Innovation Management – An Indian Experience

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Introduction

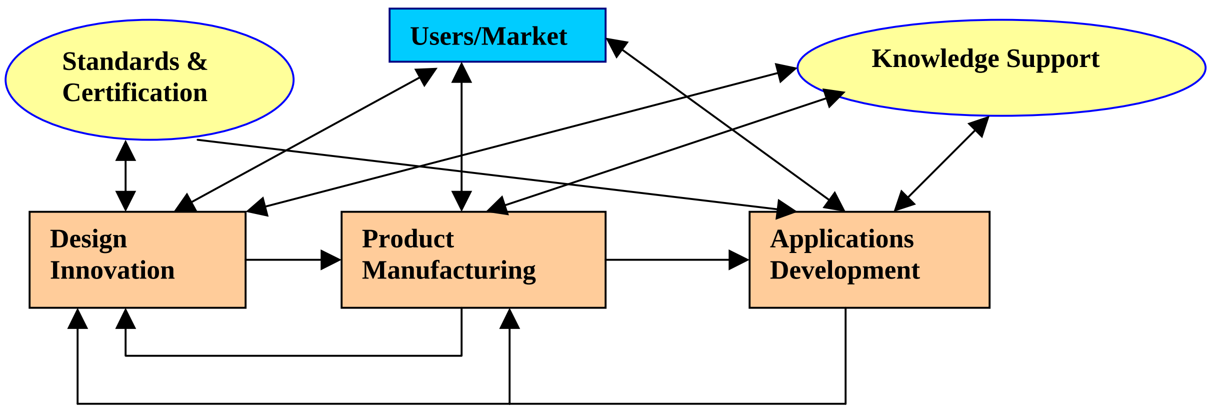
Innovation has been instrumental for technology upgradation leading to productivity, growth and international competitiveness of the industry. The technology development, its further adaptation and application have never been the straightforward process. A successful technology innovation requires a strong interactive mechanism complete with the feedback loop for various stakeholders viz. industry, extraneous knowledge sources, inspection & certification agencies and most importantly, the users or the market. However, the problems become acute in rapidly changing technological and economic environment.

Technology innovation is key to the survival of small & medium enterprises (SMEs) in India. The SMEs play a crucial role in Indian industry. They constitute 15 million units, contribute 6-7% of total GDP and employ 30 million people. More importantly, 40% of the industrial production in India comes from the SMEs. Finance is the key driver for innovation process for the SMEs and the cost of funds should be attractive enough for them for investing in projects involving technological risks. They are often beset by multi-faceted problems, which include the following :

- availability of quality raw materials
- inadequate infrastructure facilities,
- availability of skilled labour
- access to market
- development of in-house technical & managerial capabilities
- long product development cycle
- extraneous knowledge support
- lack of standards & certification process in some cases
- their internal resistance to change….

In order to mitigate such problems and to effect a seamless technology development process for subsequent commercialization, the requirement of a well-defined strategy had strongly been felt by the Government. Four decades of planned development have elevated India to a stage, where the country can show some remarkable strength in modern technologies for achieving development goals. There exists a chain of national laboratories, specialized R&D agencies in defence, atomic energy & space, Indian Institutes of Technology (IITs), universities & other academic institutions of higher learning, which are capable of providing world-class expertise, technically trained manpower and technology support to the industry. The institutes have been pursuing application-oriented research, which led to amassing an excellent knowledge pool. However, the extent of knowledge flow from such centres of excellence to the industry for its actual exploitation for the prototype development and reaching out to market has been limited. Various policy interventions were directed and organizational structures along with the fiscal incentives were designed by the Government from time to time to bridge the gap.

Innovation Cycle



2.0 Innovation Management Approaches

Keeping in view of the critical need for technology innovation, ***Technology Information, Forecasting and Assessment Council (TIFAC)*** was conceptualized as a unique knowledge networking institution in India for facilitating novel technology developments for the key sectors of economy. TIFAC was established as an autonomous organization under the aegis of Department of Science & Technology, Government of India.

As a follow-up of a detailed sectoral analysis coupled with the technology assessment exercise, composites were identified as an important performing material with a wide array of applications touching a large number of people from different walks of life. The increasing demand for materials with higher strength-to-weight ratio has led to the cognizance of composites. The composite technology of a matrix reinforced with man-made fibres such as glass, Kevlar, carbon etc. after meeting the challenges of aerospace sector has cascaded down for catering to the industrial and domestic applications. Composite structures are becoming increasingly significant in a number of novel applications in engineering fields. They meet stringent requirement such as performance at high temperature, pressure, corrosive environment or high stress. Due to their lightweight coupled with high strength, composites can replace wooden & heavy metallic parts in transportation (automobiles & railways) thus directly contributing to energy savings. The usage of composites for bio-medical applications can be a boon to the patients for reducing the drudgery of carrying heavy weight.

Assessing the status of composite industry in India, it was felt that there was an ardent need to boost the usage of composites through indigenous design capability, incorporation of advanced fabrication technologies, product development & testing. Any major impact in the sector seemed unlikely unless it was taken up as a mission mode programme with commitment from the Government. The ***Advanced Composites Mission,*** initiated by TIFAC, aimed to promote various composite applications in *components for railways & automobiles, construction materials, medical appliances, chemical & marine applications* and others. Important strategic inputs and specific products were developed for commercialization under the mission mode programme.

