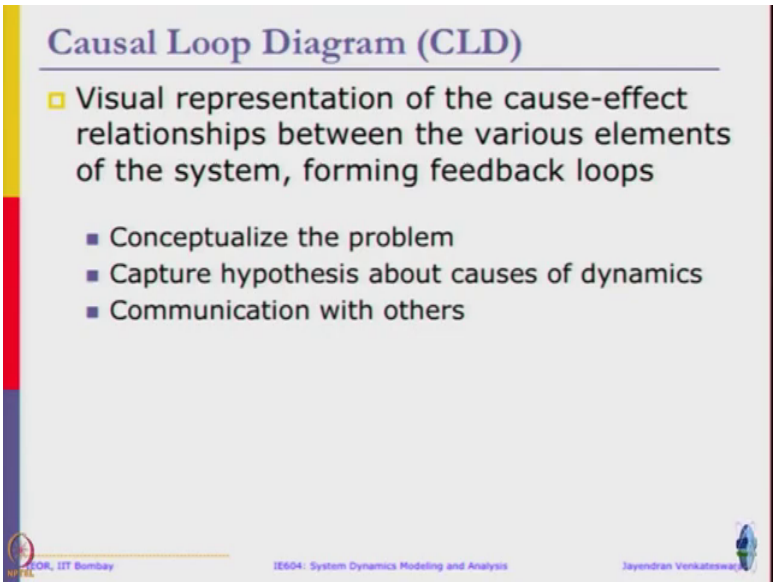
Introduction to System Dynamics Modeling
Prof. Jayendran Venkateswaran
Department of Industrial Engineering and Operations Research
Indian Institute of Technology, Bombay

Casual Loop Diagram Part – 1
Lecture – 2.1
Casual Loop Diagram (CLD)

Let us get started on today's class on Casual Loop Diagram. We introduced the very basic concepts on systems thinking and System Dynamics; and characterize that this course we are going to be looking at the dynamic behavior of systems, looking at casual loop modeling and then stock and flow diagrams to understand accumulations.

I am thinking endogenously; these were four concepts we discussed as basics for system dynamics modeling. Since the underlying theme will be to look at things that we had evolve over time that is a dynamic behavior, we will be starting with the one of the first pillars of that which is the causal loop modeling. So, let me introduce you to that. So, causal loop diagram.

(Refer Slide Time: 01:10)



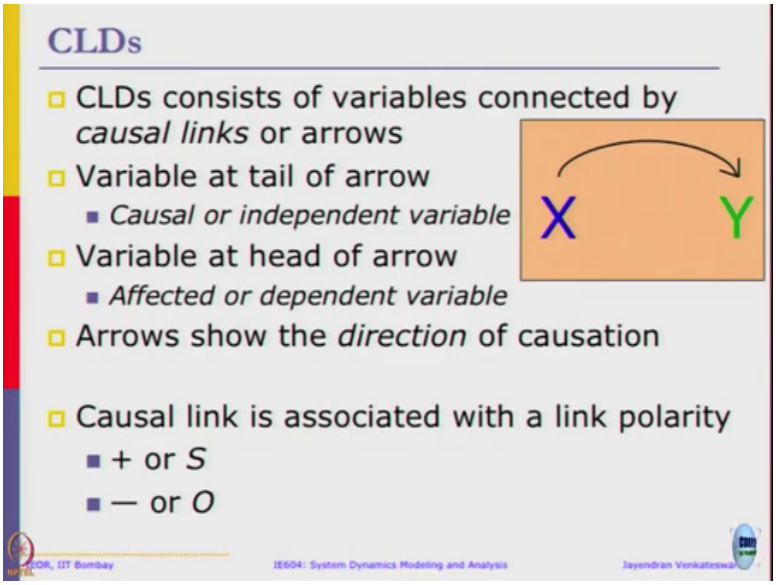
So, basic idea here is the causal loop diagram is nothing, but a visual representation of the cause and effect relationship between various elements of system forming feedback loops that is all chart is it on the board. The purpose of this CLD is three fold; one is to conceptualize the problem, understand what it is about and communicate with others that is the first and last point.

The key idea is to capture the hypothesis about the causes of dynamics, understand what are variable system; see how they are linked with each other and through that visual representation see how we can explain how the system is evolving over time. So, that is the entire idea of this developing this causal loop diagram.

