Introduction to System Dynamics Modeling
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Dynamics of Stocks and Flow
Lecture – 5.3
Stock & Flow Diagram: Basics-II

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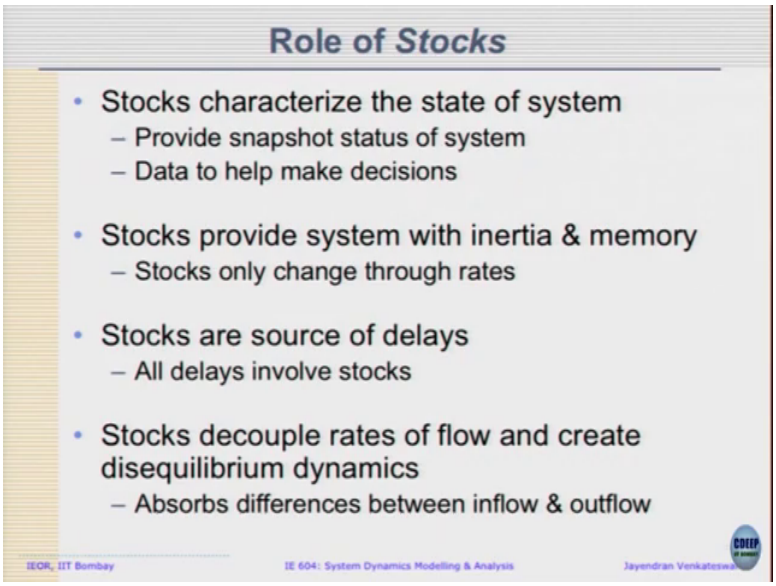

Role of Stocks. Stocks characterize state of the system, it provides snapshot status of system and helps data to make, provides data to help make decisions. So, snapshot status means to make any decisions you need some information. For example, if you are flying a plane you need to know its altitude, you need to know the wind speed, you need to know the say outside and inside temperatures you need to know the what is it the actual ground speed and what is

the speed at which they are flying, the altitude, the direction, the wherein unit various information.

So, all the information that you need to make decisions that provides state of the system at any time point in time where is aircraft, what all characterizes. So, all those things become the stock because they provide data to make decisions whatever the data maybe. So, we are going to use it that becomes a stock.

So, what else? If you are a production manager then you need to have information about what is the current inventory on hand, what is the expected demand forecast, what is expected order that is in pipeline that we have ordered we have not yet received, what is the current cost of the raw material or how much raw materials you need to make this kind of production, how many workers are there in the factory.

We need to know all the information to make the correct production decision at that point in time. So, all those information are can be classified as stocks. There is a characterize state of the system. So, in any other course if you are saying that ok, this has defined a state of system; that means, your characterize is a stock.

Stocks provide system with inertia and memory. Stocks only change through rates; not a mean by inertia and memory is that it accumulates past events. Like in the previous example once a water level reaches a desired water level, it does not disappear it just remains there forever until there is an outflow. Your system does not have an outflow it is not going to change.

You can simulate it for how many ever time period you want the stock remains. So, that is what I mean by saying that it provide memory. And inertia in sense is not going to change until there is some change in the stock flow rates, the flow is always 0, the value of stock does not change. Only flow changes then that causes the stock to change. So, in real systems where does it help?

For example, if you want to model, the amount of ozone in the atmosphere even if you stop the production of all say ozone producing equipments like you know shutdown CFCs another stuff refrigerant, but still the current ozone that is accumulated will continue to remain there. That stock does not disappear. Even the current rate of release of ozone or CFCs, ozone depleting CFCs you stop the flow stops to 0, but your stock still continues to have that value.

So, that is what is called is memory. The stock is something which characterize the data. It has to change only if some external forces is (Refer Time: 03:31), otherwise it is not going to change. Stocks are source of delays, like all delays involve stocks. Like if I want to example like in courier, suppose while sending any package through FedEx or UPS or whatever courier it does not reach instantaneously, you send it and after a time lag it reaches.

