Leadership for India Inc: Practical Concepts and Constructs
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Week - 08
Functional Leadership Models
Lecture - 36
R&D Leadership

Hi Friends, welcome to NPTEL course Leadership for India Inc: Practical Concepts and Constructs. We are in week 8 discussing Functional Leadership Models. In this lecture, we will focus on R&D Leadership.

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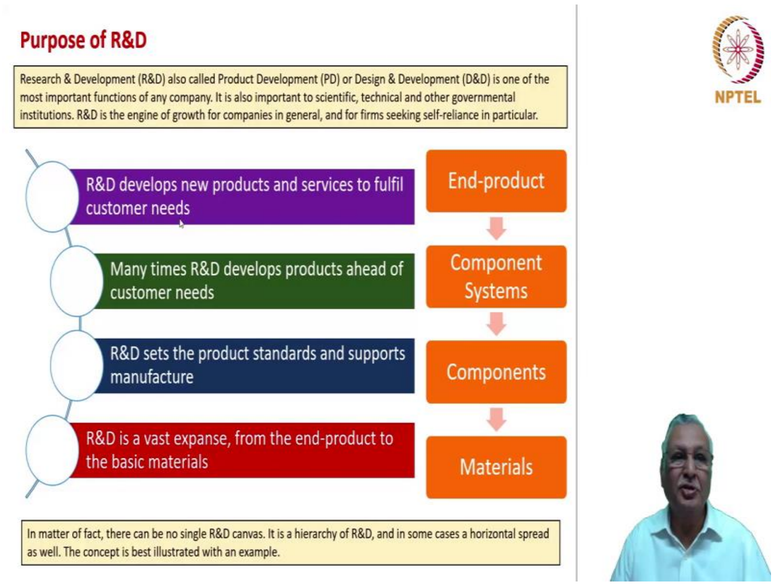

Research and development also called product development, or design and development is one of the most important functions of any company. It is also important to scientific technical and other governmental institutions. R&D is the engine of growth for companies in general and for firm seeking self reliance in particular. R&Ds main purpose is to develop new products and services, to fulfill customer needs.

Many times R&D develops products and services far ahead of customer needs. For each product developed, R&D sets the product standard, specifications and supports manufacture. R&D is also closely involved in technology transfer from R&D laboratory to manufacturing workshop. R&D is a vast expanse, from the end product to the basic materials.

You can see the illustration on the right side, we have the end-product which comprises several component systems, and each component system will have several components. And, each component will have several materials that is how the product hierarchy is established. In matter of fact, there can be no single R&D canvas, it is a hierarchy of R&D and in some cases a horizontal spread as well. Let us look at an example.

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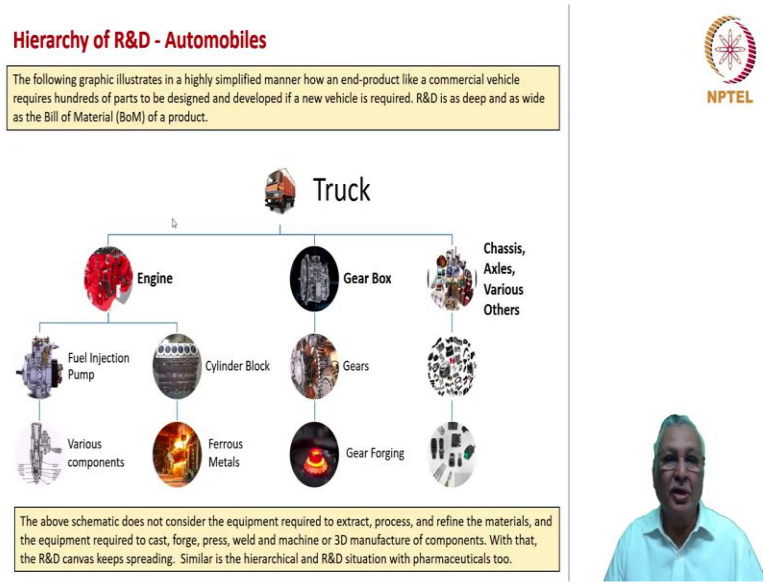

I take here truck, the following graphic illustrates in a highly simplified manner how an end product like a commercial vehicle, requires hundreds of parts to be designed and developed if a new vehicle is required. R&D is as deep and as wide as the bill of materials of a product. So, a truck comprises engine, gearbox, chassis, axles and various other components.

These will be in hundreds; each engine will require cylinder blocks, cylinder head, fuel injection pump. Each gear box will require several gears, gear casing, gear forgings and so on. And, each chassis, axle and other parts conglomeration requires individual components, at times systems of individual components like wiring harness, or headlamp assembly and things like that.

And, when you go to the fuel injection pump, you will have diesel engine equipment and also electronics to boost the performance of the fuel injection pump. And cylinder block itself is made up of ferrous metals. So, the above schematic does not consider the equipment required to extract, process and refine the materials.

And, the equipment required to cast forge, press, weld and machine or even manufacture by 3D processes of components. If you include all of that the canvas of R&D will be near universal. Similar is the hierarchical and R&D situation with respect to another type of product for example, pharmaceuticals.

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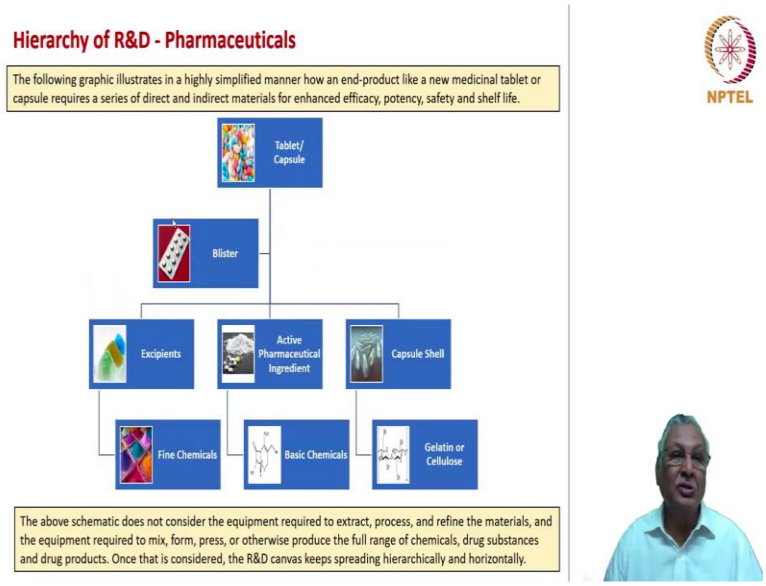

The following graphic illustrates in a highly simplified manner, how an end product like a new medicinal tablet, or capsule requires a series of direct and indirect materials for enhanced, efficiency, efficacy, potency, safety and shelf life. So, let's take tablet or capsule.

It requires excipients, it requires primarily the active pharmaceutical ingredient that is the one which is causing the therapeutic effort and, the capsule shell. Excipients, themselves require fine chemicals whereas, active pharmaceutical ingredient requires basic chemicals as well as the intermediate. And, capsule shell requires gelatin or cellulose. And to package all these tablets or capsules, we require blisters.

This again is a very simplistic presentation of how a tablets bill of material works. The main point here is that to be able to successfully develop an end product, you need to take into account the design and development of various other contributing components or materials, without that the R&D endeavor is inadequate.

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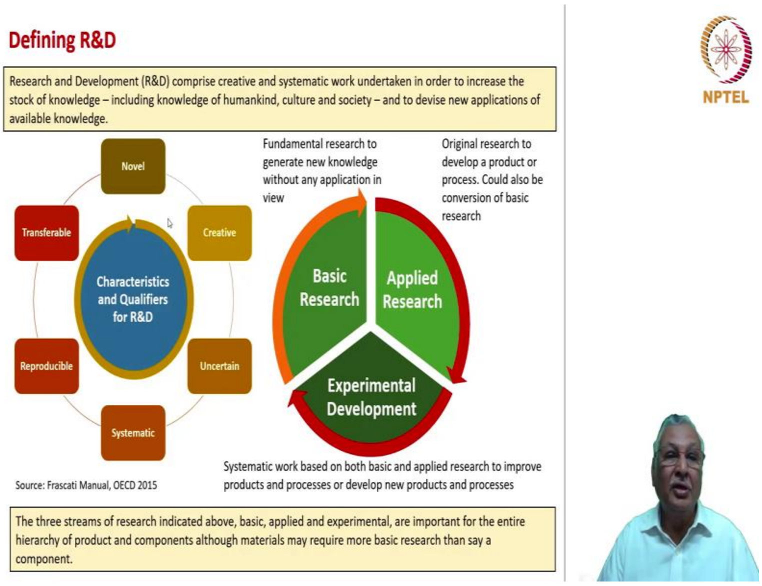

R&D comprises both creative and systematic work streams. These are required in order to increase the stock of knowledge, including knowledge of humankind, culture and society and to devise new applications of available knowledge. So, the characteristics and qualities and qualifiers for R&D are unique, one whatever is developed should be novel or creative that is very important.

Secondly, the entire R&D process or the R&Ds accomplishments could be uncertain, but at the same time R&D has to follow a systematic rigorous process. So, that whatever is developed is replicable and whatever the process by which the product is made is repeatable. And, it could also be subject to examination by various regulatory agencies.

So, repeatability is one of the characteristics of R&D and the ultimate test is its transferability in a cost effective manner to the shop floor, these are the characteristics and qualifies for R&D. R&D itself can be seen in terms of three distinct streams one basic research, second applied research, third experimental development.

What is basic research? It is the fundamental research to generate new knowledge, without any application in view. Applied research is the original research to develop a product or process. It could also be conversion of basic research into certain components or products. Experimental development is the systematic work, based on both basic and applied research to improve products and processes or develop new products and process.

A typical holistic R&D paradigm includes all of this basic research, applied research as well as experimental development. Even if a company is following only experimental development the company would need to tap into the basic research, and, applied research that is available, most probably in outside institutions or research institutions.

The three streams of research indicated above, basic, applied and experimental are important for the entire hierarchy of products and components, although materials may require more basic research than say a component. Because, material constitutes the fundamental building block of any component and the research therefore, is more in the nature of basic research as far as the materials are concerned.

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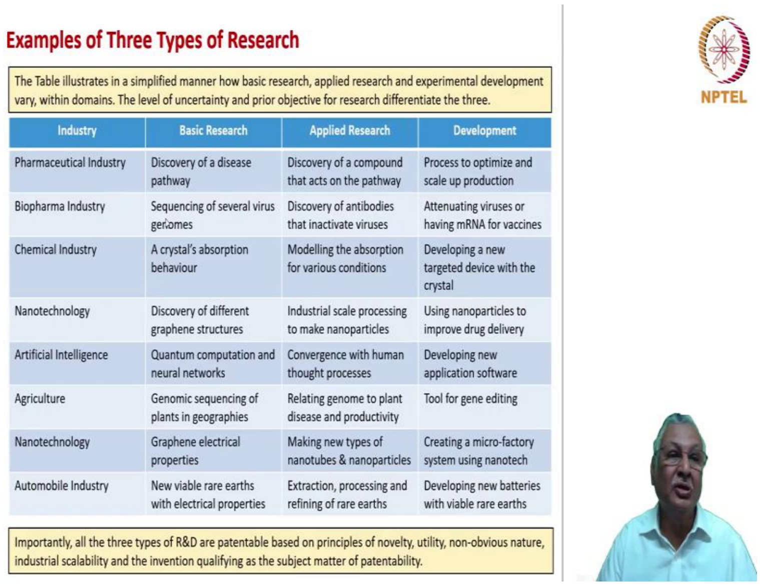

Let us try to illustrate these three types of research through specific examples. The table illustrates in a simplified manner, how basic research applied research and experimental development vary within domains. The level of uncertainty and the prior objective for research, fundamentally differentiate the three. Let us take the example of pharmaceutical industry.

