Advanced Topics in Science and Technology of Concrete
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Hello everyone, and welcome to this lecture on construction supply chains as part of this SPARC program on construction and demolition wastes. My name is Professor Ashwin Mahalingam. I am a professor in the Department of Civil Engineering at IIT Madras, and I specialize in an area called construction management, construction project management. Now, some of you might be wondering why are we in this SPARC program, listening to a lecture on supply chains? Isn't supply chain something that is really the purview of management, something that you would see in an MBA program? Why are we looking at this in the context of C&D waste? Okay, that's a good question. The answer lies in the fact that there are two parts to, you know, any project that we like to build. There is, of course, a technical part, right, which allows you to innovate, to experiment, to design technological solutions that will be of benefit to your stakeholders or whoever it is you're trying to add value to.

But at the same time, design stays on paper until it can be executed, right, and execution is where you actually realize the project. And execution is part technical and part managerial. So it's very important to look at some of the management aspects of the technological ideas that you're discussing to ensure that there is a combination or a fit between the technology and the management and that you can actually take your ideas towards practical realization. Okay.

So in the world of construction, in the world of construction projects, in the world of construction and demolition waste, a very, very important concept is that of a supply chain, right. And because the supply chain essentially is the chain that supplies whatever material it is, crushed aggregate, recycled debris, whatever it is, to the construction site. And if you have a well-functioning supply chain, then it turns out that a lot of the execution becomes easy. So to give you an example today, we have reasonably well-functioning supply chains for cement, right, as a result of which there is rarely any difficulty in getting bags of cement to your site, okay. Whereas for other materials, the supply chains do not function as effectively or efficiently.

And therefore, it is very important to understand what you can do to augment or improve these supply chains. So all put together, a basic understanding of construction supply chains is important, I believe, for every civil engineer, anyone getting into construction, but also particularly for people who are looking at construction and demolition waste, because this is a relatively new idea in terms of recycling C&D waste. And it's important to understand what is the supply chain? You know, what are some of the challenges in supply chain management? What does a construction and demolition waste supply chain look like? Where are some of the challenges with the supply chains? What could be their impacts? What could you do about it to build a more robust supply chain, things like this, right. So these questions that I've just stated, along with maybe a few other topics, are what I'm going to cover in the next, I don't know, 45 minutes or so. Okay.

So let us start with something very simple, right? Let us start with maybe defining what a supply chain is, right, so that we are all on the same page. I'm sure when somebody uses the term supply chain or value chain, everyone has a componential idea of what they mean, it's the chain through which, you know, something happens, materials pass through, etc. But let's sort of start looking at a slightly more formal definition of what a supply chain is. Okay. So, I have one definition that I picked up from a paper that, actually from an article, you know, I think, which is a very good, you know, description of a supply chain.

So supply chain, essentially, let me read it out, and then I'll break it down and explain it a little bit. It's a network of organizations that are involved through upstream and downstream linkages in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer. Okay. So, what's happening here, right? First of all, construction supply chains are constituted by a network of organizations. And I think this is very, very important to understand.

And I'll show you a few examples of supply chains in just a second. When you try to create value, right, and you create value by, for instance, building a building that somebody can use as an office space as a home, as a recreation centre, whatever, In order to build that facility, there are a number of network of organizations that are involved, right, all of which contribute in some ways, either in the form of products or services and so on, to create this value, right, so different processes and activities. Okay. So, there are three main concepts

here. There are a network of organizations that are linked that are working together, right, Each of them performs certain activities and processes, and all of that lends to, you know, tends to add value to the client, right, and that entire process is what we call a supply chain.

Okay, maybe a slightly simpler definition, right, of a supply chain is that you have, like we said earlier, a network of organizations, this is another definition that I found again in a, in a textbook on this subject. It consists of two or more legally separated organizations being linked by material information and financial flows, right. So we talked about an organizational network in the previous slide. Essentially, now we are saying the same thing, an organizational network has, by definition, at least two or more organizations that are in some way linked, right. So we said they perform activities and processes to create value.

