Metodologi *System Dynamics* (Dinamika Sistem)

untuk

Pemodelan Kebijakan:
Suatu Pengantar

Dr. Muhammad Tasrif

Ina Juniarti

Hani Rohani

Fauzan Ahmad

Eva Intan Nurwendah

Nurika Lestari Waspada

Pelatihan Analisis Kebijakan Menggunakan Model

System Dynamics

Hotel Bumi Sawunggaling Bandung, 14 - 18 Desember 2015

JADWAL ACARA

Senin, 14 Desember 2015

07.30 – 08.00	Pendaftaran dan Pembukaan
08.00 – 10.00	Sesi 1: Fenomena
10.00 – 10.15	Rehat kopi
10.15– 12.15	Sesi 2: Struktur, Perilaku dan Analisis Kebijakan
12.15 – 13.00	Ishoma
13.00 – 15.00	Sesi 2: Struktur, Perilaku dan Analisis Kebijakan (lanjutan)
15.00 – 15.15	Rehat kopi
15.15 – 17.15	Sesi 2: Struktur, Perilaku dan Analisis Kebijakan (lanjutan)

Selasa 15 Desember 2015

08.00 – 10.00	Sesi 3: *Inventory Simulation Game*
10.00 – 10.15	Rehat kopi
10.15 – 12.15	Sesi 3: *Inventory Simulation Game* (lanjutan)
12.15 – 13.00	Ishoma
13.00 – 15.00	Sesi 4: *Systems Thinking* dan *System Dynamics*
15.00 – 15.15	Rehat kopi
15.15 – 17.15	Sesi 5: *Feedback Loop*, *Delay* dan *Nonlinearity*

Rabu, 16 Desember 2015

08.00 – 10.00	Sesi 5: *Feedback Loop*, *Delay* dan *Nonlinearity* (lanjutan)
10.00 – 10.15	Rehat kopi
10.15 – 12.15	Sesi 6: Perangkat Lunak Simulasi - *Powersim Studio*
12.15 – 13.00	Ishoma
13.00 – 15.00	Sesi 7: Latihan Simulasi
15.00 – 15.15	Rehat kopi
15.15 – 17.15	Sesi 7: Latihan Simulasi (lanjutan)

Kamis, 17 Desember 2015

08.00 – 10.00	Sesi 8: Model Ketersediaan (*Availability*)
10.00 – 10.15	Rehat kopi
10.15 – 12.15	Sesi 8: Model Ketersediaan (*Availability*) (lanjutan)
12.15 – 13.00	Ishoma
13.00 – 15.00	Sesi 9: Model Energi 1
15.00– 15.15	Rehat kopi
15.15 – 17.15	Sesi 9: Model Energi 1 (lanjutan)

Jumat, 18 Desember 2015

08.00 – 10.00	Sesi 10: Model Energi 2
10.00 – 10.15	Rehat kopi
10.15 – 11.15	Sesi 11: Model Energi 2 (lanjutan)
11.15 – 13.00	Ishoma
13.00 – 14.00	Sesi 12: Model Energi 2 (lanjutan)
14.00 – 15.00	Diskusi
15.00 – 15.30	Penutupan

Sesi 1
Fenomena

Outcomes

Pada akhir sesi ini, peserta dapat:

- memahami konsep suatu fenomena dan sistem;
- memahami perbedaan antara fenomena sosial (*social phenomenon*) dengan fenomena alam atau fenomena fisik (*physical phenomenon*); dan
- mendefinisikan suatu persoalan.

1.1 Fenomena

- **Fenomena** adalah sesuatu yang dapat kita lihat, alami dan rasakan atau *something experienced: a fact or occurrence that can be observed.*

3

Fenomena

- **Fenomena fisik** adalah fenomena yang tidak melibatkan campur tangan manusia atau keputusan manusia (fenomena alam atau fenomena yang dibuat manusia berdasarkan hukum alam)[*a natural phenomenon involving the physical properties of matter and energy (physical law)*].

