STAGES OF DEVELOPMENT OF TECHNOLOGY ON INDIAN RAILWAYS

Introduction

It is universally recognised that the lives and prosperity of nations as of individuals are increasingly dependent on scientific discoveries and technological applications. The increasing exploitation of man's resources by science and technology in the 16th and 17th centuries paved the way for the industrial revolution in the Western world. While the free West greatly benefited from the economic progress due to the industrial revolution, the bulk of the population of Asia, A rica and Latin America under colonial domination, were denied such exposures and the little progress they achieved ca e as fall outs from the technology transfer from the West by the ruling nations mainly for strate ic control and economic exploitation.

Since the turn of the century science and technology have been growing at a revolutionary pace and have widened the g p between the advanced western countries and the developing nations of the "Third World". Though most of the latter countries have attained in ependence and are able to di tate their own policies, they have been able to make li tle headway in bridging the awesome gap. Apart from the scarcity of capital and educational resources, the extent of institutional cost of scientific research has augmented so steeply that for all but the largest countries the promise held out by science and technology for national well being greatly exceeds the resources which can be placed at their disposal. In spite of priorities being imposed and so e measures admittedly taken to increase international coop ration in this regard, rational policies have not yet been fully developed and many of the developing countries are still in much the same poor circumstances as ever before. They are, thus, not able to participate fully in the march o scien e, which in the famous words o Jawaha L l Nehru, is mankind's greatest enterprise today.

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No doubt to achieve quick progress, technology transfers are being attempted on an ever increasing scale. Even so, as adaption, application and assimilation with assistance by research have lagged behind, they have not been able to generate economic progress anywhere near to anticipations. Serious doubts have, therefore, been expressed in the recent past that failures and short-comings in the progress of developing countries are due to the adoption of Western technologies alien to their civilisation, culture and economic millieu. With the rapidly increasing population mainly rural, the majority living near starvation levels with low standards of health and education, most of the developing countries cannot be expected to be benefited by a technology with its patently avowed aim of reduction of labour and demands on high skills. Unless, technology can be suited to the unique features prevailing in each country, such as its resources, traditions and other values, it can even have a harmful effect on development. In any case, the transfer of modern technology from the advanced countries during the past few decades has not made any appreciable impact on the economy of the developing nations, much less generated the economic progress sufficient to reach the stage of take-off to a self-developing economy. What has been achieved in the industrial sector has only resulted in the creation of enclaves in an otherwise stagnant economy and a separate elite enjoying much higher standards of living but far removed from the majority of their unfortunate brethren.

It is, therefore, but natural that the present distressing economic conditions demand a de-novo appraisal of the ethos of technological inputs relative to the achievements. An inquiry into the compatibility of the various technologies with the prevailing social and economic millieu and the extent to which they have been indigenised, adapted and innovated to the changing pattern of development

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is also inescapable.

The emergence, therefore, of the school of thought that developing nations have to seek alternative technologies to accelerate the growth potential is inevitable. This school maintains that apart from adaptational measures for successful application of horizontal transfers of technology, attempts should be made to systematise and integrate local experience, expertise of traditional practices and knowledge and synthesise the indigenous technology alongwith the appropriate transfer technology to yield the maximum benefits. They attribute the failures of technology transfer to the lack of exploitation of the empirical technology locally developed by years of practice and tradition and conditioned by the prevailing environments. To some extent these are no doubt valid thesis particularly from the point of view of large populations of unskilled labour, the reduction in whose strength is the main emphasis in all Western technology. But the welfare and gainful occupation of this illiterate and large mass of population is essential to plan the healthy prosperity of any developing nation. There is also merit in the contention that when choosing technology the conventional tests of maximising profits, should not be the criterion and that achievement of optimal efficiency with minimal capital and maximising labour should be the objective. These are, of course, laudable objectives and have to be given adequate emphasis in future programmes and policy formulations. But the basic malaise appears to be the inability to provide the necessary investments for development of agriculture and the technological inputs in the rural sector to which most of the country's population belongs. Any scheme for economic development, by way of industrialisation or development of natural resources, cannot be sustained without

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an adequate strategy on the food front. With uncertainties of weather, seasonal visitations of draught and floods, India, for example, has been afflicted by periodic shortages of food and had to divert much of its capital resources for procuring the much needed foodgrains. This has naturally led to paucity of investments in other fields leading to stagnation of economic growth.

A global strategy on the food front and adequate international cooperation to ward off hunger from every quarter will be essential if the task of participating more fruitfully in the expanding world economy is to be made easier. Then only can adequate resources be mobilised in the industrial sector. With an increase in internal and external trade and exploitation of raw materials together with large scale investments in the agricultural sector these countries will be able to promote a policy of total employment and increasing economic well-being.

It has, therefore, to be realised that there are other factors pertinent to the widening gap in development between the more advanced and under developed countries though the inadequacies in the adoption of technologies and their methods of transfer and adaptation no doubt, are also relevant inhibiting parameters. Our examination of the causes of the present economic malaise, however, searching they might be, have perforce to acknowledge these limitations and perhaps the most realistic approach would be a discriminatory adoption of suitable technologies which could when transferred, fit in with the existing technical and sociological conditions and could be assimilated by [illegible] adaptive research and engineering. Such a selective adoption of appropriate technology to meet the needs of the country has been of particular significance in the case of Indian Railways, the biggest of the public sector undertakings,

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and has proved its adequacy.

As was discussed earlier, the industrial revolution was confined to the Western countries and was not allowed to infiltrate to the under developed nations under colonial occupation. India was no exception to this and the first ever industrial and technological venture in this country came in the form of rail transport in 1853. But the spread of the railway network over a vast country like India, naturally necessitated a strong industrial supporting structure, which, consequently, also gradually developed railway system of India can, therefore, be truly considered as the fore-runner of modern industrialisation as was predicted by Karl Marx even towards the close of the 19th century.

No doubt, the railways were first introduced in the country by the British, primarily for strategic control and security, economic exploitation and for providing famine relief. The railways in India, therefore, did not exert the same spread effects on the national economy as in Europe or America. Nevertheless their benefits have been considerable. Politically they have contributed to unification and consolidation of the country and economically they have provided the necessary mobility of men and material and the basic infra-structure for a balanced growth of all sectors of economy. As an industry they have the largest potential for providing productive employment directly or indirectly through ancillary industries. Yet again they were the main channels to promote social and cultural intercourse in vast pageant of varying ideologies, differing traditions, customs and manners and a multiplicity of languages and dialects.

The Railways have thus a predominant influence in many facets of national endeavour and any independent analysis

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into the present economic malaise will not be complete without a scrutiny of every aspect of railway activity and development. Howeve , as explained later, the technology by transference or by indigenou development at least in the Railways has been by and large on the correct lines. What is lacking is not so much o the technology and development of Railways but the matching development in other areas o activity notably in the agricultural field.

Also in considering Railway technology, the background of Railway's institutional development is of s cial significance. The Railways are only one of the four ain modes of transportation, the others being the roadways, air transport and shipping. The Railways were born out of the steam-locomotion technology, long before the first motor car or airplane was developed, and were immediately chosen by all the countries of the world as the prime mode of transport for bulk carriage of goods and long distance haul of both passengers and goods. Even today the steel-wheel over the steel-rail is the most economic means of transportation. Even if this tractive system with steel-wheels on r ils was to be discovered only today, it would have still been hailed as one of the greatest achievements of mankind. There is thus, no question of an alternate technology to railways nor any choice left to any country to adopt any local or empirical technology as an alternative to railway locomotive for bulk surface transport of goods and people in the cheapest and most fficient way. The technology of Railways is thus, unique and not belonging to any world order. When we talk of "alternate technology" for railways, we can at best think of alternative adoption of indigenous empirical technology if any suited for the manufacture of various railway components e.g., traction, power packs, transmissions, suspensions, track components, signalling and safety devices.

