Introduction to System Dynamics Modeling
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Dynamics of Stocks and Flow
Lecture - 5.1
Stock & Flow Diagram Brief History

So, today we will begin a new topic on Stocks and Flows. The stocks and flows forms the central concept for this entire System Dynamics Methodology and we will be spending most of our time this course worrying about the stocks and flows and trying to model them and using that construct to understand that model and simulate various systems.

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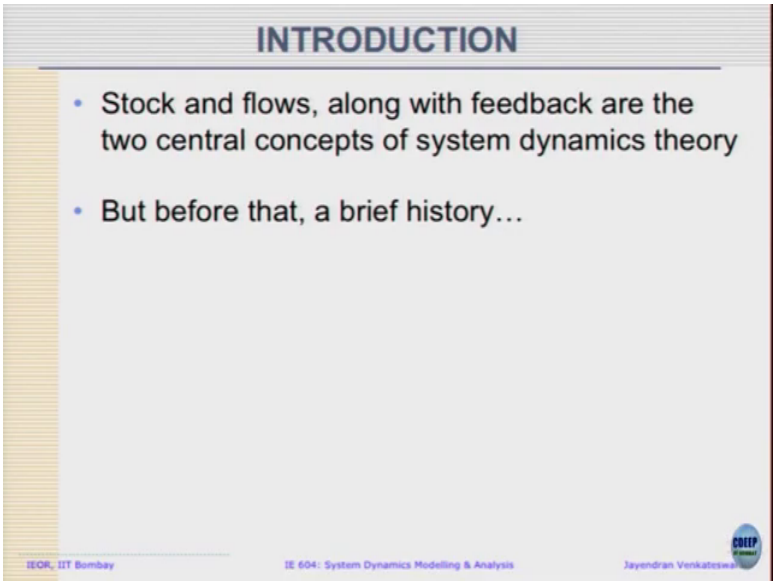

But before that I would like to give a brief history of system dynamics methodology which some of you might find fascinating this. One of those rare approaches that has a definitor, founder or a creator who have develop this methodology.

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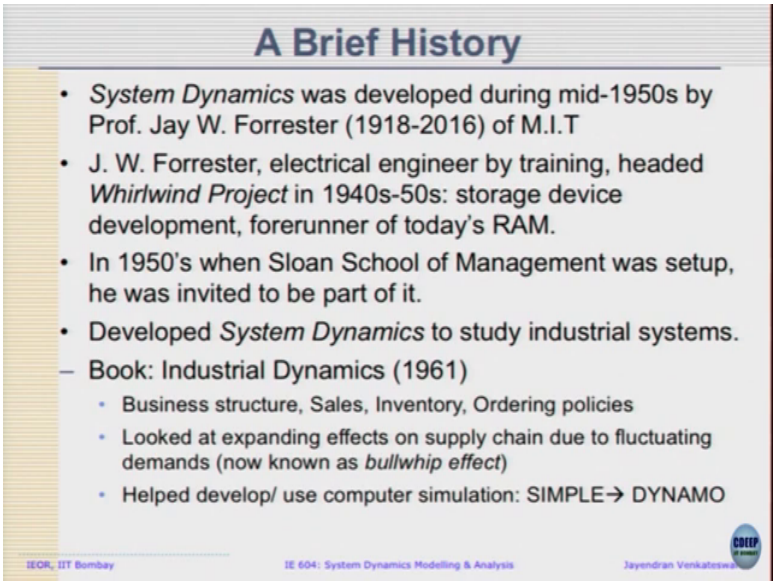

So, the System Dynamics Methodology was developed by Professor Jay W Forrester, from M.I.T the mid 1950s. The interesting was professor Forester was a electrical engineer by training and he has even participated and headed the project on the Whirlwind project as it is called in the 1940s, where he had helped develop the kind of a storage device which a precursor to today's RAM.

So, with that solid foundation, the mid 1950s when the Sloan School of Management was started, he was invited to be on board and being a true electrical engineer, he told like I do not know nothing about management; why I am a being part of it. They just said ok, you just

come and see what you can do. So, being an electrical engineer, he had a good sound background in the areas of control theory. So, he thought let us see then we can apply some of those concepts into management.

So, he spent a year or two looking at various industrial processes and trying to map it in terms of a kind of a control theory kind of approach, where we look at the state of the system and see what kind of things flow in and out and the result was this fascinating field of system dynamics. So, what he did was to look at industrial systems, where he identified various players within a supply chain.

So, even at that time people were not even common and using the term supply chain, kind of initiative say let us assume there are some. You may studied some of it and ok, there are this factories, there are these warehouses and there are this retailer and warehouses, orders material to the factory, factory produces them and after some time the material reaches the warehouse.