- **Fenomena sosial** adalah segala sesuatu yang dipengaruhi oleh kegiatan atau aktivitas manusia yang diwujudkan oleh keputusan-keputusannya (proses pegambilan keputusan) [*anything that influences or is influenced by organisms sufficiently alive to respond to one another (desicion making)*].

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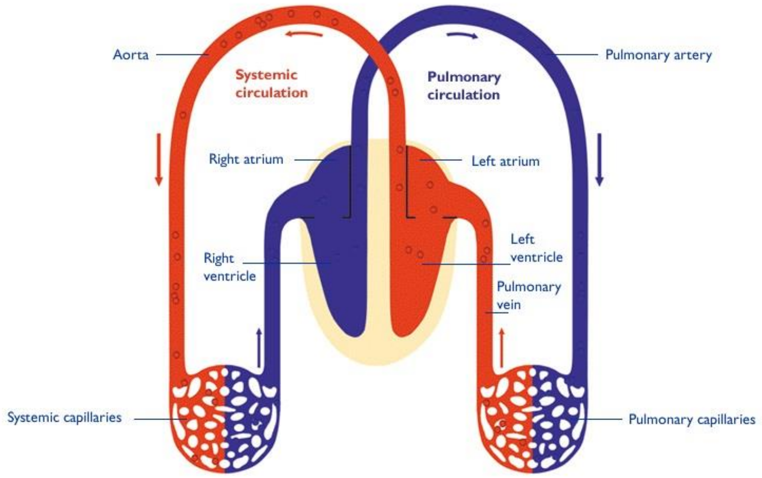
Fenomena Alam (Fisik)

Overview of the pulmonary and systemic circulations.



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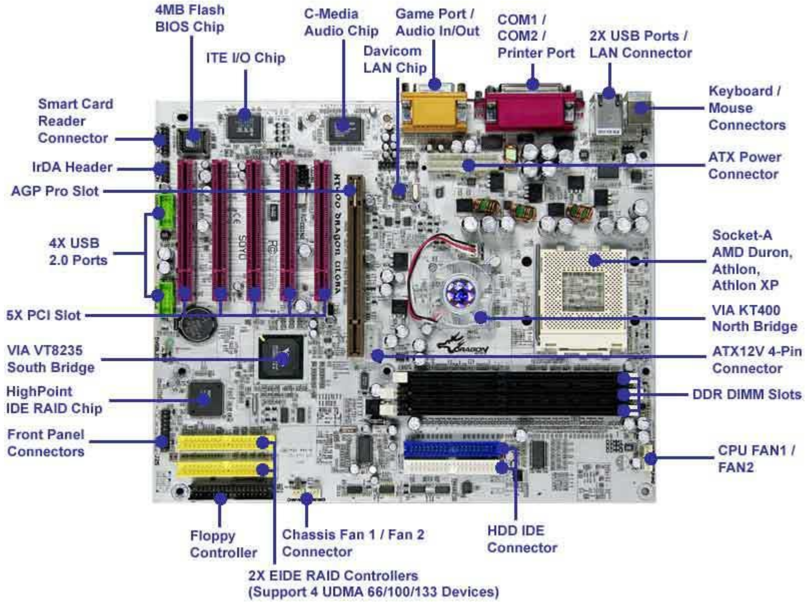

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Fenomena Sosial

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Catatan historis dinamika (*behavior*) perberasan nasional