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The concept of "alternative technology" for adoption by the Railways is not, therefore, capable of a clear definition. As a mode of transportation, it had to be the technology as it was evolved and developed in its long history of 140 years and is the appropriate technology with its immense value proved by its capacity to integrate itself with the socio-economic structure of every country. We have, therefore, in this context to analyse and identify the basic transfers of appropriate technologies and introduction of indigenous/alternative technologies involved in the stage-wise development of railway technology on the Indian Railways.

Development of technology on Indian Railways

The Indian Railways today constitute Asia's largest and the world's fourth largest system with a route kilometreage of 60,149 comprising 30,226 km. of Broad Gauge, 25,497 km of Metre Gauge and 4,476 km of Narrow Gauge. We run about 10,200 trains every day carrying over 7 million passengers, 0.55 million tonnes of goods serving over 7,0 0 railway stations spread over the vast country. The growth of this enormous net work of railway lines began 121 years ago when the first train in the country steamed off on April 16, 1853 carrying some 400 passengers on the historic journey from Bombay to Thana. During these 121 years, the Railways' system has not only expanded enormously in its route kilometreage but also has undergone a series of developments in all spheres of technology keeping pace with the changing economic and social needs of the country. Broadly speaking, the developments on the railways can be divided into two eras, the pre-independence and post-independence.

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Pre-Independence Era

The first significant stage of this era was the progressive growth of its network. In thefew decades that followed the first train, several railway systems grew up all over the country, each governed by a different management with different groups of consulting engineers, all from England. Each railway planned for the particular needs of its own terrain and traffic requirements, resulting in a multiplicity of gauges and wide variety of locomotives and rolling stock. In the beginning of this century there were as many as 175 railway administrative units in the country. While the growth of this net work was somewhat haphazard and it was mainly intended to meet the strategic requirements of the British Government, the spread of the network did, however, to a large extent match the economic and commercial needs of the country. In fact, based on the conditions then prevailing, it may not be possible to suggest many alterations in the alignments chosen for that network.

As the traffic over the railways increased, the disadvantages inherent in a haphazard growth became apparent and the lack of standards and co-ordination created serious problems in interchangeability, repairs and maintenance of rolling stock. The next important stage in the pre-independence era began with the realization of the above problem when the Government of India gave serious thought to bringing about co-ordination and standardisation among the various railway systems which were otherwise allowed to grow rather haphazardly till then. An organisation known as the 'Indian Railways Conference Association' was set up in 1903 to enforce such co-ordination and standardisation. By 1924, half of the route mileage of the Indian Railways was brought under Government control and the functions of the Indian Railway Conference Association became more effective.

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Simultaneously, a system of entrusting the responsibility of laying down standards to high level 'standardisation comm ttees' in various disciplines was also introduced in 1924 and the first committee to be so formed was the "Locomotive Standards Committee". This was followed by a number of standards committees for Carriage and Wag n, Track, Bridges, Signalling and Interlocking, Standards and Specifications, an Electrical and the first set of 46 Indian Railways' specifications w s issued in 1928. Another organisation called the Central Standards Office (CSO) was set up in 1930 in Delhi for preparing designs, specifications, tender documents etc. For the first time, research on railway technology was also undertaken in the country by CSO when in 1931 a Dynamometer Car was procured for testing locomotive performance and this was followed by the work on determination of track stresses, permissible axle loads, permissible speeds for different types of rolling stock and impact effects on track and bridges in 1935.

These developments enabled the Indian Railway personnel to develop the necessary expertise to mana e a large railway system in a co-ordinated way and also laid the foundations for an upsurge of design and research activities which was to follow in the post-independence era.

Another significant stage in the pre-independence era was the introduction between 1925 and 1935 o electric traction and automatic block signalling though on a limited scale in the areas around Bom ay and Madras. Till then the iron horse was the only source of motive power and could meet the limited requirements of the traffic in the more or less stagnant economy of the country It was, however, realised that in view of the growth of industries near Bombay and Madras, this mode of traction was no longer adequate for meeting the growting traffic requirements

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and that a more powerful and more efficient system of traction was indicated. This stage of development which set a pattern for the future growth of railways in the post independence era was particularly significant as the mode of traction was so chosen as to make use of the indigenously available resources of energy, namely electricity produced in the hydro-electric projects.

In the pre-independence era, foreign rule had, no doubt, a restrictive influence on the growth of technology in the country. Within these limitations, however, it can be said that the various stages in the development of the railway network, as also the technology adopted, though imported from England, were by and large quite appropriate to the social and economic needs of the country and also laid a substantial foundation on which the railways could develop in the post independence era.

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Post-Independence Era

There was a great upsurge in the country's economic and industrial activity in the post-independence era which generated an unprecedented demand for rail transport. The Railways as a king-pin of the national econom were called upon to meet the new challenges. They were, however, ill-equipped to meet this demand as the economic depression during 1930s, World War II and the partition of the countr had seriously impaired the railway system. The gigantic task of rehabilitation, re-construction and modernisation was taken up soon after independence and during the last 2½ decades the railways saw a series of developme tal cha ges and went through practically a technological metamorpho is. The achievements were brought about in a planned manner, through implementation of a succession of five year plans commencing from 1950-51. The period of five ye rs or a plan has, however, been found to be rather restrictive and the Railways h ve in recent years formulated a long term Corporate Plan to serve as a base not only for the current fifth plan but also for the future sixth and seventh plans. It would be interesting to review the various stages through which the railways have attained their present stage of technological growth and whether these were the most appropriate to our conditions.

The first task before the railways was to develop a mechanism for effective transfer of technology and its adaptation and indigenisation. The limited efforts in this direction, which culminated in the ormation of the Central Standards Office in 1930s were woefully inadequate to me t the demands. Quite apart from the multi-dimensional problems created b the various sizes of the railway networks and the variety a number of track components, locomotives, rolling stock and signalling equipments in use, the Indian R ilways

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had to equip themselves to assist indigenous manufacturing industries and production units to develop intra-disciplinary self-sufficiency in technological know-how to conserve valuable foreign exch nge. The Central Standards Office which was then headquartered at Simla had therefore to be expanded and a separate organisation known as the Railway Testing and Research Centre (RTRC) was created in 1952 at Lucknow for undertaking applied research, providing the basic criteria for producing new designs and testing of prototypes. As a result of these developments, the Indian Railways reached their first most significant stage of this era of attaining technological maturity and independence from foreign technology and it was then possible in 1955 to dispense with the services of Messrs Rendel Palmer & Tritton, the erstwhile technical consultants to the Railway Board and Government Railways. Whereas the Central Standards Office undertook the functions relating to design and standards, the RTRC furnished the principal criteria and parameters for creative evolution of new designs. As Research, Design and Standardisation are intimately linked, the CSO and RTRC were finally merged into a single unit known as the Research Designs and Standards Organisation (RDSO) with headquarters at Lucknow. The setting up of this unique centralised organisation which now serves all the technological needs not only of the Indian Railways but also the supporting industries in the country and many other developing countries in the world, was an important landmark in our progress. The success of our technology transfers and achievement of self-sufficiency in all fields of railway developments are essentially due to the establishment of RDSO.