So, until then the package does not disappear. It is there in the system somewhere say you can say, packages in pipeline as a stock. So, that the matter is concerned. So, whenever there is delays involved; that means, that information or that order or that material has to be there somewhere. So, whenever there is delays are involved it means that stock is there somewhere and after say the package is delivered and then that package and pipeline gets reduced.

So, we can use it to represent the difference between the inputs and outputs. So, what is the delay? Delay means output lag behind the input, right. In a delay output lags behind the input. So, until then things has to be remained somewhere, so that characterize as the stock. That is the simple definition of the output (Refer Time: 04:51) input.

Stocks decouple rates of flow and create disequilibrium dynamics, also observe the difference between inflows and outflows. Stocks characterizes state of system that is an important point. Stocks provide memory.

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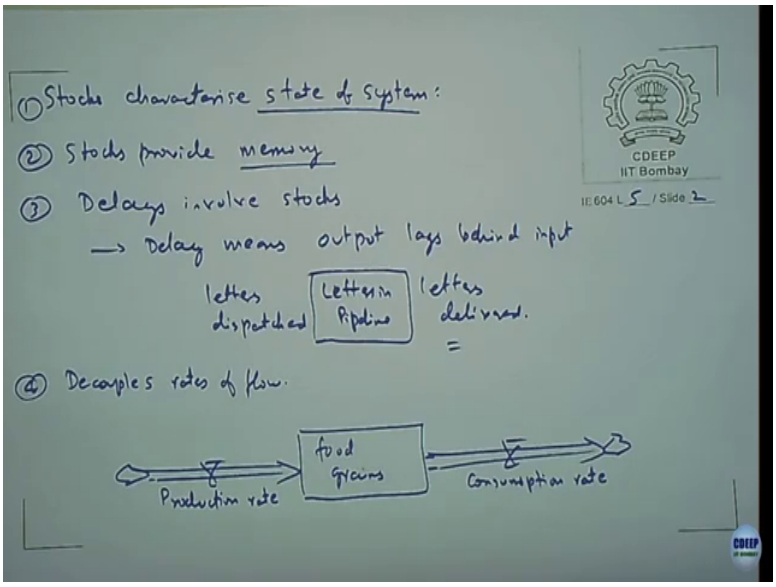

Third, we saw delays involve stocks. What we mean is delay is, delay means output lags behind input. So, if you have say letters, dispatch, then they have letters delivered, so delivered will typically be what our letters were dispatched some periods are earlier or what our letters dispatched today will be delivered say some one time periods later or say one week later. So, one week worth of letters has to be there in the pipeline. So, we can have a stock called as letters and pipeline.

This becomes your stock. Of course, these other two becomes delays, or as soon as you put raw materials into the shop floor it does not become finished product, it take some, it spends some time in the shop floor after end of week or end of the day or end of some month it becomes a finished product, right. The raw materials after a delay becomes the finished

product. So, until then during the production processes those are the kind of raw materials which is available within the shop floor. So, delays involve stocks.

It is not that everything what our letter dispatched has to come as letter is delivered, it can be completely different things. Let us look at it as an example. Decouples rates of flow. Let us let us have a stock of say food grains. So, what will affect the stock of food grains? How will it increase? How will it decrease? So, you just simply let us call it production, production rate. Let us call it consumption rate. Production rate, consumption rate.

This consumption rate changes the food grains change I mean reduces. As production rate increases I get more food grain, if the production rates come down I get less food grains. But this is not a delay, it is not that whatever I produce after some time I consume though it may happen. Production and consumption are controlled by completely different things. What you think affects the production of food grains?

