Mechanization of Construction Operations

By

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To discuss the various aspects and problems of mechanization of civil engineering projects in West Pakistan would require considerable time. An attempt, however, would be made to touch upon some of the more important aspects effecting the construction operations in this country.

As the bulk of the work in the next five years would be the so-called Replacement Works under I.B.D.R., completing or continuing other irrigation and drainage projects, therefore, in discussing this subject, irrigation and water projects are largely in view, but these remarks are equally applicable to all the civil engineering projects.

Mechanization of civil engineering projects from engineering point of view is purely a question of unit costs, other factors such as time available for execution of a job, availability of foreign exchange and human relations are also some of the important points which would need consideration when viewing the question in broad prospects.

However, before we go into these problems, it will be necessary to ponder as to why we want to mechanize at all. On one hand, we may argue that there is the problem of over-population in the country while, on the other, we are thinking of mechanizing the construction operations where manual labour can be easily and properly employed. We are short of foreign exchange, yet mechanization of civil engineering projects would involve considerable outlay and recurring expenditure in foreign exchange. It has been estimated that for every Rs. 100 by which machinery is purchased Rs. 60 is the recurring expenditure every year either for replacement parts or the cost of fuels and oils. So employment of machinery is a constant drain on the foreign exchange resources.

The answer to this question is closely related to the specific needs and the history of this country.

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The history of Asia, particularly that of the Arid Zone, is dependent on the history of its irrigation systems. As the vast tracts of land are to be irrigated artificially, it has always been the function of the Government in this region to maintain an efficient system of irrigation. The efficiency of the irrigation systems is a direct measure of the efficiency of the Governments. If there is good system of irrigation. country prospers and other developments follow in its wake. If the irrigation systems were let to fall in repairs, it effected the population who became dissatisfied, rebellious and ultimately the countries or even empires fell. We have just witnessed a political turmoil, *i.e.*, partition of India which has seriously upset the system of irrigation in West Pakistan and unless some drastic steps were taken by the Government, there was a danger that the history may not repeat itself. The Government took a bold action and finalised the settlement of this vital question by signing the Water Treaty and now it is up to the engineering profession to restore the self-sufficiency of water so that West Pakistan could feed its growing population. The following quotationa from *The Canal Builders* by Robert Payne would be of interest to engineers. It also sums up the up-to-date position of the need for building more and better canals :—

> "Soon there would arise further developments, all of them springing from that first trench. When the irrigation works expanded so that the canals served many communities, a ruling class of priests and irrigation experts came into existence to control the use of the canals and to establish a liturgy, and with the passing of the age of the nomadic farmers settled communities were established on the shores of the river, and as more and more communities amalgamated they formed a state. Because the canals must be safeguarded, armies arose to defend them. Because they must be inspected carefully, bureaucracy came into existence. These who took more than their fair share of water had to be punished ; therefore, law courts were formed and the laws codified. In time, powerful military establishments became the basis of authority, and a military caste took precedence over the priests and the irrigation experts, and the soldiers raided neighbouring territory in order to control their canals,

for the trenches filled with water were tangible assets, the greatest wealth in the world.

"Out of canal, out of that first trench, arose the great theocratic and minolithic state—Ur, Lagash, Sumer Babylon, Nineveh, Upper and Lower Egyyt. Pharaoh controlled the flow of water: from his bountry came the life flowing in the rivers and tamed at last in the neat checkerboard of canals on the banks of the Nile. To house the officials in charge of the innumerable canals he ordered the construction of the Labyrinth, at least five times larger than the Pentagon, and to house the dead Pharaoh pyramids arose surrounded by artificial lakes fed by the complex canal system. Empires arose on the work of the canal diggers, and when the empires perished the canals perished with them, leaving only shadowy traces on the desert sand. Sometimes the empires rose again, following a strange cyclic pattern and once again canals were dug in places where no water had flowed for a thousand years.

"Sometimes as we look back on those ancient canal diggers it is possible to guess at the emotions which moved them when they tamed the waters. For them, as for us, water was power, without which all life would cease from the earth. We too have watched the great rivers passing by and seen all their power, except for the small fraction which turns mill-wheels and turbines or is channeled off to irrigate the fields, going to waste. For century upon century the rivers have fallen into the sea, and men have stood on the banks, dimly aware of the vast explosive forces locked within them."

".....the course of human progress demands that we should dominate the forces of nature, or perish in the attemt. Once more the canal builders assume the role they assumed at the beginning of history, they are the creators of land-scapes, the purveyors of vast wealth, the hieratic engineers of destiny. Where once there were virign forests and granite outcrops, cities arise on the banks, industries are born, new civilizations come into being."

> ".....Yet this is only the beginning. All over the world vast canal projects are on the drawing boards. In Iraq the ancient canals between the Euphrates and the Tigris are being re-opened and re-shaped, and the wandering tribesmen are being settled on the land' no longer obedient to the local Sheikhs but to the Central Government which alone possesses the wealth to build the canals. Forty-six milion Pakistan is live on the banks of the Indus and its snow-fed tributaries over an area of 200,000 square miles. Now at least canals and storage dams are being built, and here again we can except a prodigeous increase in the population and a shift in centres."

How best this challenge of time can be met will tax the ingenuity of our engineers. The immensity of the task can be gauged from the fact that Rs. 156 crores were spent on all the irrigation works executed in United India upto the date of its partition in 1947. Allowing that all the prices have increased ten times the capital investment, as calculated at the present rate, would be in the neighbourhod of 1,560 Crores whereas the replacement works in West Pakistan would cost about Rs. 744 crores. The development of irrigation took place in India mostly in the last 100 years, yet we are asked to construct works half as big in 10 years' time.

Can we achieve this objective by mobilization of the manpower alone ? It is feared that the answer is in the negative. Historical and social factors are forcing the hands of the Engineers to use mechanization to an increasing degree to ideal with work which is beyond the scope of manual labour as there is a great need for speed.

The next point which we can consider is how much mechanization would be neccssary ? Therc is no straight-forward answer to this question. This is tied up in the methods by which we want to have the works executed, the unit-cost rates allowed to the labour, their housing, other social problems, and the particular seasons in which labour is available.

Without reliable statistics, it is difficult to asses definitely what labour can be made available to supplement the mechanized operations, but the

following figures would not be very much out :—

Peshawari labour with donkies (available for about 6 months).	6,000	to	8,000
Pawinda labour with donkies (available for 4 months).	5,000	to	6,000
Unskilled labour for basket work, such as odds, mussalies etc. (available for about 90 days in a year).	10,000	to	12,000

(*Note* :—This labour does not include skilled labour, masons, etc., for building operations and concreting, which can be made available in increasing number provided wages are adequate. Similarly, unskilled labour to help the masons etc ; is available readily).