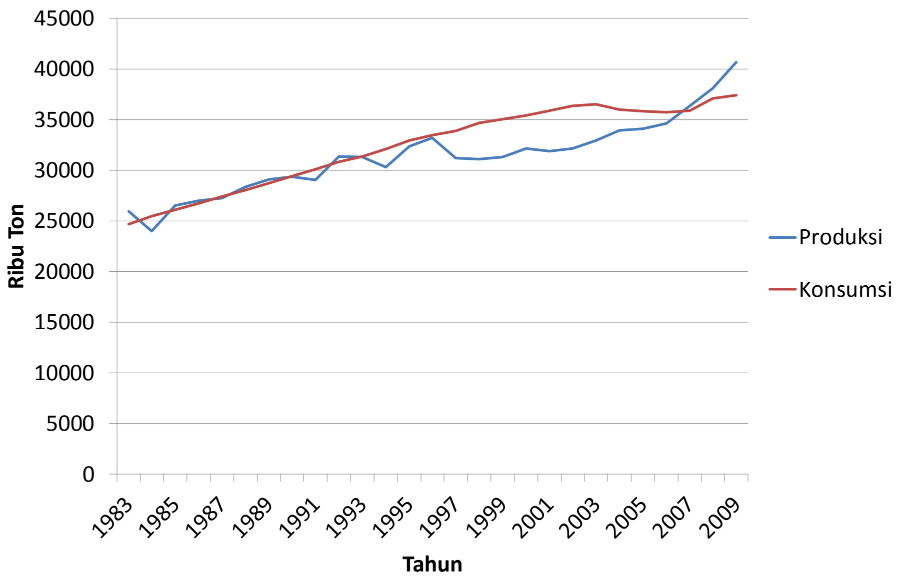
Tabel Produksi dan Konsumsi Beras Nasional

Tahun	Produksi	Konsumsi
1983	25932	24679
1984	24006	25460
1985	26542	26092
1986	27014	26738
1987	27253	27392
1988	28340	28053
1989	29072	28723
1990	29366	29410
1991	29047	30121
1992	31356	30838
1993	31318	31375
1996	33216	33461
1997	31206	33911

Tabel Produksi dan Konsumsi Beras Nasional

Tahun	Produksi	Konsumsi
1998	31118	34667
1999	31294	35033
2000	32130	35400
2001	31891	35877
2002	32130	36382
2003	32950	36500
2004	33940	36000
2005	34120	35850
2006	34600	35739
2007	36350	35900
2008	38078	37100
2009	40656	37400

Dinamika (Perilaku) Produksi dan Konsumsi Beras Nasional

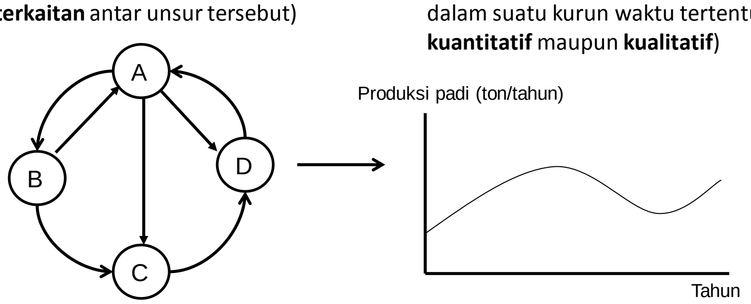


Suatu fenomena menyangkut **2 hal (aspek):**

(1) Struktur (*structure*) → **Perilaku (*behavior*) (2)**

(**unsur** pembentuk fenomena dan pola **keterkaitan** antar unsur tersebut)

(**perubahan** suatu besaran/variabel dalam suatu kurun waktu tertentu, baik **kuantitatif** maupun **kualitatif**)



Fenomena sosial :
- struktur fisik; dan
- struktur pembuatan keputusan.

Pemahaman hubungan struktur dan perilaku sangat diperlukan dalam mengenali suatu fenomena.

1.2 Sistem

Suatu sistem adalah suatu fenomena yang strukturnya telah diketahui [*A phenomenon which its structure has been defined*].

Atau

Suatu sistem merupakan suatu gabungan dari beberapa bagian yang bekerja untuk tujuan bersama. Suatu sistem dapat terbentuk dari sejumlah orang dan/atau sejumlah komponen fisik [*A* ***system*** *means a grouping of parts that operate together for common purpose. A system may include people as well as physical parts*].