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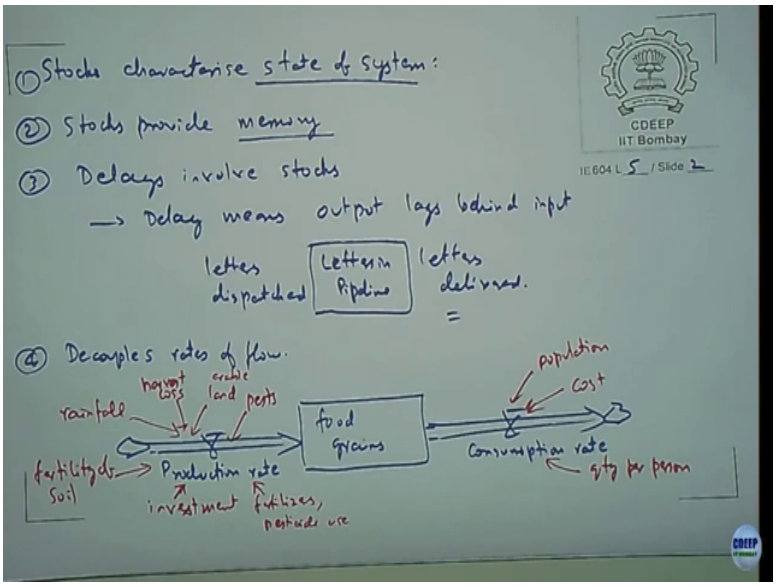

As you can see completely different things can govern your flows and rates. But in result is what you are interested in how much food grains we have. Just by mapping it out gives us some better sense because the rain falls follow some patterns and various other dynamics of effects it.

But eventually, I was indirectly how much you are willing to invest etcetera may be dependent on how much has been consumption rate in the past based on the dynamic (Refer Time: 09:11) or some feedback does occur, but this stock has helped distinguish between these two key things though link is their difference get accumulated here within the this particular stock.

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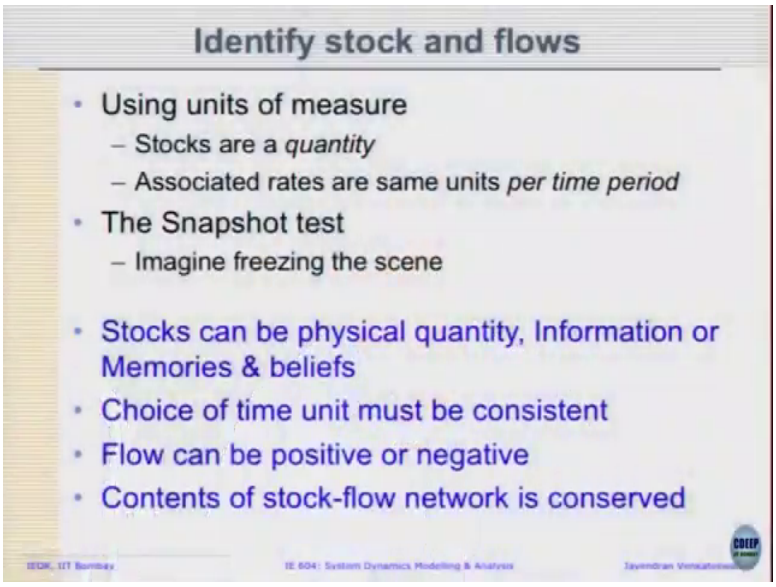

So, the identify stocks you can use things like you know my difficulties were when you look at a systems or identify stocks and flows, we can start using them as units of measure, stocks are quantities and associated rates are same units per time period that is quite simple. If you have a stock for example, if food grains are in tons then production also has to be measured in tons per time period, the tons per year consumption also should be in tons per year. So, whatever units of stock we have the same units should be a flows also should have.

Again remember because underlying you are having a differential equation, right. So, you get mix and match, you cannot get subtracting it gives as no unit units mix match cannot occur. Snapshot test this is like imagine you are freezing a scene, in the sense that is you remove your time from the picture and whatever is remaining you see those are the values of stocks.

These can be both physical or it can be informational or it can be tangible as well as intangible things, both can occur in this, when you freeze the scene.

Like when time is sub population is known not the birth rate. To put a rate you need to do different time points of what you can see is actually the population or if you stopped the factories production you can see the amount of inventories at various points in time, but not the production rate that is what I mean by saying that when you freeze time what happens.