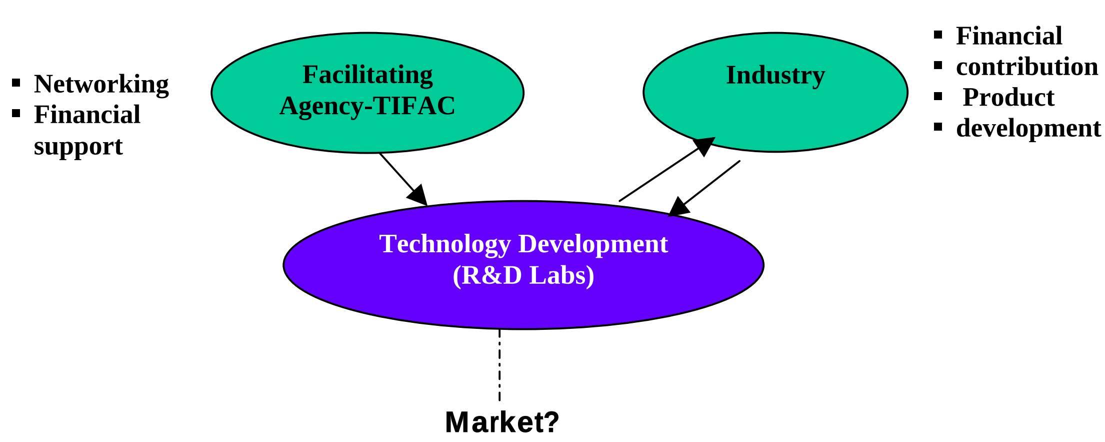
In line with the above, setting up centres of excellence for assistance in design, prototype development, product evaluation and also for technology transfer & absorption by the Indian composite industry were identified as a priority areas. The Mission had set up two composite design & development centres viz. RV-TIFAC Composite Design Centre **(CDC),** Bangalore and Composite Technology Centre at IIT-Madras, Chennai. Manpower was recognized as another key factor for development of composite technology. The Mission had launched a major project in partnership with the Central Institute of Plastics Engineering & Technology (CIPET), Chennai for developing courses & curricula for training persons in composite technology.

In view of the application potential of composites, a fast paced indigenous product development & its induction was felt necessary for important sectors. Other aspects such as usage of natural fibre (jute, sisal, pineapple, banana, coir…) in composites, development of new fibre & resin system, recyclability/reusability of composites and their effective disposal were also considered important thrust areas. The Advanced Composites Mission had experimented with varied innovation management models for the aforesaid development of composite applications. They are explained hereunder:

2.1 Model - I : Laboratory Based Technology Development

Initially the projects were conceived by the Mission wherein the technology development activities would be undertaken by a national R&D lab. The projects would be financially supported by TIFAC and the participating industry; the funds were required to be released to the R&D lab working on the project. The industry partner was required to upscale the technology for commercialization once the product gets developed successfully. Two projects were conceptualized in this mode in partnership with a defence research laboratory. The products targeted for development were high-technology applications warranting extremely critical testing & certification regime. In fact, the criticality of testing requirement was not assessed properly prior to project conceptualization. The project evaluation & monitoring mechanism did not foresee any involvement of users or certification agencies. Thus the product development process distanced itself from the market and when the prototypes were developed successfully, their induction by the users was difficult.

The participating industry was not much inclined to the aforesaid mechanism, especially for providing funding support to the R&D lab. As the lab was the centre of all actions, the industry had perceived that they were extraneous to the entire development process. Moreover, all the assets were being created within the lab premises with the financial support from TIFAC and the industry – this was not an attractive proposition for the industry. As the project involved very sophisticated level of technology development followed by critical testing procedures, the development cycle experienced many bottlenecks and delays. The industry partner lost interest in the project in due course as the project showed no promise for possibility of early commercialization.



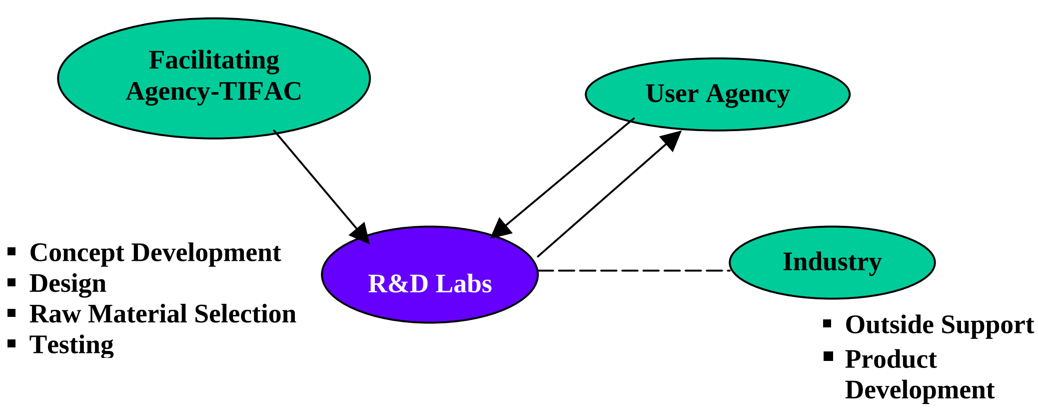
2.2 <u>Model – II : Lab Oriented Technology Development with Extraneous Industry Involvement</u>

The experience of taking up the technology development activities at the R&D lab did not meet with much success as explained above. This prompted the Mission to involve the user agencies more proactively in the project to the extent of sharing the financial assistance along with TIFAC. In this new approach, the financial support was still extended to the national R&D labs and the industry partners were not directly involved in the project.