Many are the steps taken to preserve and foster the dynamic character of the Research Organisation of the Railway to ntegrate it into the main stream of the country's scientific and technological activities and to

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protect it from isolation and gradual atrophy. Continual exposure to outside research and scientific institutions and progressive cooperation and participation with them in many fields has been ensured. Several problems are farmed out to such of those institutions who have specialise talent and resources in related fields and full collaboration is extended throughout the study for identification of methodology and programmes of evaluation. Furthermore, research activities are kept under high level surveillance and guidance from outside scientists and technologists through periodical reviews by the Central Board of Railway Research and its Sub-Committees with its membership drawn from top management executives of progressive industries, scientists and technologists from National Laboratories, Universities and Technological Institutes. In pursuance, RDSO has been able to sustain a high standard of development of technology to achieve near self-sufficiency on the Indian Railways and has also helped export of technology to developing countries of the third world.

It is most essential that for any future development of the railway system one should no longer look forward to outside help in choosing the appropriate technology. And again the assessment of the most suitable technology based on indigenous resources and talent has also to be continuous in the rapidly changing industrial structure/science and technology in the world. With these objectives the RDSO, in its nineteen years, has developed a large contingent of well trained technologists in various disciplines and also the concommitant facilities. In the context of rapidly changing technologies, the aim of staffing the Organisation has been to provide young engineers who are equipped with a deep knowledge of the subject and sufficient experience in the field, with capacity for continued learning

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throughout their career, rather than with an immediately usable armoury of techniques which may soon become obsolete.

The study and evaluation of the performance of various technological systems, making new designs, improvements and indigenisation are the main tasks of this organisation apart from the various other no less important functions in optimising the utilisation of existing assets, products and technology.

Every new design is preceded by an integrated study and assessment of the world knowledge and current technologica development in the field. This is followed by decisions on the level of sophistication upto which the design is to be attempted indigenously. Significant dialogues are held with outside research organisations, technologists, zonal railway administrations, production units and industries etc. for cross fertilization of ideas and for identifying and defining the various parameters. In many cases, engineers are sent out to study the salient features or for training in the countries where the product has successfully been evolved and adopted.

An assessment is also made of the capacity of the indigenous industry and trade in meeting with the specifications for the new designs and for indigenous manufacture. Proper communication is, therefore, established whereby regular consultations between the designer, the manufacturer and the users are continuously fostered and effective liaison maintained.

The manufacturing trade is helped extensively during the initial development by inspections, on the spot suggestions for improvements with proper feed backs maintaine between the inspector and the designer. With this system of

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involving the designer, the manufacturer and the user in the design development stage with a three-way communication well established, the RDSO is able not only to develop new designs successfully but also help in effectively shortening the gestation period.

It is in the field of track that RDSO has been able to attempt large scale innovations, to develop alternative technologies and adopt empirical technologies. Prestressed concrete sleepers and elastic fastenings are a few of the examples of improved technology being developed by RDSO with indigenous resources. The development of elastic fastenings suitable for Indian Railway track has been a significant achievement of local talent and this has resulted in substantial savings of royalties to foreign firms and imports.

The Indian Railways can take legitimate pride in the development of cast iron (CST9) sleepers of indigenous design using local resources and empirical technology with available pig iron and employing a large number of workers in small production units, which are more in the nature of cottage industries. Producing a lakh tonnes of sleepers annually, it involves only a simple empirical technology of cast iron making. Even though other types like steel and concrete sleepers have been extensively adopted in other countries, the Indian Railways have continued the use of cast iron sleepers except on most important high speed routes and for welded track. CST/9 sleepers now cover 60% of the track on Indian Railways.

In the field of modernisation, the RDSO's efforts have been for achieving quality and adequate standards of safety with less capital intensive alternative technologies, oriented to maximising the use of the large unskilled manpower available. An example of this is the Measured

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Shovel Packing. The use of machine technology to obtain better quality track has been limited to the important trunk routes. Emphasis continues on non-labour reducing methods and effort is continuously aimed at improved technologies using better skills and performance. The MSP technique effectively uses available manpower in a scientific manner and gives better quality track resulting in improved running quality and extended service life. Existing labour is retrained and adapted for better skills which has helped to make the employment more rewarding and more socially valuable.

Similarly, track maintenance is also systematically improved by continuous monitoring with the help of indigenously manufactured track recording cars. Development of track-measuring-technology on the Indian Railways has helped not only in ushering in the era of higher speeds but also in utilising available assets to the maximum extent and achieving better standards of maintenance, leading to lesser deterioration and increased life.

Systematic research on rail-wheel interaction is also in progress in RDSO and a Track Recording-cum-Research Car has been indigenously designed and developed for this purpose. It will be interesting to note that a statistical approach will be attempted for correlating vehicle performance with track defects. With the help of this Track Recording-cum-Research Car realistic tolerances can be evolved for track maintenance, as also standards for design and monitoring the performance of the vehicle suspension system leading to better utilisation of existing assets with progressive improvements to available skills.

In all these track modernisation schemes, viz., adoption of prestressed concrete sleepers, elastic fastenings, long welded track, Directed Track Maintenance and Measured Shovel Packing, etc., the emphasis has been to continually upgrade

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the skills of the workers towards gradual sophistication aimed at improved quality performance for meeting the demands of traffic. Even the change over to mechanised maintenance on a limited scale so far attempted has not led to any unemployment problem. This is achieved by advance planning of training of existing personnel in the higher skills required so that the same men are absorbed in higher grades for handling the sophisticated techniques. In addition, it is also realised that this leads to greater job satisfaction and better motivation and greater involvement of workmen in the development of improved techniques indigenously as is evident from the enormous response from the lower levels of management and inspectors in the All India Track Seminars frequently organised by the Institution of Permanentway Engineers (India).

Stages in the Development of Traction

Another significant stage in the post-independence era is the progressive change in the mode of traction. As mentioned earlier, except for a small length near Bombay and Madras, the old mode of traction over the entire railway network was with steam. There is no doubt that from the point of view of utilisation of local sources of energy, the use of steam traction is satisfactory so long as it can meet the requirements of speed and bulk traffic.

In fact, for more than a 100 years the Indian Railways operated almost exclusively with steam traction. Earlier a large variety of locomotives were placed in service but with the establishment of the Central Standards Office and further research and studies carried out it was possible to evolve standard designs with superior performance, improving thermal efficiency and using even very inferior grade coals. Towards the later years, Indian Railways were in a position to export expertise in steam traction to even advanced countries.

Though the steam traction thus had the distinctive advantages of having a well established indigenous base of design, manufacture and maintenance, it could not meet the exacting demands of the increasing traffic including heavier loads, extended runs and less servicing time in the post-independence era, notwithstanding the various improvements progressively introduced in the indigenous designs. There were inherent limitations of moving dimensions which restricted boiler capacity and hence locomotive horse power. On account of the rigid wheel base formed by side-rod coupling of driving axles, a limitation is placed on the number of driving axles. This limitation, together with that of axle loads, limited the tractive effort of the locomotive. It requires frequent watering, fire cleaning,

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oiling of se-eral exposed points and coaling. There is lso need for adjustments and repairs at comparatively short interval . As a result, a steam locomotive cannot operate on extended runs and even on the run, the number of servicing halts and servicing times are high. Dynamic augme t on the riving wheels of a steam locomotive, arising from partial balancing of reciprocating masses, is large and this limits its speed potential to about 100 km/h. Ste.m locomotive performance is vulnerable to the quality of coal and, with the prevailing element of uncertainty in the quality of co l received from different sources, its service reliability cannot be adequately assured.

