

**Design, Technology and Innovation**  
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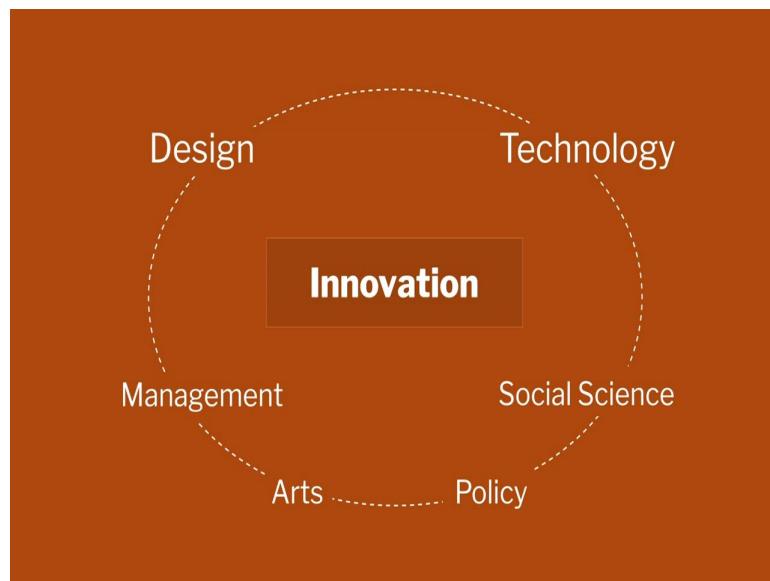
**Lecture-22**  
**Smartcane for the Blind- A Success Story Part 1**

But we are basically working on assistive technologies for the visually challenged. In fact what happened is we started looking at educational needs of the blind. Then we found that before you actually address education, you need to address their mobility needs. If you are not mobile then I think education also suffers. So, we went back and started looking at the mobility aspect and then now we went back and looking at education aspects.

So, that is a focus and it is a very different lab. Usually what happens is in an institute such as IIT's, you will have labs which are primarily either called Teaching labs or Research labs, but we call it more as an innovation lab. Because here we look at the grand challenges which are facing society in a particular domain and try to build a solution which is like end to end. In other words, our journey is complete when we know that the design and technology on which we are working has ultimately made an impact.

So, we had almost like 5 or 6 products which are now in the market. I thought today we will discuss about one of the products which was a very early product, which we worked on. And let me also tell you most of the work which is done as a part of this is also part of an interdisciplinary team. A lot of technology students working with design students.

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Innovation truly actually required a marriage of multiple disciplines. Technology and Design are major. But sometimes you also need Management, Social Science, Arts, Policy and its actually a very good marriage of these.

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**SmartCane™ Device**

So one of the products which I wanted to discuss is called SmartCane. All of you are familiar with the white cane which is used by the people with visual impairment. And this is like, a really, a true companion for somebody who is blind.

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Once you are outside, imagine that for a moment you are taken away, like somebody takes a white cane from a visually blind person who is outdoors, the person actually cannot move because you really do not know what the, lets say, the environment would look like. Because this is like a sensing instrument to know where the environment is and you get to know a lot of things whether you are working on a hard surface or muddy surface, many other things.

But the issue which comes with the white cane is that situation such as this cannot be handled by a white cane. It is a wonderful assistive technology if you want to know the obstacles which are knee below.

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But anything (between) knee to head height, people only come to know through collisions. And this is not just India it is universal. It is worldwide, whether you go to US, Canada, Germany.

But the only difference which we have is that in many of the countries, particularly Europe and the US, the environment is very structured. So, the laws are pretty strict. So what happens is it is very unlikely that you will have a lot of environment and obstacles which will have upper body injuries when you are actually moving with a white cane.

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But 90% of the world, still is very unstructured and where you will see a lot of obstacles such as this. So this was one of the problems which was posed to us, ‘Can we address this particular problem? Can technology and design address this particular problem?’ was one of them.

Rohan was one of the undergraduate students who was asked to take this as a project and he not only did a good job. But I think he spent much more time. He went to Oxford to do a PhD as a Rhodes Scholar. While he was a Rhodes Scholar, he continued to work on the project. After his Ph.D he came back and again worked on the same product for 2 years before going to MIT for his postdoctoral. Now he is back as a faculty at IIT, Delhi.

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So one of the solutions which people can think of is to use some kind of a sensor, either infrared or ultrasonic or laser 2 detect obstacles, and then convey the presence of an obstacle in the form of some output. So, what should be a typical output for such a thing? Suppose, let's say, a person encounters (an obstacle), how should this be conveyed to a user? That is where probably a little research really helps. Some of the devices which were built with auditory output did not work for a few reasons.

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## Why audio feedback was not used

- Unable to hear the audio alert from the cane

One reason is that there is an obstacle but you are not able to hear you are not able to convey this particular information, it is too risky to have. The second thing is the people who are disabled would not like to actually declare that they are visual impaired. It is like if you have a device which is continuously, let say, giving an audio output, you are declaring that, 'here I am, a blind person trying to walk and that kind of a thing', and people do not like that.

These days vibratory output is very well known. We all use cell phone vibrators etc, it is a pretty one. So, that was the kind of a solution which was initially used.

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These sensors are such that it could cover knee to head height, all the range of obstacles and one could actually go to.

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So this is one of the first prototypes which is built. When educational institutes build their first prototype, it is always like a proof of principle. It is not even a proof of concept whether the concept is going to work and kind of a thing.

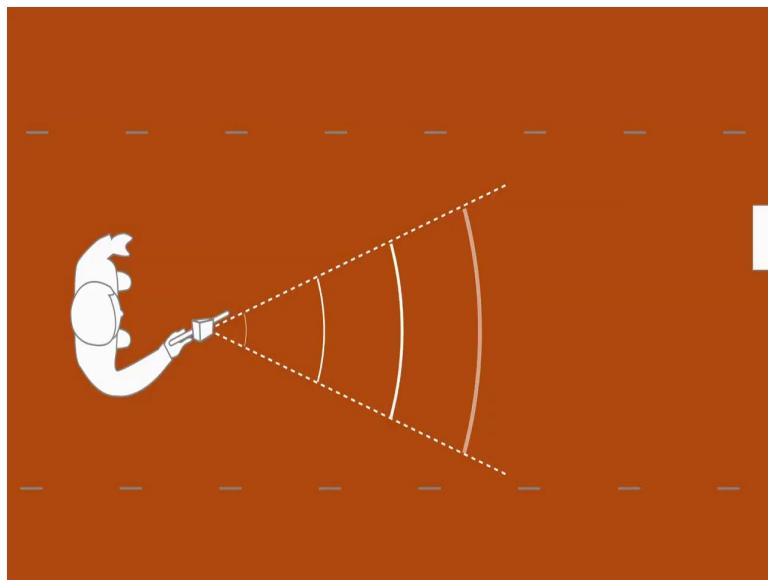
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First Prototype

And you take it to people, like, here is a blind person who is actually trying to test it and what happens is this was given to students who were in Computer Science initially. They could address all the sensors, programming issues very well but they probably did not do a good job with other aspects of engineering like material, mechanical, in terms of having a right centre of gravity.

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If you see a product such as this, you will always have a small torque which is acting, which will always take the sensor in the other direction. And these things are generally not taken care of. So, this is like a first proof of principle. And users mentioned a list of some 20 to 30 problems with the prototype and why it cannot be used kind of a thing.

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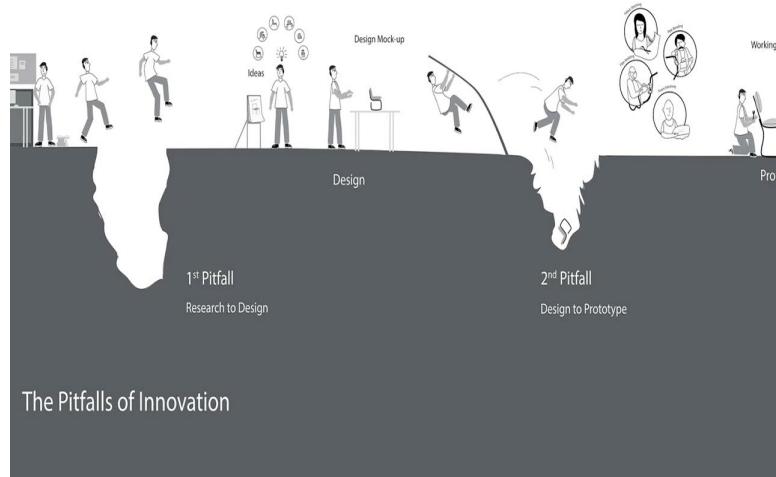
Second Prototype

Then you come back and probably take care of some of the user aspects. Now you bring a few Mechanical Engineers into your team and let Computer Science and Mechanical Engineering students work together and build another prototype and take it to people. Now you have the number of problems, which came in, is doubled. Now not only those problems that some of them remained which did not (get) solved, but now users have many more additional problems.

So what generally happens, this is how most of the projects actually get done in colleges, correct? Usually not many of them go to users. If at all it goes to users, it is something which probably may not meet their requirements. So, then we thought there is something wrong with this type of innovation process. This is ok for learning purposes, for an academic purpose. But if you really want to make an impact then you need to take care of every small aspect of what the user would need.