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1.3 Persoalan (*Problem*)

- Suatu fenomena yang kehadirannya tidak diinginkan, contoh: produktivitas padi yang terus menurun, tingkat pengangguran yang terus bertambah.
- Suatu fenomena yang ingin diwujudkan. Contoh: suatu target surplus beras yang ingin dicapai pada tahun 2014.
- (secara praktis) Suatu kesenjangan (*gap*) antara keadaan sebenarnya (*actual state*) dengan keadaan yang diinginkan (*goal*).

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1.4 Contoh Kasus

(Sumber: Tesis Emmy Farha Binti Alias, Universiti Putra Malaysia, 2013)

To achieve the intended level of rice production (higher level of self-sufficiency in rice production, currently is about 65-75% of domestic consumption), Malaysia implements a wide range of market interventions. The policy instruments include among others:

- A guaranteed minimum price for paddy;
- Various cash and input subsidies to farmers and millers;
- Import monopoly; and
- Price control for rice.

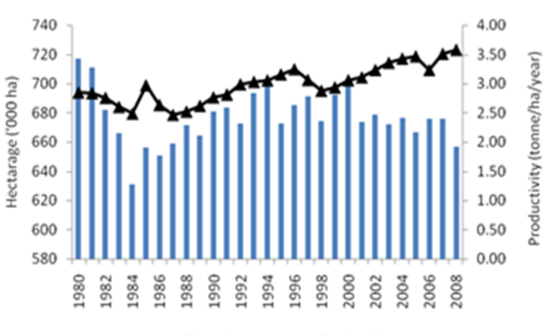

Figure 1.4.1 Planted Paddy area ('000 ha) and Productivity (t/ha/year)
[Source: DoS(2010)]

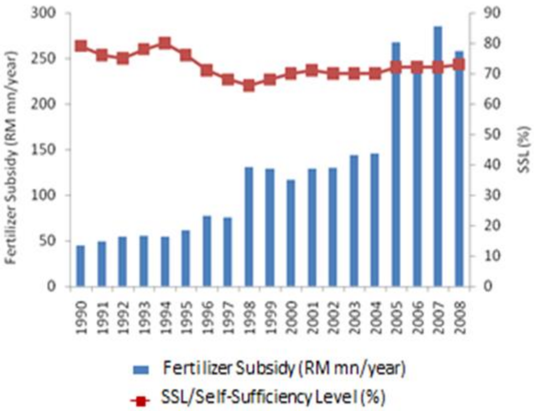

Figure 1.4.2 SSL(%) and Fertilizer Subsidy (RM mn/year), 1990-2008
[Source: MoA(2010)]

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For the future, Malaysia needs to dismantle all the policy instruments to comply with the WTO agreement.

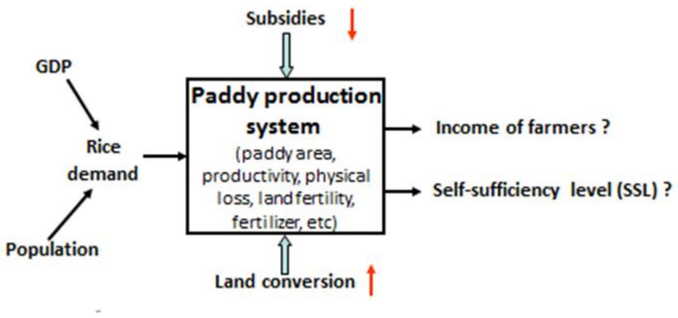

Figure 1.4.3 The Global Model

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Sesi 2
Struktur, Perilaku, dan Analisis Kebijakan

1

Outcomes

Pada akhir sesi ini, peserta dapat:

- memahami 2 aspek suatu fenomena (struktur dan perilaku);
- mengenali struktur fisik dan struktur pembuatan keputusan;
- memahami konsep kompleksitas; dan
- memahami prinsip suatu analisis kebijakan (*policy analysis*).