Now, the activities and processes are not performed independently, they are not in parallel, they are linked to each other. So think about it as a chain of organizations, one organization picks up something from the previous organization, does some activity on it, sends it to the next organization and so on. So you have, so you have a chain of organizations, right, each of them picking up activities, organization ABC, each of them picking up activities from a previous organization, doing some kind of activity process on it, transferring it to the next organization. And what is it that they are transferring? It could actually be materials, right, something tangible, and we will see examples of that going forward. It could be information, right, that they are, for instance, a drawing or a design is being sent from one entity to another, or it could be money, right, financial flows, right.

But this essentially is a supply chain, okay. It is a network of organizations, at least two or more that are all linked, not independent, that transfer material, information, finances between them to arrive at an end product, it could be a house, it could be a block, right, that creates value for an end user, right. It could be a dam, it could be a road, it could even be a beam, a column, some entity that creates value to someone, okay. So that essentially is what a supply chain is when defined theoretically, okay. We see supply chains everywhere, right, everywhere around us, we see supply chains, right.

The human society is now complex enough that, see, maybe in prehistoric times, humans were completely self-sufficient, right. You had, you know, you grew your own food, you, you know, maybe hunted, you know, or sort of went in and tried to sort of farm yourself, you

perhaps prepared your own clothes, all of those kinds of things, right. Every community or every household was doing things independently. Today we do not, each of us have a specialist function, we are a doctor, a lawyer, an engineer, a designer, an architect, whatever, and everything we do arrives at us, arrives, you know, arrives to us, I suppose, through a supply chain, okay. So to give you an example, okay, this is sort of a generic example of a supply chain, right.

So all of these, so you have a bunch of people supplying some kind of raw material, right, maybe they are in the mining industry, right, and they mine, I do not know, it could be limestone, it could be granite, right, whatever it is, okay. But these are what we call raw materials, okay, that suppliers supply, then those raw materials go to some kind of a, you know, typically a manufacturing outfit, right, where they take some of those raw materials and convert them into a some kind of a finished product. So again, if you want to take the example of granite, right, somebody has a mine where they have a vein from which they are able to extract the raw granite, but then somebody actually processes it and polishes it and so on and then gives you these sort of slabs or tiles that you can put for instance, onto your kitchen or whatever it is, okay. Sometimes it is one piece, sometimes they produce multiple pieces that are assembled, you know, and finally are stored somewhere, right, in some kind of factory. So there is a manufacturing setup here, right, so there is a raw material extraction, there is an entire processing setup to get it to a final shape, but that is not enough, because from the final shape it has to get to you, right, which means typically again to take the example of granite and household uses, you probably have some shop or store, right, it stores all kinds of tiles, finishes, you know, plumbing systems, etc, right.

So you have all of these shops and stores who contribute the third layer, which is distribution, okay. You might have a number of distributors, okay, and from those distributors, you have your ultimate consumers, right, and these ultimate consumers actually come, these are people like you and me, who come and actually buy from the distributors. And then there could be again several sub distributors, there could be wholesalers, there could be retailers, so there could be a number of people within the distribution system, just like there could be a number of people within the manufacturing system. So again, like we said manufacturing, somebody could do the polishing, someone else could do the assembly, and so on, just like that in distribution, you might have a wholesaler who gets a lot of material from the manufacturers and then sends it to smaller retailers and these are typically the shops that you see in your

neighbourhood which sell interior fittings from which you directly go and buy, right. So this is essentially what a typical supply chain would look like.

There is a raw material component, there is a manufacturing component, there is a distribution component and finally, you have hopefully satisfied consumers, right, who buy from a variety of distributors, right. So this is generally what a supply chain would look like. Let me give you a few examples of this in practice, we have just talked about one, but they are there everywhere, right. So for instance, take agriculture as a sector, right. So agriculture, just the raw material supplier there is the farmer, right.

So the farmer grows, you know, the tomatoes or whatever it is, right. In some cases, the farmer might, you know, send their produce directly to a distributor or directly to a retailer. Sometimes you have you heard these things called farm to kitchen, right. So you have you go to some of these shops sometimes and you find that farmers come directly from the farm with their produce and they sell it. But in many cases, the farmers will actually then sell it to some kind of a manufacturing agency that might do something with the tomatoes, for instance, make it into tomato ketchup or whatever it is and then sell it to you or they might actually take all the tomatoes, put them in cold storage and then transport them along long distances so that they can reach remote markets and things like that, okay.