From the operating angle, the use of diesel a.d electric traction increases the throughput capacity of a section because of better starting e.fort, greater acceleration and deceleration, better average speed and better hauling capacity, saving in time on loco requirements (coaling, watering and getting steam pressure etc.) and hence greater availability for work. This enables to some extent, elimination or postponement of investment on expensive line capacity works, such as doublings. Dieselisation or electrification of a lor g section also releases a part of the line capacity and the wagons that would be otherwise required for running of trains, carrying locomotive coal. In order to meet t. e heavy dem nds of traffic, the Indian Railways had, therefore, no alternative but to switch over to more efficient modes of traction such as the electric or diesel locomotives.

Electric Traction

ien compared to other forms of traction, electric traction requires a higher initial outlay but its working expenses are lower. The savings in working e. nses outweigh the increased interest and depreci .ion char es

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if the traffic density is sufficiently high. Where the level of traffic justifies the initial expenditure, railways by their very nature are well equipped to make full use of electric energy. In other modes of traction the source of energy has to be carried around on the engine, thereby adding to the total load. On the other hand, electric trains can draw energy from the national power grid system.

Electric traction has other advantages too. It utilises energy which originates either from hydro-electric sources which are perennial or from thermal stations which use low grade coals or nuclear material, for which adequate reserves are indigenously available. The electric energy used for electric traction is less than 3 per cent of the total generated in the country for industrial, agricultural and other purposes.

Indigenous crude oil meets only 35% of the present national demand and its availability is expected to diminish to a smaller proportion of the demand in the future. Cost of petroleum is also rising and it is becoming scarce in the international market. The pace of electrification is, therefore, being accelerated.

After the limited introduction of electric traction on the 1500 Volts DC system in Bombay and Madras areas in 1930s, electrification did not progress further for some years on account of the second World War and the unsettled conditions which followed it. Indian Railways took up for consideration electrification of the suburban lines in Calcutta area in early 1950s and electrification of the main line between Calcutta and Mughalsarai followed shortly thereafter. By this time, technological advances made it possible to use a higher voltage of 3000 V DC, with consequent reduction in the capital and operating costs. A part of this scheme was, therefore, executed on the

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3000 V DC system of traction.

The early 1950s saw very important technological developments in the field of electric traction abroad. Primarily due to the efforts made by the French National Railways (SNCF), a new system of electric traction operating at 25 kV AC at the commercial frequency of 50 cycles per second was developed and it was found that this new system not only was cheaper in capital and running costs but also was superior from the point of view of locomotive performance. After an assessment of the suitability of the new system for electrification under conditions obtaining on the Indian Railways, a decision was taken in 1956-57 that all future electrification schemes on Indian Railways would be executed on the 25 kV 50 cycles system of traction. At present over 4100 route-km corresponding to nearly 11000 track-km have been electrified and about 20% of the total goods traffic hauled on Indian Railways is moving on electric traction. It is visualised, that the Broad Gauge trunk routes connecting Delhi, Calcutta, Bombay and Madras and some other sections, covering another 10,000 kms, will be progressively brought under electric traction over the next 15 years.

While the AC system of traction has been adopted for all new schemes undertaken since the 1950s as mentioned above, and the DC electrification carried out earlier in the Madras and Calcutta areas has been converted to the AC system to facilitate integrated operation, it was found that it would not be economical to convert the electrified sections in the Bombay area from the 1500 V DC system to the AC system, considering the large assets already in operation. Certain technological advances which have taken place in the DC system of traction, have therefore been introduced into the installations in this area. When new substations

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had to be installed to augment the power supply system to meet the higher demands consequent upon growth of traffic, silicon diode rectifier sets have been installed in lieu of the old rotary convertors which used to supply the 1500 V power to the locomotives and electric multiple unit stock in the earlier days of electrification. A few thyristor invertor sets are also under installation in some of these substations in the Ghat sections to pump back into AC network the energy regenerated by trains descending the steeply graded ghats.

In the initial stages of the major electrification effort from 1950s, the French National Railways were appointed as technical consultants to the Indian Railways and the designs for the fixed installations, power supply arrangements as well as rolling stock were made out under their guidance. Most of the equipment and rolling stock had to be imported as neither the know-how nor the capacity for the manufacture of these equipments was available in the country. However, the design expertise has been built up in the railway organisation and designs for fixed installations and power supply arrangements for new electrification are now being made out by Indian Railway engineers in consultation with the Railways own Research Designs and Standards Organisation (RDSO) at Lucknow. Designs for electric rolling stock are also now being made out by RDSO. Capacity for manufacturing the various equipments required for electrification has also been built up in India as a result of an active developmental effort by the Railway Electrification Organisation and RDSO hand in hand with the Indian industry.

Diesel Traction

Since diesel traction requires the use of oil which is a scarce commodity in these days of oil crisis, it would appear as though this mode of traction is unsuitable for the Indian Railways. The fact, however, is that diesel traction

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is as indispensable to the Indian Railways now and for many years to come as electric traction. As mentioned earlier, electric traction is capital intensive and the fixed installations like overhead transmission lines, together with the provision of necessary signal facilities take time to execute. With the present conditions of resources in the country, introduction of electric traction may not be able to keep pace with the traffic requirements and adoption of diesel traction for meeting the rapidly growing traffic requirements is therefore inevitable.

Diesel traction requires diesel oil, a substantial proportion of which is produced from imported crude. However, in contrast to electric traction, diesel traction can be introduced selectively, in successive steps, embracing more and more goods services, as the traffic builds up. On congested section, the change over of even a few of the heavier long distance goods trains to diesel operation can bring about sufficient relief and help to defer heavy capital investment on electrification and/or doubling and other line capacity works. If the actual volume of traffic falls below anticipations, diesel locomotives can be switched over at short notice to other sections where they may be required. This feature of flexibility with diesel operation is an important consideration when traffic is building up in stages and changes in the pattern of traffic have to be expected. Accordingly, in the change over from steam traction, the approach has been to start with diesel traction and then introduce electric traction at a stage when the optimum traffic density for electric traction is reached.

Main line diesel traction was introduced on Indian Railways for the first time less than two decades ago. With no previous experience of such traction, it was considered prudent to import diesel locomotives from dependable sources

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with their systems well proved for the type of service duty envisaged in India.

At that time diesel traction was extensively employed in USA and it was satisfactorily meeting the demands of heavy train loads and sufficiently high speeds with a high standard of service reliability. Accordingly, it was decided to pattern diesel traction on Indian Railways on American practice. An additional advantage in adopting American practice was that American diesel locomotives worked with electric transmission and production facilities for this type of transmission were already being established in the country.

With due regard to the fact that the diesel locomotive is a sophisticated high precision machine [illegible] to Indian Railways, it was decided to establish diesel operation and facilities for maintenance and manufacture of diesel locomotives in stages that would lead to a planned growth There were in fact many important stages in the technological developments.

Initially batches of key personnel concerned with operation, maintenance and design of diesel locomotives were regularly sent abroad, to familiarise themselves with practices and problems in their respective spheres. These personnel provided the hard core of technology, in establishing and extending diesel traction. In order to orient personnel, who had switched over from the steam traction as also new entrants, training schools were set up in diesel locomotive centres. In this process of dieselisation the Indian Railways achieved a superior and sophisticated technological transformation without in any way affecting the balance of man power utilization in the earlier steam traction stage. There was no loss of employment as a consequence and on the contrary, under well planned training programmes, the men working earlier on steam traction were trained and absorbed in higher skills in higher grades for operation of diesel traction.