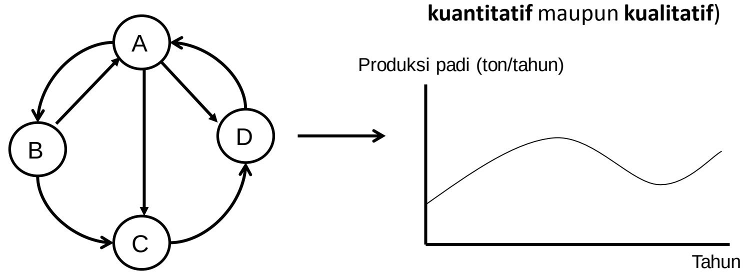
2

2.1 Dua Aspek Suatu Fenomena

(1) Struktur (*structure*) ⟶ **Perilaku (*behavior*) (2)**

(**unsur** pembentuk fenomena dan pola **keterkaitan** antar unsur tersebut)

(**perubahan** suatu besaran/variabel dalam suatu kurun waktu tertentu, baik **kuantitatif** maupun **kualitatif**)

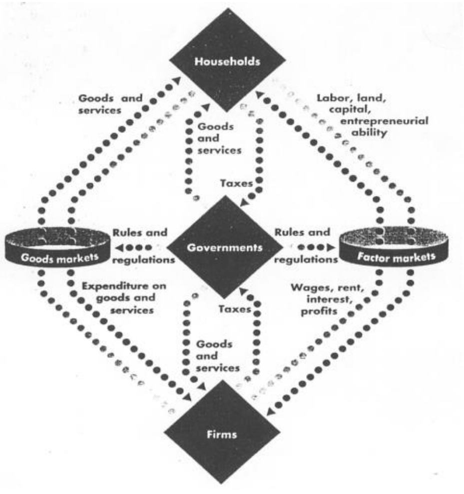


Fenomena sosial :
- struktur fisik; dan
- struktur pembuatan keputusan.

Pemahaman hubungan struktur dan perilaku sangat diperlukan dalam mengenali suatu fenomena.

3

A Picture of an Economy



- Households, firms, and governments make economic **decisions**. Households decide how much of their labor, land, capital, and entrepreneurial ability to sell or rent in exchange for wages, rent, interest, and profits. They also decide how much of their income to spend on the various types of goods and services available. Firms decide how much labor, land, and capital to hire and how much of the various types of goods and services to produce. Governments decide which goods and services they will provide and the taxes that households and firms will pay.
- These decisions by households, firms, and governments are coordinated in **markets**—the goods market and factor markets—that are regulated by rules that governments establish and enforce. In these markets, prices constantly adjust to keep buying and selling plans consistent.

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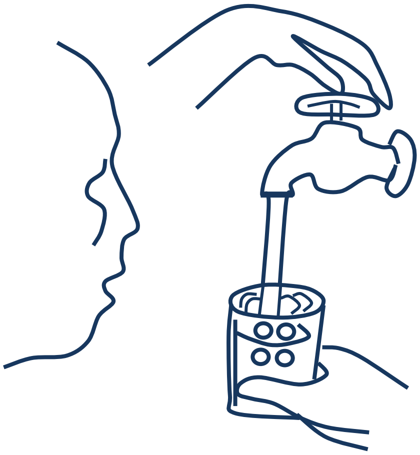
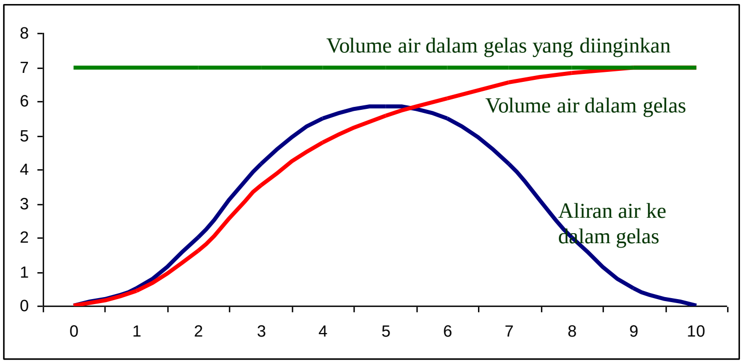
Contoh : Pengisian air ke dalam gelas sampai penuh.

