauling a 6 ton unbalanced trailer through slippery conditions and 'on the road' at speeds of up to 40 m.p.h. new hitch and suspension systems will be required."

The technical market survey was able to indicate that approximately one third of tractors on large farms could be replaced by a 'transport tractor' which did not even have to offer the facility of three-point linkage or power take-off. If, however, simple versions of these two facilities were part of the new vehicle, and could be designed so as not to detract in any way from its transport output, the potential worldwide sales could run into tens of thousands of vehicles a year!!

At the conceptual design stage, the task was to produce the technical specification of the vehicle making reference to the findings of the market survey. The findings were as follows.

(i) There was a need for a vehicle which considerably increases the rate of work when carrying out those 'transport tasks' currently performed by the all-purpose agricultural tractor. The loads of tractors doing transport work vary from 'the driver and a few tools' to about 2 tons dead weight on the hitch, when using unbalanced trailers, and the drag from 10 ton trailer loads. Transport speeds could be from under one mile per hour on slippery and tough ground to about 50 m.p.h. running light on good roads.

The technical facilities required to accomplish this work were found to be, some form of pick-up hitch, some form of suspension capable of handling the very wide range of loads and speeds, hydraulic facilities to handle tipping trailers, a load platform on the vehicle itself and seating for one or two passengers.

(ii) There was a need for the vehicle to handle some standard agricultural implements to maintain its use when there was no transport work to be done.

The technical facilities required to accomplish these tasks were, a simple form of three-point linkage with position control which would not suffer from any suspension sag, a standard agricultural power take-off (p.t.o.) which should preferably be 'live', there should be a high degree of manoeuvrability and good rearward visability.

(iii) There was a requirement for a safety-cab with low noise level and driver comfort. The technical facilities required were, a structurally reinforced cab, some form of cab suspension and good seat and driver-control ergonomics.

(iv) The price of the product should be within the range of existing, similarly powered, all-purpose tractors.

The technical requirements to satisfy this demand meant that technology should be excluded where it is not essential and this was to be combined with a policy of the 'utmost simplicity' in design work.

At the conceptual design stage it was possible to build up the broad outline of the vehicle specification and it can be summarised as follows:-

(a) Cost factors ruled out four-wheel drive.

(b) The requirement for manoeuvrability emphasised the need for two-wheel drive with a short wheel-base and smaller front wheels.

(c) Good rearward visibility, watch any implements and to pick up trailers, the need to have access to the engine, the amount of gear shift linkagas, and the need to work with a light front-loader all emphasised that a more central driving position, rather than a forward cab, was preferable. This solution was a compromise because it had the effect of cutting down the available space for the load platform which was a further requirement.

(d) The need to work in slippery conditions, towing trailers with only two-wheel drive, emphasised tha importance of the capability to handle unbalanced trailers. The rear hitch position had to be as near as possible under the rear axle to maintain longitudinal stability and, in addition, some form of waight transferring device would be required to handle balanced trailers. A pick-up hitch and hydraulics for tipping trailers would also be essential requirements.

(e) The need for higher speeds was a critical feature if success was to be achieved. No system existed which gave the required suspension characteristics. A new system would have to be created if the objective was to be achieved. This part of the process was embraced within the technology dasign stage. Other aspects connected to the need for high speeds were a more afficient braking system and better lateral stability. These factors emphasised the need for as wide a track as possible and a reduction in rear wheel diameter but not tyre-width as well as the requirement to lower the centre of gravity, whilst maintaining reasonable ground clearance.

2. The Technology Design Stage

The design of the suspension system was begun as soon as it was clear that a new kind of system would be required. Creative or inventive design is probably one of the hardest things to catalogue and undoubtedly varies from designer to designer. In the case of Trantor's designer (W. S. H. Taylor) it seemed to have four sections:-

Section A - Process Creation

The suspension system and its hydro-mechanical principle had to be invented. This was a relatively easy task since the problem was clearly defined and involved no more than line sketches and simple circuitry diagrams.

Section B - Hardware Conversion

As soon as it was known how the process could work there were, of course, several methods by which it could be transformed into mechanical hardware. Outside influences centred on simplicity in design and the minimisation of capital cost for equipment so that a big change resulted in policy. Considerations moved from a vehicle with four individual wheel units to only one unit concentrating on the hitch.

Section C - Rationalisation

The suspension unit was rationalised with regard to stress calculations and designs for one-off prototype manufacture were drawn up. These turned out to be too crude in some aspects but the main object of the first prototype unit was to confirm that the system would work without having to invest in further costly items such as casting patterns.

Section D - Modifications

This stage involved alterations to the prototype design as a result of obvious defects shown up in prototype trials where factors such as wear and accessibility for maintenance were considered.