In that sense this slightly different concept, because this on our first course we are looking at the actual modeling of a any system; how do you identify the variables, how do you identify

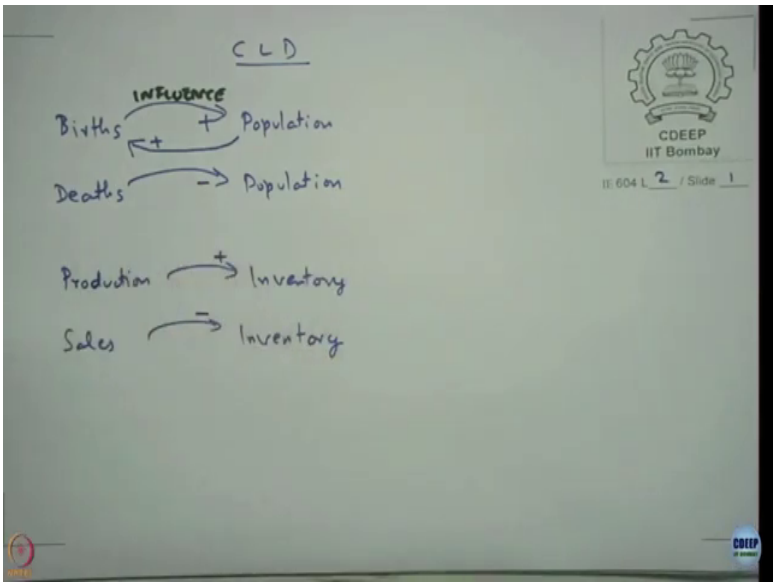
the links. And once you establish those relations, then we can later study how to come up with the equations underlying the system.

(Refer Slide Time: 02:23)



So, first is just to identify relationships between the various variables within the system. CLDs are Causal Loop Diagrams; CLDs in short nothing but consists of variables connected by causal links or arrows, it is not very difficult to visualize, we just have an x which is affecting y or x influences y as we read it. The variable at the end of the arrow are the x is independent variable and y is the dependent variable. There is nothing, it is kind of straight forward there and the arrows show the direction of causation. So, you can illustrate it is very simple examples.

(Refer Slide Time: 03:05)



So, for example, you can identify variables such as say births and population or deaths and population. Here we can say birth influences population, deaths also influences population, we could. So, how we want to read it as; births influence the population, deaths also influence the population here; but we can construct many such examples like production of x inventory, sales also affects the inventory.

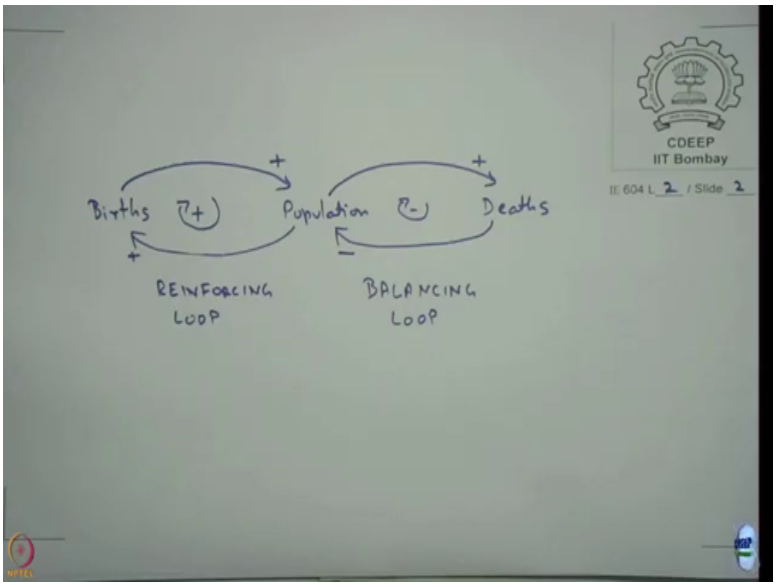
To elaborate on that causal link, we can associate it with the link polarity. We use a symbol plus or minus; plus indicates it is a strengthening and minus indicates it is a opposing or S can be for the same direction, O for the opposite direction. So, let me go back with that idea to the same examples; here what you want to do is we want to visually represent how the births affects the population, as more births happen the population increases. So, as more births happen population is also going to increase. So, it is in the same direction.

We indicate it by an symbol plus against the causal link; yeah where the plus here on the causal link. Again deaths, as more deaths happen the population falls down, as more deaths happen population falls down, right. So, as deaths increases, the population falls down. So, that we can indicate by a minus sign against the head of the arrow. So, this gives us an idea that as deaths increases, the population falls down or births increases, the population increases.

So, just see simple concepts we can establish a nice causal map of various problems that we can look at. So, we can go back to this example. Now, a small production happens, the inventory on hand should increase correct; so that we can indicate it by a plus, when a sales happen an inventory decreases. So, sales increases, my inventory is going to decrease. So, I am going to put a minus sign again sales and inventory. This is a very very simple examples on plus and minus.