Can this labour potential be increased ? It may not be possible just in the near future. This is because of the policy of trying to keep the rates in check, both by Irrigation Department and B. & R., which were the biggest employers of labour in this country. Since Partition the clamour for rapid development has been insistent, many projects were in hand, but in an attempt to keep down the rates which were not consistent with the inflationary tendency, most of the construction contractors have diverted their capital in other channels more profitable. This has not only resulted in depriving the West Pakistan of good contractors in building industry but have also dispersed the skilled and unskilled labour in various other channels. This policy may have to be reversed now because Building Industry must take its proper place in building up and rapidly developing the country. It may take some time before more resourceful contractors as well as more manual labour can be attracted in sufficient numbers to this industry.

The outturn of the unskilled labour for earth work as estimated above would not exceed 50 crores in a year, but the work load in earthwork alone for the next 5 years or so would be in the neighbourhood of 240 crores per year.

It will be apparent from the above that we have to employ machinery to a large extent to complete these jobs even if all the available

resources are taken into account, but we must maintain a correct balance between men and machines on all our major construction jobs to suit our conditions as we have to provide our men with employment. It will be profitable to review the results of the mechanisation so far brought in after Partition. Census of machinery on water development projects both of Irrigation and WAPDA was taken in 1958. It was found that that the machinery costing about Rs. 30 crores was in hand. If we add another 2 crores for the machinery with Buildings & Roads, the total would amount to about Rs. 32 crores. As a thumb rule and as per practice in America the outturn of the finished items of work in a year should be equal to the capital investment in the equipment. This should be equally applicable to this country as on large project it is generally supplemented by manual labour. With this yard-stick, 30 crores worth of machinery should give an outturn of about 30 crores of finished work each year, but the actual outturn has hardly exceeded 1/3rd of this figure. Mechanization thus has not been a success.

There are many causes which led to this sorry state of affairs. The discouraging result caused a justified prejudice against the use of machinery on construction of civil jobs. The causes can be listed as below :—

(1) The fundamental cause of all this perhaps was the failure to recognise that a good deal of planning is required ahead of the job and once the work is started by machines the work and the machines should go on continuously uninterrupted for at least 16 hours a day, if possible.

(2) It is generally not recognised that cost accounting plays a very important role in the economy of mechanisation. No standards or yard-sticks were fixed for monthly or daily outturns. Different rates were adopted on different projects. Again, the methods of cost accounting varied from project to project. Reliable and accurate cards were not maintained which could trace the history of the work performed, repairs effected, etc., of any particular, or class of equipment.

(3) Whenever any piece of equipment was brought or bought, for any particular job, the idea behind was that it belongs to that project and in any case it should not be moved out

regardless of the ultimate cost to the project or to the unit-cost rates. It was nobodys's concern whether the equipment was producing any useful work or any work at all.

Non-availability of manual labour on the scheduled rates was one of the causes which led to this mentality. This jealous guarding of the so-called interests of the project continued till the job was completed. Then, on completion of the job most of the staff concerned was shifted on to other locations with the result that equipment, without proper storage, was kept standing idle. Some parts were removed or stolen away, but gradually and surely the equipment became unserviceable. This policy has resulted in a loss of a few crores of rupees as the valuable equipment had deteriorated beyond economic repairs, because it was neither utilized after the job was completed nor it was properly stored.

(4) It was a matter of common observation that even on a single project therewere various makes of same categoryof equipment. Examples were, compressors, graders, scrapers, excavators tractors, dumpers, etc. Not only did the makes vary, but there were far too many sizes in each category.

Thus quite a jumbled situation waa created at the end of the brief initial period when each machine was relatively new and was, therefore, free from the headache of break-downs, repairs and overhauls.

(5) Many jobs had to be fed by workshops which are inadequately equipped with the result tbat the repairs effected at the best were stop-gap arrangements. It caused not only more break-down and slowing down of the job, but also damaged the equipment beyond economic repairs. The phenomenon of fatigue was not generally taken into consideration, when repairable machinery needing adjustment was forced to run.

(6) Machines costing lakhs of rupees were made dependent upon mechanics and operators who generally were not well trained and not adequately paid.

(7) The biggest problem in this country was of the spare parts. In countries, like U.S.A., and U.K., whenever a machine fails due to break-down of any part, that part is speedily replaced, but it is no so in this country where non-availability of spare parts extend to all types of machines and improvisation that has to be done is not always efficient. Therefore, out of necessity the ratio of the spare parts stocked in relation to total cost of the equipment is high which is not a very desirable feature.

(8) As already remarked, no programme of the utilisation of different units of the machinery was drawn up with the result that equipment was generally unbalanced which hampers production and results in uneconomical performance, *e.g.*, in a project although the carriage of stones for rip rap was one of the major construction items yet for loading no equipment was ordered with the result that loading had to be done by manual labour and large fleet of dumpers obtained on the job were immobilized. In other places, large concrete mixers were ordered yet without any means of mechanical loading with the result that these mixers were never utilized.

(9) Equipment in many cases was under-powered.

(10) Proper maintenance and servicing was generally neglected.

(10a) Mobile units for servicing were almost missing on all the projects. Due care was not being paid to the use of correct type of lubricants which took a heavy toll.

(11) Haul roads had too many bends and steep grades. The roads were not well designed and generally no thought was given for the alignment, upkeep and maintenance of these roads. Borrow pits were generall not made easily accessible.

(12) Prcventive maintenance was not sufficiently established or vigorously persued.

(13) Minor adjustments and repairs were not attended to immediately, thus resulting in greater damage.

(14) Log books and records maintained on the jobs were entrusted to low-paid personnel with the result that accuracy and reliability was not quite upto the mark.

The enumeration above need not be viewed with any sense of dismay or frustration, but with proper imagination and conception that we must display in construction techniques which are relatively new.

This phenomenon has occured in other countries as well, where mechanization has been more rapid than the sound development of maintenance and repair service. Perhaps this was inevitable. However, if these mistakes are not to be repeated and if mechanization is to be a success, remedial measure are to be sought, so that maximum production is obtained on commercial lines.

For maximum production there are three essential pre-requisities :—

(*a*) Good management and con trol,

(*b*) Good operation,

(*c*) Efficient maintenance and repairs.