And that is where sometimes the design and design education and design thinking helps in a much better way to do that.

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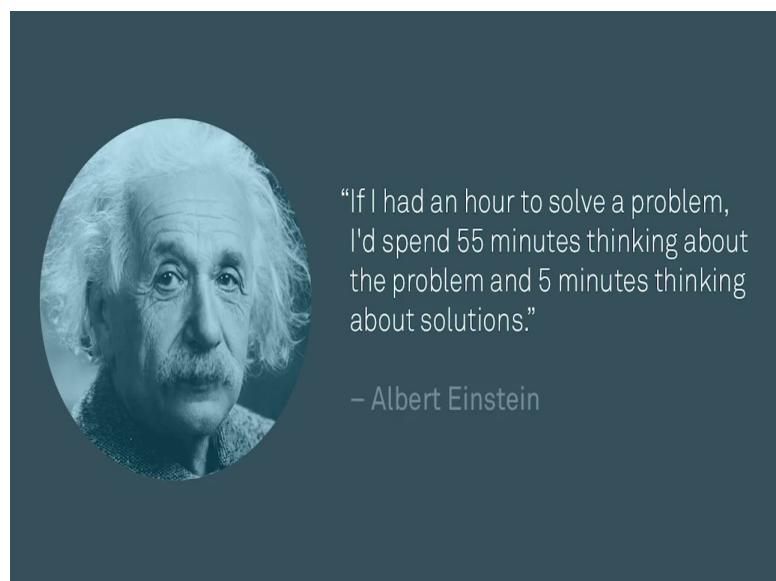


So what was done is that if you actually look at the process of innovation, where you start from one end to another, you have a lot of these pitfalls. So one of the things which was not done is, ‘Before I start addressing any problem or finding a solution, did I do enough research even to understand this particular problem completely?’ In other words, earlier attempts were more of, let us say, somebody gave a problem and you jumped onto a solution and attempted it, you know that it is not going to work.

Can there be a more systematic process to innovate?

The answer is, ‘Certainly Yes’ and it says that we have to spend much more time just understanding the problem even before you go to a solution.

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And it also reminds me of a saying once Einstein said that, 'If I have about an hour to solve a problem, I would spend 55 minutes thinking about the problem and 5 minutes to the solutions'. And probably it was not very well understood when he said, but it is becoming more relevant in today's work. Before you even start attempting such problems and solutions, you first need to do a lot of research into certain aspects.

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First thing is understanding the disability. You are suddenly asked to do a product or solution in the space of disability where you have not really studied the disability. You did not understand what disability is. When you actually look at this scenario such as India, whenever you see a disabled person, most of the people would look at a disabled person more from a sympathy or a charity point of view. And I think once you start interacting with them, you know, that that is not what they need.

What they need is empowerment. They want to socially integrate with persons without blindness and do all those things which others are not able to do. Now this comes only when you jump and start understanding interacting with the users, immerse in those environments, shadow the people, let us say, to their daily activities. Then you start understanding many things and that is very essential if you really want to build a solution which can make an impact.

If I just want to do it for academic purposes probably still ok. But if I want an impact this is an important aspect. Similarly what are the assistive technology and understanding users and user environment.

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We generally suggest that if you are trying to do a product or a solution in a space such as this, it is more of a social innovation, immersion is a very, very important to you. That means how many hours, days and weeks I spend in the environment, or put myself in the shoes of the user is extremely important. If I am not doing it, there are certain things or again when I go back to the users, they will give me a much bigger list saying why it is not going to work.

And also, it's not always true that users are customers. Customers could be very different from users. I think we all use products where we are users like Facebook but we are not the customers. Someone else is paying, if I am trying to use it and the same is here. In many cases assistive technologies are actually bought by the Government and sometimes given to the people with disabilities. So, they are not the direct users but they are still there are customers who will buy products and solutions if available in the market.

So understanding all these aspects, even it happens with stakeholders too, and it happens in multiple situations not only this. Some of our students were actually working on a medical device and they actually found that patients really need this device. They spent almost a year and took

this device to the doctor. The doctor said, ‘This device is not needed. We are not going to prescribe’. Now if you do not take a doctor into your scheme of things and make them a stakeholder, you may come up with a wonderful product, but it does not go through because you have not consulted a doctor when you started this particular project.

So, the idea is that you do not want to leave out any stakeholder who is a part in this whole game that is a very important aspect. And one should also look at how the problem is being addressed currently. What are the problems, is another important aspect. And there are a whole lot of other things.

Just to give an example, suppose you want to buy a thermometer. Where do I go and buy? Medical shop.

If I want to buy a white cane, where do I go?

Amazon. Is it available? Sure? Ok.

Other assistive technologies?

Doctor's prescription.

But disability is not, all disabilities are related to health aspect. For example if I need a new gaming console, the doctor is not going to prescribe, correct?

And I want something which is more accessible gaming consoles, so where do I get it?

And second aspect is there is an extremely small percentage of people who need them, use the E-commerce website also. Because most of the people who are with disabilities come from extreme social economically weaker conditions and usually E-Commerce is not a very big thing. Even if I put it, it is not going to sell. We have a product on E-Commerce, probably the number of units which we would have sold is extremely small because it still. It is there on Snapdeal, it is there on other E-Commerce marketplaces, but it does not sell because for this community probably this is not the best aspect.

So, how do I figure out? Like how do I reach out to, let us say, 5 million blind people in India once I have a product? I also need to figure out those aspects and probably this interaction and

immersion with the user is going to tell me that these are probably the roots through which I can actually reach out to people.

In other words what we are actually trying to say is that if you ask me to define innovation, I will say, ‘Innovation is something where, if there are 200 reasons because of which your product or solution is going to fail, you may address 199, but still it is a failure, because you left out that one aspect which became a reason for failure’. But how do I know that these are the reasons for failure? Understanding all those reasons and eliminating them is the process of innovation.

Somebody can say that I have designs but there are no takers. Very acceptable, it is very much acceptable. If somebody says I have innovations but there are no takers, it looks a little odd. Why it looks a little odd is if there is some problem because of which innovation is not making an impact, that that particular aspect has not been addressed and hence it is still in incomplete innovation. So innovation is something where you do not want to leave anything to chance etc. where as I can still say that, ‘Ok, I have wonderful designs but no takers’, that is possible.

Then what happened with this particular product is students and the team went back and said, ‘Let us go back to the research and do a much more understanding’. And almost 6 months was just spent with the users, end users, understanding, going to blind schools, going to places where the blind community actually meets, listening to them and trying to understand this aspect. And this investment in research is extremely important not only for product but for the entire life cycle till you make an impact.

But when you interact with these people you come to know that the people who cannot afford 3000 rupees can spend 20 rupees per month. This research and this information gives me that I can still sell. Probably I am going to come up with a very different business model, having understood the people. It may be an EMI or it may be something which may be a rental aspect and it is still going to work kind of. If I do not do this research, I cannot even come up with a better business model subsequently also.

So it not only helps to just find the product and solution. It is also helping you to see, 'How can I reach out to people?' So in this research we found out that this is extremely important. And I think these researches are very well done by the designers usually, we have seen that. The people who are very close to the user and co-create solutions with the users are the best people to do that. You mean to say the smart cane is not the best option for this problem.

So, I think this is a very important question. Can we have, like, a necklace or a helmet. That is where it actually answers this particular question.

How is the problem which is presently being addressed?

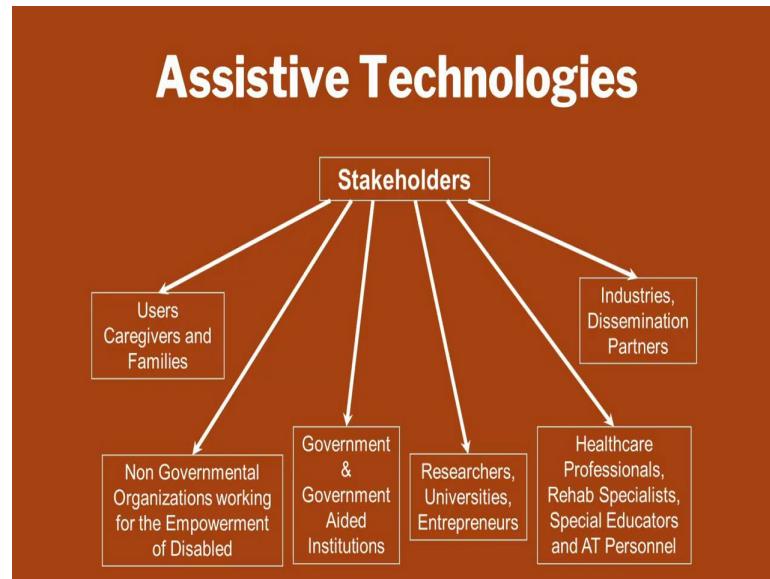
Why did these solutions fail is that they underestimated the importance and the power of white cane. They tried to replace the white cane and tried to come up with an alternative solution for that.

Imagine there is an ultrasonic torch instead of this thing. It can still, there are a few problems. First thing is your knee to, knee and below is still done by the white cane. So, now if you remove that, when I am walking there may be a serious drop off. How do I come to know that there is a serious drop off? And it is extremely risky to remove white cane in the situation.