Subsequently, for systematic examination of practices and problems connected with operation and maintenance of diesel locomotives and effective dissemination of the results of such examination, a Diesel Maintenance Group was formed on which the concerned Zonal Railways were repr sented. RDSO was intimately associated with this Group and it served as a clearing house of diesel technology that was obtained from foreign sources or developed on Indian Railways themselves.

After gaining some experience with main line traction, the Railway Production Unit (D.L.W.*) at Varanasi was set up. Concurrently, RDSO also organised Service Engineering to monitor diesel locomotive performance, in particular perform-ance of critical systems and components. On the basis of feed back from the field, remedial measures in res ect of service defects attributable to design inadequacy f r Indian conditions were also initiated.

Now with the benefit of two decades of intensive experience in diesel locomotive operation and maintenance and one decade of locomotive manufacture with parallel design activity in RDSO and the two Production Units, Indian Railways have acquired maturity in the sphere of Diesel locomotive design as well. It may be mentioned that several new designs of locomotives have been developed for spc ific service requirements making use of the well proved engine transmission, ancillary systems incorpor ted in the imported locomotives which are being indigenously produced. One such design is already in service and prototype of another has been completed.

Since its inception in the early fifties, the progr ss of introduction of diesel traction has been very rapid and today over 25,000 route kms have already been di selised. As at present, the Indian Railways are using all the three

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* Diesel Locomotive Works.

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modes of traction and still maintain a fleet of 8,850 steam locomotives.

In 1950-51, steam traction accounted for 98 per cent of the traffic and electric traction for the remaining 2%. In 1972-73, the share of steam traction in freight traffic dropped to 25%, with diesel traction accounting for 52% and electric traction 23%. Besides, a large number of important Mail and Express trains were hauled by diesel and electric locomotives. Even with the present oil crisis it is not practicable to revert back to steam traction in any significant manner. The only appropriate course of action is to intensify the pace of electrification and to produce more electric power by installation of increasing number of thermal and hydro-electric stations, and also pursue the commercial feasibility of converting coal into oil/electricity by some modern processes like magneto-hydrodynamics.

Magneto-hydro-dynamics appears to be one of the very important technological developments which offers large scope for exploitation by India. It is a new field and may form a valuable "alternative technology" in the context of oil crisis. With the considerable talent available in the Institutes of Technology and other research institutions, it should be possible to develop this technology with indigenous resources. This will help in furthering the exploitation of locally available raw materials and growth of further technological talents within the country. Like nuclear technology, when fully developed, perhaps very little dependance on foreign help or assistance would be needed for fuel requirements

Stages of development in Signalling.

Railway signalling is a prime requirement for rail transportation for improved line capacity and safety in operation. It brings into the system scientific and technological applications for better operation and safeguards against accidents. Thus, this discipline provides wide fields for rudimentary technology as well as most sophisticated electronic and semi-conductor technology which are capable of immediate exploitation to meet the Railway's needs.

In the early years, there was no interlocking between the points and signals or between signals. Manual methods of padlocking the points were in vogue. It was in India that the first ever developments took place in the interlocking systems when in 1894 they were introduced on the North Western Railway. Electrical transmission of keys was subsequently developed and early in the present century cabin interlocking was also introduced. These early technological developments in this field were ahead of even the Western countries and even though the Railways in India started with a lag of about 23 years such developments were made possible by the utilisation of indigenous talent and resources with a view to improving the system.

Further improvements took place following the First World War, in the form of track circuits and train control circuits. The electric suburban traffic established in Bombay and Madras regions between 1925 and 1935 saw the introduction of automatic block signalling and power operation of points by electro-pneumatic point machines.

It was realised early that investments in signalling and communication systems on the Railways would considerably increase the line capacity by speeding up operation and thus reduce larger investments in more sing the line capacity and rolling stock. In the post-independence period, therefore, the signalling and telecommunication system was considerably expanded and modernised. Improvements in the standards of interlocking, route relay interlocking at some of the major terminal and junction stations, multi-aspect signalling, tokenless block working and Centralised Traffic Control were also progressively introduced.

Many of these innovations and adaptations have resulted in reduction of delays at crossings and overall travelling time of trains and helped in more trains being dealt with on some of the saturated single lines, deferring the need for doublings. Electrical track circuiting on fast running lines is a step towards achieving improved safety.

Starting with telegraph working at the end of the last century, the post-independence era also witnessed considerable expansion of communication facilities, VHF and subsequently, micro wave multi-channel communication systems were introduced on a large scale. Efforts are also on hand to minimise the requirements of foreign exchange in these ventures, as for instance replacement of copper for conductors with steel-reinforced aluminium conductors and development of indigenous electronics equipment in collaboration with indigenous manufacturers.

The field of signalling provides an enormous scope for development and sophistication. The development is well planned with progressive training imparted to the supervisory staff and workmen in these sophisticated fields with the result that the existing manpower resources are fully utilised in improved and sophisticated methods of signalling and communication technology. This approach has helped in building up the necessary indigenous capacity to adapt and absorb some of the latest technological innovations in the field of

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signalling and telecommunication. The signalling and telecommunication research laboratories in RDSO are also engaged in developing further indigenous technology in their applied research programmes, in close liaison with other research institutions in the country.

Optimisation of System Performance with existing assets.

Technological research on the Indian Railways consists for the most part of applied research with just enough basic research that is necessary to support it. In an environment of scarcity of capital, equipment and material resources, attention is focussed on optimum utilisation of available assets in the form of track, locomotives, rolling stock, etc., so as to lessen the strain on limited national resources and at the same time meet the growing demands of traffic.

Under the National Science and Technology Plan, the railway research is aimed at developing areas of science and technology which can contribute to efficacy and economy by optimisation as first priority. Research projects are thus directed towards the increase of throughput, so as to meet the growing transport needs of our economy and to provide better and faster service to the travelling public without the need for substantial investments.

An important achievement by optimisation technology is the introduction of higher speeds and the Rajdhani Expresses. Elsewhere, as in Japan and European countries, higher speeds have been attained with substantial investments in track and rolling stock. Mostly, new lines to stringent parameters are built at enormous cost for the purpose. Such a capital intensive approach is beyond the capacity of developing nations. The maintenance standards of existing track and vehicles were monitored over long periods and criteria for maintenance and riding comfort were developed. Optimal utilisation of existing assets with improved methods of maintenance and higher speeds were achieved without any substantial investments in strengthening the track structure. Some of the developing nations in Asia impressed by Indian Railway's achievements, invited Indian Railway engineers

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to conduct the necessary feasibility studies for increasing speeds on their railway systems.

Planned track renewals on high density routes, use of released materials on branch lines, rail joint welding, reconditioning of worn out Broad Gauge steel sleepers for use on Metre Gauge are some of the techniques followed to increase the service life and optimum utilisation of existing materials and assets.

Towards Self-Sufficiency.

The next important stage in our developmental activity is a concerted drive towards self-sufficiency and import substitution. Railways were one of the first undertakings in India who made systematic efforts to achieve this goal, as a result of which we have at present reached near self-sufficiency in practically all our requirements of materials, equipment and rolling stock.

Steam and Electric Locomotives.

Production of steam locomotives in India at the Chittaranjan Loco Works, i.e., C.L.W. commenced as early as in 1950-51 and the annual production targets (168 steam locomotives per year) were even exceeded during 1959-60. Diversification of production commenced in the CLW from 1961 onwards, when manufacture of B.G. electric (25 kV) locomotives was undertaken and this was followed by production of B.G. diesel hydraulic shunting locomotives from 1967. The production of steam locomotives in C.L.W. was gradually tapered off and discontinued from January, 1972 and simultaneously the production of electric and diesel shunting locos was stepped up.