Most of the construction equipment imported in this country belongs to the Government, and so the Government agencies have been entrusted to run this. This is not a very efficient way of doing the job, but since foreign exchange was very limited this was perhaps unavoidable, but now if the building industry is to be set up on its own leg, it is necessary that the building contractors shouldbe encouraged to purchase locally made construction equipment, maintain and run them. Pumping sets, suitable for canal bridges. culverts, regulators, falls are available from the local market, so are concrete mixers. Similarly, it is better if contractors are forced to make their own arrangements of carriage, at least for buildings, canal bridges and other masonry works on the canals, for maximum efficiency.

A bad management in operation, servicing and repairs usually make the down time to about 75%. In a recent census taken, the operational efficiency on a big-sized project was only 37%.

It would be advisable if the statistics are maintained on all the projects for each piece of major equipment tabulating the time actually

machine is producing and compare it with the idle time and setting right the defects of management to improve the matters.

For maximum production and economic utilization of the Government owned equipment plant, it is necessary that the management, operation, maintenance and repairs should remain with one and the same Central Organization who co-ordinate the operation by maintaining repairs of all heavy equipment on various projects. The main functions of such an organizatirn should be :—

1. To provide specialised advice before the design of a construction job is finalized to check up if the design would suit mechanical operation or whether some modification would be necessary. Ease of operations, smooth flow of materials and quick completion would result if the efforts of design engineer and equipment specialist are co-ordinated.
2. To check up which equipment can be readily made available from the equipment in hand and which can be profitably used on job.
3. To advise on purchase of new and specialised equipment.
4. To standardize the purchase of equipment and to ensure that equipment is properly zoned according to availability of different makes, the equipment.
5. To train operators for efficient maintenance and production.
6. To issue, from time to time, bulletins on cost accounting, and other technical data.
7. To fix use rate of equipment so that the overall cost is controlled.
8. To inventory all the equipment in hand, card under all the spares, procure spares for overhaul and running repairs.
9. To prescribe type of log books to be maintained.
10. To fix inspection procedure and frequency.
11. To classify repairs those to be undertaken in the field and in workshop.

12. To plan repair programme.
13. To declare equipment as unserviceable.

When the civil engineer has finalized the designs, it would seem logical that work to be carried out by mechanised equipment should be controlled by mechanical engineer, since he has the direct responsibility for overall maintenance of equipment at site. Mechanical engineer would organise machine groups to carry out the work designed by the civil engineers on the basis of plant performance and availability.

Similarly, the mechanical engineer with his mechanical supervisors would organize and be responsible for servicing, maintenance and repairs. He should be the authority for withdrawing equipment from operation when it needs attention. Individual operations of earthmoving equipment and drivers of heavy transport should receive a very good grounding in the operation schools to be maintained by this Central Organization at various places. They should fix standards and see that no operator who does not conform to the rigid test of exposure by sustained outturn, passes out of the School. The operators should be drilled to a rigid routine of servicing.

Irrespective of emergency of construction work it is of paramount importance that periodical servicing and preventive maintenance should be strictly adhered to. Only correct lubricants should be used. Central Agency should also publish Operations Hand Books and Lubrication Charts for equipment in use. It should be ensured that all the fuel used is properly filtered. Filtering plant and drum cleaning equipment is made available at all sites.

Filter elements should always be available at site and should be changed strictly to makers' instructions, or site conditions.

Daily servicing and refilling should be carried out by maintenance teams each under the control of an experienced hand.

For servicing of equipment, special lubricating units preferably mounted on trucks should be made abailable for all isolated pieces of machinery. On large concentration of machinery, service stations and special lubricating units may be set up.

Routine inspections are vital and may form integral part of the maintenance system. Both the frequency and routine system must be laid out and strictly enforced.

The Central Organization should be able to establish a sound system of repairs, for which it would be necessary to maintain workshops at various locations. It would also be necessary for this Organization to impose limitations on the extent of repairs which may be carried out in the field.

In addition to adjustment of external parts not involving disassembly, field repair should be limited to changing complete sub-assembly or assemblies, where the latter can be easily and conveniently removed with hand or by use of simple appliances.

On no account assemblies should be opened up in the field. Other repairs and overhauls should be carried out in properly equipped workshops, which, over and above the normal workshop kits, should be provided with special tools for assembly and dis-assembly. Torque Wrench and Steam Cleaning Equipment for quick and efficient repairs, a regular supply of components, sub-assemblies and assemblies should be available in appropriate quantity in warehouses attached with these workshops.

It is necessary to centralise the procurement of spare parts, otherwise an accumulation of unusable parts would result, as recent inventory has revealed that we have accumulated over the last few years Rs. 1·25 crores worth of unusable spare parts.

A minimum number of spare parts of each make should always be available, for which limit should be prescribed. It is understood that in India they are more liberal in the import of spare parts thus minimising the storage required for the spare parts. If a few well-known makes are allowed to do the same here, it may solve the spare parts problem to a great extent, which is the biggest problem in repair and overhauls.

Strip and overhaul should be carried out at fixed intervals and a properly planned repair schedule may be worked out.

A considerable portion of heavy construction equipment acquired in this country had come through various aid-giving agencies. They had

also invariably deputed representatives of their own at project sites to see that the equipment is being properly utilized. The points enumerated in the foregoing paras were brought into focus by them and particularly the I.C.A., it is understood, made a definite proposal for the setting up of a central body in the West Wing of the country and to take care of the existing construction equipment as well as eliminate the past errors and offsights in further purchase of new construction equipment.

The West Pakistan Government being alive to the situation ultimately decided at the high-powered Food Conference held in West Pakistan Governor's House on December, 13th 1958, and presided over by Field Marshal Mohammad Ayub Khan, to pool under one Organization all State-owned Agricultural and Engineering machinery. As a result of this, Machinery Pool Organization was created in West Pakistan in April, 1959 for looking after the machinery of Irrigation and WAPDA.

This Organization has carried out detailed surveys and inventories of the existing construction equipment in the country and had established four zonal Equipment Repair Workshops located at Lyallpur, Hyderabad, Kashmore and Jamshoro instead of numerous ill-equipped workshops all over the country. Arrangements have been made for adequate stock-piling of correct types of spares.

This Organisation in a short time of about 1½ years have taken care of points 2, 3, 4, 5, 7, 8, 9, 12 and 13 as detailed in the functions of Central Organization proposed to be set up in the foregoing paras on page 3. Efforts are being made to implement and take care of the remaining objects of such an Organization as early as possible, but a good deal of reognization in operational field and re-orientation of ideas are needed to make the mechanical operations in the execution of civil engineering projects a commercial success.