And the other thing is white cane gives you a lot of information. If you see people who use white cane they sometimes probably also, you can see them waving that is basically trying to understand the environment. And Now what happens if I have an ultrasonic torch then there is an extra thing that I scan it in such a manner, that I am not going to miss anything. If I miss then it's going to be

a risk. Those aspects become extremely important, that anything which you try to replace generally have not worked and they have closed. People have tried and given up. So this is important that people have tried and given up for this reason, becomes extremely important for me not to try and probably try something which is a new aspect.

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So, what we found is that often we give a lot of importance to understanding the user and user environment, but a large number of innovations, which have been done in assistive and medical, we found that the stakeholders, all the stakeholders are extremely important. For example, somebody who is called as a Healthcare professional is a person who trains visually challenged people on mobility. So one of the versions of the product which we built, the person came and said your product looks good, but it is extremely difficult to train people on.

Since we did not consult those people from the training perspective, they kind of rejected our product in one of the versions. So then we realise why each of these stakeholders is extremely important and where failure is likely to happen. Let me give a very interesting example from Mumbai for the stakeholders.

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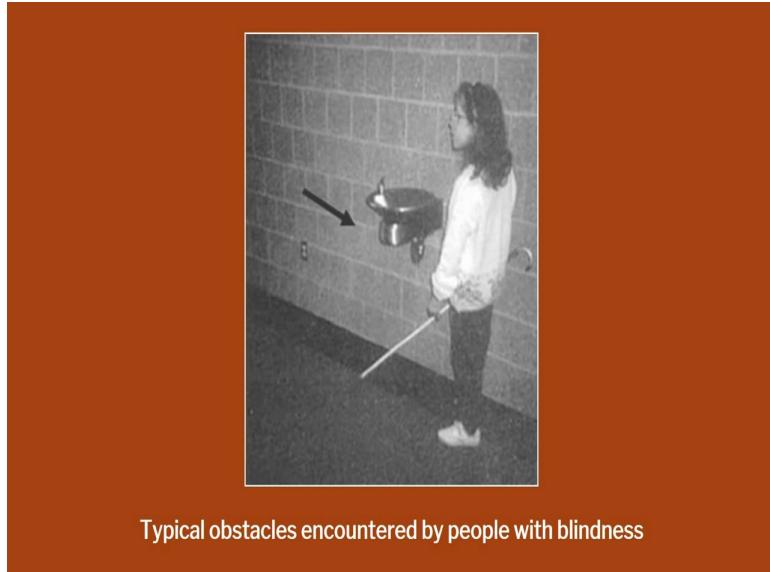


A case of Stakeholder  
(Bus identification system)

We were working on another product and solution where a visually challenged person can board a bus independently without sighted assistance. So there is a small handheld device which helps me to know two things. The first thing is which number bus has come and the second thing is where the entrance to the bus is so that I can actually walk and board independently. Now, when we did this particular product, we thought, we did not consult many of the stakeholders, and when we came to deploy this particular thing in Bombay in one of the depots called Back Bay depot. So we wanted to put it in 25 buses, then we discussed, we found that there are at least about a dozen stakeholders in this whole process, starting from General Manager who heads, like, BEST (Brihanmumbai Electric Supply and Transport) to the conductor, the driver, the depot manager. Unless you take all of them on board, they are not going to let your innovation go ahead. Then you need to convince the value which it brings before you can actually take them onto a board aspect.

This is, like, the real life solutions where you go through a process and realise how important this stakeholder was and how ignoring this stakeholder has cost me things which probably would not have. And then when you do a research you not only come to know it is not just the tree branches which are there, there are dozens of other obstacles like standing trucks to protruding air conditioners, all require a visually challenged person to negotiate. And this is also probably needed for most others because you are not going to build a solution for one obstacle, it's for all types of obstacles kind.

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Typical obstacles encountered by people with blindness

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When you give one of the prototypes to try to the people you also come to know that you expect people to hold the smart cane or a white cane in a particular manner. But when you come and do research you see that people hold it in 4, 5 different ways, the product. And how they hold it is extremely important for your product and solution to work. Because why it is important is the vibrations which are felt is important to know what are the obstacles in your knee to head height?

But whatever is the information which you are getting from the White cane, like surface texture etcetera, that should not be lost because of the vibration. The moment you, like, one type of output dominates, you again fall into a risk and you have to rework kind of the thing. And for that you

need to know how the people are going to grip. Depending on the grip your sensor position is changing, you know, whether it is actually pointing out to head, or below head, or above head is also all that information becomes extremely important.

And all these things generally come when you do more user interaction. Technology sometimes happens quickly, but at least the first cut of technology. But the real problems are very different. What we did is we also bought all the existing products in the market, particularly the international market and gave it to users for one week and said, ‘Try and tell. Give the feedback about the existing product’.

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What are the existing products in the market?

This is like an ultrasonic torch which I mention and people said this is something they would never like to use.

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What are the existing products in the market?

There is another one where the vibrations are felt in your head. And people said they, many of them did not use it, not more than 3 minutes. They said, 'I do not want my vibrations in the head'. It is a very awkward kind of a thing.

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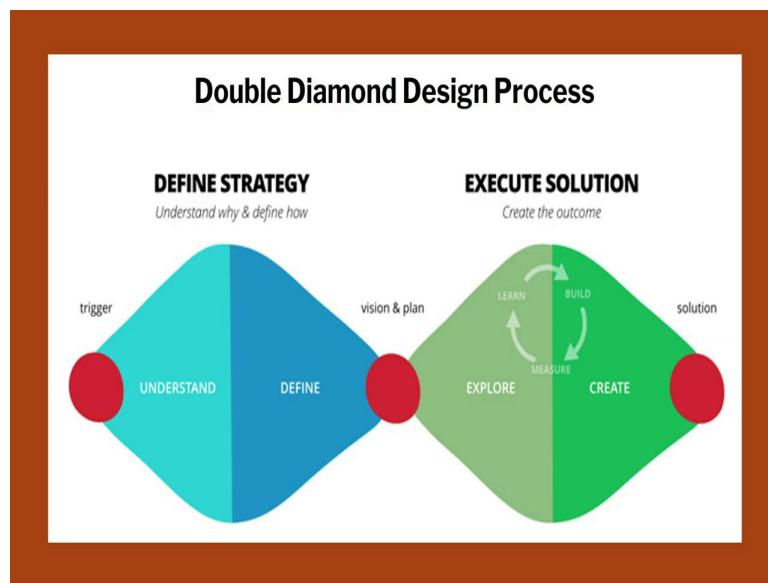
What are the existing products in the market?

The feedback which came for this is they said, 'I have been used to using a white cane with a particular grip for the last 15 years. Now you are asking me to change my habit'. And people are extremely reluctant to change their habits just because you are now trying to design a new product. People will do that only when the value addition is extremely high. You think of any innovation where you bring a very small value and ask people to change their behaviour and habits, it is not going to happen.

So, there are various feedbacks, but they also gave good points in this. So now as a designer and as a technology person, I know what are the choices which I can make in terms of sensors, in terms of form, in terms of this thing, so that I bring my own USP where probably I am going to do better than the existing one. Why these existing ones did not reach the people is that they typically cost anywhere from 600-700 dollars to 1,500 dollars and you are actually trying to sell to people who have difficulty in many of them buying a cane of 200 rupees.

So, that is a bigger challenge. Even though these are in the market for quite some time, some of them are of course now close, but still they are not able to reach out to the 90% of the world population.

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What we found is that it is extremely important to go back and apply the design principles. So we always say about divergent convergent thinking, which is there. So we thought let us do both for the problem as well as for the solution which is there.

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## Multiple Iterations

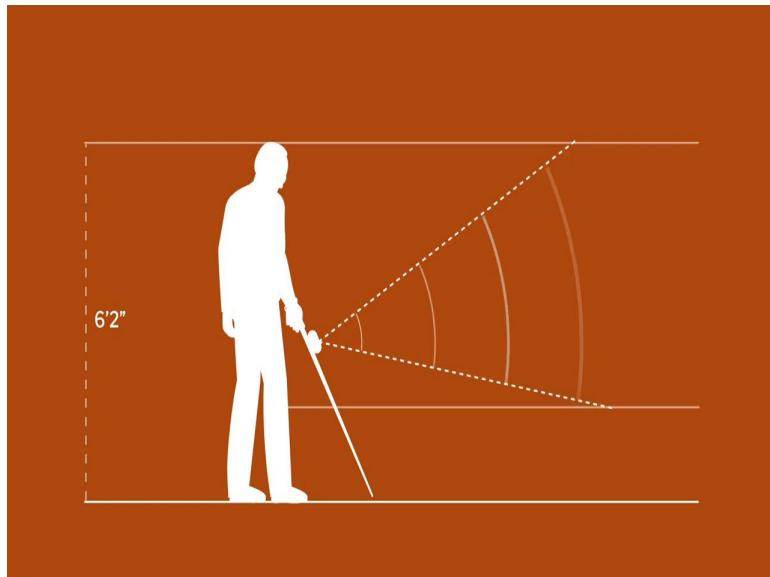


Then it went through a lot of iterations and I think the one common rule in all the innovation is fail, but fail fast. And probably one iteration is not going to give you all the inputs and take care of all the user requirements in one. You can take care of most of them but, again, you have to come back to your prototyping and redo when probably rebuild the prototype solutions in order to do the kind of thing, which is there. And it went through a multiple prototype.