The manufacture of traction motors required for .C electric locomotives is also undertaken at Chittar njan Locomotive Works. To meet the specified requirement o W stern Railway, 25 kV ac/1500 V dc dual voltage locomotiv has also been designed and its prototype is nearing completion stage. As soon as the prototype is proved in service, series production would start.

After gaining some experience in diesel traction with imported diesels, a Production Unit was established (DLW) at Varanasi to manufacture ALCO family of engines and locomotives. DLW commenced assembling with imported locomotive components in 1964 and became fully operational in about 5 years' time thereafter. Production of Metre Gauge main line diesel-electric locos was also started in 1968-69.

In the manufacture of diesel electric locomotives, DLW's own contribution is about one-third. Another one-third for electric transmission equipment is contributed by BHEL* and the balance one-third by several vendors in public and private sectors. DLW serves as a clearing house for technological guidance for the last group of vendors. An important aspect of this activity was adaptation of design, material specifications and standards to suit indigenous resources, without detriment to functional effectiveness.

Passenger Coaches.

The Integral Coach Factory, Perambur(Madras) commenced production of passenger coaches in 1955-56. By adopting the most modern design, the I.C.F. produces light weight skin stressed, all steel welded coaches of tubular design with anti-telescopic ends to ensure safety and comfort of passengers. Originally planned for the manufacture of 350 Broad Gauge III class coach shells per annum, the I.C.F reached the target production by 1959. Since then the production has been progressively increased and its present capacity is 750 coaches per year. Manufacture has also been diversified to include various types of broad gauge and metre gauge coaches and electric

*Bharat Heavy Electricals Ltd.

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multiple unit (EMU) stock. In November,1956, a separate furnishing unit was also added so that the complete coach could be assembled in the factory.

A part of the requirements of passenger coaches of Indian Railways is met by Bharat Earth Movers Limited, Bangalore (BEML), and by Messrs Jessops and Company Limited, Calcutta, both of which are public sector undertaking.

BEML have capacity for production of 300 broad gauge coaches per annum which is being expanded for the production of 400 coaches per annum. M/s Jessops are manufacturing broad gauge DC EMUs along with conventional metre gauge coaches. Their annual production capacity is 300 coaches, including EMUs.

Freight Wagons.

The manufacture of wagons is a highly developed industry in India. The requirements of wagons both for Indian Railways and for export are met mostly by the private sector industries with railway wor shops also supplementing the same.

A notable development during recent times is the substantial growth in the demand for special purpose wagons b the industries, which are being successfully designed and manufactured indigenously. Over the last decade, considerable improvements in the designs have been made in the provision of Centre Buffer Couplers, high r pay loads, better suspensions for increased speeds and compressed air brakes for closed circuit operation, etc.

New Produ tion Units.

Railways have or some time been considering setting up factories for manufacture of balancing equipment like traction motors for electric locomotives and wheels nd axles for rolling stock.

With the progress of electrification, requirement of electric locomotives has been steadily going up but without matching capacity for the manufacture of such locomotives, the main bottleneck being the availability of indigenously manufactured traction motors. This shortfall could only be made good by import, entailing a heavy drain on the country's foreign exchange resources. As for wheels and axles, Durgapur Steel Plant and M/s. TISCO were originally expected to meet the railways requirements of these items. But in practice they were unable to meet more than half the requirement, the balance having to be imported at a heavy cost.

Preliminary investigations for the setting up of two plants for the manufacture of traction motors and wheels and axles were completed during 1972-73. Necessary capital investment decision has since been taken. Collaboration agreement with a Japanese firm for the traction motor plant has been signed. For the wheel and axle plant, two agreements are envisaged, one with a USA firm for the manufacture of cast wheels and the other with a Czechoslovakian firm for axles. These are in the process of finalisation.

Railways are making an all out effort for developing indigenous capacity for manufacturing the sophisticated signalling and telecommunication equipment required by the various modernisation schemes mentioned earlier. In recent years, the railway workshops, particularly Podanur Signal Workshops on the Southern Railway, Gorakhpur Signal Workshop on the North Eastern Railway and Mettaguda Signal Workshop on the South Central Railway, have been developed for enabling manufacture of electric point machines, signalling relays, point contactor units, tokenless block instruments, panels, electric signal machines, etc. to progressively eliminate their import. Some of the equipments have already been successfully manufactured and supplied to railways.

Steps have also been taken to meet the increasing requirements of safety equipment like automatic train control and axle-counters by manufacturing them indigenously with the technical know-how developed within the country.

Railways' requirements of telecommunication equipment is being met by the public sector undertakings like M/S Bharat Electronics, Indian Telephone Industries, Hindustan Cables and Hindustan Teleprinters. Recently, special efforts were made to develop microwave trans-receivers to suit railways' requirements. Indian Telephone Industries have now started manufacturing this item which was hitherto being imported.

Import substitution and Export Promotion.

Indian Railways are making significant contributions to the economy of the country through striking advances in import substitution and export promotion. All the three major manufacturing units viz., the Chittaranjan Locomotive Works, the Diesel Locomotive Works and the Integral Coach Factory, have developed indigenous materials, components and know-how and thereby conserved valuable foreign exchange. The import content of locomotives manufactured by Diesel Locomotive Works and Chittaranjan Locomotive Works has been progressively brought down. During 1973-74, import content of an electric locomotive was 23.7 percent as against 25 percent in 1971-72, while that of a diesel electric locomotive was 26.2% against 31% in the previous year.

Indian Railways have also achieved a major break-through in recent years by securing export orders for coaches and other railway equipments. Recently, Integral Coach Factory have exported six coaches to Zambia valued at Rs.14.81 lakhs. Earlier, they had supplied 113 coaches to Taiwan Railways. Integral Coach Factory's quotation for the supply of 30 coaches to Phillipines valued at Rs.2.4 crores approximately has been reported to be the lowest. In addition, quotations have been submitted for the supply of coaches, bogies and spares to Sri Lanka, Thailand, Burma and Taiwan.

Human Engineering.

In a labour intensive technology as has been adopted on the Railways, employing as many as 1.7 million regular workers, the effective system functioning largely depends upon the human element, be it the maintenance technician, the workshop mechanic or the drivers and guards. For an efficient and productive utilization of the machinery and material resources and safety in train operation, it is essential to identify the capabilities and limitations of the human resources engaged in different fields of activity. Being the single largest employer of manpower in the country, and a highly safety conscious enterprise, the Indian Railways have recognised the need for developments in the field of human engineering and application of psycho-techniques in railway operation. While large investments are made from year to year in the railway system and advancements are made in railway technology, the effective utilization of human resources by a systematic and scientific study of the effect of human psychology in various fields of operation and application of labour sciences to man - machine systems acquire importance.

A beginning in this area was made in 1964, when in pursuance of the Railway Accidents Enquiry Committee's recommendations, a Psycho-Technical Cell was set up to analyse the causes of railway accidents arising out of human failure and to develop aptitude tests for selection of staff connected with safety in railway operation.

Human failures were found to figure prominently in a number of railway accidents and it was realised that neither technological solutions nor educative and punitive measures offer a complete solution to the problem of railway accidents.

scientifically developed aptitude tests are now prescribed for selection of certain categories of train operation staff. Comprehensive studies of job requirements personal and health factors and personality dispositions of the employees which made them susceptible to various kinds of operational lapses are some of the fields where researches are being conducted. Based on these investigations, orientation programmes and psychological counselling for staff are organised with a view to orienting them towards healthier modes of work adjustment.

In view of the importance of human factor in the system productivity, it is also realised that the organisation should develop norms for occupational health and hygiene and ageing factors in psychological capabilities in important fields of train operation.