The knowledge partner (R&D lab), identified for the project, had sufficient expertise in product design & development, selection of raw materials and necessary product testing. The user agency had identified the product to be developed under the project and shown keen interest in participating in TIFAC mode of project implementation. They took a very active part in the project by extending financial assistance to the R&D lab to the tune of 50% of the total project cost. The user agency helped in finalizing the design approach, carrying out necessary in-house testing & field trials for prototype approval. Such an involvement by the user agency was expected to play a catalytic role for early induction of the product. On successful technology development and transfer of technology licensing rights to the user agency, they also ensured repayment of funds to facilitating agency, TIFAC. As technology facilitator, TIFAC had extended financial support to the tune of 50% of the total project cost to the R&D lab for undertaking developmental project.

This technology innovation approach was followed in ***development of FRP sleepers*** for railway girder bridges. The Research & Development Establishment (Engineers), Pune was identified as the R&D lab and Research, Design & Standards Organization (RDSO), Lucknow acted on behalf of the user agency (Indian Railways) for the project. Composite sleepers were designed to replace the existing wooden and steel channel sleepers on girder bridges. The sleepers were successfully tested at RDSO & Structural Engineering Research Centre (SERC), Chennai and finally accepted by the Indian Railways due to excellent vibration absorption, extended life cycle, considerable weight saving and improved maintainability.

However, there was no direct involvement of the industry in the entire development process. While the R&D lab designed the product and finalized its fabrication process, they could not develop the prototype for lack of advanced fabrication equipment. Hence, the technology was required to be transferred to competent composite fabricators with good technical capabilities for prototype development and its large-scale replication in case of commercial induction. Though industries were identified at later stage for the prototype development, they were not fully geared to adopt and absorb the technology from the R&D lab. This led to delay in entire product development cycle.



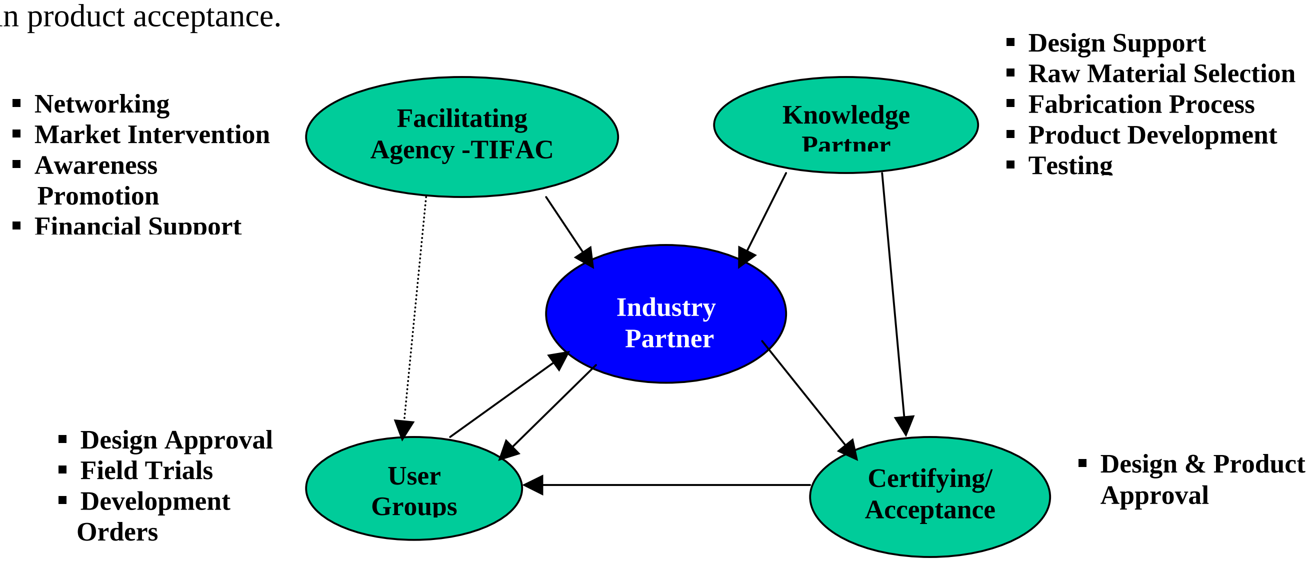
2.3 Model – III : Industry Centric Innovation

Based on earlier experiences of mixed successes, a new strategy was adopted and the Mission policies were reoriented considerably for ensuring an active involvement of the industry in the entire process of technology development. It was realized that successful technology development model should be industry centric, keeping the industry as the centre of all the actions namely, product conceptualization & design, assets creation for prototype development, testing and finally large-scale replication for wider induction. This called for extraneous knowledge support from the leading centres of excellence across the country and brought the industries closer for technology absorption, development & dissemination. The knowledge partner provided design support to the industry in terms of engineering drawings, preparation of data sheets, reports and advice on raw material selection, fabrication process, testing etc. for successful development of the prototype composite product. The programme involved faculty members from the renowned institutes such as IITs.