(Sumber: “The Fifth Discipline”, Peter M. Senge, 1990)



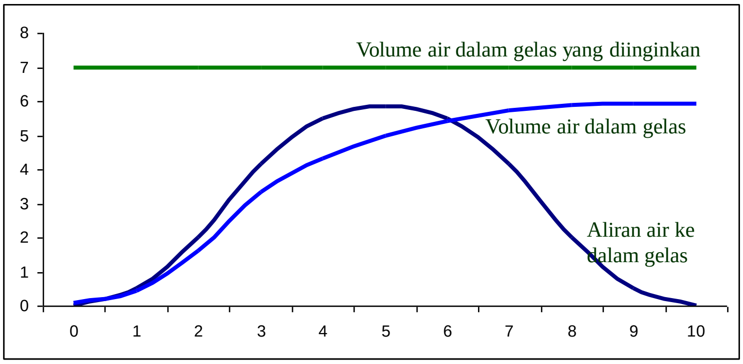
Kemungkinan Perilaku

A. Jika sumber air mencukupi

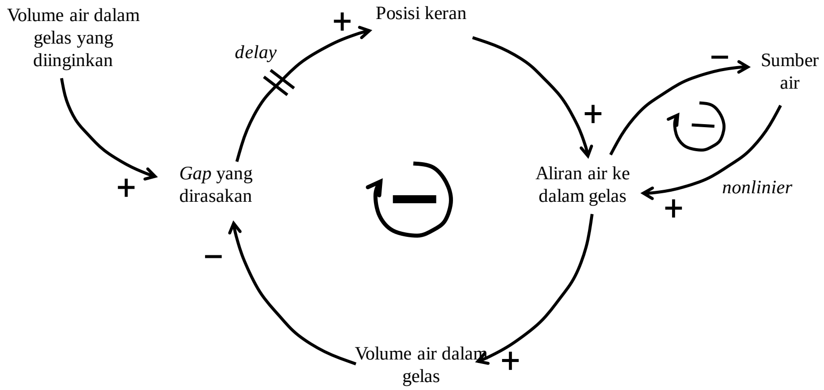


Kemungkinan Perilaku

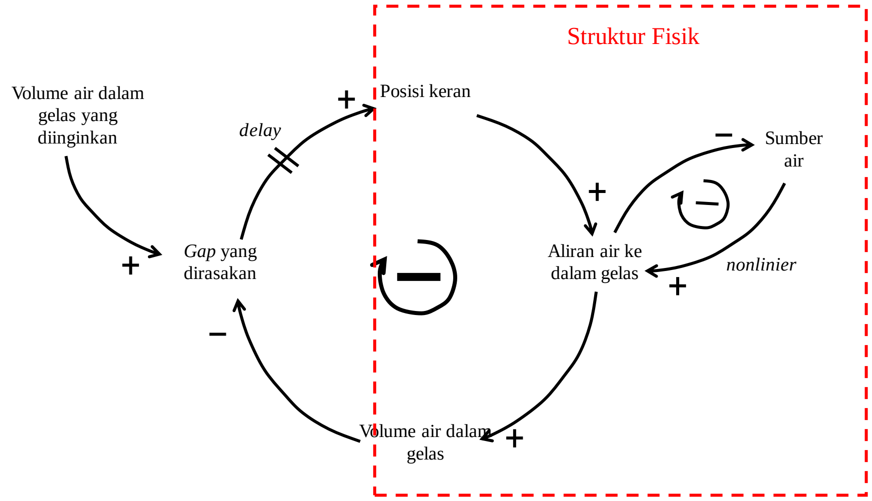