Cost Accounting

The biggest snag felt in West Pakistan on all the projects on which the machinery was employed was that detailed and accurate cost accounting was not being done on sufficiently scientific basis. There was a general lack of authentic information about the exact working cost of various types and sizes of equipment. There was also no uniformity in the useful life of equipment assumed for calculating depreciation. Since the working

conditions vary from job to job, there is a great disparity in the unit cost. Due to lach of standardized accounting, the job costget into clear picture much too late. An accurate and authentic cost accounting can only come in when reliable data is available, which unfortunately is not forthcoming, but there is no reason why we should feel shy of adopting the standards as prevalent in other countries where all jobs are mechanised. It is recommended that for cost accounting the data supplied in the pamphlet attached herewith, as an annexure may be adopted and each project engineer be requested to maintain an accurate record of cost accounting so that it may serve not only as a future guide in estimating in future projects, but may be used in controlling expenditure on his own project. As an illustrations. take the example of excavation rates, which have been considered cheaper by mechanical means than by manual labour. The average out-turn of 12 yards scraper unit with usual canal slopes and graders is about 1,000 c.ft. per hour. Thus, the depreciation alone will amount to more than Rs. 25 per %0 c.ft. (the price of this Scraper Tractor unit is Rs. 2·5 lakhs at site). In addition to these charges the operating cost per hour would amount to Rs. 25. Thus, the average cost of earthwork by scrapers would Rs. 50 per %0 c.ft. against the rate of Rs, 25 to Rs. 30 paid for manual labour with a lead of 3 to 4 chains. The earthwork by draglines would be cheaper by about 10 per %0 c.ft. but these rates do not favourably compare with manual labour rates.

So, utmost discretion is needed when deciding to entrust the earthwork job to machinery. It is certainly not advisable to use machinery on digging water courses, small and minor distributaries, road-making in the plains and other small and petty jobs, such as levelling, dressing with machinery.

Modern Trends

As we do not manufacture any machine in this country, we have to depend upon the imported machinery. The trend in modern equipment is for bigger and larger machines. The reason underlying this is mass production and thus keeping the unit costs low. The prices of labour have trippled in the last decade in America, but by employing bigger machines, the price of earthmoving equipment has been kept down.

As we have to import most of the machines from abroad, we will

have to follow suit as there is some pheno menon for wage inflation here, only to a more pronounced degree.

But in the midst of the trend to bigness in the machines, there are other requirements that must be satisfied. In many of the earthmovers the growth in size and cost of the machine has made it more and more specialized tool, a scraper that can load 30 or more cubic yard at a time, a crane that can lift 150 ton, a belt loader that can move 12,000 cubic yard in an 8 hour shift, a dump body that can carry 50 cubic yard, a batching and mixing plant that can turn out hundreds of cubic yards of concrete an hour. These are expensive mechanical giants and require special working conditions and huge production schedule for efficient use. For these special machines, (which are in use on almost every project) such as tractors, dozers, cranes, excavators, shovels, pile driver immense technological advances have been made which can be enumerated as under:—

1. Composition and manufacture for better rubber tyres.
2. Use of specialized metals.
3. Use of better lubricants.
4. Use of torque convertors.
5. Less serviceability, more and more parts are being manufactured in sealed units.

The higger and better machine has become another problem for the Government agencies and contractors that may be using the equipment. "If the efficiency of the machine is a function of the efficiency of the operators, then the operators' efficiency is a function of the efficiency of the management but the management has to be a specialized one. This cannot be done by every engineer unless he has previous experience in this direction. However, some of the conclusions which have been arrived at for plant planning and plant use in this country are as follows :—

(*a*) The larger sizes of the equipment are steadier.

(*b*) Standardization of power units is most essential in all equipment It will be more advantageous to have the same make of engine even if we have to content with the second best for the sake of uniformity and economic and speedy replacement.

(*c*) Crawler tractors should preferably be more than 80 H.P.

(*d*) The excavators should be of standard size not less than $1\frac{1}{2}$ yards and not more than $3\frac{1}{2}$ yards capacity.

(*e*) Bottom dump trucks should not be smaller than 12 cu. yards capacity, for our dump trucks the minimum should be 10 cu. yards capacity.

(*f*) Portable compressors should not have a size of 315 c.f.m.

(*h*) It is better to execute isolated small jobs by labour than have small mechanical equipment which is expensive to maintain and not very reliable in performance.

The conclusions can be summarized as under :—

1. To mechanize or not to mechanize is question of economics and no hard and fast rules can be laid down, but it is advisable to minimize the use of machinery in this country as much as possible.

2. For every lakh of money spent on the purchase of equipment there is a recurring expenditure of Rs. 60,000 each year in foreign exchange either in the shape of spares or oils and lubricants.

3. If it is decided to mechanize a job no major design should be finalised till the equipment engineer has been consulted because a design may need radical changes on account of difficulty of handling the materials or uneconomic operations for a particular job. There should be detailed planning in which the ease of mechanical operations and steady flow of materials should be of paramount importance.

4. For economic utilization of the plant a central organization should look after the procurement, operation, and repairs of all the major Government-owned equipment. The stress should be on efficient maintenance and continuous running of the fewer units rather than on the number of equipment.

5. Only efficient operators should be employed. The wage scale needs revision.

   There should be more mobile units for lubrication. Stress should be laid on correct use of oils and proper maintenance ; literature printed both in English and Urdu should be available to all the operating and supervising staff.

6. Stress should be laid on proper maintenance and upkeep of forms of log books, fuel consumption statements and inspection reports, forms should be standardised for all the projects. Preventive maintenance should be strictly enforced.

   The repairs should be classified under running repairs light repairs and overhauls. Only running repairs should be permitted in the field. Operators should not be permitted to open up assemblies in the field.

7. Cost accounting should be accurate and uniform over all the projects.

8. Due to lack of reliable data, the data as published in the pamphlet, reproduced from *Hand Book of Heavy Constructon* struction by Stubbs may be adopted.

9. The purchase of equipment should be standardized and limited to few makes.

10. Adequate stock of spares and assemblies should be maintained in the central warehouses, but it is most desirable that the equipment suppliers import their own spare parts and supply the projects if and when the necessity arises.

11. Machinery, when it is not being used, should be returned immediately to a central organisation. This can only be effected by introducing necessary use rates and a disciplinary action against the officer or officers concerned may be taken if the out-turn is not consistant with the period in which the equipment was with the officer concerned.