Basic research looks at discovery of a disease pathway that is if you want to control your blood pressure. What disease pathway is available, in addition to whatever is known that is the fundamental approach of basic research. Applied research looks a discovery of a compound that acts on the pathway the scientists have already found out that, if you use a potassium channel blocker or a sodium channel blocker, you will be able to improve the cardiac function and the blood pressure syndrome, having got that information applied research looks at discovering a medicinal chemistry compound that acts on the pathway.

Development for these two looks at the process optimization and scale-up of production possibilities. This is the way in which basic research, applied research and development get distinguished. Let us look at the biopharma industry, basic research is the sequencing of several virus genomes, applied research is the discovery of antibodies that inactivate the viruses. And the way those antibodies should work that is the applied research.

Development comprises attenuating viruses or having mRNA for vaccines, in respect of chemical industry a crystals absorption behavior is the fundamental research. Modeling the absorption for various conditions is the applied research, developing a new targeted device with the crystal is the developmental phase.

Nanotechnology discovery of different graphene structures is fundamental. Industrial skill processing to make nanoparticles is applied, using nanoparticles to improved drug delivery is development. Let us look at artificial intelligence, quantum computation and neural networks are fundamental to artificial intelligence, but convergence with human thought processes is applied research and developing new application software is the development phase.

In agriculture, genomic sequencing of plants in various geographies is the basic research. Relating the genome discover to plant disease and productivity is applied research and development comprises tools genetic editing. In respect of nanotechnology again, graphene electrical properties are extremely important, making new types of nanotubes and nanoparticles is another important aspect.

And, creating a micro factory system using nanotech is another option which is available. Automobile industry, you have new variable viable rare earths with electrical properties, extraction, processing and refining of rear earths that constitutes the next step of applied research. And, developing new batteries with viable rear earths is the final development.

Importantly all the three types of R&D are patentable based on principles of novelty, utility, functionality, non obvious nature and industries scalability. Each invention will qualify based on the subject matter of patentability as may be decided by the patenting authorities.

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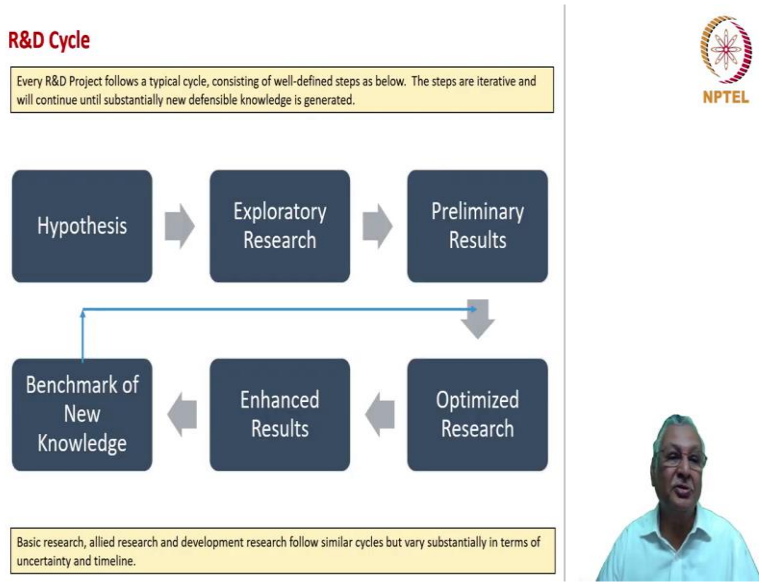

Every R&D project follows a typical cycle consisting of well defined steps as below. These steps are iterative and will continue, until substantially new defensible knowledge is generated, defensible is extremely important. Because without peer review, without peer defense and without regulatory examination an R&D product cannot be considered to be a fully developed, and fully useful product. So, defensible knowledge is the ultimate goal of R&D.

So, it starts with hypothesis moves into the exploratory research then gets the preliminary results then, the optimized research, enhanced research, and benchmark of new knowledge. If you take the example of pharmaceutical industry when you get a pathway that is discovered. And, you need to have medicinal chemistry molecules, you would first explore which kind of bonding would be the most appropriate to work on the pathway. So, you create several alternative chemical structures.

And see how these chemical structures bond with the pathway and either strengthen the pathway as required or block the pathway as desired. So, those experiments will be done and once that is done. And, the preliminary results are obtained, they will probably test in vitro biological models to see whether they are actually effective in terms of a biological phenomenon.

Once that is done and iteration may start again, from that hypothesis that this type of medicinal chemistry structures would be most appropriate for this new pathway.

Again you start on little more deeper exploratory research and get preliminary results again. Once you get results which assure you that you are on the right path, you go to the optimization phase. And the optimization phase will include both product optimization, as well as the process optimization. And finally, you will get enhanced results and that constitutes the benchmark of my knowledge.

Similarly, applied research and development research follow somewhat similar cycles, but vary substantially in terms of uncertainty and time line. The uncertainty in terms of basic research is extremely high whereas, the uncertainty in terms of applied research and development research are progressively lower.

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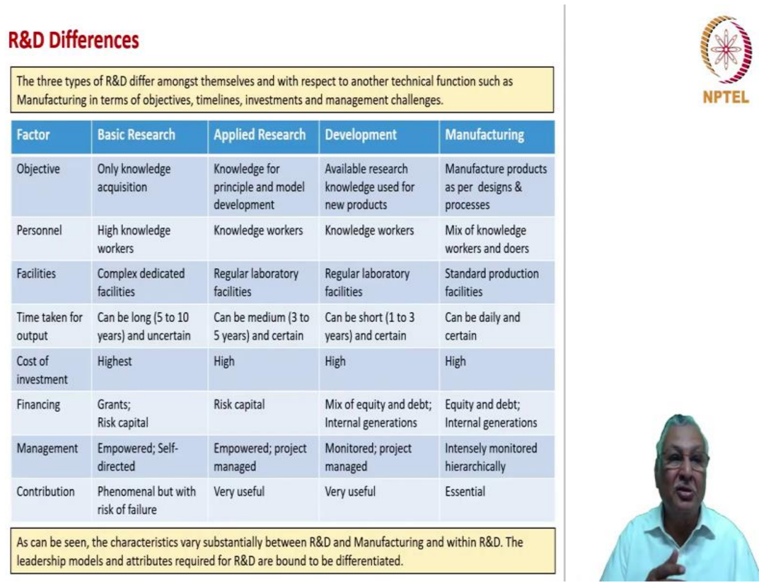

R&D Differences

The three types of R&D differ amongst themselves and with respect to another technical function such as Manufacturing in terms of objectives, timelines, investments and management challenges.

Factor	Basic Research	Applied Research	Development	Manufacturing
Objective	Only knowledge acquisition	Knowledge for principle and model development	Available research knowledge used for new products	Manufacture products as per designs & processes
Personnel	High knowledge workers	Knowledge workers	Knowledge workers	Mix of knowledge workers and doers
Facilities	Complex dedicated facilities	Regular laboratory facilities	Regular laboratory facilities	Standard production facilities
Time taken for output	Can be long (5 to 10 years) and uncertain	Can be medium (3 to 5 years) and certain	Can be short (1 to 3 years) and certain	Can be daily and certain
Cost of investment	Highest	High	High	High
Financing	Grants; Risk capital	Risk capital	Mix of equity and debt; Internal generations	Equity and debt; Internal generations
Management	Empowered; Self-directed	Empowered; project managed	Monitored; project managed	Intensely monitored hierarchically
Contribution	Phenomenal but with risk of failure	Very useful	Very useful	Essential

As can be seen, the characteristics vary substantially between R&D and Manufacturing and within R&D. The leadership models and attributes required for R&D are bound to be differentiated.

Let us look at the three types of R&D in terms of their approaches to the whole research process itself. The objectives, timelines, investments, and management challenges differ. We have earlier looked at these three different researches in terms of specific examples of what constitutes such kind of research.

Here we will look at the process aspect. In respect of basic research, the objective is only knowledge acquisition, you want to create a new nanotechnology material you do not know at that stage where it will be useful. You would like to create graphene as a usable material, but you have not yet figured out why and how that knowledge should be used.

So, only knowledge acquisition is the basic research objective. Applied research looks for knowledge, which is useful in terms of certain principles, and also can be modeled for further development. And, in development you look at available research knowledge and use it for new products or new process.

And, in manufacturing you convert those applied research and developmental products, and processes into actual manufacture based on designs and processes. Personal: basic research employs high knowledge workers, applied research knowledge workers, development knowledge workers, whereas manufacturing will have a mix of knowledge workers as well as execution implementation doers.

Facilities: for basic research you really require complex dedicated, facility. You cannot undertake pharmaceutical research without NMR without HPLC, GCLC and mass spectrum these are all advanced research equipment that are required.

Similarly, you cannot do automotive research without understanding, how the heat dispassion works. Therefore, you require a heat chambers you should be able to simulate the thermal conditions, you need crash test facilities, you need sound chambers and you need strong simulators for computer aided design. So, the facilities that are required for basic research tend to be very advanced and very costly as well. Applied research requires typically regular laboratory facilities, as also development.

But, manufacturing requires a completely different set of equipment. If you are doing a liveliest pharmaceutical product, you require pilot lyophilizer in laboratory which probably is adequate to do maybe ten lyophilizer vials. And, that is a pilot scale development at the applied research level.

But, if you want to manufacture you require a lyophilizer of 26 cubic meters or 52 cubic meters that is the kind of through put that is required. And it will have all the bells and vessels as also the conveyors for movement of input material as well as the output vials. And, the manufacturing facilities are standard production facilities, once established they cannot be tweaked.

Time taken for output basic research could be very long, anything between 5 to 10 years is the common timeline, and the outcome is uncertain applied research medium 3 to 5 years are certain. Development can be shorter 1 to 3 years and again certain, manufacturing has to be a daily repeatable activity, and certainty is what constitutes the manufacturing feature.

Cost of investment basic research will be the highest followed by applied research development and manufacturing in that order. Manufacturing depending upon the scale of production may of course cross R&D even basic research in terms of the overall cost. But, then if you look at the unit cost, I am sure basic research would be many times costlier compared to the unit cost as in the case of manufacturing.