In order to reduce technology development cycle, the Mission started involving key persons from the user groups, certifying agencies etc. in the project monitoring committees for effective project management, technology support, product evaluation etc. The Committee provided a right mix of expertise on design, process, machine/equipment, testing & quality assurance. Such user oriented project monitoring has been the cornerstone of project management and it has greatly helped in improving the market reach of composite products and their acceptance in the shortest possible time. Thus, the projects were more focused with clear time bound objectives and most of them were completed with successful product development and user acceptance.

With the modified Mission priorities, the Technology Development Assistance was extended directly by TIFAC to the industries on repayable basis. The major thrust was on generating market-driven projects with potential applications in sectors such as railways, telecom, building & construction, bio-medical etc. With this change in focus, industry's participation was intensified & many new projects with novel composite applications were initiated.

Supported by the Technology Development Assistance from TIFAC, the industries had set up advanced fabrication system in-house and testing & quality control facilities for manufacturing composite products meeting the international standards & quality norms. This has contributed significantly to the up gradation of composite technology for a wide array of applications. This greatly contributed to the capability improvement for the industry and generated confidence among the users in product acceptance.



3.0 Achievement Highlights

The Advanced Composites Mission made substantial contribution towards development and growth of indigenous composite products. With the evolution of optimally workable technology innovation mechanism, a large number of projects was initiated in partnership with the Indian composite industry and academia. The composite technology originally developed for the aviation and space sectors has started reaching common market in a cost-effective manner. The Mission was successful in bringing a culture of technology development towards commercialization especially for the technology starved SMEs. In view of the achievements and successes of the Advanced Composites Mission, the Advanced Composites Programme was taken up by TIFAC as a regular activity. Some of the products developed under the programme for different sectors are highlighted as follows:

- ***Composites in transportation* – gear-case** for diesel locomotives, energy efficient **axial flow** radiator cooling **fans** for diesel locomotive, modular **toilets** for railway coaches, main & sliding **doors** for railway passenger coaches, interiors for **drivers' cabin** in diesel locomotive for railways, interiors for railway **passenger coaches**, **Sky bus** coach for Konkan Railway, **bracket assembly** for overhead railway electric traction, **houseboat**, components for high-end **passenger buses**, filament wound **road tankers**, high speed **boats**
- ***Industrial composite products* –** double-wall **vessels** for chemical storage, **axial flow fans** (for cooling towers, textile mill dehumidifiers, air heat exchangers, mine ventilation), **pressure vessels**, filament wound **pipes & pipe-fittings**, filament wound **venturi scrubber**, **CNG cylinders** for automobiles, **grids/gratings** for chemical industry, modular **acoustic enclosures** for DG sets
- ***Building & infrastructure*** - multi-purpose modular housing system
- ***Bio-medical application***- below knew **artificial limbs** for physically handicapped, carbon fibre external **ring fixator** as an orthopaedic appliance
- ***Natural fibre composites*** - **jute-coir boards** as wood substitutes, **bamboo laminates** for flooring tiles and shutters, jute composite components for footwear

3.1 Select Case Studies

The Advanced Composites programme has proven itself as an efficient delivery mechanism imparting excellent economic advantage in terms of creating material with superior properties, substituting scarce materials, developing value-added applications and most importantly business volume generation. The industry partners for the programme have achieved strong and profitable growth (+10% to 30% of sales increase per year generating 10% to 40% of return on capital employed). The following section discusses select case studies concerning technology development projects with the details on the need for developing such products, process of development and the outcomes.

3.1.1 Composite modular toilets for railway passenger coaches

Indian Railways have been striving to improve passenger comfort and amenities with better reliability. It was felt that the toilets at the passenger coaches needed gross improvement in aesthetics and functionality. The toilets, presently built integral with the coaches, are not at all aesthetically appealing. The toilet floors are provided with faulty gradient and thus they are prone to water accumulation and heavy leakages. The leakage from the toilet floors corrodes the undercarriage structural elements. All these called for frequent maintenance and expensive repairs especially for the undercarriage. In such a scenario, the toilets made of composites with a moulded floor could be the right step for preventing the leakage and corrosion. This has been the collective view of the Carriage Directorate of RDSO-Lucknow and ICF-Chennai of Indian Railways.

In view of the above, the development of composite modular toilet units of improved aesthetics and maintainability was identified as one of the priority projects for Indian Railways. In line with the identified requirement, the project was launched by TIFAC in partnership with ***Hindustan Fibre Glass Works, Vadodara*** with technology support from ***IIT-Bombay***. Apart from the involvement of Industrial Design Centre (IDC) of IIT-Bombay for improved aesthetics, ergonomics and usability, support from Department of Aerospace Engineering was also sought in terms of structural design of composite toilets, reinforcement lay-up, mould design & fabrication, selection of suitable raw materials, testing & mechanical characterization and quality assurance norms for fabrication. In order to bring in the right expertise and assistance for performance evaluation & guidance, the Advanced Composites Programme involved experts from various units of railways such as Railway Board, RDSO, RCF, ICF etc in the project evaluation committee.