The version which was launched in the market was the 12th prototype. Some of them were probably not the functional prototype. There may be, like, look alike, work alike prototypes. Some of them are functional prototypes, but all together we had to do about a dozen prototypes before we could say that here is something which people are going to accept. And now I am very confident that during these prototyping sessions I have addressed all aspects, or at least the most of the aspects which the user would require.

So, I think this is a very good question in the sense: What should be the detection range? Which you are saying. So, typically one is of course knee to head height.

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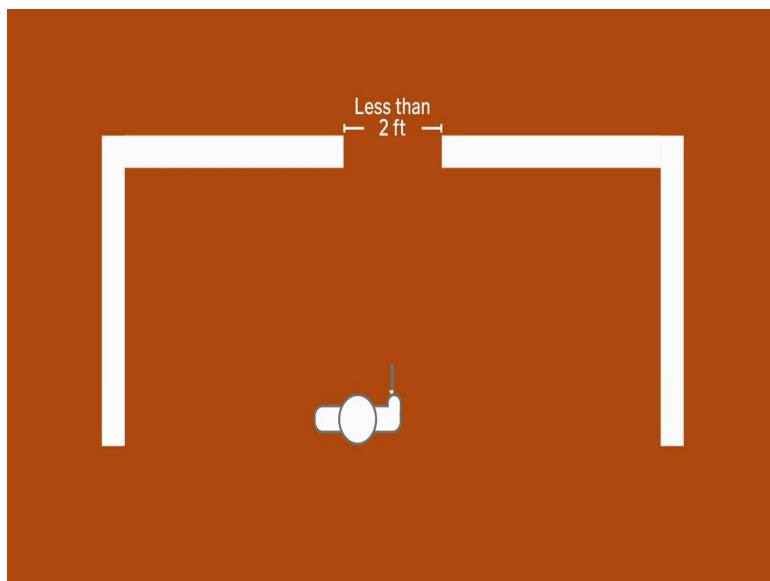
So usually you take a certain thing, for example, we took typically 6 feet 2 inches as the height, which is the height it should cover. You can also broaden a little bit, there are methods to do that. The second thing is it is not only important to cover the vertical one. You should be able to cover the horizontal one also.

So, how much horizontal? What would be your answer? Suppose if I wanted to know?

Around 4 feet? But that is, like, not 4 feet. That would be much smaller than that, correct?

So, the problem with 4 feet is, let us say, I am inside the room. And have to exit from this particular room.

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And if I have, let us say, a door which is less than, let say, 2 feet, then I will never be able to detect that there is a gap through which I can actually go. So, you need to keep it narrow as he said, you take the width and add a plus or minus, and that is how probably you should be able to do. The moment I make it this thing, my obstacle detection increases, good, but path finding becomes very difficult. You know, if you know ultrasonic ranging, it is basically a conical correct? Which is there. So, that means the more the distance it covering, more of a diameter kind of a thing.

So, it can detect anything up to 3 metres. 3 metres is the range. Now 3 metres also when you have a range, you do not want to have just telling that there is an obstacle at 3 metre and there may be something which is just very close to you, in both the cases you are saying an obstacle does not help you. So what you what one needs to do is that you need vibratory patterns which in some way are also proportional to your distance.

So, when you are at 3 metres, you are walking and suddenly at 3 metres you encounter, you have one type of a vibratory pattern, it only alerts you it does not stop. And what happens is when I am using a white cane, when I am still, let us say, waving it to find an obstacle which I still do, then I know that in one particular direction there is no beep, there is no vibration, but in other direction there is, that basically gives a clue that probably right side there is no obstacle and I can still clear it off.

So, it also requires a little bit of training. And users have to use, are given a 2 hour training and orientation to understand this, and we found that is enough for people to be independent, but you keep learning for a period of time. But after, like, a few weeks you are probably as good as using your white cane facility. It is basically, like, when we start driving a car for the first time we know how we make our decisions and once, let's say, you have been driving for 3 years or 4 years, your maturity level is entirely different.

Same thing happens, in the same mobility, here too. How do I restrict, let us say, the width to be a smaller and vertical to be higher is that you can do it through programming. If you know how to program for the sensor and sensor information, you can always actually do this particular aspect.

So, what happens every time when you go to a user you always have a big checklist. So from the checklist the first thing which you are going to decide is. What is that you are going to address and what is it that you are not going to address?

When we took this particular product people wanted a few more things on this which we did not address. Somebody said, ‘Can your smart cane, can also detect, for example, the dogs?’ In one of the campuses there have been too many dog bites of the visually challenged people. Can there be a sensor to know that there is an animal or a dog. We said that is not we are doing. If I want to do that then probably I need a slightly different technology, different cost and different market. So, that decision has to be made when you actually do that.

Another person said, ‘Suppose, let us say, if I keep my smart cane somewhere in the room and I do not know where it is. How do I know? Can there be another sensor which can be like an object detector? Ok through my mobile phone I should be able to know. You have another sensor which beeps, so that I can use the audio close to find out’.

We said we are not going to do that. If you look at their wish list, it is always much more. But I think somewhere you need to say, once you have decided that these are going to be specifications, at some stage you need to say this is going to be the specifications of my product.

And once you know that those have been addressed, tested, that is a time when, it is also like a gut feeling. I do not think there is any rule or a green light or a red light which says, ‘Oh, now it is a green light. Stop the iterations’. And it can always happen that even after you launch a product in the market you may still have a couple of things which you may have to change and sometimes for very different reasons.

I will just give an example. When we took this particular product we launched this product, most of them asked, ‘What is the colour of this product?’ Now, probably you did not think colour is something which is very important, but colour was extremely important for them. Like, that is the mistake which we do that somebody who cannot see, they do not have a colour choices etc., that is not it. Somebody in fact, very arrogantly asked also, ‘How does the colour matter to you?’ I

think that is probably the one of the biggest mistakes the person is committed in asking this question.

And everybody was angry. They also answered a little arrogantly. They said, ‘When you buy a shirt, like, I think you are, this thing, it is not just that you like it. You also want others to like it. Then why are you denying that opportunity for us?’ So, the aspirations is an extremely important aspect and unless we do a good user immersion, we may ignore the aspirational aspects and at the end of it the product which may fail because it did not meet the aspiration.

So, it is a very balanced kind of thing. And it is also possible that if somebody does an urgency and does not do enough prototypes and goes to market, the product may be a failure and somebody may probably do more iterations, but then there is also a risk of, probably, not being the first to market. So it is a very balanced view. But if you think that the prototypes which are doing is going to add a lot of value then I think it certainly is.

I think there is a very interesting paper which you should read called Second Paradox of Toyota. So when the entire world was reducing the number of prototypes to capture the market, Toyota went and did more prototypes and came up with the product which kind of captured the major US market. In fact people thought in a world when there is a lot happening digitally, why did Toyota go and do a lot of physical prototyping and spend more money and time and delay their launch.

But I think ultimately the launch proved that it is something. So it may not be the case always but we need to make a very judicial choice when to stop the prototype. And sometimes prototyping may be for just, testing one particular feature of the product. So that can be done very quickly. You do not have to build another functional prototype.

The market consideration actually comes, the earlier they can come the better you would be placed.

That is what I think you have seen the slide which is Pitfalls of an Innovation, you have, like, there is a thesis to design, design to prototype, prototype to scale and scale to market. What happened is if I look at this process as very sequential then it is quite possible that somewhere in the 3rd Pitfall,

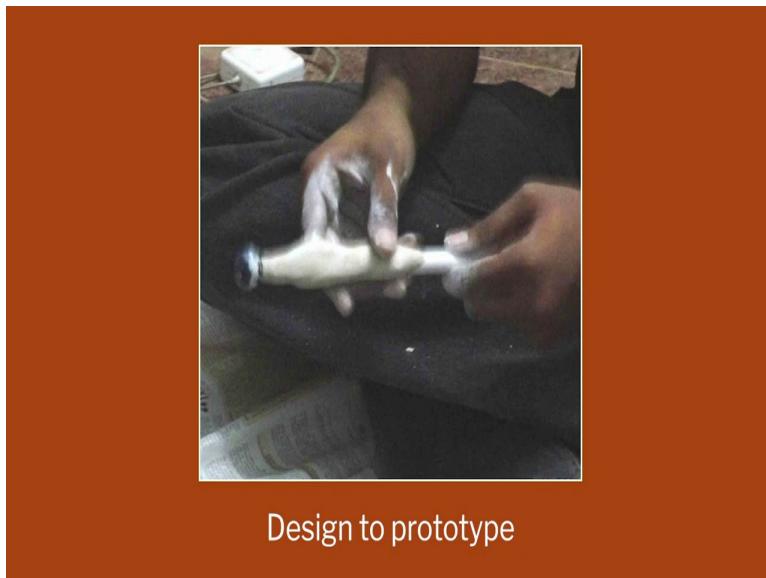
I realise that my design is not going to go through the 3rd Pitfall. Then you have to go back and re-do this particular aspect.

But if you had a little, lets say, an idea how the market is going to look like, probably your solution will take a very different path and it is more likely to succeed or you end up doing less number of iterations. You may still succeed but end up doing more prototyping and more iteration.