Usually, basic research is funded out of grands and risk capital that is equity capital, applied research also is funded, but mostly by risk capital. Development requires mix of equity and debt internal generations, because you are assured that the development will lead to a product which probably could be manufactured. In case of manufacturing again equity and debt will be deployed and internal generations will be relied upon.

The management for R&D has to be empowered, self-directed. Whereas, applied research requires project managed R&D and management approach, development requires regular monitoring and should be project managed. Manufacturing has to be intensely monitored hierarchically.

Contribution is phenomenal in respect of basic research. If you make a discovery in basic research, it could even alter fundamentally the structure of the industry and the competitive positioning of the firm. But, there is a huge risk of failure that comes along with basic research. Applied research is very useful and most probably, it would provide the biggest value for a unit investment.

In respect of development again the use level is very high and manufacturing of course, is essential to convert the R&D ideas of whatever stream into physical products and services and earn cash for the business. As can be seen the characteristics vary substantially between R&D and manufacturing. And, also within R&D the leadership models and attributes required for R&D are bound to be differentiated naturally.

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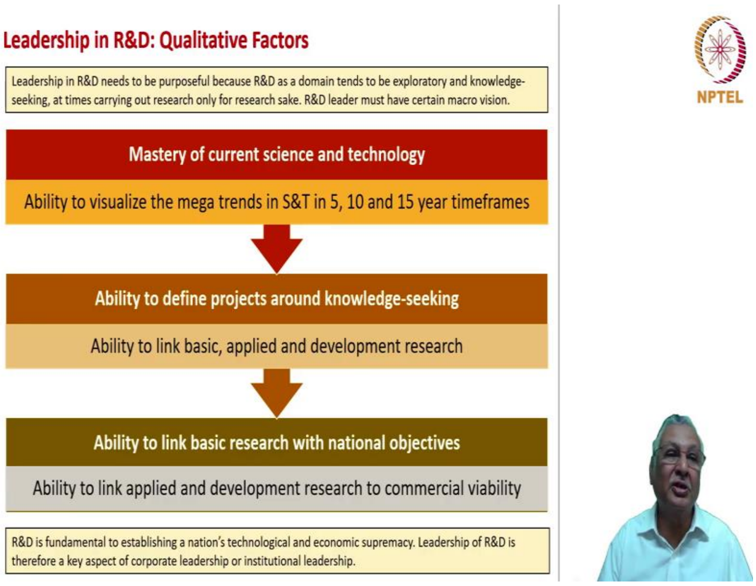

So, what are the qualitative factors that are required for R&D leadership? Three principle factors, one - the R&D leader must be a master of current science and technology, the leader must be able to visualize the mega trends in science and technology in 5, 10 and 15-year time frames.

The leader must be able to define projects around knowledge seeking. Ability to link basic, applied and development research. Also ability to link basic research with national objectives, ability to link applied and development research to commercial viability. These are the six factors which are involved in a very strong qualitative manner in a R&D leader.

R&D being fundamental to establishing a nation's technological and economic supremacy, leadership of R&D is a key aspect of corporate leadership or institutional leadership. We have seen our Indian institutions, whether it is ISRO or the space research centers or the CSIR laboratories lot came up, because of the R&D leadership that was available in those R&D institutions.

But for Homi J Bhabha we would not have had the atomic energy research carried out in India, without Dr. Kalam defense research and particularly missile research would not have happened so, successfully. So, the R&D leadership is extremely important in understanding futuristic science and technology, ability to create projects which develop knowledge. And to link all the three streams of research to the national objectives. This is extremely important from a qualitative angle.

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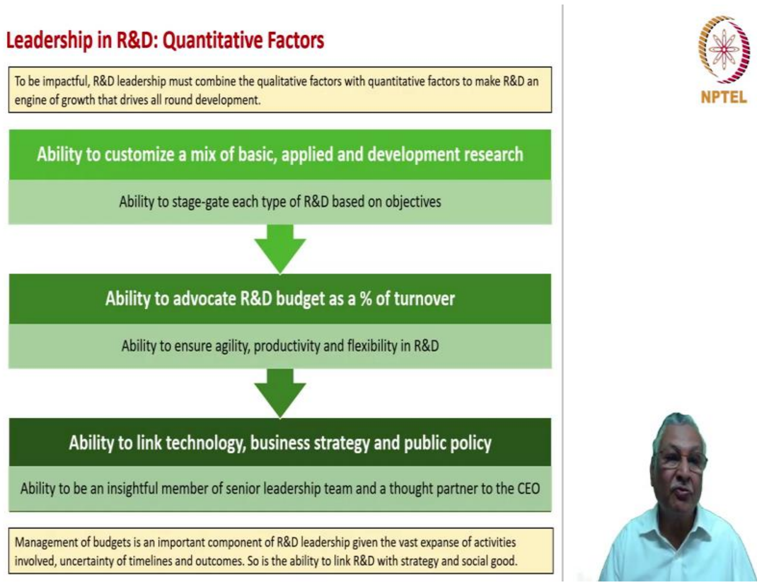

From a quantitative angle, because quantitative performance provides impact to R&D leadership, we need to have an ability to customize a mix of basic, applied and development research. And, ability to stage gate each type of R&D based on objectives. Stage gate is a gate which is kind of imaginary gate, but very specific gate though in the R&D process, which must be crossed for an R&D project to go further, ability to advocate R&D budget as a percentage of turnover.

And, also correspondingly ensure agility, productivity and flexibility in R&D processes. The third quantitative factor is to link technology, business strategy and public policy. You must understand the kind of functionalities the product would have. And therefore, the kind of demand this kind of product would generate and therefore, again the kind of business that would accrue to the company from these products.

So, ability to be an insightful member of senior leadership team and a thought partner to the CEO is an absolute must for R&D leader. Given that research is investment intensive and is uncertain in varying degrees, management of budgets is an important component of R&D leadership.

The expanse of activities is very vast, the people who under take are very individualistic and empowered. There could be uncertainty of timelines and outcomes nevertheless. So, the ability to link R&D with strategic performance and with social good is important to inspire the R&D teams to have good quantitative as well as qualitative performance.

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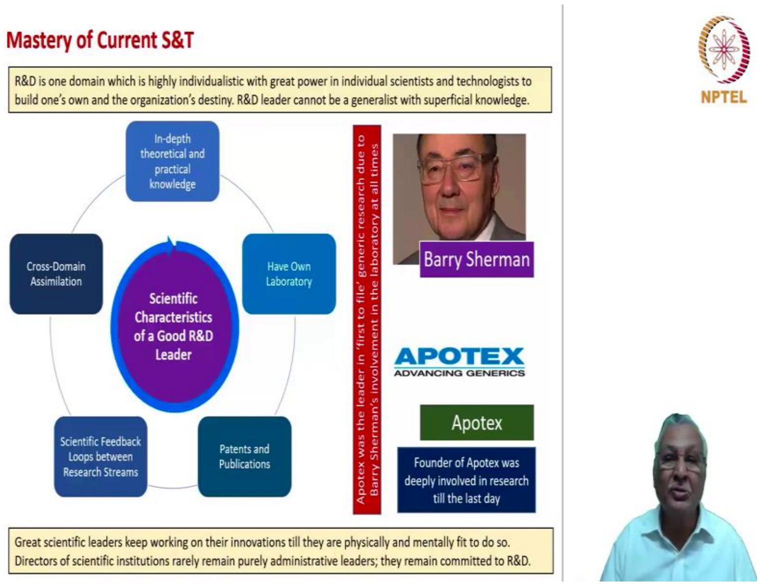

So, how do you master the current science and technology? There is great power in individual R&D scientists and R&D technologies, and they really feel passionate about what they are doing and their linkage with the organizations destiny. R&D leader cannot be just a generalist with superficial knowledge, and R&D leader has to be an in depth scientific person and a technical expert.

So, the scientific characteristics of a good R&D leader are as follows, one, in depth theoretical and practical knowledge, ability to have and run one's own laboratory. A slew of patents and publications to one's credit, scientific feedback loops between research streams and cross domain assimilation.

I will quote the example of Barry Sherman who was the founder chairman of Apotex and till the last day of his life, he was only into creating new innovative generics, which can challenge the innovators product patents or process patents. The, company was the first company to take leadership position in first to file generate research, because of Barry Sherman's investment in R&D infrastructure, and also his personal commitment to continue to drive R&D all through his life.

Great scientific leaders keep working on their innovations till they are physically and mentally fit to do. So, directors of scientific institutions rarely remain purely administrative leaders, they remain committed to R&D at all times.

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Let us take three other examples. Let us see how this visualization of mega trends work. Today biotechnology is commonly understood by all of us. But, one only has to see the biotechnology timeline to appreciate how from the 1950s several distinguished scientists had the foresight to advance bio technology, way back in 1919 Hungarian agricultural engineer Karl Ereky foresaw a time when biology could be used for turning raw materials into useful products. He coined the term biotechnology to describe that merging of biology and technology, imagine how visionary he was at that point of time. And, also how mainstream that concept has now become.

George Rathmann founder of Amgen; he was an American chemist, biologist, pioneer in biotechnology and in corporate excellence. In 1980, he cofounded Amgen with William Bowes and associates. He served as the first CEO of Amgen, which has become the world's largest biopharma company.

And no one thought that the biologic drugs would be of this importance in the forthcoming world, but Amgen's founder visualized that kind of capability the polyclonal antibodies, the monoclonal antibodies, and then brought those things into fruition. Another biotechnology pioneer Genentech, it was founded more than 40 years ago in 1976 to be exact, by the biochemist Dr. Herbert W Boyer and the late venture capitalist Robert A. Swanson.

And, they were visionary they along with Amgen foresaw the biotechnology revolution that would come in the pharmaceutical industry. They proved in no uncertain terms how visualization of mega trends has led not merely to founding of two businesses, but to the initiation of transformative biological medicine for patients. That is the beauty of mega trends, they completely transform industries.

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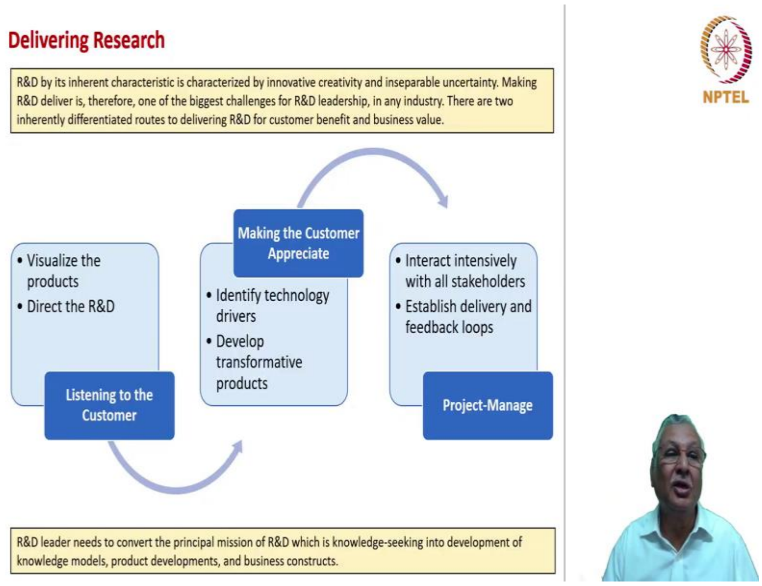

So, how do we deliver research? R&D by its inherent characteristic, is characterized by innovative creativity and inseparable uncertainty. Making R&D deliver is therefore, one of the biggest challenges for or R&D leadership in any industry. There are two inherently differentiated roots to delivering R&D for customer benefit and business value.