3. The Assembly Design Stage
(Maximise the use of proven units for specialist manufacturers, e.g. engines, brakes, electrics)

The market survey had shown that there is a preference for a system of units which are bolted-on to a major structure whereas the modern all-purpose tractor has become a totally integrated unit. The bolt-on unit approach was found to be more accessible for servicing and less complicated to repair.

The policy adopted was quite a simple one - where there existed, in a catalogue, a unit which could be bolted-on then this would be used providing that unit had been properly proven and tested under similar conditions to its new use. Of course, there are also (at present!) cost advantages where such units are used by others in large quantities and there are similar advantages too when reliability of supply is considered. For a new product to embrace units that are already well known and proven provides a distinct market acceptability, particularly when the product is quite new in concept and where purchasers, e.g. farmers, may be very conservative.

The assembly-design stage was concerned with translating this policy into practical design. It consisted of devising a 'space-frame' and considering the individual characteristics of the product which made it possible to join the bolt-on units to the space-frame in some organised manner. This process was largely one of selecting the units, devising the methods of holding them together and establishing which units needed to be specially designed to produce the required product characteristics.

The designer, whilst trying to observe himself at this stage, was rather more concerned with small quantity production than large, but when his mind turned toward the possible or eventual requirement for large product quantities he realised that there were two alternative methods of manufacture. The first was based upon a system where the production relied heavily on high quantity to be economically viable. This would have involved heavy pressed chassis members with semi-stressed pressed-steel body panels. The designer, who saw himself also as part entrepreneur, never considered this alternative to be a viable proposition because of his belief that any production involving him, as owner or part-owner, would start with extremely small quantities. It was this point that interested the researchers working in group and cellular production systems because they could see that here was an opportunity to design a 'group' factory from first principles in a real live situation.

The second alternative, therefore, became the only viable one and involved a relatively sophisticated raw material state and the need for a complex welding assembly jig. The stressed space-frame system, with non-stressed body panels could produce a complex shape requirement without the need to invest in expensive high quantity machinery. Alloy panels were decided upon from similar considerations but also because of corrosion and ease of working.

At the assembly design stage any complications resulting from bolting various units together were resolved and this involved stress analysis of the transmission line and suspension.

4. The Sub-Assembly Design Stage

At the sub-assembly design stage, the designer concentrated on those units of the product which could not be purchased in standard form from suppliers. These were units such as certain gearboxes, the hitch unit, the front suspension, the rear axle-casing and other units which would have to be sub-contracted but would be designed to meet the particular specification of the Trantor and concerned items such as the fuel tanks, radiator and rear wheels.

At this stage, the technical specification of each unit and the stresses on the components in them was the first task. Secondly, the designer was forced, as at stage 3, to make maximum use of standard mass-produced components, such as certain components in the steering box and the more obvious items like bearing races and oil seals. Production engineering and jig and tool influences were restricted and were broadly concerned with minimising component complexity, machining complexity and variety. There was also a need to reduce the amount of machining at the assembly stages of manufacture. This meant that components were designed to be totally machined in component form. Where a component had to be accurately aligned at a subsequent assembly stage, location features were added to the component to make this possible.

5. The Component Design Stage

This stage largely concerned reducing the work content of manufacture through simplification and the use of more sophisticated states of raw materials. The state of raw material was chosen for its closeness to the final component. The reduction of variety of components and raw material states was closely interwoven and as a consequence each was considered separately and together before a final decision was taken. Variety control was considered also in production; production operations on components were analysed so as to reduce any unnecessary work in production.

VIII THE DESIGN OF A NEW KIND OF FACTORY BASED UPON GROUP OR CELLULAR PRODUCTION

The Trantor project was the basis for a fundamental analysis leading to the design of a factory which would be acceptable for people to work in but would also be acceptable to those concerned with economic efficiency.

The general strategy of the research team, operating in the corporate strategy and policy area, concerned people, product and market.

(i) <u>A statement of the generalities of strategy and policy are as follows:-</u>

1. People should be the prime consideration.

2. The product should reflect this as well as the production system and the factory.

3. The product must therefore serve the people and be seen to do so.

4. The people using existing near competitive products were examined in relation to the use to which they put existing products. (An 18 month survey of farmers, farmhands, local authorities, etc. was conducted.) The existing products observed were tractors and land rovers.

5. The product was designed to suit not only the work needs of the people using the product but also their safety, comfort and financial viability. N.B. These aspects, (for example, noise in tractor cabs) were designed into the vehicle from the beginning and not added later. The safety cabs are now being fitted to tractors at a time when 'society' has begun to recognise the importance of safety and noise; when in fact such observations were as clear in 1923 as 1973.