Stocks can be physical, physical quantity information or even memories and beliefs, right. So, what is the expected orders per week? What is the expected price of onions? We have some mental beliefs which are accumulated that also will be calculated as a stock. What is the say employee morale? What is the inflation, expected inflation? Those are again values that we have in kind of what can you say, this was part of a memories and beliefs which also is a stock as I told stocks uses memory so all memories can be modelled as a stock.

Choice of time units must be consistent, like done the agriculture example consumption time being tons per day while the production is in tons per annum. Simulation will not work unit should match. Flows can be positive or negative, please remember that we are just dealing the simple simulation. It has no extra logic built into that; it does not it is just a variable names for it.

So, just be looking at the variable you may have a sense of direction of positive, this is a this cannot go negative and things like that, but for computer it is not going to do anything. You have to be careful in defining whether that sense of direction is positive or negative and accordingly model the system. Contains the stocks of network is conserved. So, whatever leaves the stock, leaves the flow kind of goes into the stock whatever stock drain it goes into the next stock and so on. It does not just disappear from the network. So, we have to remember that.

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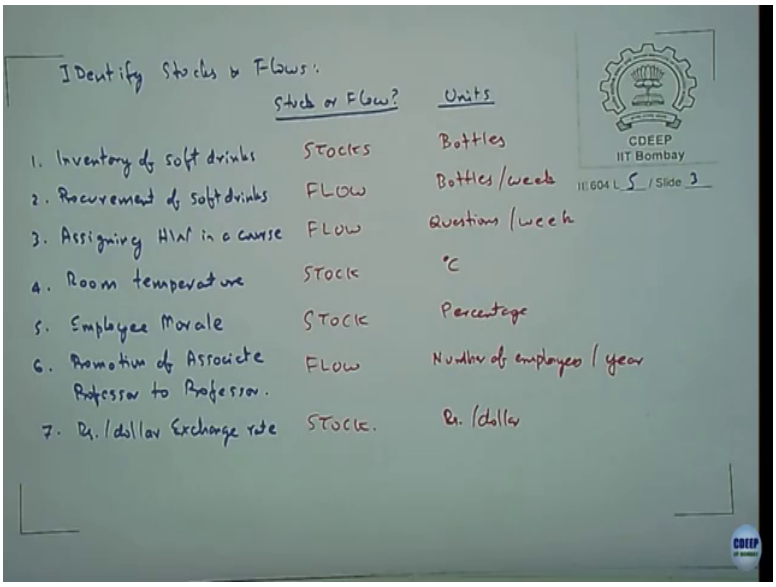

Inventory of soft drinks. What you think stock or flow? It is a stock. What could be its units? Bottles procurement of soft drinks. So, flow what could be its units, bottles per some time period it is going to shop is buying it every say week, we can put a week, bottles per week. Assigning homeworks in a course flow or a stock. There is only two you guys are, some are half of you have do it correct.

Say let us look at the word is assigning homeworks in a course. So, it is flow that is units, let us go to let us prepare questions per week, that is an assigning home works comes as a rate. The number of home works due that will be a stock number of uncompleted pending assignments, number of pending homeworks will be a stock a assignment assigments are given that stock increases; assignment when we completed that stock goes down.

Room temperature, units, degree Celsius, fine. Employee morale, units; no, no time being units plus you have to come up with some unit. We just come up with the, so let us keep it simple and call it say percentage. What is it? Sorry. Salary that is not the units I do not think so, not everything is governed by that.

Student: (Refer Time: 15:20).

We can assume whatever morale is extremely high, will say 100 percent is a morale and then we will (Refer Time: 15:35), I am just making into scale between 0 to 100. Promotion of associate professor to professor. So, flow and the number of say employees per promotion does not happen every day, month, maybe we will put it a year. So, we will put number of timescale, number of employees. Rupees to dollar exchange rate.

So, it dependents how your models. So, someone's absolute information they are modeling something else and you just want that information for now and that remains constant and does not change the system then we can consider it like that, but there is no option I have only stock or flows. So, I have not given the context, but here it is like a stock.

At any point in time even if there is now you know the exchange rate right now. Various things you know how the stocks have being traded keeps changing this rupees to dollar, the rupees per dollar. So, the units is again comes to the same as rupees per dollar. This entire units or it. So, this is your ways we can actually try to quantify it we are very cool and we are kind of very used to things which are physical, you know informational to some extent.