One root visualize the products direct the R&D by listening to the customer, the other route proactively identify technology drivers develop transformative products and make the customer appreciate. So, you can listen to the customer and develop your product visualization, or you can visualize the product apriori and make the customer appreciate.

And then project management, interacts intensively with all the stakeholders, establish delivery and feedback loops. R&D leader needs to convert the principle mission of R&D which is knowledge seeking, into development of knowledge models, product developments and business constructs. That is the overall corporate and business expectation of an R&D leader.

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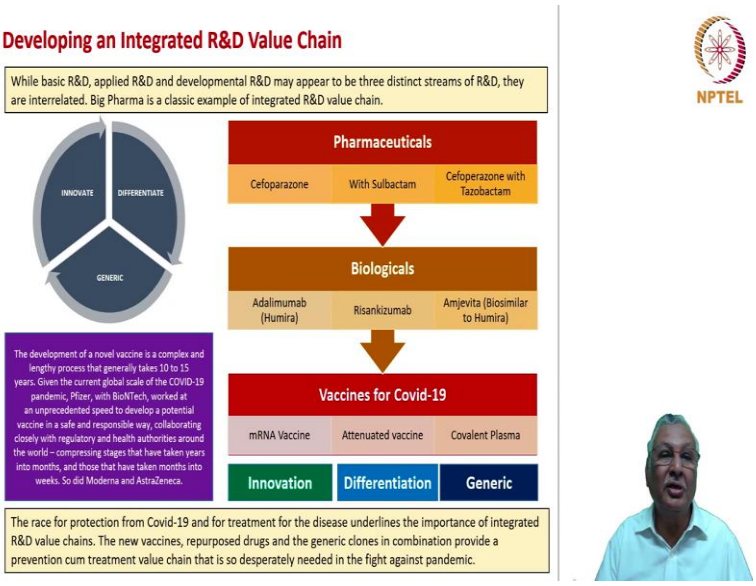

How do you integrate R&D in terms of all its parts and develop an integrated R&D value chain, while basic R&D, applied R&D, and developmental R&D may appear to be three different and distinct streams of R&D, they are interrelated.

Big Pharma is a classic example of integrated R&D value chain innovate, differentiate, generic. These are the three pillars of Big Pharma today, some examples, I have given pharmaceuticals cefoparazone is the Big Pharma innovator molecule, but it was combined with sulbactam to make it much more effective. Later on others came up combining cefoparazone with tazobactam, another beta lactamase inhibitor as a result of all of these things. Pharmaceuticals in anti-infective field became very effective.

Biological you have mAbs and there are three different types of mAbs which were produced and each between similar, but superior. Vaccines for COVID 19 we have mRNA vaccine which is the Pfizer BioNTech kind of vaccine, we have attenuated vaccine and also we have covalent plasma therapy. And, these are characterized by innovation, differentiation and generic.

And, also development of a new product in pharmaceutical industry or for that matter any other industry probably to a different degree is dependent upon working on R&D related to various other components, it could be even related to logistics. Let us look at first the vaccine itself, the development of a novel vaccine is a complex and lengthy process that generally takes 10 to 15 years.

Given the current global scale of the COVID 19 pandemic Pfizer with BioNTech work at an unprecedented speed to develop a potential vaccine in a safe and responsible way, collaborating closely with regulatory and health authorities around the world, and in this process it collaborated with BioNTech. It compressed stages that have taken years into months and those which normally take months into weeks or days.

And these enabled Pfizer and BioNTech to bring a vaccine in less than a year from the time the vaccine has taken up for development, but the research does not stop here. Because, the logistics also require a different kind of storage media and storage systems, this particular vaccine requires minus 75 degrees cold storage, which means that you need to innovate on the types of storage systems and the transportation systems.

So, R&D goes there as well. So, the race for protection from COVID 19 and for treatment for the disease underlines the importance of integrated R&D value chains. The new vaccines, the repurpose drugs, and the generic clones in combination provide a prevention cum treatment value chain that is so, desperately needed in the fight against pandemic.

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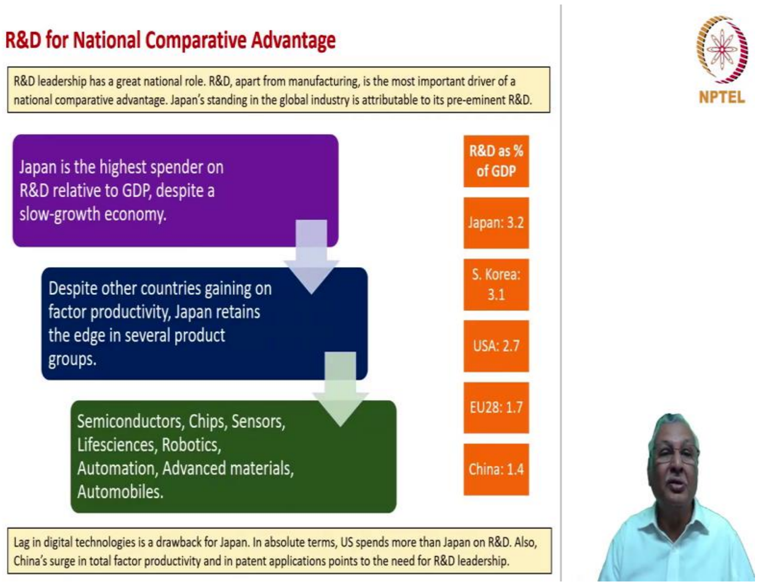

How does R&D help in national comparative advantage? Comparative advantage is a feature of a nation, wherein every entity in the nation would be capable of providing a similar advantage to the society as well as to the other customers. R&D provides national comparative advantage to any nation, the great national role can be seen in terms of Japan.

Japan standing in the global industry is attributable to its preeminent R&D. Japan is the highest spender on R&D relative to GDP despite a slow growth economy. You can see the statistics of R&D has percentage of GDP. Japan scores the highest at 3.2, followed by South Korea 3.1, followed also by USA at 2.7, EU28 nations 1.7 and China 1.4.

Despite other countries gaining on factor productivity Japan retains the edge in several product groups, semiconductors, chips, sensors, life sciences, robotics, automation, advanced materials, automobiles are the domains where Japan still has a comparative and competitive edge. And that is because of the R&D investments, and also the ability to harness the investments into all the three types of research, the basic research, the applied research and the experimental development.

Lag in digital technologies has been a setback for Japan, but hopefully Japan would be able to integrate that as well. So, that better products will come out faster and the world has a whole benefit, in absolute terms US spends more than Japan on R&D. Also China's surge in total factor productivity and in patent applications points to the need for R&D leadership on the part of India as well.

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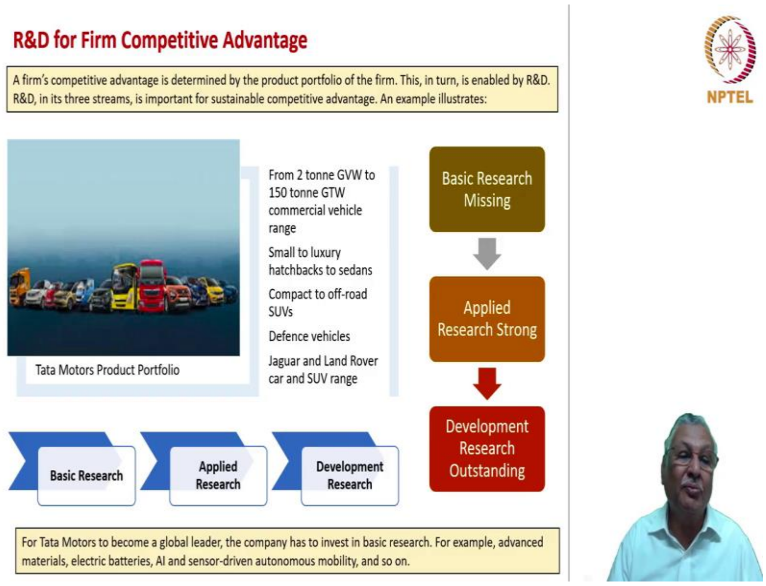

Let us look at how R&D will provide firm level competitive advantage, a firms' competitive advantage is determined by the product portfolio of the firm. This intern is enabled by R&D, in its three streams R&D is important for sustainable competitive advantage. Let us look at an example, from two ton gross vehicle weight to 150 ton gross train weight Tata Motor offers a commercial vehicle range.

It also offers small to luxury hatch bags as well as sedans, it offers compact to off roads sport utility vehicles, defense vehicles are also offered and in addition at a global level Jaguar Land Rover car and SUV range is available and many of these products are getting developed in electric versions. So, the product portfolio that is offered is extremely wide, for Tata Motors to become a global leader the company has to invest in basic research.

Because, most of these developments have come about through strong applied research, and outstanding development research, but if the company wants to join the electric movement in its vanguard you require basic research as well. And the company has to invest in basic research for example, advanced materials, electric batteries, AI and sensor driven autonomous mobility and so on.

And to be able to do that leaders must connect the dots within the group like Tata chemicals getting tapped for battery development, Tata Elxsi getting tapped for autonomous software solutions.

And, Tata Motor upgraded to make different types of native electric vehicle designs. And, that is how the leader at the helm connects all the dots which are available within the conglomerate and, makes a conglomerate value chain that delivers an industry transformation, even if it is in respect of just one product group.

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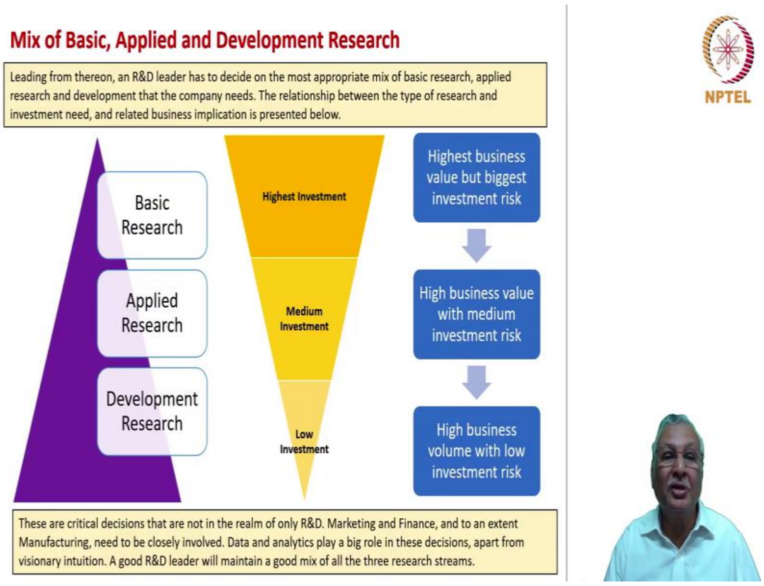

The mix of basic, applied and development research can be looked at from these two pyramid and inverted pyramid relationships. Because, from the time the product strategies thought about and the business strategy is linked to the product strategy, an R&D leader has to decide on the most appropriate mix of basic research, applied research and development that the company needs.