6. The analysis of users of existing similar products showed that 75 per cent were exported and that the market in U.K. had passed its rapid growth stage.

   The market potential was enormous in terms of potential units sold in the world. Competition was very well organised around existing products and consequently any new independent manufacturer would find it difficult to compete at high volume levels for some time. The need to make small quantities early in the life of the product was considered essential to establish the product - unless, of course, the designer sold his design to one of the established firms making tractors.

7. The designer's first task was to ensure that the product would function and be capable of doing those things asked of tractors by users. This was an activity that involved sketching out designs.

8. The designer of the product always recognised that he would conduct the study of users and then he would build the prototype. As a consequence every complication meant more working hours for him rather than others and he therefore had a vested interest in simplicity of manufacture.

9. The designer realised that it was only necessary, in 1971, to actually make those things which were individual to the product. Engine, electrical system, tyres, etc. are obviously well developed as specialist items and were simply purchased at the assembly stage.

10. For manufacture the need to machine was considered very early in the process of design because more sophisticated material states, available from stock, could reduce more effort in manufacture, e.g. structural box section for chassis and cab rather than pressings; ground bar instead of machining black.

11. The designer built the prototype product with simple, easily obtained, machinery that would be available in most countries of the world (note 75 per cent export potential).

12. The company, formed to hold patents etc. between the designer and his associates was very limited as far as availability of capital and income was concerned. This encouraged care so that the simplification concept was reinforced.

(ii) A new concept in factory design

1. The researchers refused to accept that assembly flow-lines, or functional layout-based manufacture were essential for economic production since they wished to approach the task from first principles.

2. People should feel proud of belonging to their firm. This, however, has to be a policy since it rarely, if ever, occurs by accident. Increased size has made many people feel like numbers and consequently a major objective was to limit the factory size by the number employed rather than by other, less important, details.

   The researchers decided upon 100 employees as their objective maximum and then began work to establish whether there was a need to vary from this figure in either direction.

3. The objective was for the factory to make the entire product and manufacturing workers to join with assembly workers and administration in a manner which would encourage and develop identification with the market, quality and financial viability of the firm.

4. Arising from these decisions, plant output was calculated and fixed at around 20 per week, constrained, as stated, by people considerations. Demand in excess of this figure entailed the duplication of these resources elsewhere. (A new factory would be on a new site in a new area and would be the same as, or very similar to, the first unit depending on local or cultural differences of course.)

   Note Marketing, Product Development, Buying and financial considerations may be elsewhere in a kind of 'centralised office services' although this was considered subsidiary to the main research task and may be dealt with at a later stage and embraced within the main concept.

(iii) Production system design (manufacture and assembly)

1. People were the primary considerations and it became a policy that:

   (i) If people were involved with tasks they should be:

      (a) Skilful rather than not (where possible)

      (b) Encouraged to continually increase their skill, and

      (c) Encouraged to be capable of working on a wide variety of work tasks.

(ii) If people were working together they should also be involved in the organisation of work by being encouraged to organise it themselves or, at least, to contribute their knowledge and skill.

2. Where there is an opportunity for complete automation then the man must be removed entirely.

   There must be no half measures. Either there is a man or there is not. If there is a man he must be encouraged to be involved. If he wishes to rotate his task, to increase his skill content or skill variety then he and his group should be encouraged to do so.

3. Stock in the system would either be raw materials, finished components or finished products and a very small amount at 'between stages'. This would be a policy dictated by finance, market and production efficiency constraints and not either alone, except as opportunity stocks!

4. The system of production would be designed jointly from the technical and social systems viewpoints. One must not precede the other. Where conflict occurs the people (social system) must be given priority.

5. The design of the manufacturing system should be conducted separately from the assembly system.

6. The group or cell system of manufacturing and the group assembly system would be the basis of the research experiment conducted within the group technology research unit directed by G. A. B. Edwards and supported by research funds from S.R.C. at Bradford Management Centre.

IX CONCLUSIONS

1. The project has proved a successful one in respect of combining the experience of 'engineering' and 'management' into a co-ordinated whole.

2. The factory has 'proved itself' to be a viable proposition on paper and it now remains to be built.

3. A series of different countries have already expressed a willingness to build it and negotiations are currently being pursued between the various parties and the firm owning the product and its patents.

4. The product itself has been 'introduced' to the market and a most favourable reaction has been received from some of the specialists in agricultural machinery. (References are available from P.M.R. Unit at Bradford Management Centre.)

5. Preliminary investigations in the British market, prior to Trantor's first public showing and journalistic comment, show a marked reluctance to 'believe' that speed, safety, comfort and noise are possible in a vehicle of the tractor-type.