**Design, Technology and Innovation**  
**Prof. P. V. Madhusudhan Rao**  
**Department of Design**  
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**Lecture-23**  
**Smartcane for the Blind- A Success Story Part 2**

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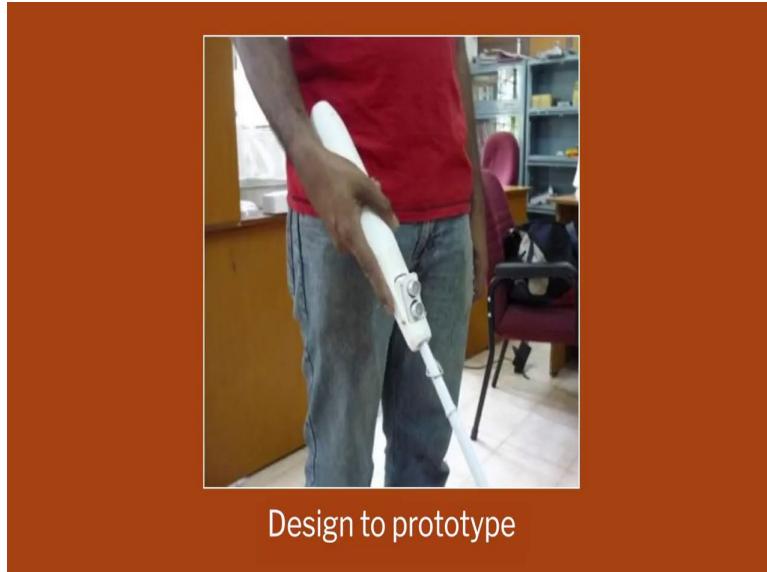


**Design to prototype**

As I said a lot of prototyping probably we would have spent just 2 years doing prototyping, building and testing before we could actually go to market. That was also the first product. We did not understand the complete, this chain of innovation. If you ask me to do a similar product I can do it in much less of iterations, because now we know where the failures are likely to happen and you understand the community and the market better which did not happen with the first product.

So, that is also one reason why we have to go to the 12th version which went to market. When we did the subsequent product, they did not go through those many iterations.

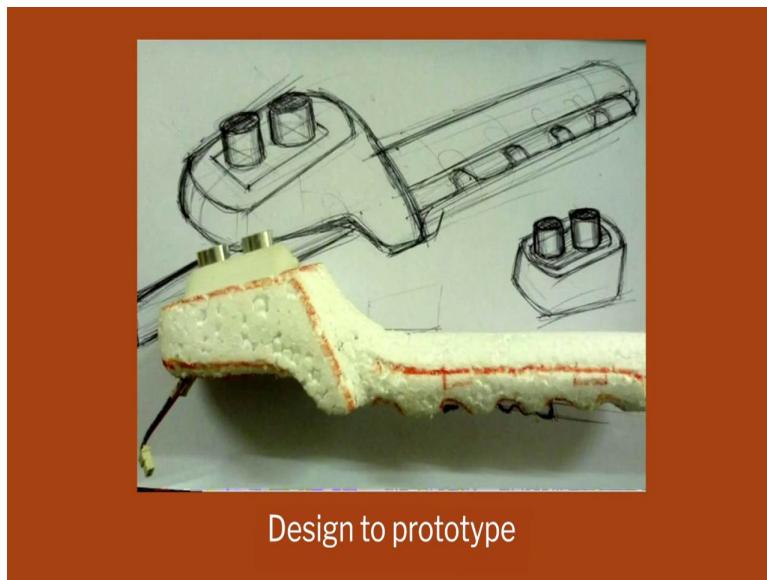
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Design to prototype

This is a lot of testing. Every time you do (make changes), you need to go test with the people some are more of functional prototype.

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Design to prototype

Some more like models in styrofoam or thermocol, but you had to go through these aspects.

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This is one of the versions 9 which is there and also people said that there are controls in the smart cane: How do you indicate?

Somebody put Braille points in this. Now the moment you put a Braille, this also goes into mould, correct? Because when you are doing a 3D printing it is easy, but when you go for a mass you need to do it. But this was a mistake to put Braille. Why was it a mistake?

No. Which Braille?! Hindi Braille? English Braille? Tamil Braille? Correct? So the Braille is different. Only, it is still a 6 or 8 dot system, but the combination is different for different languages.

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You cannot just prepare a mold for one language and do it which is there. So what we had to do is we had to come back and remove the Braille and just put it as symbols and let the symbols be explained in the manual for people to know that this is a on off button.

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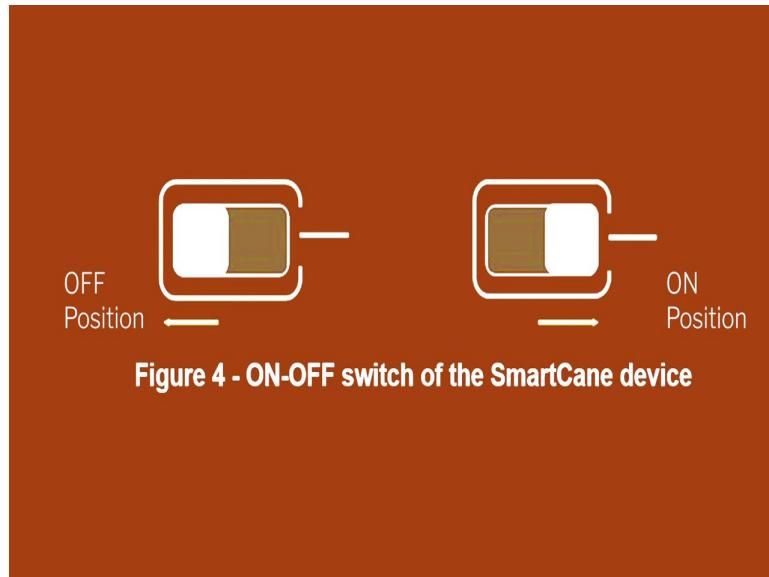


Figure 4 - ON-OFF switch of the SmartCane device

And there is also a button where you can set your range to 1.5 to 3.5 meter.

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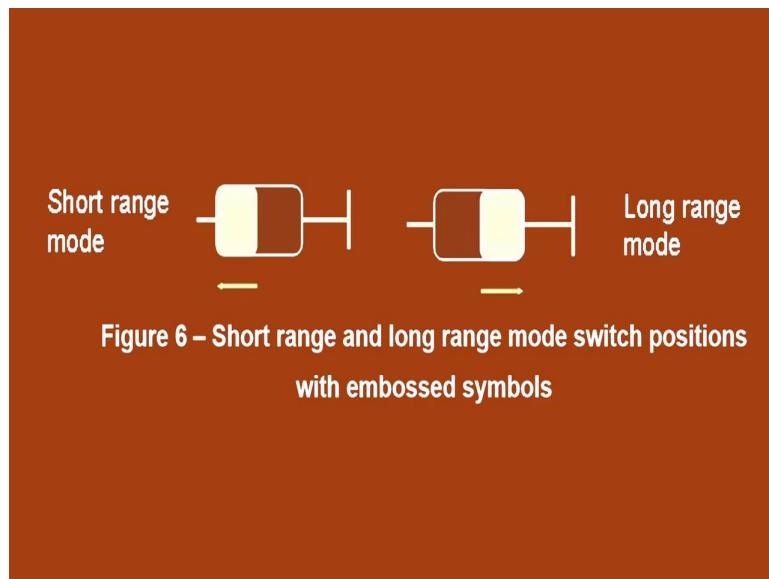


Figure 6 – Short range and long range mode switch positions  
with embossed symbols

Why 2 ranges were given is that in a place like this many of them are within 3 metre. It will always be giving vibratory feedback. So I would like to set a smaller range when I am indoors. So you have a control for that. Now, how do you tell the users that these controls exist and these are the

symbols? Now that is another research which has to be done. How do you indicate a power button on any of these devices? What symbol do we use?

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A circle with a line. But that does not make any sense to them. Because that is more symbols, those symbols are designed for visual route to comprehension. But I think when you are going through a tactile route to comprehension the same symbols do not make sense. Then we look at what is the power symbol for, if you want to use a touched route, then we found that there is nothing like that exists in the world.

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So what was basically done is a small symbol which is in the form of a T shape. One end is on and another end is off, so we just put a T symbol and explain in the manual that this end is a power on and this end is power off. And we had to do it because symbols for them are still not standardized and do not exist, and all these things are important. Suppose if this symbol exists, and if I do not put still it is a crime because they (will) say they would be looking for that symbol which is the standard and if they do not find, they cannot find that there is a power symbol.

But only have to do research and find out if such a standard does not exist so you have a choice to do it. Now, the world is meeting. There is a big consortia in the world who are actually trying to make such symbols for the blind person in the world, but it will take many years before they become a standard.

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So, if you look at the prototype, the first one and the one in the market, all the features have changed and all of them are user ratified. So, that is where you know somewhere, 'Ok, now that it completely co-created with the user, it is less likely to fail.'

White cane comes into version. One is a foldable version. Another is a non foldable version. Many of the people use the foldable version.

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So, here also you can do the foldable version. And the moment you say fold, the users came up with another aspect: 4 folds or 5 folds?

Some people use 4 folds and some people use 5 folds. So, we thought ok we go with 4 folds. But then most of the women were very not happy. They said, ‘When you have 4 folds it does not come in my purse. But the moment you put it is a 5 fold it comes in my purse’. So, then we have to switch over from 4 folds to a 5 folds.