The composite modular toilet unit was developed with four parts: the flooring trough, one L-shaped sidewall, one C-shaped sidewall & roof. All these composite components were fabricated by resin transfer moulding (RTM) process; such large components were fabricated by RTM for the first time in India. The modularity in construction for the toilet helped in taking its each part inside the compartment through the main door and they could be assembled in situ within a short time. The composite toilet unit has been light in weight, corrosion resistant, fire retardant; it has longer life with easy maintainability. Salient features of the toilets are as follows:

- Composite sandwich door, lipped with pultruded composite frame on all four sides of the door
- Ventilation provided in the toilet on the side-wall and at the lower part of the door
- Sacrificial PVC flooring with improved anti-skid and anti-abrasion properties used above the composite trough
- Concealed type Ki-tech flexible conduits with aluminium core encased within two HDPE layers for longer life with virtually no maintenance and required contours during fixing
- Light-weight 110 V DC fan, one CFL light (110 V), push type flush valve, longer vertical handle for support on right side of the pan etc. incorporated in the Indian style toilet unit

Various other features such as space for toiletries, mug space & its mounting arrangement, taps for washbasin & near pan, wall protector, mirror positions etc. were finalized for the composite toilet unit.

Four toilet units were fitted into an AC-II tier coach of Mumbai-Delhi Rajdhani Express. The coach with composite toilets was inaugurated by Dr. R Chidambaram, Chairman-TIFAC, on October 20, 2001, at Carriage Repair Workshop of Western Railway, Mumbai, in the presence of a galaxy of senior officials from Indian Railways. Based on the initial field trials, composite toilets were inducted by the Indian Railways for many important trains. The project bagged the *Certificate of Merit* under the National Award for Excellence in Consultancy Services–2001 awarded to IDC/IIT-Bombay by the Consultancy Development Centre of DSIR, Govt. of India. The technology for composite toilet units was licensed to nine composite fabricators due to its large demand by the Indian Railways.

3.1.2 Composite interiors for driver's cabin in diesel locomotive

There are two driver seats along with the consoles as mirror images at two ends of the driver's cabin for diesel locomotives. The driver's cabin accommodates the tool kit, almirah, panels for various instruments & control etc. The cabin in its present design is too cramped for free movement & comfort for the operators. The consoles appear cluttered with not so well designed placement of several dials & gauges. The Indian Railways have been seriously contemplating ways and means for an ergonomic improvement of driver's cabin interiors for diesel locomotives along with an improved aesthetic appeal.

In view of the long felt needs by the Indian Railways for modernizing the driver's cabin interiors, the project was launched with ***M/s. Black Burn Co. Pvt. Ltd., Kolkata*** with technology support from ***IIT-Bombay***. The project aimed at developing the driver's cabin interiors for diesel locomotives using composite components thereby improving the aesthetics and ergonomics for improved user comfort. The Industrial Design Centre (IDC) of IIT-Bombay helped in prototype design & development, preparation of various design drawings, fabrication of full-scale prototype etc. For a user oriented development approach, the experts from Railway Board, RDSO, DLW, DLMW and Western Railway were inducted in the project review & monitoring activities.

The new design of the cabin as evolved has addressed appropriate paneling, comfortable seats, clear visibility while operating the locomotive, proper arrangement of gauges, provision of space for tools & kits etc. The problems of heat & sound insulation were also addressed while developing the cabin interiors. In addition, the safety features such as increase in roof height inside the cabin, scientific illumination of the cabin, ergonomically correct placement of various instruments, indication regarding driver's attentiveness were all addressed in the driver's cabin. The modifications as suggested by the users were incorporated at various stages.

The design of interiors comprising wall & roof panels, flooring, console panel etc. was carried out based on human body clearances, space requirement for ingress & outgress, tool box dimensions, minimum space for drivers' belongings etc. The side panels & console panels were given an off-white granular granite finish. The roof panels were painted white to improve the interior light condition. A cupboard was provided at the short-hood side to accommodate tools and other accessories. The space between the consoles was increased considerably to facilitate free movement of personnel and height adjusted to ensure eyeball contact between driver & assistant. Openable hatches were provided below the console desk for access to the cables, gauges & other mountings. The roof comprised of two arched panels on either side and a central panel to accommodate lighting fixtures with shadow light. The set of wires/cables feeding the two console panels were laid below the floor. The floor of the cabin was made in three-piece modular composite panels for accessing underneath. Wide openable hatches were provided at the long-hood side for access to various MCBs/switches/knobs, gauges and other accessories. The existing metal door was cladded with composite panels inside and a standard lock was provided.

On approval of the full-scale mock-up of driver's cabin, the drivers' cabins of two diesel locomotives (WDM-2A) were furnished with composite interiors at Ratlam loco-shed of Western Railway by Black Burn & Co. The users' feedback from the field trials of the diesel locomotives furnished with composite interiors has been quite encouraging. The diesel loco maintenance unit from Ratlam loco-shed had inferred that the newly furnished diesel loco driver's cabin has created quite a conducive workspace. STR covering the technical specifications, design drawings, fabrication process and testing requirements for the newly developed composite interiors has been finalized by RDSO and efforts are underway in inducting them on large-scale by Indian Railways.