So, we can as more population occurs more births occur yeah; we can do that, we can put in to indicate that we can close the loop by adding this population and birth and have a plus sign here. So, we can reconstruct, the similar thing will happen in deaths also, so we can extend this idea.

(Refer Slide Time: 06:56)

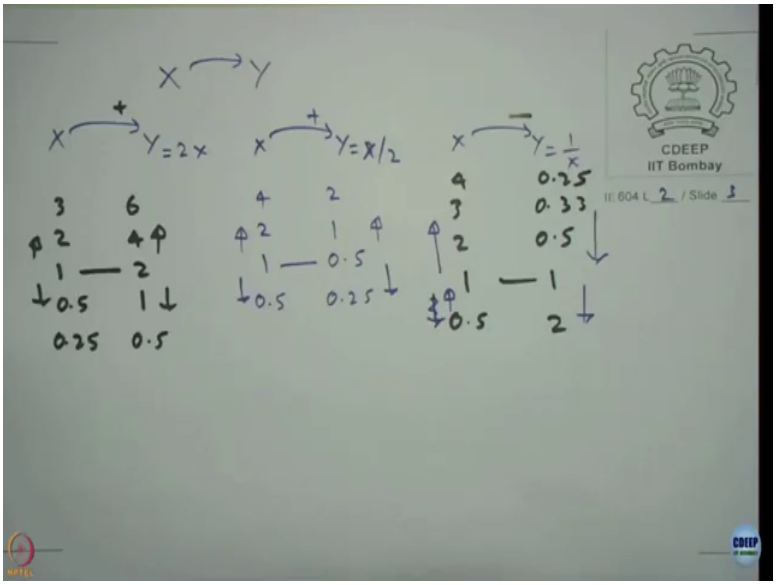


Simply here let us write it births, population, deaths; as more births happen the population increases, it is the same direction. Let us use a symbol plus, as more population is there more births will also occur. So, direction is still the same. So, we will put a plus; as more population is there, we can expect more deaths to be there right. Let us share the number of deaths; this population increases the deaths can increase.

There is more deaths are there, the population is supposed to come down; more people die or more what are the population of whatever community or species you are looking at the population has to come down, as more births happen population comes down. We can indicate it by a minus sign right here. So, what here just drawn is a, it is not just the causal link; we have even moved ahead and drawn a causal loop. As you can see, we did a drawn our first simple feedback causal loop here and there is loop here.

If you look at the loop on the left side here; as births increase population going to increase; as population increases births further increases etcetera, it keeps on going to increase, in fact it will increase exponentially. So, this entire loop is what we call as a reinforcing loop. Now, if you look at population and deaths; as population increases more deaths happen and more deaths happen population decreases, at some point it is it can reach some sort of a equilibrium can be expected there. So, this loop is called as a balancing loop.

(Refer Slide Time: 09:52)



There are two types of loops; one which we can expect an ever increasing behavior influence of births on the population and as population increases deaths can increase, which kind of limits to growth of the population. So, that loop is called as the balancing loop. Examples on to work; suppose we have two variables let us say x affecting y, we can have various kind of relationships just to put a numerical sense of things because you are used to that. Suppose we

take the first case, let us say x of x y and the relation you give as x is equal to say y equal to 2 times x, right very simple example.

Suppose in this case, because the value of x is 1, y is 2; as x increases, as x increases here from 1 to 2, y is also going to increase to 4, as this goes 3, it is going to 6 etcetera. But as y comes down, see x comes down; say from 1 it comes to 0.5 this is going to come to till 1 right. As this comes to a 0.25 this comes to 0.5 etcetera, still that is a decrease. So, it is you can take this as a reference point.

So, initially started with the x as 1 and y take the value of 2, so as x increased from 1 to 2 and beyond y is also continues to increase from it is reference point of 2. If x falls below from 1, y also falls below 2, so the direction of movement is the same. So, direction of movement is the same; that is the case we indicate this link with the plus sign. Let us take a y and x as different colors, but it is let us say just do x by 2. Again let us take the same reference point, so when x is 1, y is going to be 0.5. So, x increases to 2, y will take a value 1; x is 4, y is going to value take value 2.

So, as x increases, y continues to increase again this is a reference point. Let us see as x falls down, so instead of 1, it becomes 0.5. So, y will be 0.25, right. So, as x falls, y also continues to fall. So, they just, it is still multiplying the constant right; we have multiplying between a multiplying 0.5. Say multiplying the constant, the direction of movement is the same. So, you continue to represent it by a plus sign, say x influence y with positive direction. So, these kind of thing can lead to some tricky behaviors that is why I explained it.