And then they again will give it to a wholesaler or a distributor, right, who will have a large number of these are your big vegetable markets that you see, right. For instance, if you are from Chennai, there is a place called Coimbatore, right, which has a huge wholesale vegetable markets where farmers from all over or food processors from all over come in and provide the vegetables. But then people from individual shops go to those wholesale markets, buy some vegetables, bring them to their shops, buy the tomatoes and sell them. So you do not have to go all the way to Coimbatore, you can go to your neighbourhood shop and buy what is hopefully a good quality tomato, right and that is your consumer, okay. So this for instance is an example of a farm supply chain.

As you can see there are there is no one single variant, there could be multiple variants, you can have farmers directly working with retailers or farmers going through industry processors, wholesalers, etc. And by the way, there are also this is not even a complete supply chain, because the farmer also needs things in order to farm, they need seeds, they need

fertilizers, they need maybe water electricity. So when you look at the supply chain, it could be larger and larger, right. A seed supplier supplies to the farmer, the farmer then plants those seeds, right, grows the produce, then, you know, sells it to the to the industrial processor, who then takes it sells it to the wholesaler, the distributor and so on, right. So these are very large and complex supply chains, right.

So even something like the shirt that I'm wearing or the shirt that you may be wearing, you know, if it's for instance, a cotton shirt, right came in because somebody provided seeds to a farmer, the farmer then grew the cotton, the cotton was then bought by some industry that processed it, you know, into a shirt and that could have taken several stages. From there, the shirts were sent to some kind of a retailer, and then you or I then go to that retailer and pay money and buy the shirt, right. So there's an entire supply chain, right, that leads to the arrival of this shirt, you know, in my possession or in your possession, right. So this entire process where every stage there is an organization, organizations are linked, each of them is passing on some information, some material, some money from one to the other, that essentially is what we call a supply chain, right. And so here in this previous picture, you can see that the, you know, material flow goes from left to right.

On the other hand, the information flow goes from right to left, the consumer is the one who is saying, I would like collared shirts that are blue, and then the supply chain works backwards. So the information gets passed through. So that, you know, then when the cotton is grown, and it's dyed and all of that, and the indigo is brought in, right, you get a blue shirt. So information sometimes flows from right to left, material flow from left to right.

Okay. Again, I know, you can look at manufacturing as another industry, right. And again, we have very, very similar, you know, supply chains, you have again, raw materials, these are the fellows who are like I said, mining the granite, right, so they extract the raw materials and then sell them to a supplier. The supplier then takes it to a manufacturing entity and says, look, you know, can you take these raw materials and convert them into some, some kind of a process into some kind of a finished material, like I said, the granite countertop or whatever it is, then there is, you know, something that we will discuss, I have not mentioned it, but I think it's quite obvious, there is a distribution function, right? There are trucks, right that you see which load all of these and take them to multiple wholesalers or retailers from where you buy, right. And this trucking operation that's right here is very, very important, right? Because

this is a time consuming step. I mean, I can take it to a factory and typically factories might be relatively close by where the raw materials available, but the demand could be anywhere, right? So I have a factory that produces these granite countertops, demand could be in the north of India, east of India, southwest, right? So I need to distribute, I need to have a logistics function that distributes what I'm, you know, what I'm developing all over the country.

So it's accessible to consumers from everywhere, right? So this again is a very, very important aspect of supply chains, logistics and distribution. Okay, coming closer to home, because we are in the construction industry, right? Obviously construction also has supply chains, right? Everything that you see right in front of you came from somewhere. So you have created a house primarily based on reinforced concrete, right? So you've got reinforced concrete beams and columns and so on, right? Now, in order for you to pour the concrete, you needed bags of cement, right? That probably came, let's assume that you're mixing at site and not sort of purchasing, you know, ready mix concrete. So you actually had to purchase bags of cement. Now where do those bags of cement come from, right? Somebody somewhere was mining limestone, right? And they were then sending it to some production facility, which was then taking the limestone, you know, you know what the constituents of cement are putting it together, going through an industrial process, manufacturing cement, putting it into bags, those bags were then being shipped to a variety of wholesalers and retailers, right? So retailers anywhere you are in India, there's probably a shop close by selling Ramco cement or Chettinand cement or whatever it is, right? And then you go in and buy from that shop, bring it to your site, okay? And even if you were an RMC supplier, you know, you're doing something very similar, you're still mixing the concrete based on the design mix and proportions and so on.