The effective utilization of a large labour force with the application of such ergonomic appraisals and development of human engineering concepts will augment the system output in areas, the existance of which would otherwise remain unexplored and untapped.

Review of Transport Policy

The developmental stages in the various disciplines of the Railways are too numerous to be discussed fully. Hence, those stages of development which have a direct bearing on the Railways have only been elaborated. By and large what has been done in the past in the field of railway technology was quite appropriate to the less capital intensive requirements and utilising indigenous resources to the maximum and there is little scope or need to make any drastic departures. The question may arise that if all that has been done in the past is on the right lines, how the present stage which by no means can be called quite satisfactory, has been reached. As mentioned earlier, what has gone wrong is not so much the technology adopted by the Railways from time to time but the transport policy of the country as a whole, to which the Railways contribute only in part. This aspect has now assumed the greatest importance in view of the oil crisis which has come to the fore during the last two years. Placed at the near bottom of the oil producing countries, India's position is any thing but happy with more than 2/3rd of her annual consumption of about 22 million tonnes of crude oil being imported with the foreign exchange position already severely strained. On the other hand, consumption of oil in India has been increasing rapidly and probably much faster than can be borne by country's economy. While the figure was 6 million tonnes in 1960, the figure today is about 22 million tonnes giving a rate of increase of 10% per annum. The major consumer of the oil products is the transport industry, the road transport accounting for the lion's share. Among the major transport systems in the country, namely the Railways, the sea/waterways, roadways and airways, the Railways is the one mode of transport which if properly developed can reduce appreciably the dependence on oil, as the energy consumption in railways is only about 1/6th and 1/80th as compared to road vehicles and aeroplanes respectively per ton-kilometer. Even so, the growth of road transport and airways has far overtaken the growth of railways during the last 25 years. From 1950-51 to 1971-72, the freight and passenger traffic carried by road has increased by 963% and 577% respectively. The Airways have registered a similar growth of 142% and 317% respectively. Comparative figures for the railways are only 302% and 138%. From these statistics, it would be evident that the two modes of transport which consume the maximum oil per tonne km, or passenger km have grown quite out of proportion to the more economical railway system. While improvements and flexibility of operation offered by the road transport cannot be under-estimated, the fact remains that a more balanced growth between the roads and the railways is essential if the limited oil supplies have to be used for providing the maximum transportation in the country. This can only be achieved if the funds placed at the disposal of the railways are substantially increased, if necessary, by re-allocation from allotments to road transport. A national policy may also have to be evolved so that the road transport is not allowed to compete with rail transport as long as the railways are capable of moving the traffic. The aim should be to increase the total transport capacity and make the most optimum use of the limited resources of oil and not to allow uninhibited growth of one mode of transport just because of its flexibility of operation and additional convenience.

In this context, a review of the policy on urban transport is also urgently called for. At present, the growth of automobile transport in the urban areas is practically uninhibited. This gorwth is not only placing a serious burden on our oil reserves but also creating numerous other problems such as road blocks on our inadequately designed road network in the urban cities, pollution, etc. The most ideal form for mass transport in urban areas is provided by the railways which suffer from none of the above disadvantages. This aspect has received little attention in the past, obviously due to the heavy capital outlays involved in the construction of a rapid transit railway system. Already, however, a beginning has been made and it is necessary that these projects are given adequate priority and financial outlays so that they could be pushed through to completion without any further delays. There need not be any fear of labour reduction by going in more and more for railway transportation and in fact the most suitable technology from the point of view of scarce use of capital, less of imports and maximum utilisation of labour is essentially the transport system provided by the railway technology.

THE COMING YEARS - PERSPECTIVES ON TECHNOLOGY.

Modern science and technology with its phenomenal growth is revolutionising surface transportation in the more advanced countries. Automated travel at super speeds using new concepts of magnetic levitation, air-cushion, turbine engine, linear motors, cybernatics etc., are all likely to be realised in the not too distant future. No doubt, given a reasonable time and sufficient resources, it would not be outside the capability of Indian Railways' technology to assimilate these developments and to catch up with the advanced countries, fantastic though, it may appear.

But the adoption of these super-technologies in the realm of surface transportation is open to serious misgivings even apart from other practical considerations. Should available and scarce resources be wasted on research for development of such high speeds and for automation which are more or less aimed at national prestige rather than in the increase of the sum total of social happiness? Should we not divert our energies and resources for the development in other fields where the marginal increase in social utility will be comparatively much larger in proportion to the use of capital and skills? Should we promote the concentration of production and high skills, which will lead to the formation of elite enclaves in an otherwise low level society? All these are relevant questions to ponder.

However, for a developing nation with an increasing population and limitations on capital and resources priorities will certainly have to be essentially different. Emphasis will have to be on increasing the capacity with improved labour productivity and adoption of less capital intensive methods. The Corporate Plan exercises now nearly completed, indicate that the Indian Railways will have to carry 100% more of goods and 50% more of passengers by the '80s. This enormous challenge will therefore, have to be met by intensive utilisation of existing assets and improvements in performance. Efforts will have to be concentrated on system optimisation in operations and maintenance so that the utilisation of assets can be maximised with least investment in capital. Higher horse power ratings from the existing engines and their improved performances will have to be attempted with marginal in-puts. Increased pay loads, heavier trains and closed circuit operation of block trains with heavier horse power locos, improved track and signalling systems etc. will have to be planned. Electrification will have to be extended to cover the heavy density routes and the lines connecting the major cities.

Though increase of speeds is very relevant in the context of developing capacity, the capital in-puts required are highly dis-proportionate. However, the importance of the maximum operating speed as an efficiency index in a transport system has to be recognised. Besides, as a leading exporter of railway technology to the developing nations of the 3rd world, its value as a status symbol of technological prominence cannot also be ignored. In this context, limited increase of speeds of passenger trains at least upto 160 km/h and goods trains upto 100 km/h which could be realised with the existing assets and improved maintenance will have to be attempted This might also perhaps satisfy in part the demands from industry and business. But even this limited increase in speeds will per se require concurrent developments in improved technology in the design of coaches, high power locos, signalling and track maintenance etc. and considering the long gestation periods, suitable beginnings will have to be made to develop and improve, sufficiently in advance, in all spheres of technology, so that the progressive growth in traffic can adequately be catered for.

In the realm of higher horse power diesel engines, there is potential for uprating the horse power of the existing diesel engines. Steps are being taken to develop advanced expertise for diesel engine uprating. This expertise would also permit valuable improvements in the systems and components of existing diesel engines to yield lower consumption of fuel and lubricating oils and advanced component service life. It will also pave the way for design of new diesel engines with indigenous competence. In this manner, products of DLW and CLW could be kept continuously up-dated and in due course they can find their legitimate place in the export market also.

For improvements in Electric Traction, Indian Railways have undertaken development of the latest high current semiconductor technology. Replacement of obsolete equipment like excitrons and tap changers have already been proposed to achieve an improved version of locomotives capable of better performance. The job of conversion of electric locomotives from excitron type to thyristor type has been programmed in collaboration with Electronics Corporation of India and the Bhaba Atomic Research Centre.

For the purpose of better starting and speed control, it has been proposed to adopt chopper techniques utilising the semi-conductor technology for EMUs. Consideration is also being given to adoption of chopper techniques for metropolitan stock.

A proposal to set up a laboratory for Control Engineering and development of chopper and thyristor technology is under consideration. This laboratory will develop the necessary expertise for the design of control systems and full indigenisation of production technology.