B. Jika sumber air terbatas



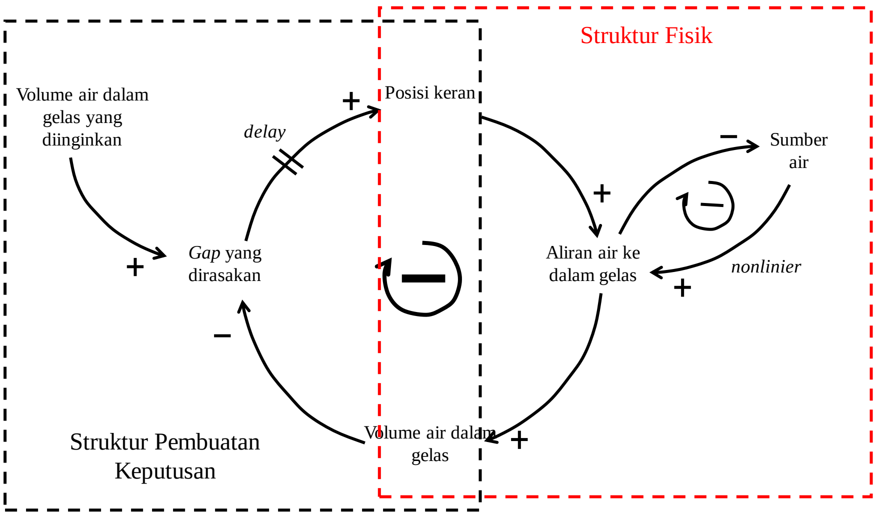
Struktur Fenomena



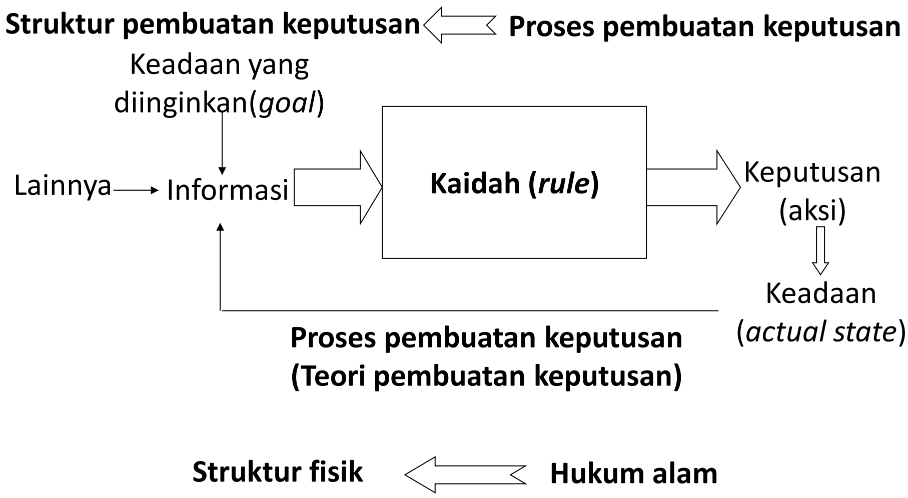
Struktur Fenomena



Struktur Fenomena



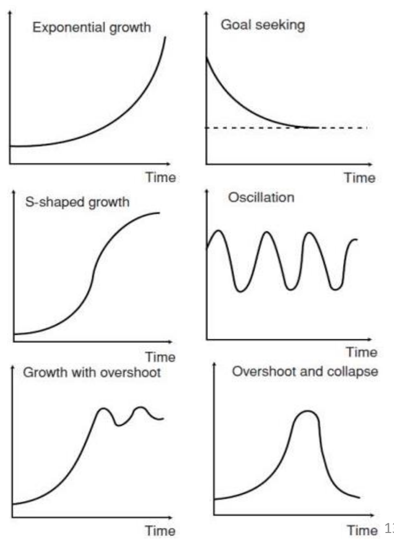
Struktur: (1) pembuatan keputusan; dan (2) fisik.