And even before ordering there are various sorts of delays that can occur and systematically brought them out as a set of equations; time difference equation or differential equation that is we see. See it, and the end result was this interesting book on Industrial Dynamics which came out in 1961. So, where he actually identified the business structures, looked at the sales inventory, order policies in very systematic manner.

And looked at the business how can I say the expanding effects on supply chain, due to fluctuating retailer demand and this book, now it is known as the bullwhip effect. Some of you might have heard of bullwhip effect, it has its origins right here 1950s work of Forrester. At that time, we did not use the term bullwhip effect. He just pointed out the fluctuations and very interesting and new to that period in time, this book is full of illustrations.

It has full of computer-generated graphics to show how if an inventory changes, what happens to dynamics upstream within the warehouse, retailers, warehouse, distributors as well as the factory. But to do that simulation, remember when 1950s and that is when computer getting set up each computer was probably as big as this room, that has probably hand full of

computers in entire united states and predominantly was used in manhandling project and stuffs M.I.T had one.

So, he had approached the computer department and I told he has set up these equations, but I cannot solve them there we know getting highly non-linear. So, can we at a time stimulate them. So, computer department took it up as a challenge and built this simple standing for simulation of industrial management problems, using lot of equations. That is what simple stands for.

There was a very first attempt to move away from coding; in the coding sense, to bring it into symbolic language because what we have on the in the top side is just a set of differential equations and using its symbolic structure, we want to simulate the system. So, we do not so, there are this very first attempt to actually move away from coding into use of a symbolic structure.

So, that can be used by others who are non-coders. So, its foundation went way back in 1950 almost the very first development of a use of computers and this is probably one of the very early use of computer rather than military purposes. That has the later meaning within the next decade itself, let the development of what is called Dynamo standing for dynamic models, the little more powerful interface which does based on symbolic input. It could use to simulate the differential equations and dynamic system rather than; so dynamic model mean.

And, this spurts the development and use of computers by non-programmers, that had a very very interesting origins. So, it is not the; it is not that the programming came first and then, we went this. In fact, effort to develop and use computer models for non-programmers started way earlier than you might have known. So, in this industry dynamics game there was very new, we are looking at even in management or industrial system; nobody has looked at. The system as in a set of equations that can be model that was kind well receive.

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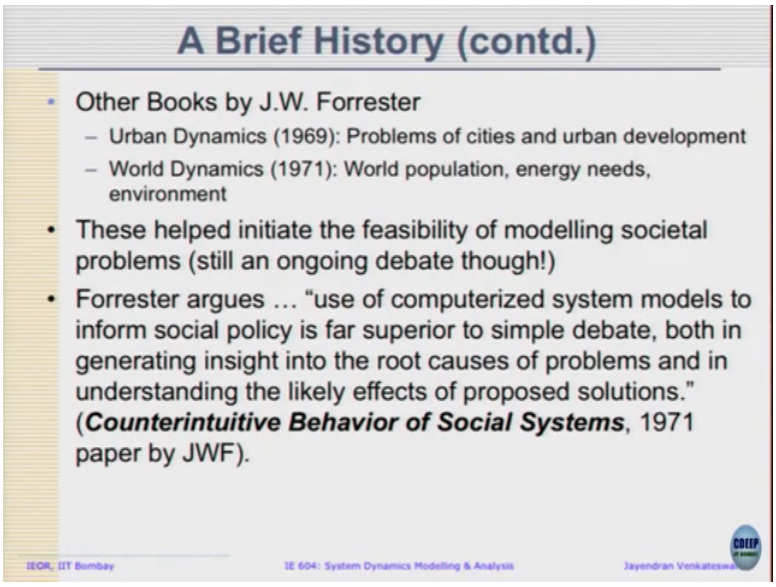

But soon the potential for this approach in other domains become apparent in mid entire 60s, when Forrester had encounters with other colleagues in various departments as well as in the administration. The result was in 69, he did help on work on book on Urban Dynamics, where he looked at more problem of cities and urban development, where is able to use a same system dynamics methodology to actually map and identify various variables as stocks and flows with underlying structure as being a differential equation concepts.

And then, in 71 he helped developed this world dynamics, the model of how the world population evolves energy needs, environment etcetera way back in 1971. Now, all this three were came out as nice big fat books. So, what it did and then Forrester devoted rest of his life to expansion, education as well as the use of system dynamics methodology for various societal problems as well as looking at complex issues and how to abstract them.