Development research is at the base of the research pyramid, above that applied research and above that basic research. And, we have seen that basic research calls for the highest level of investment, applied research calls for only medium level investments and development research low investment. Basic research gives the highest business value to a company, but also carries the biggest investment risk.

So, how do you optimize the basic research, applied research and development research, which have got different business value and investment risk parameters. These are the critical decisions which R&D leader need to take, but those decisions are not completely within the purview of the R&D leader marketing, finance and to an extent manufacturing need to be closely involved.

Data and analytics play a big role in these decisions apart from visionary intuition of the leaders as well as the Apex leader. A good R&D leader therefore, will need to maintain a good mix of all the three research streams, and also maintain a good connectivity with all his peers and with the Apex leader. Then, only a true exploitation of R&D capabilities and a true exploration of the research potentialities can be undertaken in a firm.

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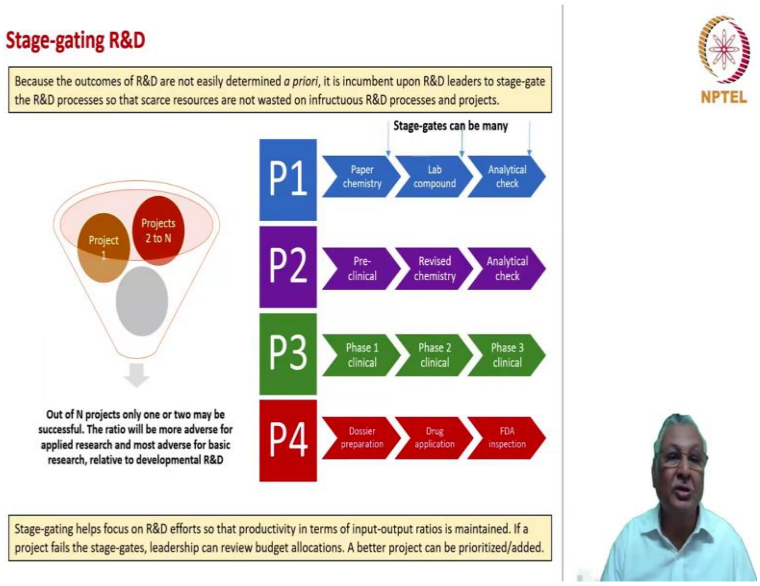

I talked about stage gating R&D, because the outcomes of R&D are not easily determined apriori that is in the beginning, it is incumbent upon R&D leaders to stage gate the R&D process. So, that scarce resources are not wasted on infructuous R&D processes and projects. There could be several projects where this gates could be many and there could be a few projects where there are the fewer stage gates.

So, if you see a project P1 another project P2 the stage gates could be different. For a medicinal chemistry project the stage gates are end of paper chemistry, end of lab compound work and analytical check. In project 2 of exploring it further from a biological concept, preclinical is one stage gate reversed chemistry is another stage gate, and again analytical recheck is another stage gate.

As a third project within the overall project, phase 1 clinical is one stage gate to be passed, phase 2 clinical I mean of course, when you say phase 2 clinic this is not just the activity the completion of the activity is extremely important. Phase 3 clinical represents the ultimate; if the vaccines are now seeking emergency authorizations in US and UK, it is because these stage gates have been successfully completed by all the candidate vaccines.

And to be able to ask for emergency authorization or even normal authorization for other products, you have the other project as well, which is dossier preparation, drug application, and FDA inspection. Out of N projects which a company may undertake only one or two may be successful. The ratio will be more adverse for applied research and most adverse basic research relative to developmental R&D.

Stage gating helps focus R&D efforts. So, that productivity can be optimized across the various streams of R&D with the objective of getting a product ultimately into the business horizon. The input output ratios can be maintained at optimal levels with stage gates. And, if stage gates are not crossed by certain projects, because of certain failures then the opportunity exists to prioritize other projects, as also add new projects that is the advantage of stage gating.

Stage gating also applies when a company is in the CDMO business, that is contract development and manufacturing organization space. In this case you typically give your medicinal chemistry compounds, or preclinical compounds, or even paper chemistry compounds to another company which is going to use them.

Typically, the way it happens is that the CDMO company in India will optimize the product, and give it to the Big Pharma. And, they would further technology transfer it and start up the regular production. And like we have our stage gates, they also would have their stage gates and they also have value chain.

When to get the other materials from other countries and how should the process be optimized, if stage gating is not done with the CDMO, then the entire value chain related to the overall product will go topsy turvy. So, stage gating at every hierarchical level of the product development is extremely important, and stage getting starts fundamentally from the R&D domain.

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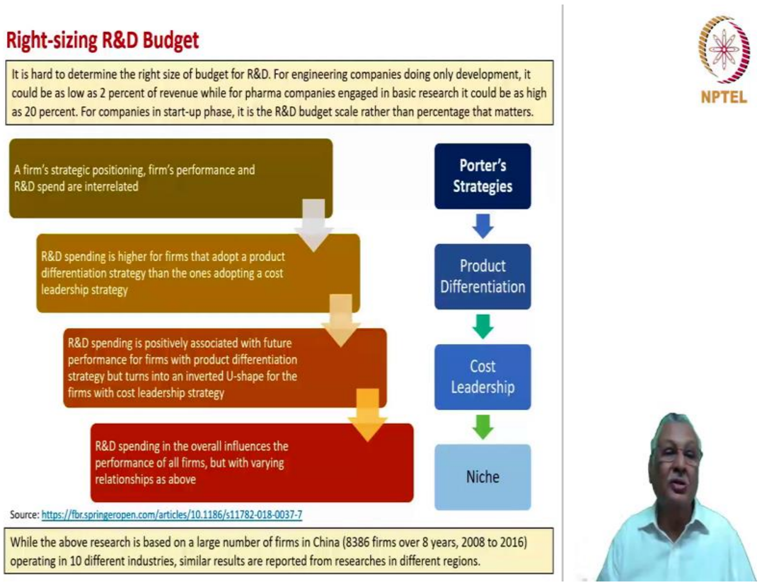

How do we write size the R&D budget? Because, different industries require different types of R&D, for an engineering company 2 percent of revenue could be an adequate R&D budget, but pharma companies engaged in basic research it could be as high as 20 percent or 25 percent. And, when we say 20 or 25 percent imagine that such companies have turnovers of 55 billion dollars or so; that means, we are trying to commit 10 billion dollars to 15 billion dollars on R&D alone with all its uncertainty.

But, even if one product clicks then the entire business horizon will be transformed. For companies in startup phase, it is the R&D budget scale rather than percentage that matters. And to be able to decide on this R&D budget requirement, we have to understand the firms strategic positioning, the firm's performance and the affordability of R&D to a firm these three are interrelated.

R&D spending is higher for firms that adapt a product differentiation strategy, compared to the ones that adopt a cost leadership strategy. Because, cost leadership strategy requires only improvement type of experimental R&D whereas, product differentiation strategy requires applied R&D at the minimum.

R&D spending is positively associated with future performance for firms with product differentiation strategy, but turns into an inverted U shape for the firms with cost leadership strategy. Because, higher R&D can probably improve your products, even if they are in the follower category for higher levels of functionality and higher levels of cost leadership. But, pumping R&D beyond a point for generic products could lead to lower returns.

So, you have to be careful as to how you spend your R&D in different types of business strategies. R&D spending in the overall certainly influences the performance of all firms, but with varying relationships as above. So, we have to see which are the strategic frameworks, the company is wanting to adapt, is it product differentiation, cost leadership or niche or a combination of both of these things.

Lot of research on this basis has been done by and is available in Springer, and you could also go through that as per the link above. Well, the above research is based on a large number of firms in China 8386 firms over 8 years covering the period 2008 to 2016 also operating in 10 different industries.

Similar reported results are available from other different regions as well. So, right sizing in terms of different types of research stream, and linking with the product strategies and business strategies is an R&D leadership role.

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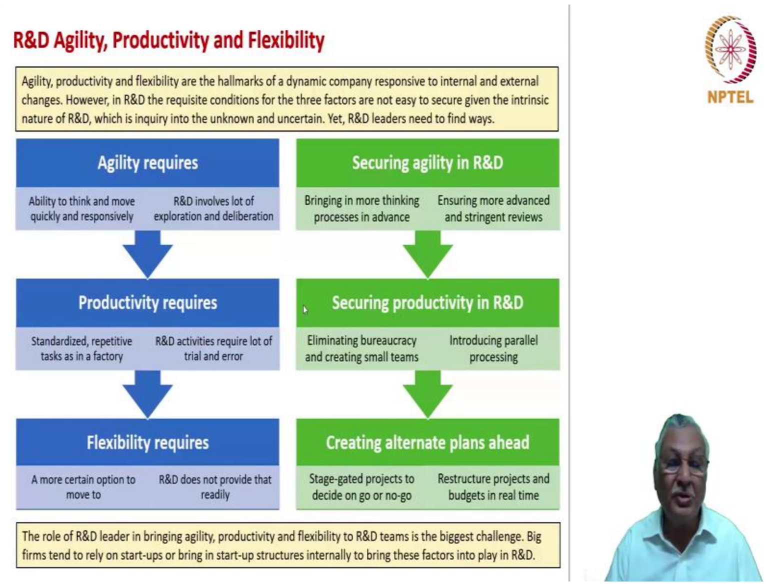

The other R&D leadership responsibility is to have agility, productivity and flexibility, built into the company. The company has to be dynamic in response to internal and external changes. And, some companies have to be also proactive in visualizing mega trends, but to get these things R&D leadership has to have certain specific capabilities.

Agility requires ability to think and move quickly and responsibly, and for that because R&D involves lot of exploration and deliberation. The R&D leader must create the ecosystem, which enables exploratory research and deliberative confabulations amongst the R&D scientist.

Productivity requires standardized repetitive tasks as in a factory. Whereas, R&D activities require a lot of trial and error, and combining the both of requirements for productivity is a true challenge for R&D leader. Again R&D leader needs to be flexible, a more certain option must always be desired.

You can develop a compound having an exotic process, what we call a gold platted process with intermediates and materials that are not easily available. But, if you develop such a process probably you will get the compound faster, but you cannot always be tied down to that process.

Even as the product is getting developed and tested, you should think of having another process, which could be more flexible and more adaptive. Because, R&D does not provide that readily R&D leader has to spend that extra effort, and extra focus to ensure flexibility in product and process development.

So, how do you do these things? How would you secure agility in R&D? First you should bring in more thinking process in advance, you should also ensure more advanced and stringent reviews, R&D does not mean giving a project and forgetting it and thinking of only knowledge acquisition, through books or seminars.

No, the R&D leader has to spend significant amount of time in generating the thinking process within the company, and also ensuring that these thinking processes are reviewed, dissected, challenged, analyzed so, that when something is taken up it could be taken up with speed.