But there is a supply chain to the point where the cement arrives and then you do something with the cement, create concrete, right? And then concrete is then sent to the site and is poured to create a column, which is what really adds value or a beam or a slab or whatever it is, right? Similarly, the reinforcing steel, right, is very, very similar. Somebody is extracting iron ore from somewhere, there is an extraction mining component, then that iron ore is processed, etc., you know, converted into steel, right? Then those steel, you know, steel bars are then cut to various dimensions sold to you. Again, they come to sort of retail outlets, right? You go buy from there, you bring them to your site, you do some processing your site

in terms of cutting, bending, etc., right? Put it into the slab or the beam or the column that you're trying to cast or develop. And then you finally have something that adds value, right? So in construction, we have, take anything, right? You have a building which has aluminium cladding or glazing, right? Where does that glazing come from? I mean, Saint-Gobain may have supplied that glass to you, but Saint-Gobain has an internal supply chain where again, there are raw materials that are sourced, there is a process, right? And then you go to a distributor who finally gives you the product that you then install on your facade or your window or whatever it is, right? So, again, if you see the R's here, these are all raw material suppliers, right? Whether it is iron ore, whether it is limestone, whatever it is people are supplying, there is some kind of a transportation function here, which then takes that to somebody who manufactures components. Again, this could be, there are several steps involved, but essentially, there is a manufacturing stage which leads to, you know, some storage facility, storing a lot of whether it is cladding, whether it is glazing, whether it is bags of cement or whatever it is or bars of steel. And then there is again, you know, a transportation function that takes it to your construction site, right? Where then you finally install it and again, there may be things that are done in the construction site. And there is something called inventory, right? Which is stuff that you store on a, so you get something, you store it again temporarily on your construction site and then finally install. So this again is an example that I took from the web on construction supply chains, okay.

So everywhere we look, there are supply chains and if you want to get a building built, right, it is very important to understand the supply chains that stand behind that, that building because if you do not understand the supply chain, then that particular material or component will not come to you. And if it does not come to you, despite how well you have designed it, you cannot erect it on time within budget, to good standards of quality, etc. So it is very, very important, most companies do this, most companies keep a watch on their supply chains and understand what supply chain is functioning well, which supply chain is broken, things like that, okay. Okay, so now we have understood what supply chains basically are, okay. So let us now look at what are some of the challenges in supply chain management.

I think we all understand now that having a good supply chain is very critical, because then whatever material it is gets to your site on time, okay. So what are some of the challenges to creating a good supply chain, okay. There are four or five key challenges that I want to talk to you about. The first one is something that we, the first challenge that I want to talk to you

about, talk to you about is a challenge with regards to supply and demand. And in supply chain parlance, this is called the bullwhip effect.

So I am going to see if I can play a video on the bullwhip effect. It is a very short video, so let us watch the video and then I will explain what the bullwhip effect is about. What supply chain term is named for its resemblance to the cracking of a whip? That is the bullwhip effect. The bullwhip effect happens when retailers make inaccurate demand predictions, and the gap between supply and demand gets bigger and bigger up the supply chain.

Here is a well-known example from history. When green Volvos sold really well mid-year, Volvo production made the logical assumption that green was the new black. In response, it churned out more green cars. But at the end of the year, Volvo had excess inventory. Why? The previous demand was due to dealership bargains meant to clear out an overstock of green cars. And in the end, the company faced the very problem it was trying to solve.

Retailers make a guess about future customer behavior based on current behavior, often ordering a bit extra as a safety net. Wholesalers respond to retailers, often giving themselves a safety net by ordering a bit more, and so on, resulting in a larger and larger effect up the supply chain. By the time things get to raw material suppliers, the overordering, or underordering as the case may be, has increased exponentially, resulting in inefficiencies, loss of profits, and so on. The bullwhip effect can work the other way, too, where one or more supply chain partners don't anticipate how popular a product will be, and in turn end up with shortages. If you've ever run from store to store during the holiday season looking for some must-have gift or toy, you know this one all too well.