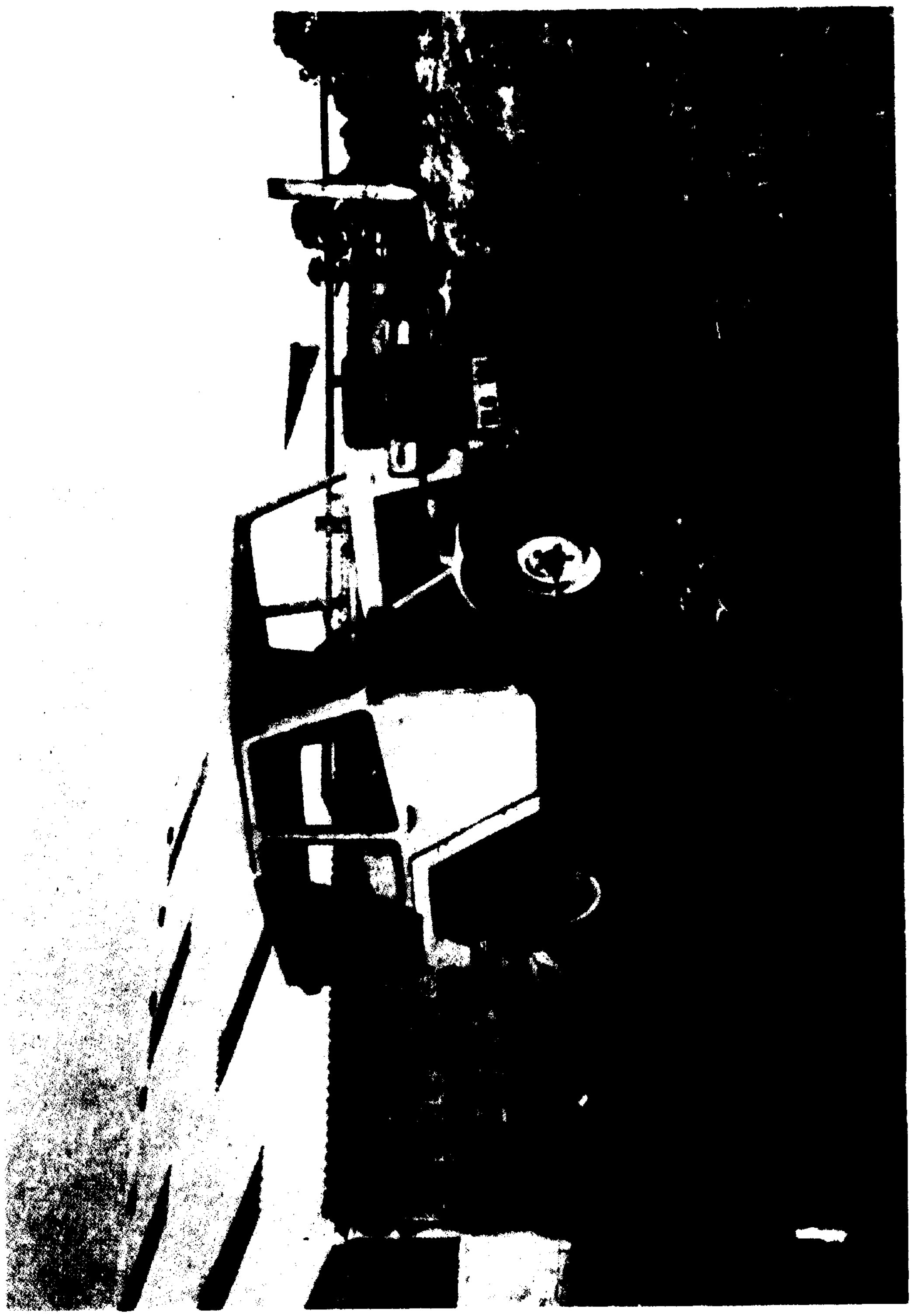
6. The concept of Trantor Limited is clearly of practical interest to those concerned with 'Appropriate and Intermediate Technology' for the developing countries.

7. The project has caused the research group to re-examine many of the basic laws of economics and to change some.

8. The recent O.E.C.D. report on Alternative Transport Technologies has featured a section on the Trantor and its factory.

9. The prototype is currently in Nigeria and the first pre-production model is complete. Five more will be available to be seen in July 1975 and on 20th August the production rate will reach one per week.

10. A seminar has been arranged for November (9 - 12), 1975 to explain some of the findings of the S.R.C. supported work and its association with other research groups in Europe. Trantor Ltd. will be a central feature of the discussion periods.



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