How do we secure productivity in R&D? We should eliminate bureaucracy, R&D is a perfect place for having a flat organization structure, and also is a perfect place for creating small teams. Big Pharma R&D has relied upon small teams in recent times to create innovations, one reason why startups are so, successful in the pharmaceutical space is that Big Pharma has recognized the strength of small compact startups to develop novel R&D mechanisms and novel R&D products.

We should also have productivity coming through parallel processing. We should not say that everything can only be sequential; I talked about the gold plated process being replaced with the normal process, even as the product is getting to be tested. The third one of flexibility can come about by creating alternative plans, in anticipation of any likely course changes.

Stage gated projects definitely help you decide on a go and no go aspect; however, you should be able to restructure projects on budgets in real time. You cannot lose weeks and months in trying to re-strategize the whole R&D development budget, once something unknown has been encountered. So, this adaptive flexibility is very much required for R&D.

So, the role of R&D in bringing agility, productivity and flexibility to R&D teams is the biggest challenge for the leader. Big firm tend to rely on startups as I said or bringing startup structures themselves within the Big Pharma setup to bring these factors into play in R&D.

And, many companies are also looking at employee entrepreneurship, that is an employee who has got one special skill to develop a product, is being enthused to do that by providing an entrepreneurial opportunity, even outside the company. So, that what he could develop in the company will be accelerated in such an ecosystem these things are also possible.

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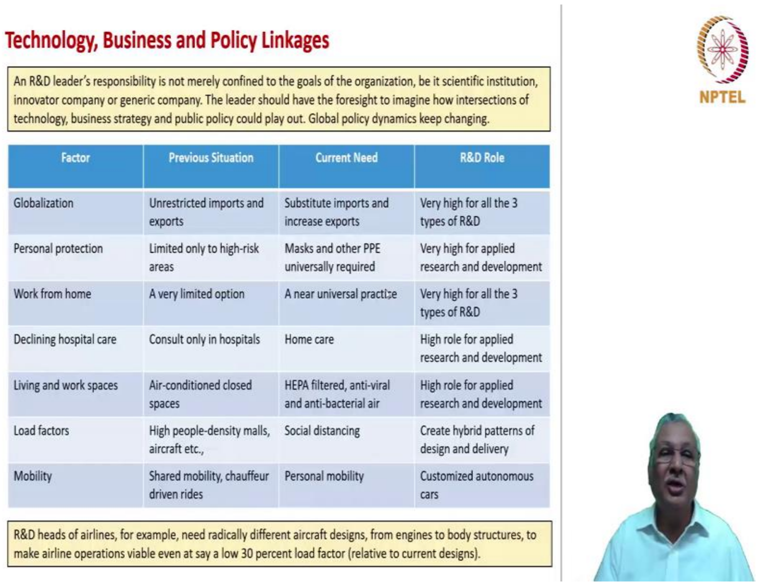

We have in the earlier discussions considered the linkages between the three types of research, basic, applied and experimental. We also considered how they are different in terms of their special features, special structural features so to say. We also considered how in terms of process perspectives R&D, manufacturing differs. We also considered how each stream of the R&D differs from the other, in terms of the process parameters.

Now, let us look at the technology, business and policy linkages. And R&D leader's responsibility is not merely confined to the goals of the organization. This is true whether the institution is a scientific institution and Innovator Company or a generic company, ISRO as a scientific institution will have its goals, like landing their person on the moon. An Innovator Company will have a goal like bringing a new vaccine into the market at the earliest, or creating a new product for a disease which is not been treated so, far that is an orphan trend.

And for a generic company bring as many products as possible into the market space. So, that the whole health care system becomes more affordable. The leader in charge for R&D in any and all of these should have the foresight, to imagine how intersections of technology business strategy and public policy could play out, global policy dynamics keep changing.

So, if you look at globalization in the previous era, we had unrestricted imports and exports. And the current need is substitute imports and increase exports Atmanirbhar self reliance. But, without forgetting globalization and R&D role is very high for all the three types of R&D in a globalized environment.

Let us look at personal protection, earlier personal protection was limited to pharmaceutical companies, and different levels of personal protection depending upon the gradation of the environmental conditions. This sterile filling being the most protected in terms of personal protection devices.

Today, we require masks and other PPE universally. So, to speak, the R&D role is very high for applied research and development, from just having a one layer mask to having 3 to 5 layer mask. Having breathability parameters put into those mask, having antiviral coatings for the mask, having probably air recirculation in more advanced versions.

The role of R&D can just not be ignored, sooner than later you might also have a situation where the mask can be a smart variable device stream as well. That is if you have oxygen saturation impacted, because of the mask you might get a signal that you need to unmask yourself or have some change in the masks parameters.

So, R&D could keep on pushing the envelope and boundary for any product and that could be even for PPE. Work from home, earlier the situation was that it was a very limited option. Today it is a near universal practice again, very high for all the 3 types of R&D.

Declining hospital care is a new factor that has come. Earlier everyone has to go to the hospitals to consult; today home care is the need. But, home care is coming up as a substitute rather than an equally impactful healthcare mechanism. So, we need a new type of healthcare by which you get treatment which is as good as that obtaining in the hospital, which means that probably you need many more mobile testing devices, you should be able to get first level scrutiny of the condition while being at time, but not just being looked at passively.

Let us think of a deep vein thrombosis risk in a patient, who is not mobile. Today he has to go to the hospital to have a Doppler test through the ultrasound mechanism. But, if you are able to develop a Doppler which every doctor can carry, as easily as a stethoscope then you are bringing part of the hospital care into the home care.

And, this is possible only if the medical device industry has high level of R&D. And that high level of R&D must comprise basic research, applied research as well as the experimental research that is how it works.

Then, let us look at living and work spaces, we used to have only air conditioned closed spaces. Today, we require HEPA filtered, anti-viral, anti-bacterial air and high role for applied research and development in this arena.

Load factors people generally wanted more people to make more money and more business; high people density malls aircraft or the norm. Today social distancing is the essential factor of safe living. So, how do you create hybrid patterns of design and delivery is an R&D role. Although probably, it is in part applied research and part developmental research.

Previous situation was shared mobility shattered driven rights. Today, again because of the pandemic related situation you need personal mobility, but at the same time you cannot afford to put millions more vehicles on the roads, how do we have customized autonomous cars or how do we have cars which are probably partition able.

So, that if four people travel in a car they have their own personal space and non infringing air environment, maybe it could be possible so, that is where technology business and policy would link with each other, and that is where R&D leader plays a crucial part in direct in product strategy and business outlook.

As I said when the airlines have to be profitable in the new situation, R&D heads of airlines need radically different aircraft designs, from engines to body structures to make airline operations viable. Even at a low viability factor that is 30 percent load factor relative to current designs that is required.

You must have more wide bodied aircraft which can land more smoothly, even with shorter runways that is a design challenge. You need a heavier larger aircraft, but with the greater fuel economy. So, that the operational economics of the aircraft are not impacted, again lot of synergy and involvement between R&D leaders, technology leaders, business leaders and manufacturing leaders to make this happen.

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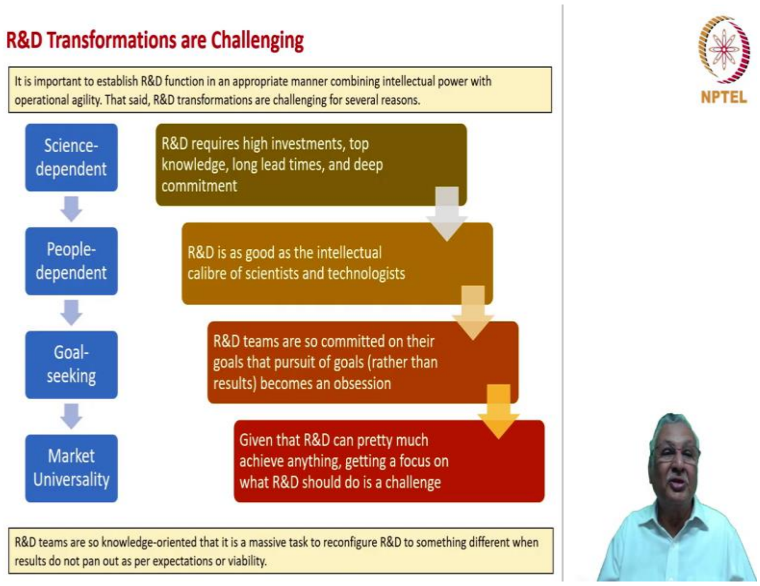

R&D transformations by definition are challenging, it is important to establish R&D function in an appropriate manner combining intellectual power with operational agility. But, as I said R&D transformations are challenging for several reasons. One, these are science dependent and science requires much higher level of fundamental enquiry and investment than technology improvement.

So, top knowledge, long lead times, deep commitment call for high investments. R&D is highly people dependent any R&D division is as good as the intellectual caliber of scientist and technologies. So, it is expensive to hire such great people skills, and also equally expensive to retain them. And, at times to retain them, you need to keep giving R&D projects, they are inspired to be in the system.

R&D is also goal seeking, R&D teams are so enamored and so, committed about their goals that pursuit of goals becomes the main objective. Rather than getting the output which is feasible and viable. So, this obsessive pursuit of goals also needs some level of moderation. And the fourth challenge is market universality, given that R&D can pretty much achieve anything, getting a focus on what R&D should do is a challenge.

You can have different kinds of products in any domain, when you talk about collar mics, you can have a collar mic which is hidden, non-hidden, on table top, computer top these are all the accessorization. But, internally itself the condenser technologies, the filtration technologies the noise cancellation technologies could be vastly different, across various devices.

Not only that, you may have a situation, where the voice is evaluated by the mic, even before you get on to your normal lecturing mode and advises you. How the machine can be calibrated? It also can establish the linkage between the computer system and the mic itself, through these kinds of artificial intelligence being deployed in what you seen simply as a sound wave capturing mechanism.

And electro mechanical device can be a digital device in character, and that could mean a fundamental shift in how the audio industry would move in future. So, to be able to do that R&D leaders must be having high ownership of such goals, but at the same time they got to understand, when ownership becomes possessiveness and obsession. Putting a kind of a distraction to the way in which R&D goals can be finally achieved to productivity and fruition.

So, this summation line for R&D transformation is that R&D teams are so, knowledge oriented that it is a massive task to reconfigure R&D to something different. When results do not pan out as originally encased or when viability is a little different than what is envisaged. So, that transformation of the R&D goal as well as the process and the project management mechanism is a challenge by itself.