Okay, so again, just very quickly to recap what that was about. In supply chains, if you have constant demand, it's easy for the supply chain to work. So let's say you need every day, we need 100 bags of cement, right? Then it's very easy to produce 100 bags of cement every day, it's a constant amount, you know exactly how much limestone you need, you know exactly how long it takes to process, you know exactly how many trucks it needs, and so on. So when you have uniform demand, right, it becomes very easy to have fully functional supply chains. But what if you don't have uniform demand, right? What if you have one day you need 100 bags of cement, the next day you need 50 bags of cement, the third day you need 200 bags of cement, right? This creates a little bit of confusion because people down the supply chain

don't know what to do, right? So should I manufacture 50 bags of cement today? Should I manufacture 100? Should I manufacture 200? If I manufacture too many, and it doesn't get sold, then unfortunately, I have spent all that money in manufacturing and all those cement bags are just sitting in my, you know, in my warehouse.

On the other hand, if I manufacture too little, right, and I don't have enough, then you might go and then start buying cement from someone else, right? And as a result of which you may never come back to me because you'll always think, oh, I went to this person, he didn't have enough cement available, okay? So this is a very, very important problem in supply chains. Very often if you if you ever take a course in supply chain management, you will come across a term called economic order quantity, which is what is the amount that you should order from people, say upstream of you, right? In order to ensure that you don't run into too much of a shortage and it also in order to ensure that you don't have too much of a of an excess inventory sitting here, right? So there are some formulae, there are some analytics to do this. But what happens in practice is, let's say that, you know, you've been ordering a certain amount for a while, and you increase that order, right? By just a small amount, right? By just about 5%, the Khandero people say, okay, it's not 100, it's about 105, okay? What happens is, it takes a little bit of time for retailers to for the person with a distributor who's storing the bags of cement to understand that you want

105, okay? And by the time they understand they already have a little bit of a backlog. So they start stocking a little bit extra, right? So this might increase their demand by about 10%, okay? So the retailer increases the orders and the forecast. Now the distributor suddenly says, oh, something is happening, right? Because they don't see that you only need five bags more, right? They see that the distributor who's already late, right, has ordered 10 bags, okay? Because the distributor has to supply yesterday's demand and today's demand, so they've ordered 10 bags.

So the distributor says, oh, you know, maybe I need to manufacture or I need to somehow get more than five, I need to get about 10 or 15 bags. And they start ordering, you know, about 15 bags of cement, okay? And the manufacturer then sees this and again, there is a delay here. So for the distributor to have 15 bags of cement, they will have to order 30 because by the time that 30 comes, you know, then the pent up demand would have increased. So the manufacturer thinks of it and says, oh, there's a 30% increase in demand or a 20% increase in

demand and starts overproducing, okay? So you only wanted five bags, but because there is a supply chain, right, and each part it takes some time from getting from one part to the other, right? Each party looks at it and says, oh no, this person needs 10, this person needs 20, this person needs 30.

So it's like a bullwhip. If you've seen the whips that whip the bull, your arm just does a small motion right here, but the whip, right, has a huge amplitude, right? The whip with a small motion goes up and down, right? And that's why it's called the bullwhip effect. So what happens in supply chains is that small changes in demand tend to play havoc within the manufacturing of the supply chain. Suddenly people are overproducing and then at some point they realize that they cannot sell. So they completely underproduce, stop producing at which point there is a demand and they cannot supply.

So these kinds of vagaries tend to happen. In fact, sometimes in my class, I play a game called the beer game. And the beer game is very simple. There is a manufacturer of beer, there is a wholesaler, there is a retailer, there is a customer, okay? The customer orders beer, okay? And typically the customer orders four beers at a time, right? So for a while the supply chain works. Then once the customer goes from four to eight and remains at eight all the time, that's all.