So that women are also happy and the normal bag which they carry can also have, fold and keep it, this aspect. Just, it is a very small thing but it can probably please or displease somebody. And that could be the reason for your failure too.

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So in fact, one of the things probably I did not bring out is that this smart cane is actually an attachment. It is actually detachable and you can put it and any of the white canes. And the good thing is worldwide people have standardized the diameter of the white cane and that standard came to us very handy that I can make it detachable. So it can detach, and do that. And this detachability is extremely important.

Suppose in case I, my white cane gets damaged because of certain things, sometimes it happens. What happens is you are actually going and suddenly somebody who is actually going on a bicycle or a bicycle wheel can entangle with your white cane. It happens sometimes. So, when your white cane gets damaged, you do not have to throw away an expensive one, you just have to replace your white cane and still the smart cane still works.

There is another important question. Can the people use just a white cane, a smart cane only, without white cane?

Some people tried and though we said it is a smart cane is something which complements the functionality, it is not an independent product. But still some people used and they shared their experiences how they could detect some aspects in this, but it is still a risky proposition?

The risk, which is there is, as I said, if it is a structured environment still there is a less risk, but in an environment suddenly, let us say, the municipality has opened the manhole cover for this thing,

and they have not put it. Then how do you come to know that there is a serious drop off. And this brings a very important aspect. When we do the user trials, we generally do a multi location trial. When we did 30 user trials of the first product, we went to 5 cities. In 4 cities it worked very well but in one city it was a failure.

It worked very well in Bangalore, we went to one rural area called Chitrakoot, which is also well known, so we went to Chitrakoot. We did it in Delhi. We went to Shimla. In Shimla it did not work. We came to know that in cities like particularly in hills, people do not use even the white cane. It is very risky to use even the white cane when you have serious valleys and drop offs. And they generally use only sighted assistance to move.

Now how do you tell the people that it cannot be used?

You have to put it in your manual clearly. If you do not put it and if they still use it, you are still legally culpable. So there is a legality also when you prepare a manual etc., that what it is that you put. Some risks you can mitigate in the product, those things which you can mitigate in the product, you still warn the people. I think that is what most of the medical devices and drugs would do. They say there are certain risks associated with this, please read that carefully. You cannot use the drug during any situation.

Same thing happens with assistive and medical technologies too. So these are products where there is a risk. Now whenever there is a risk, it will be regulated also and you have to follow those regulations which is very important.

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Improved design of smartcane (Iteration 1)

When colours were demanded we just also made it in different colours.

It (Center of mass) is solved because the problem is you had a huge centre of mass, so every time I would move it actually turned, so the, then you do not know whether the sensor is pointing out in the right direction etc. Now the geometry itself gives you the tactile features on the surface where you are holding, tells you clearly what is the direction in which the sensor is moving. So those tactile features have to be built in while you are doing this thing.

And ultimately when you are doing a form you need to take care of certain ergonomic and human factors that require you to come with a more optimized form, that time you can also incorporate this. You have to solve that. There are certain features, which you do not solve people would not accept. There are certain things which probably still can be accepted or your market may shrink.

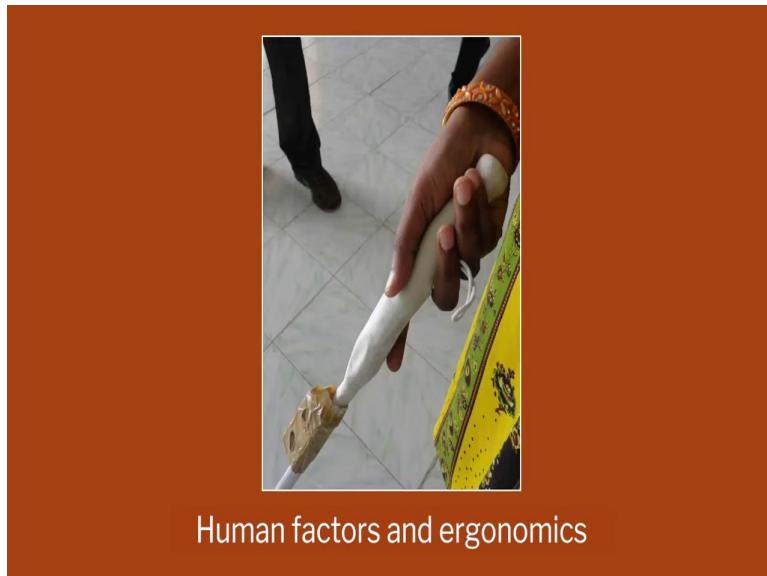
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Old and Optimized Design of Smartcane (Iteration 2)

Various aspects, like one of the versions we did, the colour choices for men and women is very different for visually challenged. So you need to do a small survey to know what their colour choices are.

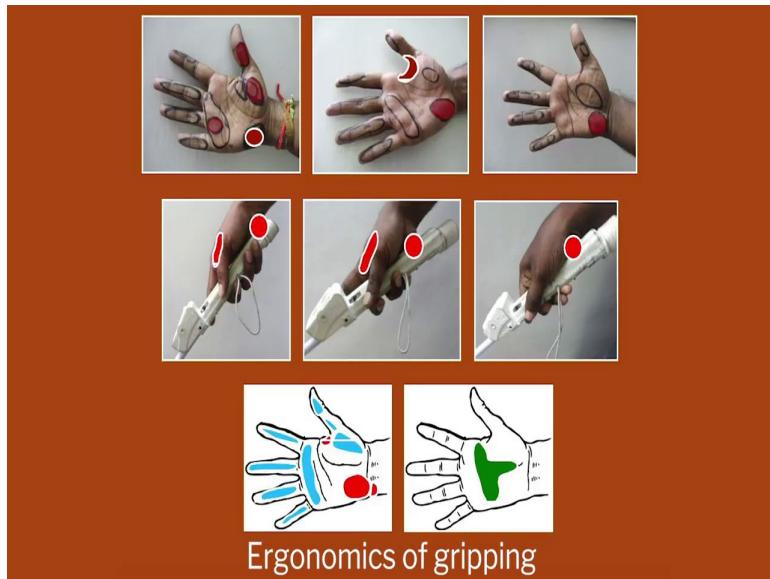
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Human factors and ergonomics

Lot of issues came from the school going girls. They said the form which you have come up with is something which is probably, pains at certain positions.

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So then we had to actually go to the schools, give them clay models and do a complete ergonomic analysis to know. For example, what are the regions, like, you can also know how the pressure is being distributed on your palm for a given form. You can do a very simple study and then see what are the regions where it actually pains because typically a user is going to use it for about 2 hours a day.

And if you are using it continuously it can be very painful. And that is what most of the elderly people complain about their cane which they use. And still in the market, this is an unsolved problem, something which is a good ergonomic cane is still, many of them are not very ergonomically designed. It is still an unaddressed need in some way. So this has to be done with various people and, then do optimize, and then once you have a clay model, which is kind of an optimum, then you can do a scan, build a CAD model and then go and build the molds and etc.

So, but a continuous process of reverse engineering etcetera; had to be done if you want to incorporate user choices.

It is not only important to have a product but how you package, what are the manuals. One aspect is that they are given one hour training, but other than that they also need manuals. Now, how do you write these manuals?

See you need to do it in Braille. Now once you say it has to be done in Braille, you do in multiple languages.

And then you also need a charger, and initially the first few versions your charging used to be for 4-5 hours, but later this was done almost, like, 30 hours of charging. If I am using for 2 hours per day, I had to do (charging) once in a fortnight and they (the users) were very happy. Initially when it used to drain this thing. There the technology optimization comes. So you need an electrical engineer who is very good in terms of power electronics, optimising, (to) bring their own domain knowledge. So that is why this team which actually built, had mechanical engineers, computer scientists, electrical engineers, industrial designers, social workers, and it is a highly multidisciplinary team.

That is a very, very good question. Let me demonstrate through this. So, how do you know that the battery is left?

Now, this string is a, many of them used with the white cane and they wanted even if there is a smart cane you have to give this. What people do is actually put this and hold this. Why they hold is they see that under any circumstances your cane is not separated.

Somebody said: Is this detachable? Like, you can always detach. This is the smart cane and this is the normal white cane which you get. And since the string has to go you need to have features to do that and a, so when I actually switch it on it had two beeps and also two vibrations.

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Battery Charge level	Device turned ON in long range mode	Device turned ON in short range mode
Full: 70% to 100%	Three beeps with three vibrations	Three vibrations
Medium: 30% to 70%	Two beeps with two vibrations	Two vibrations
Low: less than 30%	Single beep with single vibration	Single vibration

Now 2 beeps say that your battery is 40 to 70%. Single beep is less than 40%, 3 beeps is 70% and above. There is no other indicator to do so you need to use audio. But there is also a vibrator. India also has a large number of people who are both deaf and blind and for deaf and blind, tactile is the only route. So this is a device which can be used for deaf blind also, and we have a large number of deaf blind users who are using this particular product. So all the vibratory, the tactile hepatic aspect takes care of this particular aspect. So this is the one, this is the indoor outdoor navigation I can set.