Once you get into memories and beliefs it starts becoming controversial or rather subject lot of discussions, I may prefer percentage, you may prefer a scale between 0 to 10 or minus 10 to 10, it is fine. So, we just pick up some units and be consistent with that the unit and how it affects you I believe 0 to 1 and make a measure and then come up with the employee morales. So, this is not all whatever Jason have ordered does not need to be exchange rates. So, whatever they expected value, whatever is the current value can continue to be a stock.

Let me give another example. Now, let me draw it different (Refer Time: 17:55) units (Refer Time: 17:57). Let us take another example.

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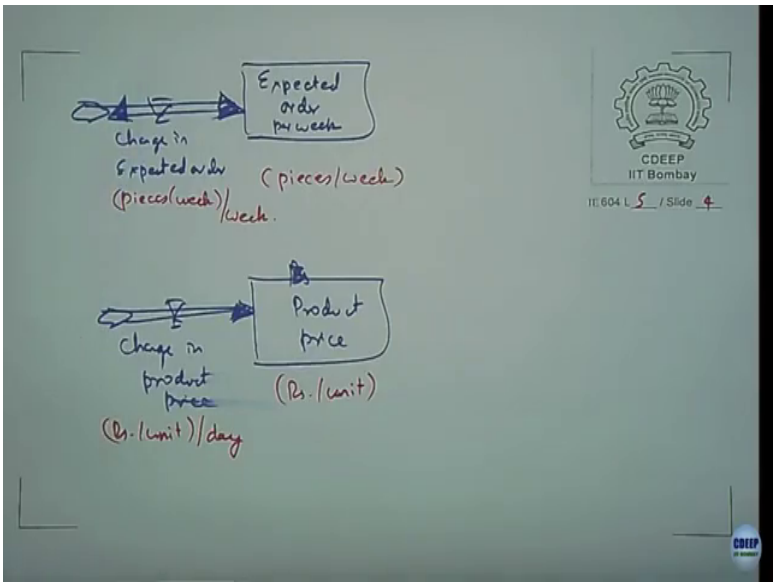

Let us say customer demand when you say customer demand occurs is easily units per week sales, units per week. But then demand when you ask a stock or when you find out we all know the values of the demand, what is the forecasted demand for the next or the expected order. So, the expected order, expected order per week could be very well be a stock and this could be the change in expected order. So, the units for this is a pieces per week and change in expected order could be pieces per week which is units of the stock per week.

Similarly, the exchange rate whenever you go there is a board money exchanger where the value is written for you, that is today's rate; is not going to change it every minute for you. The rate is already given. May be computerized systems still some more updates are current

that acts as a kind of a thumb rule people, but at any point in time you are able to freeze it and get that value.

So, that sense you are modeling rupees per dollar exchange rate and rupees per dollar exchange rate how would changes every minute we can then model as a change in the exchange rate as a flow like the similar to this change in exchange rate and this can be the exchange rate actually. And having done that maybe I can do some more examples like with units. For example, let us take it as product price and change in product price. So, product price is typically say rupees per unit, right.

Change in product price is rupees per unit per let us assume its fluctuation daily per day some can change over time over years etcetera. So, these also. Others some of it are very intuitively for example, population, then you know the populations were number of people and birth rate is people per annum, death rate is also people per annum, ok, population is quite straightforward. Inventory production, inventory is a stock keeping unit. Let us say all what I say.

Cases, bottles in an example bottles; production rate bottles per minute, consumption rate also can be in bottles per minute. Then this change know the direction is only one, so some of the modeling convention dictates us to do with this one also. This is actually a bi-directional arrow to model it. So, as a change caused due to increase its exchange rate change becomes negative it decreases the exchange rate.

So, when you are adding a negative or subtracting a positive, it is better to just do not worry about double headed arrow just put one headed arrows showing the direction and so that is a direction which is getting added. So, the value becomes negative it kind of subtraction, that becomes fine.