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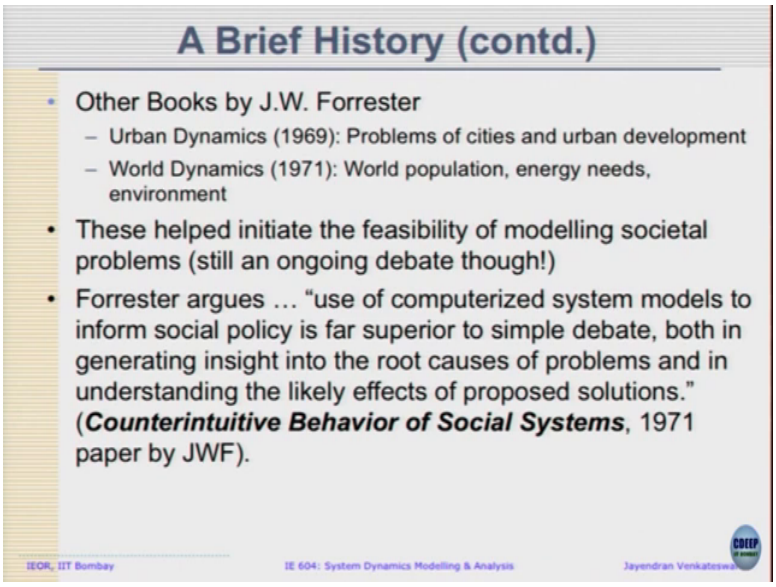

So, all these work help initiate this dialogue on how feasible the modeling of societal problem is. Still of course, it is an ongoing debate you may find people have either really into the system dynamics break it or they just dismiss it how friends saying no this is this is still giving us a very still more still more complexities which you cannot capture it. So, it is still ongoing debate.

It is all stems from Forrester's early argument, where he is told that use of computerized system models which he believed in. "Use of computerized system models informs societal the social policy is far superior to simple debate, both in generating insight into the root causes of the problem and in understand the likely effects of proposed solutions" way back in 1971 which hopefully some of us will share.

The idea here being when we engage in some of with you know when we looking at the social or more complex socio-economic kind of problems, we did various viewpoint. We cannot just sit in a room and just ideate on what will work. So, when we started engage in dialogue, it eventually leads into moves away from dialogue to discussion to hated debates on various (Refer Time: 09:14).

So, what this can help bring to the table is as and when where a viewpoints are presented we can try to map it out into kind of nice causal kind of diagram, identifying stocks and flows and then, trying to see understand how the dynamics evolve over time. Yeah. So, that is kind of nice a history of how system dynamics has evolve. When we started off with we started off directly by identifying the stocks and flows that we are going to see and only later people told that you know jumping to stock and flow itself is quite difficult.

Let us you know first develop what we call as a causal mapping, which led to a development of causal loop diagrams. To identify what are the key variables in the system, let us map out their interaction and then, let us use that to move into stock flow diagram, where once you start doing stock and flows, you are already one step towards building a computer based model which you will see by in a minute. Because they are just visual representation of the underlying equation: that we are trying to model and establish ok.

So, and it is quite easy to teach, use that takes time; yeah. So, still say M.I.T and some of the school managements has a pretty strong group on this system dynamics group, still there most of the activities are concentrated there. Far bit of participation of from various industries and countries and applications from the government all the way to people wanting to just learn and understand the systems individual level.

Various nice thing that has happened over time. People have then use the model to well predict (Refer Time: 11:04) classical book by (Refer Time: 11:06) on limits to growth. It actually finds out how no that was a time remember in 60s things was all great that is fantastic, there is no in fact there is no limits to growth at that point in time and this book on

based on system dynamics ideologies, methodologies came about, talking about; then, that is going to be limits to growth and then, that started unfolding in 70s and 80s.

1980s system dynamics methodology was used in a Supreme Court or maybe a District Court, I do not know some legal hearings between a customer and the government saying that I mean the client was telling the telling that the delays in the project was due to interference by the government because of changing requirement. Government was signed to sue the company saying that you delayed the project unnecessarily; so, I am not going to pay you a full money.

But then, system dynamics model was used to understand actual dynamics within the government as well as the company and it was found that there was excessive in interference in the government which cause the delays and the ruling was and used this system dynamic methodology. So, that has quite and how often you recovery that actual math is used in road case schoolings. So, it was quite interesting and more recently, the and how much of you are following that debates and discussions on climate change that is this conference of parties and one climate change model has been adapted by all the countries.

So, this model is being has been developed based on system dynamics methodology. It underlying model or system dynamics model, it has been adopted as one of the most accurate models to represent what can happen in climate change and what are the potential pathways that it predicts based on our current consumption and usage patterns of various fuels etcetera and economies stuff like that. So, on sea roads climate to map something; so, you to look it up; so, there are lot of interesting and very high-level application that is coming out. Please do not talk.