12. For small jobs, it is advisable to encourage the contractor to purchase the locally manufactured equipment. They should maintain and run it themselves so that the contractors may make a start for mechanization.
Utmost discretion may be exercised in the purchase of the new machinery and stock should always be taken of whatever is available in the country which is not being utilized on any other project.

13. All major repairs and overhauls should be centralized in workshops. To cut cost, all the spare parts that can be manufactured in this country should be manufactured in specially equipped workshops.

14. Endeavours should be made so that 60 to 70% of the equipment is always in the field and in working condition. "A most careful balance must be maintained between the number of new equipments introduced with service and capacity of operation, maintenance and repair and facility to handle the load efficiently, otherwise the programme of mechanization may be a complete failure and programme of planned construction work might be jeopardized."

Pamphlet

In estimating the production of a unit, it must be remembered that people and equipment do not work 60 minutes every hour ; therefore, a correction is made against total cycle time to provide for operator fatigue, job layout, and everyday service and maintenance. This correction does not include major shop servicing, equipment breakdown, or unfavourable weather conditions.

Track-type equipment ordinarily works 50 minutes out of every hour. Rubber-tyred equipment works 45 minutes out of every hour. These efficiencies apply to equipment working under average conditions and do not make allowances for equipment breakdown or major shop service.

An approximation of various efficiency hours is given in Table 1-8 :

Table 1-8

Efficiency Hours

Tractor		Efficiency hour, minute/hour	Efficiency factor
Day Operation :			
Track type	...	50	0·83
Wheel type	...	45	0·75
Night Operation :			
Track type	...	45	0·75
Wheel type	...	40	0·67

If the total cycle time for a track-or wheel-type unit is known, it can be corrected as follows :

$$\text{Corrected cycle time} = \frac{\text{total cycle time}}{\text{efficiency factor}}$$

Note. The efficiency so far attained in this country is between 40—50%.

Production Analysis

Basic Considerations. Thus far, earrhmoving operations have been broken down into certain power requirements and limitations. When these were determined, gear selections and speed of travel were considered. Material swell has been calculated to determine the number of bank yards the unit was carrying. Cycle time and efficiency completed the necessary fundamentals needed to estimate hourly production.

Production estimates are based on trips per hour, bank yards per trip, and efficiency of operation.

Owning and Operating Costs.

There are as many ways of figuring equipment hourly owning and operating costs as there are equipment manufacturers. The material in the following pages is one method that has proved successful. Experienced equipment owners agree that accurate cost records are invaluable aids when bidding work, selecting equipment, or replacing machines.

Accurate cost records are one yardsstick by which equipment can be rated. The value of knowing at all times what equipment costs to own and operate cannot be stressed enough.

In order to estimate the hourly owning and operating cost of earth-moving equipment on varied job applications, the conditions of a particular job must be determined and classified as excellent, average, or severe. Each individual should carefully consider all conditions which apply to his particular job berore choosing one of these classifications.

The purpose of the following information is to provide a method of computing the hourly owning and operating cost of a equipment. In those instances where conditions are quite different locally than the example shown, common sense should be exercised.

Owning Costs

The hourly owning cost is the sum of the hourly charges for depreciation, interest, insurance, and taxes.

Depreciation. Depreciation is the decline in value of the equipment due to wear and obsolescence. The hourly depreciation charge for equipment, with the exception of rubber-tyred units, is the cost divided by the total number of hours of useful life. In the case of rubber-tyred units, the cost of the tyres is deducted from the total cost and the result divided by the number

of expected hours. Tyre costs, except for tractor-drawn scrapers, are accounted for in the operating costs rather than in ownership cost because of varying job conditions. Freight and delivery costs should be included ; generally salvage is disregarded.

In 1954, an amendement was made to the Internal Revenue Code by which taxpayers can get a higher depreciation allowance during early depreciation years and taper off to lower rates in the remaining years of useful life. These two depreciation methods are called (1) double declining balance (2) the sum of the digits. Two provisions must be met before these new methods can be used : (1) the property must have a useful life of at least three years ; and (2) the property must have been purchased or acquired new after December 31 1953, or its construction, reconstruction, or erection must have been completed after December 31, 1953. However, where construction is begun before 1954, the new depreciation methods apply only with respect to the part completed after December 31, 1953.

Straight-Line. Under this method the annual depreciation is equal to the cost of the equipment divided by the number of years it is expected to be useful. For example, assume a track-type tractor valued at Rs. 100,000 with a life expectancy of 5 years. Each years' depreciation value would then be Rs. 20,000.

The owner can exercise an option of establishing a resale value for machine, subtracting that figure from the original cost, and then dividing by the life expectancy. For example, with a Rs. 100,000 machine, with a resale value of Rs. 25,000, the annual depreciation rate would be Rs. 15,000 per year.

If a fully depreciated machine with a book value of zero is sold, the price obtained therefrom is capital gain. If the unit is sold while it still has book value, the difference between that value and the selling price will be either capital gain or loss.

Because of the uncertainty of resale prices and because the machine is often sold before the completed depreciation period, the standard practice is to figure machinery at zero salvage value.

Double-Declining Balance. Under the double-declining balance method, the taxpayer works with a useful-life figure as he did in the

straight-line method. In the previous example, a Rs. 100,000 machine with a life expectancy of 5 years and a 20 per cent depreciation per year of Rs. 20,000 was used. Under the double-declining-balance system, the owner begins with double the straight-line deppreciation and applies that rate each year against the cost less depreciation already taken up to that year. This results in high depreciation allowances for the first years which taper off to low deductions in the last years of useful life.

Example : Consider a piece of machinery valued at Rs. 100,000 with a life expectancy of 5 years.

Depreciation Allowance

Year 1. Rs. 40,000.00 (40% or double the straight-line method).
Year 2. Rs. 24,000.00 (40% of Rs. 60,000 depreciated cost).
Year 3. Rs. 14,000.00 (40% of Rs. 36,000 depreciated cost).
Year 4. Rs. 8,640.00 (40% of Rs. 21,600 depreciated cost).
Year 5. Rs. 5,164.00 (40% of Rs, 12,960 depreciated cost).

Under this method a complete write-off is not achieved over the useful life of the machine. To remedy this situation, the new law permits a taxpayer to switch from the double-declining balance method to the straight-line method at any time. In doing so, the taxpayer would effect a complete write-off during the estimated useful life. For instance, in the above illustration, the taxpayer could switch at the end of the second year and take the Rs, 12,000 depreciation for the remaining three years on the Rs. 36,000 depreciated cost. Again, he could switch at the end of the fourth year and take the Rs. 12,960 deduction, the depreciated cost of the asset with only one year of useful life remaining.