3.1.3 Composite houseboat for tourism

Originally known as *'kettuvallom'* and used for carrying rice & other grains in the villages dotting along the backwaters of Kerala, houseboat is a rather recent innovation positioned as the unique attraction for an already thriving tourism industry in the state. A houseboat can be the ultimate statement in luxury. The tour operators in Kerala have experimented with many variants of the houseboat. While the standard houseboat is equipped with two or three bedrooms, some have been made into a honeymooner's haven with one large bedroom. Some have also been designed with a double-deck configuration with top deck being used for conference and the lower one serving as the dining hall. Conceptualized around 10 years ago, houseboat in the backwaters of Kerala has become quiet a rage with a current population of around 250 and about 15-20 boats being built every year for catering to an ever rising demand.

A houseboat is traditionally made of resinous wood and it takes 8-10 trees (70-80 years old) to build one. Apart from denuding the forest cover, building a traditional houseboat is extremely manpower intensive and nearly 40 man months of skilled labour are required to shape it up. The wooden hull is highly prone to decay due to its continuous contact with water calling for regular tarring of the hull and frequent outages of the houseboat. The superstructure outer surface thatched with woven bamboo mat requires replacement every year due to an excessive fungal attack in a moist environment. Thus the cost of maintenance becomes quite prohibitive for the houseboat and for the tourists to enjoy that ‘ultimate in luxury’ the cost of occupancy rises! The introduction of diesel engines into houseboats has made them economical to operate, but it has become uncomfortable due to noise and vibrations. All these made houseboat a good candidate to be developed in composite for corrosion resistance, ease in fabrication and maintenance free service.

The development of ***composite houseboat*** for tourism was taken up as a project under the Advanced Composites Programme of TIFAC for improved aesthetics, boat stability, comfort level and maintainability. The project was launched in partnership with M/**s. *Samudra Shipyard Pvt. Ltd., Aroor near Cochin.*** A multi-agency approach was adopted for seeking expertise in hull design, testing, fabrication assistance, design of superstructure, interiors, amenities etc. ***NGN Composites-Chennai***, a consulting agency working in composites technology development, had assisted in mechanical design & fabrication of hull, deck & superstructure. The technology support from NGN Composites included design and development of patterns and moulds for boat hull & superstructure and quality control during fabrication process. The ***Dept. of Ocean Engineering*** **of** ***IIT-Madras*** had provided hydrodynamic design of boat hull, bulkheads, ballasts and conducted the necessary tests for boat stability. The ***Industrial Design Centre (IDC)*** of ***IIT-Bombay*** had extended design support for developing a superstructure with improved space utilization of the available envelop, aesthetics and ergonomics of the living area with the detailed design of bedrooms, toilets, dining area, lounge, kitchen etc. including design of panels, partitions & other interiors. The important milestone of IDC’s contribution has been modular design approach of the entire superstructure.

The scaled down (1:17) version of composite hull was designed & fabricated by IIT-Madras and tested for its hydrodynamic stability in their towing tank. The model hull behaviour was studied at various speeds and the hull profile was determined for scaling up. Finally the full-scale hull size measuring 26 m long x 4.50 m wide x 1.50 m deep was firmed up. IIT-Madras has also designed the propeller profile, shaft & the drive mechanism for the propulsion system.

The sandwich hull with polyurethane foam core was fabricated in composite. The decking for the houseboat has always been a problem area with a whole lot of wooden planks being used in the conventional ones. This problem was addressed by using moulded resin infused composite gratings, developed under another TIFAC project. The gratings were vertically supported along the centre line of the hull.

For superstructure, efforts were made to retain the traditional look with curved wall profiles and pagoda type roofing. The entire superstructure was made into five modular parts requiring only three moulds for fabricating the half modules. The pagoda style roofing with flat false ceiling inside the bedrooms provides good thermal insulation due to the available air gap. The superstructure was configured to accommodate two bedrooms each measuring 4.00 m x 3.50 m with large windows, attached toilets, a 1.0-m wide passage, living room with open deck, kitchen, crew toilet etc. Hard wood like bamboo composite flooring tiles, developed under a TIFAC project, were used in the bedrooms. The houseboat components such as the hull, deck and the superstructure consumed about 19.20 tons of composites, thus making the houseboat one of the largest composite products in the country.

A 104 HP Cummins diesel engine, used for the propulsion system, was housed inside the hull with anti-vibration mountings. An acoustic barrier in the form of high resilience foam was used in the engine enclosure for a noise free operation. A 10-KVA DG set was installed inside the hull for the power back-up when the engine is not in operation as the boat is anchored during the night. Polymer concrete ballasts weighing 1.50 tons were added inside the hull to improve boat stability. Three bulkheads were provided in the hull to isolate the hull puncture and water leakage. The composite houseboat has been operational in the backwaters of Kerala and its services are being enjoyed by the tourists on regular basis.