The customer's demand doesn't really vary. They've done four bottles of beer and then they go to eight bottles of beer, right? Just one spike once in an entire game. But just that one spike, you can see destroying the supply chain, right? People overordering, undersupplying. So this is a very, very important aspect of supply chain management, managing this bullwhip effect, right? And we'll talk a little bit about how you might manage it. Second is, how do you manage again? When you're on a construction site and you want, let's get back to the topic of this session, construction and demolition waste. Somebody is going to give that construction and demolition waste to you, not the waste itself, but process it into aggregates and then give it to you that so that you can use it on site.

How do you ensure that you have a trusted supplier or suppliers, right? How do you ensure that these people will deliver things on time, that they will deliver on good quality, right? How do you ensure these kinds of things? Okay, and again, there are things that you'll have to think about, maybe you have more than one supplier, okay, that might help, all right? Or you

might enter into long term partnerships with suppliers. In other words, you almost integrate them into your organization, right? So that they understand what your requirements are, there's a little bit of give and take, right? And you're able to sort of come up with a trusted group of suppliers. But managing suppliers, right, is extremely critical. Strategies like diversification and partnership are strategies, right? If you think about the bullwhip effect, strategies for managing the bullwhip effect are, if you can have automation, digitalization and full visibility across the supply chain. So the moment there is a shift in demand, everybody straight up to the manufacturer understands where that demand is.

And if you can reduce the travel times, you almost have a just in time kind of system, okay? So these are two challenges. A third challenge in supply chain is yes, all is good, there is the demand is constant, vendors are good, but there is a huge processing function. So again, in the C&D waste world, you collect the construction and demolition waste, and then you have to actually process it. And sometimes if it takes a long time to process, to create aggregates out of the C&D waste, then the whole point may be lost because sites may not be able to benefit from the process C&D waste on time, right? So how do you bring about manufacturing efficiency? So this diagram that I am showing you is something called a value stream map, right? Which is a way in which you map the process, so you map okay, this is the supplier, this is the process, but then you also sort of look at what is the cycle time for each step? What is the cycle time for each step? You know, what is the uptime? What is the downtime, etc? How much time is it taking between steps? Right? What is the information is being how much, how much raw material is being stored at each stage and then you go through a process of optimizing, right? So that you try to manufacture in as lean a manner as possible, right? So third challenge is ensuring that the manufacturing processes within the supply chain are efficient. Then fourth, I talked about okay, you manufactured, you have got some bags of cement.

Now you have got to take and they are centralized in a factory. Now you have got to take them to wholesalers, you have got to take them to distributors, right? There is a very important term that you would have heard about called logistics management. How do I manage this? How many trucks do I need? Do I do only trucks or do I do a combination of rail and road or maybe freight, cargo, air, right? So how do I manage all of this? And this again is very, very important from a construction and demolition supply chain perspective. You have got a factory that is making aggregates. How do I now get this to the various

construction sites? Do I take all of these aggregates and set up a store somewhere in the center of the city? Do I take up several stores? Do I supply directly to site? If I supply directly to site, how do I do it? How many trucks do I have? Two sites require aggregates. Do I put both of that on one in one truck and go north of the city first and south of the city? How do I do the operations management of all of this, right? So logistics is a very, very important part of the whole supply chain and one, one big challenge that you will have to think about, okay.

And then of course in C and D supply chains this may not be as important but it is very important in all kinds of supply chain or in most supply chains. Once you have sold something to the customer, what happens post sales, okay? What happens if your material is defective, okay? Will it be returned? So how will it be returned? What will be the terms, etc? What happens if material is returned? And most importantly in construction and demolition waste, so you supply something, a building gets built but once the end of that building's life is attained, you want to start reusing that material again. So you need to start thinking of not just supplying the material to the building but also then when the building is demolished, bringing it back, right? And how is that going to work? How will you monitor when the building was being demolished? How will you bring it back? What trucks will you use? All of those kinds of things. So supply chain management is complex.

Supply chains do not just happen. You will have to manage supply and demand at the bullwhip effect. You will have to make sure you have reliable vendors and efficient manufacturing process and efficient logistics and distribution process and after you actually deliver the material, what happens to the circularity in bringing it back are all things that as a project manager, you will need to manage, okay. So these are some of the basics of supply chain management, okay.