Sum of the Digits. The sum-of the-digits method works in the following manner : Add the actual digits representing each year of useful life of the machine. For example, a machine with a 5-year life would have a sum of 5, 4, 3, 2, and 1 for example, for a total of 15. Each year's depreciation rate is figured as a fraction consisting of the remaining year's digit divided by the sum of the digits. The fraction for the first years' depreciation would then be 5/15 and for the second year 4/15.

Example : Consider a machine that cost Rs. 100,000 and has a useful life of 5 years,

Year 1. 5/15 of cost or Rs. 100,000—Rs. 33,333.35 depreciation allowance.
Year 2. 4/15 of cost or Rs. 100,000—Rs. 26,666.65 depreciation allowance.
Year 3. 3/15 of cost or Rs. 100,000—Rs. 20,000.00 depreciation allowance.
Year 4. 2/15 of cost or Rs. 100.000—Rs. 13,333.30 depreciation allowance.
Year 5. 1/15 of cost or Rs. 100,000—Rs. 6'666.65 depreciation allowance.

Rs. 100,000.00

The taxpayer has the right to use the three methods on different machines at the same sime. It is permissible to change from the double-declining balance to straight-line at any time, but other changes in method on a perticular machine must be approved by the tax officials.

Under the new methods, increased depreciation in the early years is apparent. This enables the over-all cost of operation to be spread over the useful life of an asset. For example, in early years, depreciation is high and the cost of maintenance is normally low : in later years, the depreciation decreases while the cost of maintenance normally increases.

Increased depreciation in the first years also helps to ensure against a loss on the sale of an asset, if the same must be retired or sold during the early years of its useful life. And, if the asset is sold at a gain, such gain would be taxed at a capital gain of 25 per cent while the depreciation provided to date of sale would have been charged off as ordinary operating expense at the taxpayers' maximum effective rate.

To determine the cost per hour due to depreciation, the above information may be used as follows :

$$\text{Depreciation cost per hour} = \frac{\text{purchase price-tyre value total}}{\text{depreciation period in hours}}$$

Table 1-9

Depreciation

Type of equipment	Excellent conditions		Average conditions		Service conditions	
	Hours	Years	Hours	Years	Hours	Years
Track-type tractors	12,000	6	10,000	5	8,000	4
Tractor shovels	12,000	6	10,000	5	8,000	4
Wheel-type tractors and scrapers.	15,000	7½	10,000	5	8,000	4
Pull type scrappers	15,000	7½	10,000	5	8,000	4
Wheel-type tractors and wagons	15,000	7½	10,000	5	8,000	4
Motor Graders	12,000	6	10,000	5	8,000	4
Rippers	12,000	6	10,000	5	8,000	4
Dozers, capable and hydraulic	12,000	6	10,000	5	8,000	4
Cable controls	12,000	6	10,000	5	8,000	4

Note—In the absence of any depreciation data, these figures may be adopted.

Bulletin F—Tables of Useful Lives of Depreciable Property, United States Treasury Department, Internal Revenue Service, Publication No. 173.

Regulations Relating to Depreciation, Treasury Decision No. 6,182 United States Treasury Department, Internal Revenue Service, Publication No. 211.

Interest, Insurance and Storage. The charges of interest, insurance, and storage amount to about 10 per cent of the average yearly investment. This is divided into approximately two parts : 6 per cent to interest and 4 per cent to insurance and storage.

Operating Costs

The hourly operating cost is the sum of the following items.

1. Fuel.
2. Gasoline.
3. Lubricating oil.
4. Hydraulic oil.
5. Grease.
6. Repairs, including labour.
7. Tyres.

Fuel. The approximate fuel consumption for diesel engines used in earthmoving equipment is given in Tables 1-10 and 1-11.

Table 1-10

Diesel Fuel Consumption of Wheel Vehicles

Engine horsepower	Gallons per hour		
	Excellent	Average	Severe
250—350 ...	5·5—7·0	6·5—8·5	7·5—10·0
150—250 ...	4·0—6·0	5·0—7·0	6·0— 8·0
100—160 ...	2·0—4·0	2·3—5·0	3·0— 6·0
75—100 ...	...	2·5—3·0	
50— 75 ...	...	2·0—2·5	...

Gasoline. Gasoline for engines incorporating gasoline starting of the diesel engine and for miscellaneous cleaning is Rs. 2 per hour of operation.

Lubricating Oil and Filter. The approximate hourly consumption of lubricating oil and the hourly filter cost are shown in Table 1-12.

Table 1-11

Diesel Fuel Consumption of Track-Type Tractor

Engine horepower, flywheel	Gallons per hour		
	Excellent	Average	Severe
250—350 ...	8·0—12·0	10·0—13·0	13·0—14·5
150—250 ...	5·5— 8·5	7·5— 9·5	9·0—10·5
100—150 ...	3·5— 4·5	4·5— 5·5	6·0— 6·5
75—100 ...	2·0— 3·0	3·0— 4·0	4·0— 4·5
50— 75 ...	1·5— 2·5	2·0— 3·0	2·0— 3·0
35— 50 ...	1·0— 2·0	1·5— 2·5	2·0— 3·0

Table 1-12

Consumption of Lubricants Oil and Filter Cost

Engine horsepower	Oil consumption ga.l/hr.		Filter cost Rs./hr.	
	Average	Severe	Average	Severe
250—350 ...	0·175—0·185	0·175—0·350	0·15—0·40	0·30—0·60
150—250 ...	0·140—0·160	0·150—0·185	0·10—0·40	0·25—0·60
100—150 ...	0·040—0·100	0·040—0·120	0·08—0·10	0·08—0·20
75—100 ...	0·025—0·060	0·025—0·080	0·04—0·09	0·04—0·20
50— 75 ...	0·020—0·050	0·020—0·060	0·04—0·05	0·04—0·09
35— 50 ...	0·020—0·045	0·020—0·060	0·04—0·05	0·04—0·09

*Local prices should be used to determine lubricating cost per hour.

Hydraulic Oil. Hydraulic oil issued is the operation of the steering mechanism of the prime mover and to operate the various components

of hydraulically operated scrapers. The hourly consumption of hydraulic oil for wheel-type tractors and trailing units varies from 0·01 to 0·12 gal. per hour of operation.

Grease. Grease consumption is tabulated for each type of equipment in Table 1-13.