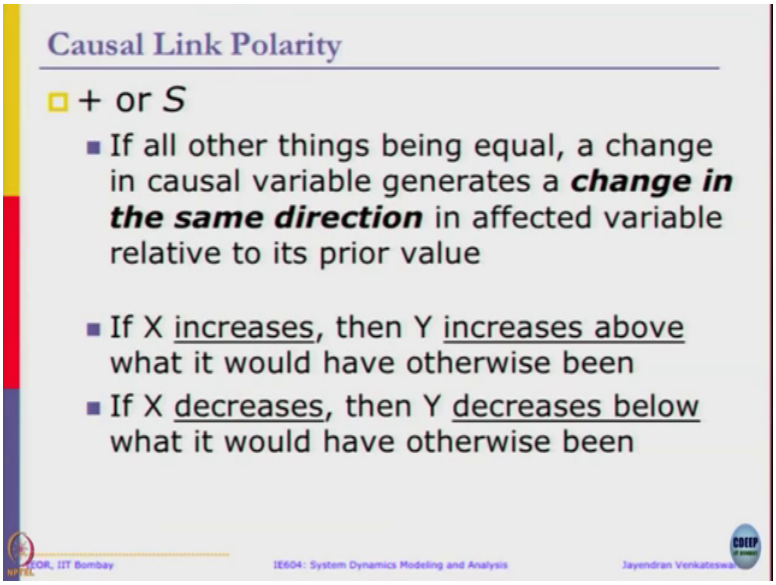
So, let us take up a the third case; so x influences y, let us take y in this case is equal to 1 over x ok. Let us again take the same reference point as 1, y is 1 that is again a reference point. So as x increases 2, y becomes 0.5; x goes to 3, y becomes 0.33; x becomes 4, y becomes 0.25. Here you can clearly see as x is increasing, y is decreasing, correct.

Now, let us see what happens in the opposite direction as x becomes 0.5, y becomes 2 and so on you can expand the case, ok. Just to make you understand, so here it was relative movement. So, to indicate this kind of relation as x increases, y increases. So, then we do a

plus sign or x decreases y decreases it is a plus sign, same direction. Other option where x increases y decreases or x decreases y increases this is an opposite direction or opposing we indicated by a minus sign.

It is a very simple artifact of as using the thumbs, it is a simple trick; but if your thumbs are in the same direction that means, the positive link. So, x increases y increases or x decreases y decreases, then this plus sign; x decreases y increases opposite direction and it is a minus sign, ok. So, here plus and minus are just symbolic this is nothing to do with addition or subtraction; it is just symbolic to indicate the direction of causation ok. So, that is the simple idea.

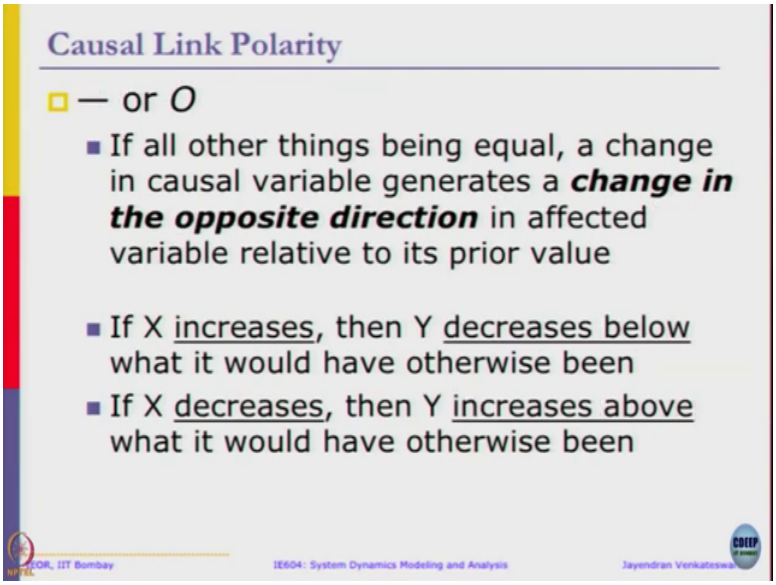
(Refer Slide Time: 15:06)



Just to go or what we did. So, on a formal definition; if all other things being equal, a change in causal variable generates a change in the same direction affected variable related to its prior value, that is the kind of formal definition of it.

But if you are going to get a feel of it, it just says that if x increases y increases above what would have otherwise been; but if x decreases then y decreases below what you could have otherwise been, that is what it simply means is a plus sign. So, in this course we will be using this symbol plus, but there are some books and papers which use the symbol S instead of plus; but that is very very few, most general convention nowadays will just use a symbol plus.

(Refer Slide Time: 15:49)



But minus if all things being equal, a change in the causal variable generates a change in the opposite direction of the affected variable relate to its prior value, that is as x increases y decreases below what it would have otherwise been; then we use a negative sign or a minus.