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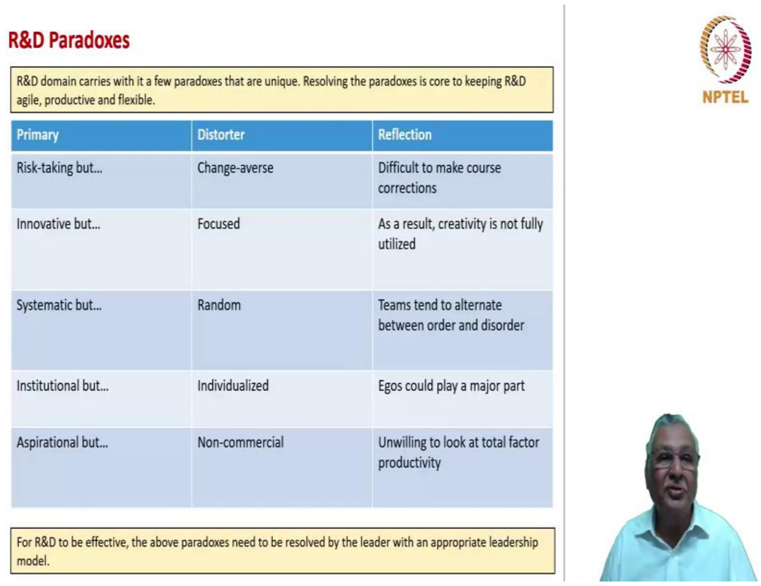

R&D domain carries with it a few paradoxes that are unique, resolve the paradoxes is core to keeping R&D agile, productive and flexible. R&D takes risk, but it also is a change-averse process. So, one must really reflect why it is so, difficult to make course corrections and try to do them in time, R&D granted is innovative. But, it also tends to be so, obsessed and focused as we discussed earlier that creativity is not fully utilized.

Even if you are developing particular compound for a particular pathway, if that compound seems to be working better on a different way why not we explore that, that kind of reflection must be there in the creativity system of the R&D. R&D is systematic, but also tends to be random, teams tend to alternate between order and disorder that is a paradox. Ability to manage this paradox is extremely important for R&D leader, R&D is an institution by itself although it is.

So, much focused on individual capabilities, R&D is a key institution of the corporation, they distorter the individualism. So, how do you ensure that egos could not play a point? How the extremities of individualization and institutionalization are handled for proper processes for proper products? R&D is aspirational, but is also non commercial.

So, R&D tends to be very unwilling to look at the total factor productivity, how do you resolve this paradox you get something, which cannot be used productively in the manufacturing setup or offered in the marketplace, how do resolve this paradox. So, the leader for R&D must resolve these paradoxes with appropriate leadership model.

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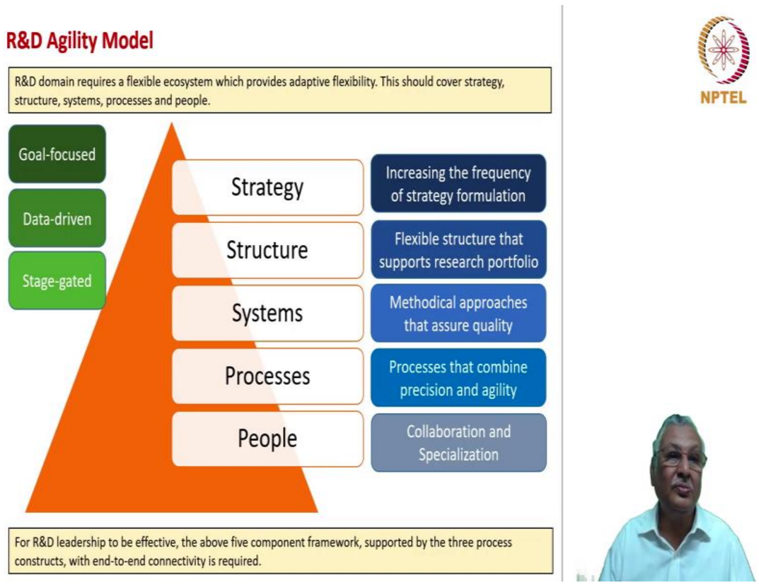

So, let us look at the agility model, like with every domain or unlike with the corporation itself from vision we have strategy, structure, systems, processes and people, it is true of R&D as well. You have to ensure goal-focused, data driven, stage-gated approach as we have discussed.

But, we should increase the frequency of strategy formulation in an R&D system. We should promote a flexible structure that supports research portfolio; there should also be methodical approaches to system quality. Process must combine precision with agility for that if small equipment are required to optimize on the process the R&D leadership should be able to provide.

The more pilot development facilities are offered for an R&D scientist or engineer, the greater would be the flexibility and productivity in the process. And people should be encouraged to actively collaborate while specializing, this five component framework which is supported by three process constructs of goal focus, data driving, and stage gated is extremely important.

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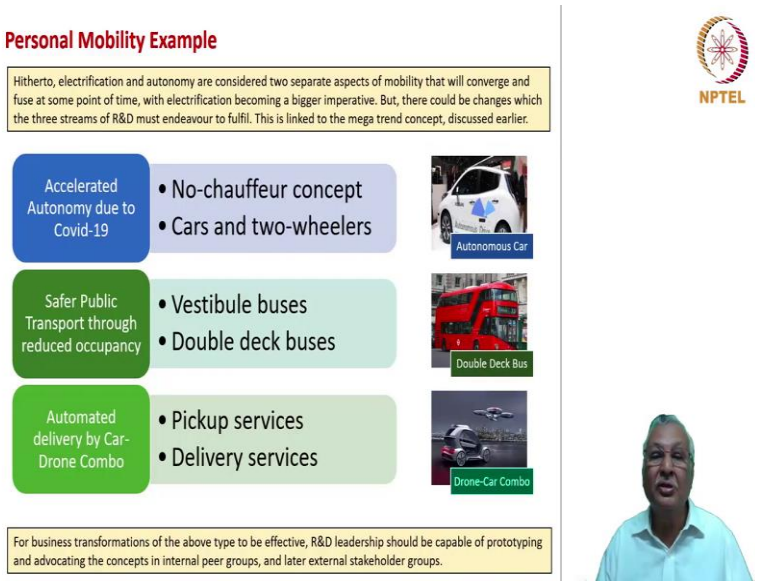

Let us look at the personal mobility example, hitherto electrification and autonomy are considered two separate aspects of mobility. That will converge and fuse at some point of time, with electrification becoming a bigger imperative. But, there could be changes which the three streams of R&D must endeavor to fulfill.

This is linked to the mega trend concept which are discussed earlier. See everyone envisaged an autonomous car as a mega trend. But, that mega trend is coming to the near term in an accelerated fashion, because of COVID 19 the no chauffeur or no driver concept has gained ground particularly in cars. And two wheelers also could have autonomy put in because nobody wants a pillion rider.

So, how do we handle these kinds of mega trends getting advanced? We will look at the public transport. Earlier public transport was the preferred mode in respect of affordability; public policy also emphasized public transport to reduce the overall fuel consumption in the economy. But, today we have public transport almost abandoned there is reduced occupancy, but we cannot afford to keep public transport in this negative situation.

So, we need to find out how a vestibule buses, double deck busses, which have high passenger capacity, but could also provide sort of and has the social distance be put into practice that is the challenge. Quite apart from autonomous and electric concepts that could be integrated in these buses as well.

Earlier we used to have physical deliveries, tomorrow you will have automated delivery by car-drone combo in pickup services as well as delivery services. For business transformations of these types to be effective R&D leadership should be capable of prototyping, and advocating those concepts in internal peer groups and later external stakeholder groups. So, lot of advocacy is involved.

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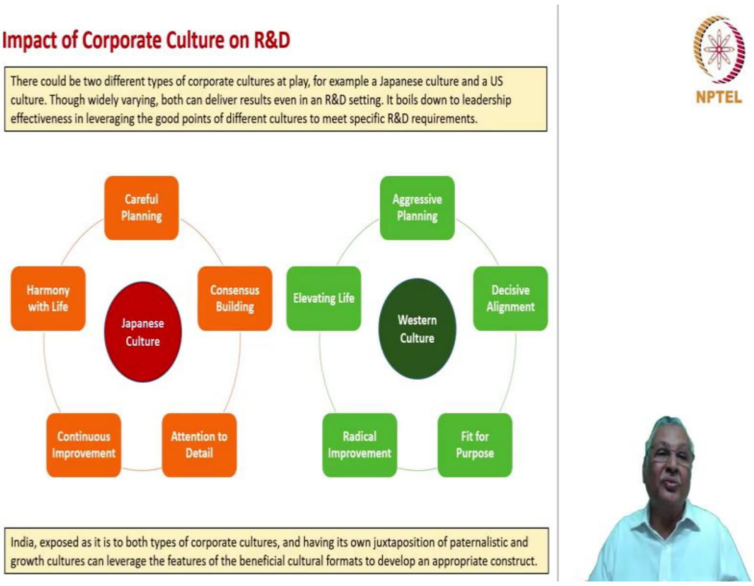

Let us look at the impact of corporate culture on a R&D, because R&D cannot evolve in a completely differentiated manner, when the corporate culture is of a particular type. There are generally two types of corporate cultures at play, for example, a Japanese culture and a US culture though widely varying, both do deliver results even in R&D setting.

It all boils down to leadership effectiveness in leveraging the good points of different cultures to meet specific R&D requirements. What is the western culture? wants to elevate life with more products, wants to do aggressive planning. Looks for decisive alignment, looks at fit for purposes one of the key drivers and radical improvement is looked at from time to time.

The Japanese culture looks at very deliberative careful planning, believes in consensus building, lot of attention to detail and to perfection, continuous improvement, and harmony with life. Now, these two different cultural factors lead to different types of R&D in product groups or service delivery systems.

When, you compare a Japanese product to a US driven product, you can see some of these cultural differences having an impact in terms of the elegance, aesthetics the well rounded nature the form factor and various other aspects of products. India is exposed to both types of cultures as we all know, we also have our own paternalistic and growth cultures. So, there are four types of cultures which are inherent when we look at R&D in the Indian context.

It is the growth oriented culture that we have, the paternalistic culture that we have, the Japanese proven culture of elegant aesthetics and the western culture of a being radically different at the earliest time frames to impress the market segments. All of these things need to be combined to have our own unique cultural play.

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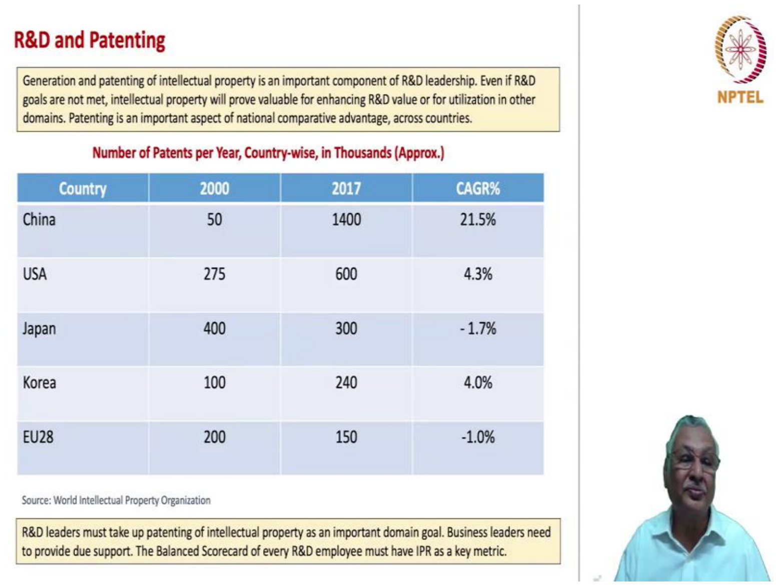

An important aspect of R&D is the patenting portfolio, without patents a country cannot have superiority in the global committee. Even if R&D goals are not met, the ability to patent the intellectual property that is involved in the projects and processes related to that R&D goal is by itself a value creator.