Table 1-13

Grease Consumption

Equipment		Lb/hr.
Track-type tractors	...	0·01—0·40
Wheel-type tractors with scrapers or wagon	...	0·10—0·30
Motor graders	...	0·05—0·20
Four-wheel scrapers	...	0·10—0·30

Repair, Including Labor. Cost records should be used whenever they are available. If they are lacking, a percentage can be applied to the hourly depreciation cost.

Table 1-14

Hourly Repair Includiug Labor Costs

Equipment	Per cent. of Depreciation		
	Excellent conditions	Average conditions	Severe conditions
Track-type tractors ...	90	100	100 and up
Rubber-tyred tractors with wagons.	80	90	100 and up
Motor Graders ...	...	80	...
Four-wheel scrapers ...	80	90	100 and up.
Cable controls ...	...	100	...
Dozers ...	90	100	100 and up
Tractor-shovels ...	75	85	95

Note :—1-15. Ratio between labour and spares in this country is 25 : 75, in America 40 : 60. The spares in this country cost 100% more than in Ameriea, as indicated in Table 1-14. These percentages are approximate, but they are based on averages owners' records.

Tyres. The approximate average mileage to be expected under the best, or optimum, conditions has been established as 50,000 miles or 5,000 hr. Very few operations provide optimum conditions. A detailed study of many conditions in a particular service is necessary to determine tyre-mileage expectancy or life. Items, such as maintenance, speeds, surface conditions, tyre location on the unit, loads, curves, and grades affect the life of tyres. The opproximate tyre life for any off-the-road job may be obtained by multiplying 50,000 miles by the factors which best suit the conditions. For more detailed information, refer to Chap. 27.

When tyre life expectancy is not known, Table 1-15 can be used to to determine the approximate hourly costs of tyres.

Table 1-15

Approximate Tyre Life Expectancy for Wheel-Tractor and Hauling Units

Factor		Excellent conditions	Average conditions	Severe conditions
Estimated mileage	...	50,000	40,000	25,000
Average life, hr	...	5,000	4,500	3,000

When the expected tyre life is known, the following formula may be used to compute the hourly cost of tyres :

$$\text{Hourly tyre cost} = \frac{\text{replacement cost of complete set of tyres and tubes.}}{\text{estimated tyre life, hr.}}$$

Table 1-16 gives approximate hourly owning and operating costs of track-type tractors. The figures are based on average conditions, with representative list prices and weights. All operating costs should be determined from local rates. If possible, cost of repairs should be based on operating records.

Horsepower ranges listed in this chapter for all production figures are engine flywheel horsepower ratings. Flywheel horsepower is the output which an engine delivers to its flywheel or output shafts at its rated

full-load speed. This output is determined by limits of fuel injection rate which are present according to engine capacity and load requirements.

Bulldozer Production. Bulldozers are used primarily for short-haul excavation and as auxiliary machines to other construction equipment. The economical hauling distance for a dozer ranges from 25 to 300 ft. In bulldozing, consideration must be given to material type, blade capacity. travel and return speed, and efficiency. Production in yards per hour is figured in the following manner :

$$\text{Yards/hr.} = \frac{60 \times \text{min} \times \text{dozer capacity}}{\text{fixed time} + \text{haul time} + \text{return time}}$$

Fixed time = 0·15 min when only forward and reverse lever is required to shift.

0·30 min when both forward and reverse lever and gear selector are required to shift

Example, Consider a 150 to 250 flywheel h.p. tractor, straight blade, capacity 5 yd (loose), 50 ft. distance, haul and return in second gear.

$$\text{Fixed time} = 0{\cdot}15 \text{ min}$$

$$\text{Travel time} = \frac{50 \text{ ft.}}{160 \text{ fpm}} = 0{\cdot}31 \text{ min}$$

$$\text{Return time} = \frac{50 \text{ ft.}}{225 \text{ fpm}} = 0{\cdot}22 \text{ min}$$

$$\text{Production} = \frac{60 \text{ min} \times 5 \text{ yd}}{0{\cdot}15 \text{ min} + 0{\cdot}30 \text{ min} + 0{\cdot}22 \text{ min}}$$

$$= 450 \text{ loose yards/hr}$$

Table 1-17.

Estimated Bulldozer Production

(Loose yards per 60 -minute hour)

Tractor flywheel hp		Haul distance, ft.				
		50	100	150	200	300
250 and up...	...	782S	441 S	360S	288S	216S
		610A	343A	280A	224A	168A
		950U	560U	450U	375U	280U
150-250	...	450S	250S	180 S	142 S	100 S
		432A	240A	173A	136A	96A
		585U	325U	234U	182U	130U
100-150	...	390 S	215 S	176 S	139 S	91 S
		361A	201A	163A	129A	31A
75-100	...	284 S	154S	127 S	101S	73 S
		273A	147A	123A	98A	70A
50-75	...	184 S	105S	72S	55 S	38 S
		165A	94A	65A	49A	34A
35-50...	...	97S and A	55S and A	38 S and A	29S and A	

S = straight blade.
A = Angle blade. U = U blade.

Data Used for Production Estimates.

Data	250 hp and up	150-250 hp
Tons per load.....	17·5 U	11·0 U
	14·4 S	9·0 S
	12·0 A	8·8 A
Dozing speed, fpm... ...	225	245
Return speed, fpm ...	520	335
Fixed time, min ...	0·30	0·15

Dozing will generally be done at slow speeds from 100 to 170 fpm forward and 220 to 400 fpm in reverse. For actual tractor speeds, see manufacturer specification sheets.

To obtain the actual production, load factor and job efficiency should be included. Assuming a 8·80 load factor and a 50-minute hour efficiency, the actual production would be—

450 yd/hr × 0·80 load factor × 50/60 = 300 bank yards/hr.

The quantities given in Table 1-17 are based on 60-minute-hour efficiency; no grades, single dozer, and no trench. Forward speeds of approximately 160 fpm and reverse speeds from 220 to 400 fpm were used. These quantities may be increased as much as 75 per cent by trenching and downhill dozing. To convert loose yards to bank yards, multiply the tabular value by the load factor and the efficiency.

Bulldozer Capacities

Table 1-19.

Bulldozer Blade Capacity.

(Cubic yards loose measure)

Tractor flywheel hp	Angling blade	Straight blade	U blade
250 and up	7·0	9·0	11·5 6·5
150-250	4·5	5·0	...
100-150	3·5	4·0	...
75-100	2·5	2·6	...
50-75	1·5	2·0	...
35-50	0·8	1·0	...

Table 1-22

Tractor-Drawn Scraper Production
(Bank yards per hour.)