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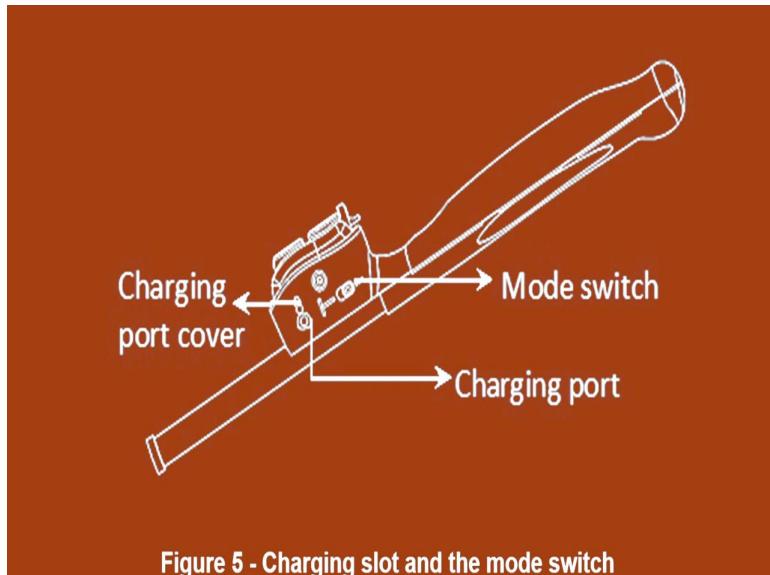
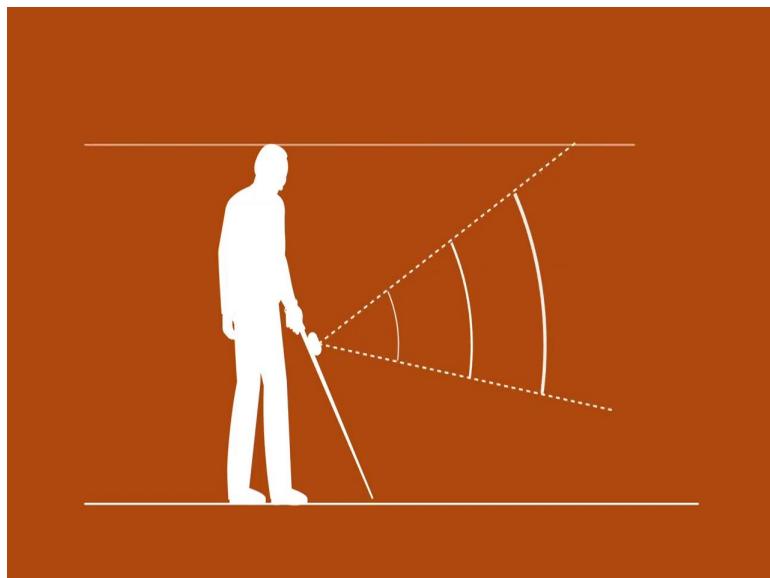


Figure 5 - Charging slot and the mode switch

And then this is the charging port where I can charge. Usually people sometimes hold like this, sometimes they hold and when you are holding your angle is changing, so you should be able to adjust your sensor to a different angular position.

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The sensor should ideally be put in such that that ultrasonic ranging covers from knee to head. And there is also a methodology to set this particular angle, which is there, if you are standing at such a metre then this should be pointing to a, like basically, the chest of a person and there is a methodology which you will also find in the manual.

Very simple in terms of technology, ultrasonic ranging is there for many decades now. The challenge is not just with the technology. Technology is one aspect where you need to optimise but also you need to work with the design and the features etcetera.

What happens is there are International Standards for objects which are vibrating where the vibration is felt either to hand or to body, and what is the extent of vibration which is permissible. So, when you design such a product you actually go and do this testing. For example, there are some products where your whole body vibrates.

Like for example, a bus. A driver is sitting in a bus, for a certain hour the whole body is vibrating. But then it says what is the vibration intensity? Which is generally measured in terms of acceleration. If my acceleration levels are this, then you are allowed to have 4 hours. If acceleration exceeds then you can only have 2 hours. If acceleration even further, you can only tolerate 1 hour. So these standards have been made. So when we put a vibrator and do, before we launch a product we need to do these testing and see that this is safe for this thing.

If I do not do, you are right. Then, if somebody the vibrations are really, this thing. Then you will have a repetitive stress injury. After sometime your palm will become numb, which is a serious medical condition. So those regulations, the risk which is caused by the product has to be mitigated before you do that. So, that is the regulation part. Suppose if I want to launch this in one of the countries, will they permit me to do so or will they check whether there is any risk this product is going to offer.

So what we generally do is we apply for certain regulatory standards. Like one of the regulatory standards, which is commonly used is CE (European Conformity) marking. You may have seen, correct? Most of you may have seen the CE marking which is there. So, this is a CE marked product. The moment it is a CE marked product, in 90 countries I do not have to take any permission to go and, let say, launch this particular product. The problem only comes in case if I am infringing any intellectual property.

Somebody has, let say, a patent or a design registration and if I am mitigating, only in those situations come. If I have freedom to operate, then as long as I have taken care of the regulation.

So, in the US if you want to use this, this should be approved by the FDA (Food and Drug Administration). And FDA regulations are very, very strict. People do not even try making products because it is very difficult to get an FDA. So this is an FDA approved product. So, I can go and sell, there is no problem.

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So, this is right now (at a) price of 3500 rupees. So the 3500 rupees, you get the white cane, you get the smart cane, you get the charger, you get an audio manual, you get a Braille manual and 2 hours of training.

Same thing, when you put your specifications, you need to say what is the temperature, humidity and other aspects which you do. Somebody says, like for example, is this waterproof? Correct? So even that, there are many levels, for example, this is a Splash proof.

What do I mean by a Splash proof is that suppose the, if this gets wet. Some of the water goes inside. It may stop working, but once it dries up it starts work. So somebody, when we said, this is waterproof and splash proof, one of the users went and put it in a bucket of water, just to try. And luckily after drying it started working. So that shows, ‘Can I use this when there is rain?’ Answer is many people do not use it when there is rain.

There are 2 reasons. One is that there is also a splash proof requirement which is one, because your electronics etcetera become the problem. The second thing which people say is even the water

droplets are treated as the obstacle. So it is beeping, you do not know whether the beep is because of the water droplets, or is it because of the real obstacles. So those regulations become very important. Like for example, is this material good for skin?

Is this material biocompatible? You need to tell that when you go for regulation. So biocompatibility also has a dozen levels. If the material goes inside your body. It is a very serious biocompatibility required. If it is only touch, you have less of a biocompatibility required. So biocompatibility testing is also done and there are different levels to do it. So, getting all those technical tests done to get this regulation itself costs about 50 lakh rupees. Just the tests and regulation and getting FDA, CE approvals. So that is the money which goes into also building a product.

And the important thing is if I can say that I am not doing all of them. I primarily want to sell it in India. I can probably reduce the cost, but I am giving you an inferior product, that people do not accept. Usually if you say that an affordable product which is less quality, usually that does not work and because the aspirational aspects are very, very important. People do not want to compromise anything. It is like saying here is a poor man's product.

Go ahead. So what happens is, say, you are very right, how is this regulated, technologically, is, in fact, in some of the cases when the risk is less, you can do a self certification, what you are saying is. But in case, suppose let us say, because of that risk happened to the users then you are liable. Suppose if I have a, if somebody else does the test, a regulating body and then they say you are safe, then you are much better off. Then you say that we did not do the testing, testing was done by the Laboratory which approved the safety norms of that, so I am not liable.

When we were doing this research to design, when we shadow a large number of users, we came to know that most of them go to the nearest social organisation or an NGO to show such products because there is no other serious marketing channel which is available.

And it is not only this concern, last month WHO was debating what should be the marketing channels for this, in Geneva, when we had a meeting. Because it is the same situation worldwide, not only in India.

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Self learning manual

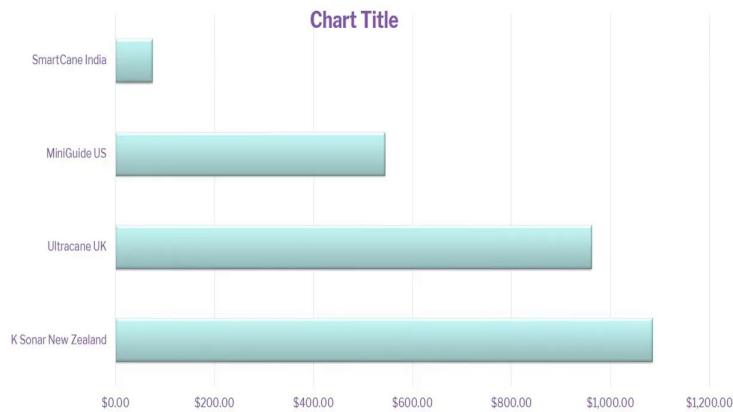
And also you have to do a manual in multilingual. Very interesting thing is, one of the persons said, 'What is this ultrasonic ranging? I do not understand'. How do you explain to a blind person that ultrasonic ranging is a cone which probably diverges kind of thing.

Then we have to make diagrams and then we realise in India, making diagrams for the blind is still not a mature technology. So, we have to come up with a methodology to prepare these embossed figures where you can actually touch and feel the ultrasonic ranging etcetera.

We found that this is a gap, now we have a complete startup, which does only these books for NCERT (National Council of Educational Research and Training) making maths and science books accessible to the blind.