Because, that intellectual property can be used at some other point for some other use, or having such intellectual property estate prevents other companies from dipping into such developments for their other products as well. So, patenting is both very aggressive way of protecting your competitive position, and a very defensive way of preventing competition from getting into your field of operation.

So, if you look at the number of patents per year country wise in thousands, you can see the compound annual growth rate China is leaping ahead in terms of the number of patents, nearly 22 percent CAGR of course, from a low base. USA at 4.3 percent, Japan is more or less plateaued, Korea again reasonably the mid level growth and, European nations again are plateaued. So, the highly developed nations are seeing a plateau while the fast emerging economies of Korea and China are seeing higher growth rates.

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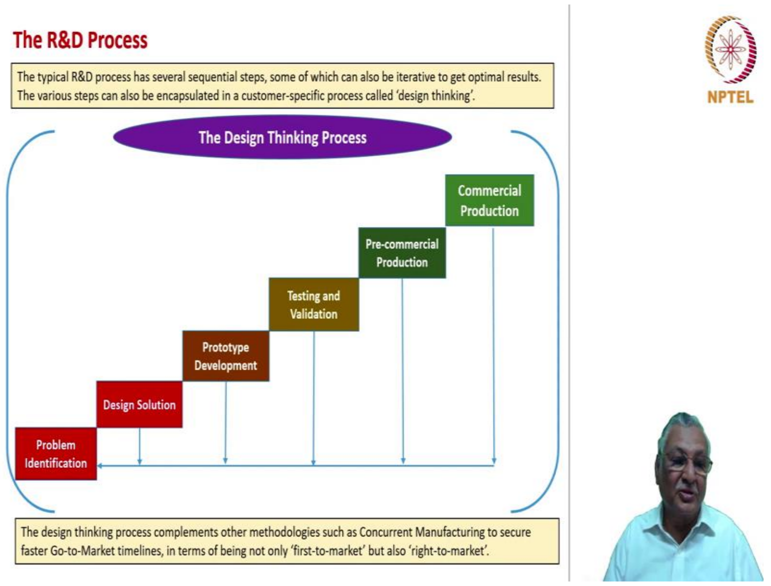

The R&D process is in fact a design thinking process. You start with problem identification, you come with the design solution, you develop a prototype, you test and validate the prototype, you under take pre-commercial protection. And finally, have the commercial production. And each of these steps are iterative, at any point of time you can go back to the problem identification phase, or from a testing and validation phase you can go to a design solution phase.

This design thinking process which is very customer specific and sort of Gemba with the customer that is working with the customer on the field to resolve his problems. And, also to discover more problems, new problems to come up with first to market and right to market products is design thinking. Any R&D process must reflect design thinking.

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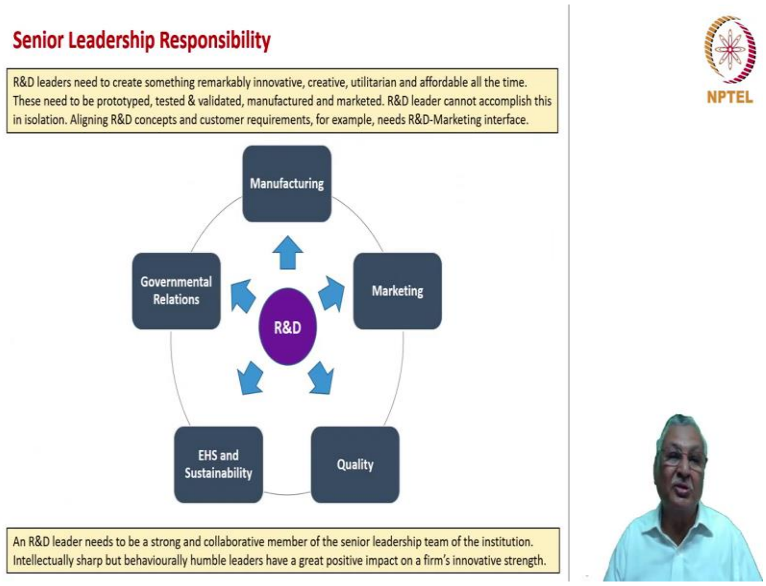

The senior leader's responsibility in R&D capturing, what all we have discussed is as follows. One should have orientation not merely to the R&D aspects of the domain, should be linked with manufacturing, marketing, quality, EHS and sustainability and government relations.

All the five are important. R&D should not confine itself to developing only products for, R&D gate crossing purposes. Products should be developed in a manner that they could be produced affordably in the manufacturing workshops. Marketed with attractiveness in the field, reflect the highest standards of specifications and quality.

And, also are sensitive to the environmental sustainability components of today's ESG governance. So, an R&D leader needs to be a strong and collaborative member of this senior leadership team of the institution. He should be intellectually sharp, but behaviorally humble such R&D leader make a great positive impact on the firm's innovative strength.

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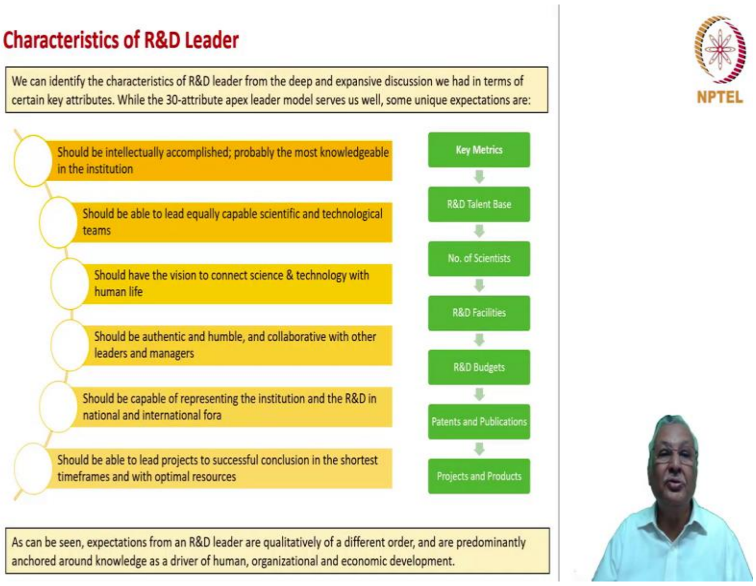

So, I would like to kind of present the characteristics of R&D leader, from the deep and expansive discussion we had, there are certain key attributes. Should be intellectually accomplished probably the most knowledgeable leader in the institution, should be able to lead equally capable scientific and technological teams.

Should have the vision to connect science and technology with human life, should be authentic and humble and collaborative with other leaders and managers, should not allow the fact that an R&D leader has the highest level of knowledge. And, probably develops a product which redefines the business or the company that should not make the R&D leader feel that he or she is superior to any other leader.

Should be authentic and humble and collaborative with other leaders and managers, should be capable of representing the institution and the R&D national and international fora. Should be able to lead projects to successful conclusion in the shortest time frames and also with optimal resources.

So, then key metrics for R&D we should not think that R&D leader cannot be measured by performance. The R&D talent base which he is able to develop one metric, number of scientist, the kind of R&D facilities and the up keep of R&D facilities, the R&D budgets. The number of patents and publications, the types of projects and products, these are all the characteristics of R&D leader that can be measured in terms of key metrics.

As can be seen the expectations from an R&D leader are qualitatively of a different order. These are very unique to the R&D leader nobody expects a manufacturing leader, to be the most knowledgeable in the institution, but that is expectation as far as the R&D leader is concern. Given that they are so, focused on the knowledge dimension, we should also bring to the attention of the R&D leader that the other 29 attributes beyond the knowledge are also equally important.

But, certain aspects will be more important than other aspects in order for the R&D leader to be excelling in these six important dimensions that we have highlighted here, that is having the highest level of knowledge, ability to lead scientific and technological teams, vision to connect science and technology with human life, authenticity and humility, collaborative spirit.

Should be able to represent the institution that is personal gravitas, should be able to lead projects productively with agility and with flexibility, optimizing resources, these are all the special characteristics of R&D leader. To be able to enable these characteristics come up, what are the leadership qualities which an R&D leader should have in him.

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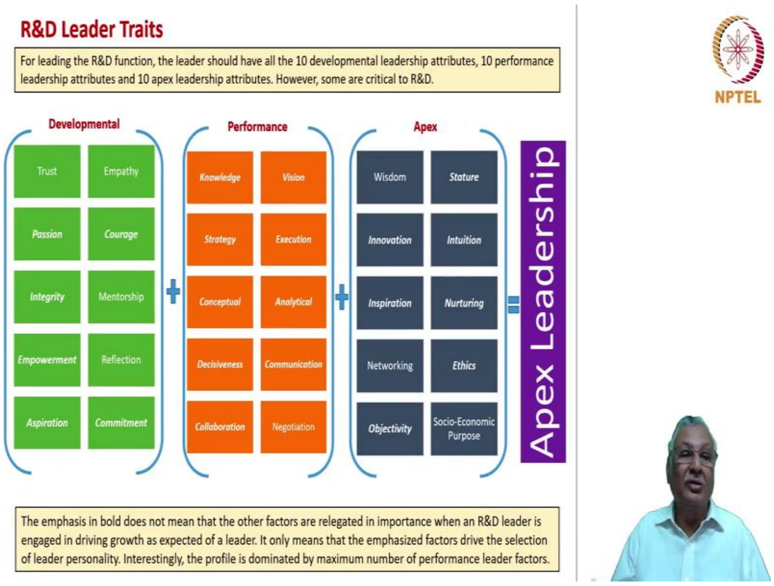

Again these 30 leadership qualities we have talked about are extremely important for any type of leader, any domain leadership. But, as with one discussion we had earlier, certain qualities require greater emphasis for certain types of domain leadership. In respect of an

R&D leader, you need to have lot of passion, courage, integrity, empowerment, aspiration and commitment within the developmental spectrum.

In respect of performance, probably barring a negotiation, every other factor of performance quality that is knowledge, vision, strategy, execution, conceptual and analytical skill, decisiveness communication, collaboration, they all must be available at high standards. And, in respect of Apex leadership stature, innovation, intuition, inspiration, nurturing, ethics, objectivity, they become extremely important.

As I said earlier, other characteristics other qualities are also important, but R&D leader special characteristics which we discussed in the previous slide are enabled by the highly emphasized leadership qualities that I have mentioned here. With all this R&D leader would be an extremely effective and impactful leader.

And if an organization is fortunate, to have a highly impactful effective R&D leader, it would also be fortunate to making businesses transform themselves. Every now and then with greater viability, greater feasibility, with greater profitability. In fact, the firm a create a whole new industry based on the R&D leaderships efforts and contributions. So, with this we conclude this session and see you in the next lecture.