Prime mover flywheel hp	Load bank yd	Length of haul one way, ft.								
		200	400	600	800	1,000	1,200	1,500	2,000	2,500
250 and up	30	...	418	360	316	285	257	224	186	173
	25	...	348	300	263	238	214	187	155	144
	20	...	278	240	210	190	171	150	123	115
150-250	18	...	224	189	196	146	130	112	92	77
	16	...	200	168	148	129	115	100	81	69
	14	...	195	161	140	121	107	92	75	68
	12	...	167	138	120	104	93	79	64	58
100-150	12	...	180	150	131	114	101	88	71	60
	10	...	150	125	109	96	85	73	59	50
	8	...	121	100	88	76	69	59	47	40
75-100	8	151	124	106	91	81	72	63	51	43
	6	113	93	79	69	60	54	47	38	...
50-75	4	74	60	51	44	38	34	29	...	...
	3	55	45	38	33	29	25	22	...	...

Conditions

Material weight, 3,000 lb. per yd.
60-minute-hour efficiency
Rolling resistance, 150 lb per ton
Loading times. 15 yd and over 1·5 min.
14 yd. and under 1·0 min.
No grades present.

Note. Actual production so far attained in this country are about 1/3rd of these. Figures of actual output of of various types of equipment in this country are given on the last page of this pamphlet.

Table 1-23
Rubber-tyred Tra tor-scraper Production
(Bank yards per hour)

Haul distance one way, ft.	Average speed. mph			
	25	20	15	10
500	...	...	...	385
1,000	...	...	330	270
1,500	355	320	270	210
2,000	310	270	222	168
3,000	238	220	168	120
2,500	270	240	192	140
4,000	230	168	132	96
5,000	168	140	112	78
10,000	95	80	58	40

Conditions :

Assumed scraper load, 17 bank yards.
60-minute-hour efficiency.
Production figures include a fixed time constant of 1·5 min which includes time for loading, turns, and dumping.

Acceleration and deceleration time is included in average speed.

The horse power-weight ratio and travel speeds of all sizes of rubbe-- tyred prime movers is approximately the same. Therefore, production figures for varying capacity hauling units is proportional and can be figured by adjusting haul unit capacity.

Table 1-28

Estimated Production Figures for Elevating Graders

(Bank yards per hour)

Type of work	Job conditions		
	Excellent	Average	Severe
Truck loading ...	500	400	250
Side casting ...	800	600	400

With sufficient number of hauling units under the loader. These production figures are observed estimates.

Conditions :

Motor grader operating approximately 3·5 mph.
Conveyor belt width 42 in.
Belt speed, 500 fpm.

Table 1-29

Estimated Production of Towed-type Loaders

(Bank yards per hour)

Material	Top-ioading haul units	Side casting
Dredge tailings ...	500—600	1,000—1,200
Decomposed granite (tight) ...	600—700	1,200—1,400
River sand and gravel ...	500—600	1,000—1,200
Adobe ...	700—800	1,400—1,600
Pre-ripped hardpan and cemented gravel.	500—600	1,000—1.200
Silt and topsoil ...	800—1000	1,500—2,000

With sufficient number of hauling units under the loader. These production figures are observed estimates.

Conditions :

Tractor operating approximately 1·8 mph.
Conveyor belt width 48 in.
Belt speed, 575 fpm,

Tractor Shovels

Table 1-35

Production Per Hour

(Loose yards)

Tractor-shovel capacity, cu. yd.	Haul unit capacity, cu.yd.			
	4	6	8	10
3/4—1 ...	95·5	93·5	...	...
1—1½ ...	131	135	140	...
2—2½ ...	...	207	220	221

Conditions :

Assume 0·25 min per truck load for spotting.
For bank yard production apply the proper load factor.

ANNEXURE

End Prices of some of the Construction Equipment purchased during 1960 :

	Description		*Amount* Rs.
1.	Crawler Tractor Dozer TD 25	...	1,82,434
2.	Dozer Attachment for TD 24 Tractor	...	24,455
3.	Ruston Bycyrus 38 RB Draglines	...	2,92,175
4.	Motor Grader Caterpillar No. 12-E	...	92,111
5.	Joy Rotary Compressor Portable Model RP-600	...	61,408
6.	P & H Dragline Model 655 BLC	...	2,98,154
7.	Motor Crane 20 Ton, Ruston Bycyrus Model 22-RB.	...	2,37,018
8.	Mobile Workshop	...	1,30,019
9.	BG Locos Plymouth Diesel Hydraulic Model HDT 40 Ton.	...	33,480
10.	Double Side Tipping Wagons 5 cu. yds.	...	6,288
11.	Caterpillar D. 3·11 Diesel Electric Generating Set, 25 KW's.	...	37,299
12.	Air-Compressor 300 CPM	...	29,400
13.	International Harvestor 75 Payscraper 15/20 cu. yds.	...	2,31,060
14.	Gallon 10/12 Ballast Type Diesel Road Roller	...	53,794

Transport

1.	Mack Truck Tractor 75 Ton	...	1,83,695
2.	Leyland Super Hipo 9 cu. yds.	...	79,751
3.	Rear Dump Haulers Euclids B7 FD	...	2,01,000
4.	Dump Haulers Euclids 1 UD,	...	1,77,240
5.	88" W.B. Regular Land Rovers (Petrol)	...	12,589
6.	Dodge, Power Wagon	...	25,462
7.	Ambulance with Body-Willys Jeep Deluxe	...	32,902
8.	Willys Jeeps-4 Cylinders	...	11,962
9.	Willys Jeeps-6 Gylinder	...	19,470
10.	Leyland Abon Rover	...	58,667

11.	Austin Cypsy	...	12,685
12.	6 Ton Trucks Chevrolet	...	77,033
13.	2½ Ton Trucks Chevrolet Chassis	...	32,290

Actual production of different types of Tractor-Scraper units and Draglines in this country

(2 shifts of 8 hours each and 25 working days in a month)

Average Haul-500′—800′

1.	D-8 Tractor-15/20 Yard Scrapper	5·5 Lakhs CFt/month.
2.	Tractor-Scraper D-7 (10/14 yds).	3·7 Lakhs CFt/month.
3.	Draglines 1-1/2 cu. yds	
	Dry : Excavation	8·0 Lakhs CFt/month.
	Wet : Excavation	6·0 Lakhs CFt/month.
4.	Draglines 3 Yds.	
	Dry : Excavation	16·0 Lakhs CFt/month.
	Wet : Excavation	12·0 Lakhs CFt/month.