The composite houseboat has been a small step in technology development but this would go a long way in saving the environment. Involvement of the multi-agency expertise and a user-oriented approach have been instrumental in reducing the product development cycle limiting the entire exercise to under one year. While boat building in India has been a traditional activity, it is now important to introduce new materials such as composites and processes such as vacuum infusion technique. With very long coast lines along the peninsula, large natural inland water bodies and long rivers, development of composite boats of various forms & functions in India would certainly assume importance and attract investment in the near future.

3.1.4 Jute-Coir composites as wood substitute

Natural fibre composites have gained interest in the last decade, especially in the housing & construction sector. In view of the indigenous wood supply for plywood industry having been stopped virtually and with increasing landed cost of imported plywood veneers, the natural fibre composite boards were required to be developed without compromising any properties and simultaneously offering good value to the customers. Value-added composites from natural fibre could be excellent revenue generation proposition for the farmers.

Keeping in view the aforesaid objectives, the project was launched in collaboration with ***M/s. Natura Fibretech Pvt. Ltd., Bangalore*** for the development of jute-coir composite boards with face veneer (oriented jute) and coir/rubber wood veneers inside. A thin layer of jute fibres impregnated with phenolic resin was used as the face veneer for improved aesthetics and to impart a wood like finish. The orientation & uniformity of jute fibre improved with carding and this also helped in better penetration of resin into the fibre. As colour of face veneer is important for appearance, a mixture of brown & bleached jute would resemble the natural wood. The thin jute face veneer, supported by a craft paper sheet, serves as an impervious layer resulting in reduced consumption of paints while finishing the board. For inside veneers, needle felted coir mat was impregnated with specially formulated coir compatible phenol-formaldehyde resin with reasonably fast curing properties. The waste rubber wood veneers were also impregnated with phenolic resin. For the boards containing rubber wood, the resin impregnated wood veneers are arranged as intermediate layers during assembly. The assembling is carried out by placing oriented jute layer at two outer faces with semi-cured coir felt sheets inside. The number of coir and rubber wood layers to be used as inside veneers depends on desired thickness of the finished board. The assembly of various layers is compression moulded and cured in multi-plated hydraulic press with continuous monitoring of temperature, pressure & time.

In the project, 80% of the material used in the composite were renewable natural fibres such as jute and coir. The coir fibre contains ~46 % lignin as against 39% in teakwood. Therefore, it has improved resistance against rotting under wet and dry conditions and has better tensile strength. Similarly lower cellulose content in coir (43%) as against 63% in wood makes it more durable than teakwood. Several applications were identified for jute-coir composite boards: *building & construction, furniture industry, transportation* etc. The project evaluation committee was constituted considering the product acceptance, usage & induction by involving experts from BMTPC, CPWD, RDSO, IJIRA. The characteristics of natural fibre composite boards are as follows:

- Attractive natural look; it can be painted, polished or laminated at will
- Water proof with minimum surface absorption
- Economical
- Strong and rigid
- Fire retardant
- Environment-friendly
- Can be nailed, screwed and cut sharply

The product range developed under the project, comprises **coirply** (jute+coir+rubber wood waste) boards as <u>plywood substitute</u> and **natural fibre reinforced panel** (jute+coir composites) as <u>MDF substitute</u>. The jute-coir boards as MDF & plywood substitutes was tested satisfactorily at IPIRTI-Bangalore as per relevant IS codes. The performance of jute-coir composite boards has proven superior to plywood & MDF boards. Typical MDF boards do not prove well on the grounds of moisture absorption & screw holding strength. Detailed evaluation of the jute-coir board samples was also carried out by RDSO & ICF for their applications as berth backings in railway coaches; the results conformed to the railways' requirements. In fact, with sustained efforts by the Programme Scientists & the industry partner, the Indian Railways had approved the product for coach interiors. Indian Railways inducted the jute-coir boards (8 ft. x 4 ft. x 6 mm thick) on large-scale for berth backing at ICF-Chennai.

The Bureau of Indian Standards (BIS) has brought out the relevant standards (**IS 14842 : 2000**) for **coir veneer boards** and the product developed under the project conforms to the codes. These natural materials have all the properties required for a general purpose board and can be used in place of plywood or MDF boards for partitioning, false ceiling, surface panelling, roofing, furniture, cupboards, wardrobes etc.

With active pursuance of the Advanced Composites Programme, the product made excellent in-roads to railways, CPWD, BSNL, Govt. of Karnataka and others. Apart from the domestic market, the product also enjoys very good technology transfer possibilities in the international arena especially in the coir producing countries in Africa and South-East Asia. As the product is derived from fast renewable natural resources, the project does serve its basic objective of saving forest.

3.1.5 Development of artificial limbs for physically handicapped

Artificial limbs can be quite effective in restoring the normal movement for victims of trauma, accidents and other amputees. In addition to replacing lost functions, artificial limbs can result in cosmetic improvements for the patient and help build the self-confidence. The artificial limb developed initially in the world has been an exoskeleton, which was more of a cosmetic replacement rather than a functional one. Though these appear like natural limbs, they cannot impart normal gait to a person. The conventional exoskeleton types of artificial limbs are heavy in weight and are not at all comfortable for the patients. Subsequently efforts were directed internationally to develop endoskeleton type of artificial limbs. Modern artificial limbs have come a long way from the old wooden exoskeleton type of artificial leg. The endoskeleton replicates the functionality of bones for load bearing and involves proper mechanical joints for normal gait. Advanced endoskeleton type artificial limbs are now made from modern lightweight materials and often-incorporate electronic & pneumatic mechanisms.