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## Affordability and Quality



And this is the issue which is there with some of the products. So where do you position it is very, very important. These were there in the market but not within the reach. The question is even that is a little, many people feel, how is that we are able to go to that small, is a very important aspect. What happens with technology such as this is that the user does not have a buying power. All the countries like the US and UK, what do they do, they give every visually challenged person certain amounts of money or subsidy to buy these products every year.

Like in one of the country's, every blind person gets a \$1,000 coupon. Every year you get \$1,000. Out of these thousand Dollars, you can buy products from the market and the government will pay for a thousand. Anything above thousand dollars, you have to pay yourself. Now in India we still have those aspects but not for products such as this. So, if you put it in a market and say this is going to cost 20,000 rupees, it will not sell. Or it may sell but the numbers or volume would be so low that you cannot make a profit out of this.

What was done is we went to a charitable organisation which is called Wellcome Trust. And this organisation said, 'We will take care of all the development cost of this product, like making moulds, setting up manufacturing, all the regulation calls, getting CE marking, getting FDA approval'. It's going to cost about 3 crores of rupees or 4 crores and they said, 'We will give you that money, but in view of this you have to price it low'. So we went to a manufacturer, if the manufacturer would have taken up and made it, it would have been 20,000 rupees.

But since all his development costs were met by another organisation, we negotiated and said they should be priced at 3,500 rupees. If you do not do that then this person probably may not even take it up, this product would have never happened. So the charitable organisation is happy because the whole idea is to reach out to such people and do the charity, and the company is also making profit even with 3500 rupees. That means there are certain products which need very different business models, and very different ways to reach out to people, they are not market driven.

It is not like a mobile phone, if I suddenly have some wonderful feature a million people or 10 million people would buy. That does not happen with such products. And that is assistive technologies are particularly ramping. What the government does is they sometimes buy wheelchairs and white cane and give free of cost to the users. That Indian government also does, but they are able to reach out to a very small populations, but not to a large population still.

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And though this product was designed for obstacle detection and negotiating the pass, but people came and told very different uses for which the product is not defined or designed for.

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Like one the person came and said, ‘This actually helped me to follow a queue’. We did not know what the person was saying. He says, ‘Every time I keep my cane, I know how far the person in front of me is. If the person is moved a little, then my vibratory pattern has changed and I take one more step to know that the queue is moving kind of a thing’. This we never even thought of this as one of the specifications when it was given.

Most of the young girls are very happy, young women are very happy. They say, 'Before this even with the white cane we were able to be mobile, but there used to be very, many unwanted collisions with the people'. And particularly women did not want that. They say, 'With this we are now able to avoid unwanted collision with other people', which is another use case. So, sometimes you design for something and people come up and say very interesting stories for which it was not designed.

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## Scaling and reaching people

- Product release in various cities
- Referrals
- Channel Partners
- ADIP Scheme

So since you mentioned that how we actually reached out, so one is that we went to, we did the product release in multiple cities to know that such product is now existing. And referral is still very important in this community. The moment they come to know that there is a wonderful product, they have their own communication system and it spreads very well unlike an advertisement etcetera. So, referrals helped us a lot. We also had a channel partner.

We have 50 organisations in India which are basically working for, these are people, these are organisations working for the visually blind. They take the orders, and then the industry which is actually manufacturing in Chennai, it's called Phoenix Medical System, which has been given this particular licence to manufacture this product. They ship out to these people and these 50 organisations also provide that 2 hour training, and then give the product to the people.

And there is a scheme of the Government of India which is called ADIP. If your product is less than a certain amount, then the government can also buy it and they can give it to people in a lot of camps etc. A lot of our sales have also happened where the government has bought the product and given it to people too. And it is important to know what that amount is. Suddenly one of the products, very recently launched, they priced it as 20,000 rupees and the Government said 20,000 rupees is too high compared to the 12,000 limit we have and hence the entire Government market is now closed. So even to know that these things exist when I am designing a product is an important aspect.

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## Scaling and reaching people

- E-Commerce
- Marketing channels specific to AT
- Rehabilitation centers in various hospitals
- Blind Associations for Various Countries

And we have E-Commerce but it is not, the numbers are very, very small. We also did small innovations there. We negotiated with the E-commerce website, you put two options for the people: Either buy or you can also give users to donate. Suppose if somebody donates 3,500 rupees, one person gets it free also. So, few of them also happened through donations because sometimes donations do happen in this space.

And then there are some marketing channels which are specific to AT (Assistive Technologies). There is one in Bombay and one in Delhi, 2 organisations. One is called BarrierBreak in Bombay and Saksham in Delhi. They sell only assistive technology products. We have products with Aravind Eye Care, L.V. Prasad which is a very big hospital. What they do is when in the ophthalmology department you try to restore, let's say, vision of a person through surgery. In case

the surgery is not successful, then the hospitals do a rehabilitation aspect. So in that part of rehabilitation, they also suggest SmartCane as a tool for probably living with blindness.

So you also need to go to that and there are few blind associations in countries like Canada, Australia, US. We work with those aspects.

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Training

And then a lot of training. You need to take care of the training required for children, elderly. One of the first lessons in innovation, Who are your early adopters of your solution? If you start with people who are not very excited about your product. It may even have a failure. You go to a particular community, like, elderly people have a lot of inertia to accept any new technology. So, we went to elderly people almost towards the end. And the initial population which we targeted was 15 to 35, and they were our early adopters. And that is also an important decision.

**(Video Start Time: 36:36)**

**(Video End Time: 37:30)**

Piyush is a PhD student who is working on mobility for the visually challenged and he was a part of training a large number of users. And then there is another category of people who train users in mobility. These are called Orientation and Mobility Experts. So he trained a lot of orientation and mobility experts and then those people went and, like, we now have launched in multiple countries, 20 countries. So how do you train the people there? We train their (the country's) orientation and mobility experts, then they train the people in these things.

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And then you have to do a lot of testing with various obstacle courses, etc. This is also one of the requirements before you actually launch a product.

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And as I said a lot of technology related testing which I mention biocompatibility, ElectroMagnetic interference, EM interference is a very big thing, what about, like, if there are two people using the SmartCane come face to face. Or you have another ultrasonic sensor which is coming from, let us say, a car is backing off?

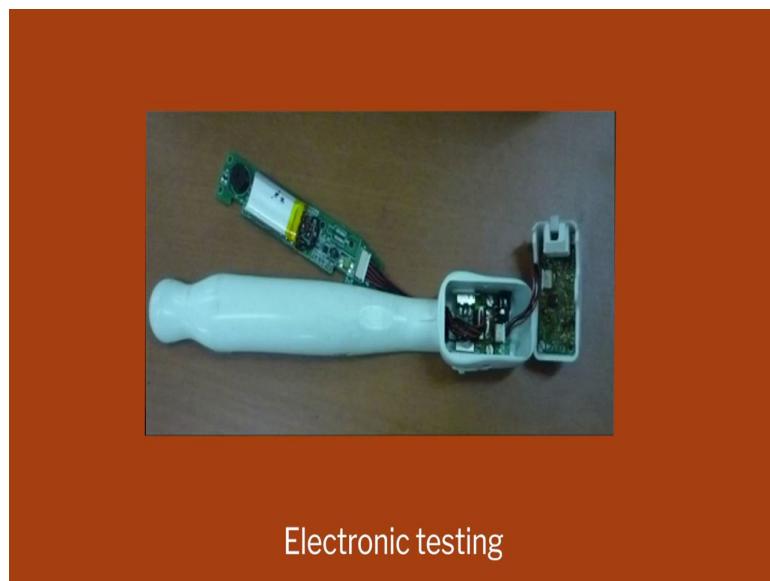
They also use ultrasonic sensing, what about the interference with those products? You need to test that and see that you still do not have a risk. And here you need to do a lot of technology optimization.

So another thing is just to use the technology, but to use optimum technology there is a lot of research in engineering also has to be done.

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And a lot of compacting in terms of electronics, because you need electronics for multiple things. One is for sensing and another for vibrator.

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All those aspects have to be incorporated, and all of them should be within the handle. They should all actually go inside this small body and you have to do multiple technology related iterations to compact them and fit into this small.

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Product release to people

And then we did a product release to people. The Prime Minister himself bought 3,000 units because he distributed them in his constituency, Varanasi. MP's also have a fund and a certain percentage can be used for distribution of that.

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Product release to people

We had a Mumbai release by Vidya Balan (Indian actress from the Bollywood industry) in this city. (We had) different camps which we had initially for people to know that such products exist, one needs to reach out in large numbers.

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Dissemination in India

There are also a lot of similar training programs. You can see Piyush probably training all the people in various countries. And these all Orientation and Mobility Experts who will now train their people in the SmartCane. So, there is a request from 65 countries. We have launched only in 20. We still have to reach out to other countries. We have not done that.

And I think the product, one thing which people found out particularly, because from the design perspective people think that this product is very simple to use. In spite of all the things the product finally comes out to be very simple. That is why this also now has more number of awards, (for) both the students who worked and others.

For example there is a TR35 which many of you may know which MIT review gives, technology, that is 35 innovations below 35 year every year get it.

Then this is also there in many international design museums like Smithsonian, then it is also there in Bill and Melinda Gates Foundations Discovery Centre. Also places like Scotland national Museum you can see the; and we did not go to anybody to this thing. I do not know how they came to know but this has also been accepted as a product for those exhibitions because of its impact.

This is excellent again, you have taken a lot of effort. I think the way you captured the total journey from the design is fabulous.