With the global phenomenon of general price rise and difficulty in obtaining scarce metals like copper, serious efforts are being made to minimise its use. Three phase induction motors which are much cheaper to manufacture and which utilises much less copper are proposed to be introduced. However, the success of these induction motors would be linked with the successful development of thyristor and its manufacture within the country. Preliminary work in regard to the form of development of single phase to three phase converter has been taken up in collaboration with Central Electronics Engineering Research Institute, Pilani. The technological success in this field will open up new areas and the manufacture of locomotives with three phase induction motors can then be taken up.

The Indian Railways are actively engaged in studying the feasibility of utilising aluminium catenary and contact wires in place of copper catenary and contact wires in general use at present. Preliminary trials have shown promise and hence large scale field trials over 100 track-km have been proposed. If these trials prove successful, a major break through would be achieved.

In the field of signalling also sophistication is being achieved by the development of Automatic Warning Systems, Route Relay Interlocking, axle counters, cab signalling etc. in collaboration with the Electronics Corporation of India, Bhaba Atomic Research Centre, Tata Institute of Fundemental Research and other National Institutes.

Several studies are contemplated on development of optimisation and maintenance technologies. These will enable building up of the expertise and know-how to improve operation and substantially increase capacity thereby.

Along with the basic programme of improvements and innovations, training programmes for all categories of workers will be attempted to help meet the demands for the improved skills and adaptation to change in technology and sophistications. Diversification of production of vital components and proliferation of services in more labour surplus areas are also planned. These policies will provide the necessary mobility for workers and their retraining for better jobs. Simultaneously efforts will be made to encourage and maximise the acceptability of innovations on the part of the labour force, thus helping economically desirable changes. Policies will also be initiated to secure more productive employment for people with full freedom of choice and maximum security against loss of income.

Concurrent efforts at innovation and man-power deployment in all the fields as discussed earlier should be able to promote the growth of capacity progressively and economically, sufficient to discharge the onerous responsibilities which the Indian Railways would have to shoulder in the future. The coming years may not, therefore, witness any revolutionary changes in Indian Railway technology - yet rewarding they will be and equally exciting the task of fashioning the existing system for vastly superior performances by sophistications and innovations to erstwhile technology with least in-puts in capital.

CONCLUSION

From the brief survey of the various stages of technical development on Indian Railways it would be observed that though the initial technology in the various fields was by and large imported from the advanced countries, it was a selective approach and the technology suited to the available talent resources to adapt, develop and innovate for the specific requirements was only preferred. Besides, at every stage of development the railways have considered the local resources and the prevailing social and economic conditions in choosing the appropriate technology and sophistication. This fostered the simultaneous growth of varying technologies and co-existence of different levels of sophistication to suit the different needs of the locale and conditions of development spread over the length and breadth of the vast sub-continent which the railway net-work has been able to serve. Shri Jawahar Lal Nehru had once stated "our country at the present moment is a very mixed country; almost every century is represented in India; from the stone age in which some tribals live, you may say, to the middle of the 20th Century. We have atomic energy and also we have cow dung". Naturally the development of technology and sophistication will have to embrace a wide and mixed spectrum to suit the different stages and conditions of progress.

The fact that the adoption of such a technological approach has yielded rich dividends has been amply demonstrated by the exemplary manner in which the railways shouldered their responsibilities time and again in keeping the nation's lifelines flowing during times of grave crisis, such as the Indo-Pakistan wars and the severe draught conditions. Further in all these cases of development of technology either wholly indigenous or by adaptation and innovation, it has been possible to reach a level of expertise in some cases, even much higher than that available in the advanced countries. Such was the case with the development of steam traction in the 1930s and as it exists now in certain sectors, particularly in the fields of electronic track recording and processing of data, in the exploration of track/vehicle interaction, so essential, for introduction of higher speeds, optimisation of the design of track/vehicle, maximising safet , comfort, economy and technological elegance and longitudinal and impact forces on bridges, due to the introduction of new types of traction etc. In these as well as in several other fields of research it has been possible for the Indian Railways to actively p rticipate with the International Railway Congress Association, Economic Commission for Asia and Fast East of the United Nations (ECAFE) and other World Organisations. By and large the technology as adopted has been appropriate and suited to the talent and genius of the Indian nation enablin the development of the railways in the right direction to catch up or even surpass the advanced nations. More or less successful has also been the continued efforts to integrate the develo ment of railways' technology with the main stream of India's Scientific progress and establish meaningful collaboration with the leading scientific and technological institutions in the country in the field of innovation and sophistication.

Indian Railways have always been the largest employer in the country and has provided gainful employment to millions of persons both directly and indirectly through supporting industries. The scheme of expansion and growth has been planned with suitable diversification of production and expansion of services to get the maximum potential for productive employment. Continuous efforts are also made t improve the skills by retraining and thus enable far more gainful and ewarding employment with much more security and social r spect.

Neither in the development of the Indian Railways nor in the adoption of its technology has there been any motivation by maximization of profits as in the conventional industrial sector. Though t'e early stages of development was characterised by the need for social and political integration, the later stages have been fashioned to provide for the basic infra-structure for economic development of the country. Railways, in fact, have been instrumental in the balanced economic growth of the various parts of this far flung country and for large scale increase of the employment potential. These aims and objectives still remain unc ang d and in the pursuit of new technologies or in the develo m nt and innovation of existing technologies to m et the fresh challenges in the national growth, these very ideas and perspectives have been ke t in tact. Thus every stage of development of technology either by transfer or by indigenous growth has been appropriately chosen to minimise the use of capital and to provide for more and more job opport nities particularly for better skills adequately sup orted by training and retraining programmes to improve the sec rity and socal values.

The expertise and know-how built up over the years, by the Indian Railways has be n shared fre l with the other nations of the third world in their developmental effort In the Middle east and African countries, Indi n Railways have been able to offer technical assistance in their development programmes. In t e Far East also the Indian Railways have given expert guidance to Thailand, Phillipines, Indonesia and other countries and in some cases assistance has also een channelled through the ECAFE. The aut or himse had the privilege of advising theECAFE on the Trans Asian Railway - a project of grandiose concept of linking Eur pe and the Far East by an overlan railway touching all the important c untries enroute. This will form another impo tant commercial hannel and develop t e hinterland communication between the various countries and be a boon to some of the land locked nations.

Indian equipment, coaches, wagons, etc.have also been internationally accepted as technically and economically competitive and enjoy a large export market. To help the export promotional policy of the Government and to rationalise the external technical assistance programmes and organise it on a strictly commercial basis, recently a special Consultancy Organisation/ Rail India Technical and Economic Services Limited (RITES) have been formed which with the backing of the knowledge and expertise of the Research Designs and Standards Organisation and Indian Railways would be able to offer consultanc services in all fields of railways' operations, engineering and management. The birth of this Organisation symbolises the coming of age of Indian Railway technology and its formal debut on the stage of International Consultancy.

All these and the visions of the railwaymen for the future, can only come true when the people in all walks of life are able to contribute to the all round prosperity of the Nation. Without a Green Revolution, it is not possible to achieve a Technological Revolution. The base for technology has to be provided by our land, the farms, the rural community and untapped genious and traditional brilliance of the Indian Society. As a pre-requisite, it is most essential that proper inputs are given to the agricultural section and cottage industries and a bulk transport system embracing even the remotest areas for efficient transportation. If this is done, in the not too distant future, we would not have to specifically look for any 'alternative technology'. New technology in abundant measure in every field of human endeavour will be born out of this country and from the genious of the Indian nation as with the sciences, astronomy, mathematics, geometry, medicines etc. in the esplendent past.