In India, commonly used artificial legs are exoskeleton type made of high-density polyethylene. Though the imported endoskeleton types of limbs are available in India, they are very expensive. As physical deformities aggravate the economic woes of the victims in our country, it called for an indigenous development to restore the functional normalcy of physically challenged people at an affordable price. On assessing the present scenario towards improving design, functional needs & aesthetics of the artificial limbs in India to cater to societal needs a project on developing ***'composite artificial limbs for physically handicapped'*** was launched in collaboration with ***Mohana Orthotics & Prosthetic Centre, Chennai*** with technology support from ***IIT-Madras*** and ***Madras Institute of Technology, Chennai*** in terms of design, prototype development and complete testing of composite limbs.

The below-the-knee endoskeleton artificial limbs developed under the project were lighter in weight and better appearance than ever before with improved gait for the patients. This below-the-knee endoskeleton limb consists of five parts: a *composite tubular structure* fabricated by filament winding of glass fibre in epoxy matrix, *top & bottom connectors* made by injection moulding of glass filled nylon, a *polyurethane foot* with *composite keel* embedded in it and a *polypropylene socket* to accommodate the amputee stump. The socket is patient specific and does not create any problems like pressure sores even for diabetic patients. All the five parts and the socket are adjustable to meet individual requirements and to take care of static & dynamic alignment patterns.

A very innovative design approach was adopted for designing the composite keel, fabricated by compression moulding, for providing improved strength & flexibility in the foot piece. Provision was made to take care of the alignment when they were fitted to the patient. The new polyurethane foot allowed a foot to press and spring on the ground very much like a real foot. 3-D modelling of the endoskeleton with all the embedded components considering actual properties of various materials was carried out. A simulated endurance test was conducted for 5-year service life of the artificial limb considering average stance duration of 0.5 seconds for normal gait and three hours walking time per day thus testing the limb for around 40 million cycles.

The indigenously developed artificial limb has high modulus, long-term dimensional stability, high fatigue resistance, long-term bio-stability excellent abrasion resistance and bio-compatibility. They look like a natural foot, it is sturdy, durable, waterproof and made of locally available material. The unique design of this composite limb permits walking, cycling, climbing and even driving a vehicle by a person physically challenged otherwise. A whole lot of innovative technology inputs from MIT was instrumental in developing a user friendly & world-class artificial limb with excellent market potential in India and abroad.

Such indigenously developed below-knee artificial limb cost maximum **Rs.3,500/-** only as against **Rs.40,000/-** for the imported ones. The endoskeleton type below-knee artificial limb developed by Mohana Orthotics was awarded the prestigious **National R&D Award 2001** by the Department of Scientific & Industrial Research (DSIR), Govt. of India.

4.0 Conclusion

The Advanced Composites Programme has been a truly successful experiment in innovation management in Indian context. Each of the earlier described innovation management approaches as adopted under the programme had their efficacies in specific cases. The first approach of laboratory based technology development exercise was typically suitable for the composite applications involving cutting edge technologies. The expertise as well as the facilities for application development were available only at a defence lab and such projects could not be initiated by an industry on its own. In the second approach for the technology development, the prototypes were developed and tested successfully. This was due to the financial stake of the user agencies and their complete involvement in the project especially for facilitating the testing & product certification. The entire technology development exercise could have been faster if the industry were involved right from the early stages of the project and not only for the prototype development.

Building on the experiences of earlier approaches of innovation management practices, the optimal mechanism of industry centric innovation had emerged with the promise of near-term deliverables. Around 30 projects were conceptualized following this approach and a large majority of them were concluded successfully with the products reaching out to the users. The attributes such as attractive scheme of financial assistance, technological risk sharing and knowledge-based project monitoring by experts coupled with the market intervention by reaching to the user agencies had all helped the programme to record its achievements in a short span. The programme had roped in a good number of academicians with excellent expertise in product design & fabrication and effectively utilized their knowledge in realizing the applications. The networking by the programme among the academia/ research institutions, standards & certifying agencies as well as the experts from the actual users has gone a long way in reducing the product development cycles.

Glossary of Terms

RDSO – Research Design and Standards Organization

ICF – Integral Coach Factory

RCF – Rail Coach Factory

DLW – Diesel Locomotive Works

DLMW – Diesel Locomotive Modernization Works

STR – Schedule for Technical Requirements

IIT – Indian Institute of Technology

CPWD – Central Public Works Department

IJIRA - Indian Jute Industries Research Association

IPIRTI - Indian Plywood Industries Research and Training Institute

BSNL – Bharat Sanchar Nigam Limited

MDF – Medium Density Fibre

BMPTC - Building Materials & Technology Promotion Council

DSIR – Department for Scientific & Industrial Research

IS – Indian Standards

PVC – Poly Vinylchloride

HDPE – High Density Polyethylene

CFL – Compact Fluorescent Lamps

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The views expressed by the authors are their own and they do not necessarily reflect those of the organization they belong.