- Struktur terdiri atas **struktur fisik** (stok dan jaringan aliran materi) dan **struktur pengambilan keputusan** (*decision-making structure*) bermacam aktor di dalam sistem.
- **Struktur pengambilan keputusan** di sini dimaksudkan sebagai kaidah-kaidah pembuatan keputusan dan sumber informasi yang digunakan untuk pembuatan keputusan tersebut.
- Oleh karena itu, model untuk **analisis kebijakan** dalam kasus suatu fenomena sosial haruslah merupakan suatu **model dinamik** dan mampu merepresentasikan secara relatif **cukup rinci** (*detail*) aras-mikro (*micro-level*) individu dan industri (perusahaan), **relasi-relasi fisik dan teknik**, dan **proses-proses pengambilan keputusan** yang digunakan oleh aktor-aktor di dalam sistem.

2.2 Pola Karakteristik Perilaku Sistem

- **Exponential Growth**
- **Goal Seeking**
- **S-Shaped Growth**
- **Oscillation**
- **Growth with Overshoot**
- **Overshoot and Collapse**



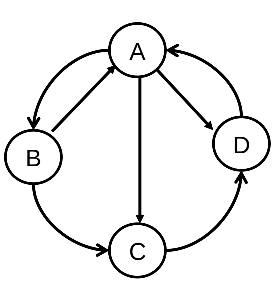
2.3 Konsep Kompleksitas

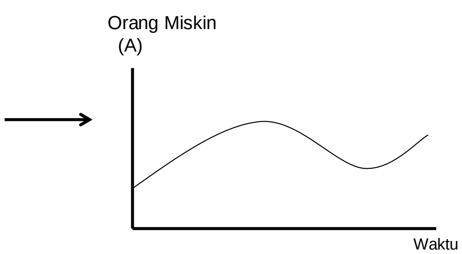
(Sterman, J.D., *Business Dynamics: Systems Thinking and Modeling for a Complex World,* 2004, Mc Graw HIll)

(1) Struktur → Perilaku (2)

(**unsur** pembentuk fenomena dan pola **keterkaitan** antar unsur tersebut)

(**perubahan** suatu besaran/variabel dalam suatu kurun waktu tertentu, baik **kuantitatif** maupun **kualitatif**)





Fenomena Sosial:
Struktur fisik; dan struktur pembuatan keputusan.

- **Detail complexity**

  Complexity in terms of the number of elements (components) in a phenomenon (system), or the number of combinations one must consider in making a decision.
- **Dynamic complexity (Kompleksitas Dinamis)**

  Arises from the relationships (interactions) among the agents (elements) over time.

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Kompleksitas dinamis muncul karena fenomena mempunyai karakteristik:

- **Dynamic**

  Heraclitus said, "All is change." What appears to be unchanging is, over alonger time horizon, seen to vary. Change in systems occurs at many time scales, and these different scales sometimes interact. A star evolves over billions of years as it burns its hydrogen fuel, then can explode as a supernova in seconds. Bull markets can go on for years, then crash in a matter of hours.
- **Tightly coupled**

  The actors in the system interact strongly with one another and with the natural world. Everything is connected to everything else. As a famous bumper sticker from the 1960s proclaimed, "You can't do just one thing."

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- **Governed by feedback**

  Because of the tight couplings among actors, our actions feed back on themselves. Our decisions alter the state of the world, causing changes in nature and triggering others to act, thus giving rise to a new situation which then influences our next decisions. Dynamics arise from these feedbacks.

- **Nonlinier**

  Effect is rarely proportional to cause, and what happens locally in a system (near the current operating point) often does not apply in distant regions (other states of the system). Nonlinearity often arises from the basic physics of systems: Insufficient inventory may cause you to boost production, but production can never fall below zero no matter how much excess inventory you have. Nonlinearity also arises as multiple factors interact in decision making: Pressure from the boss for greater achievement increases your motivation and effort-up to the point where you perceive the goal to be impossible. Frustration then dominates motivation and you give up or get a new boss.

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- **History-dependent**

  Taking one road often precludes taking others and determines where you end up (path dependence). Many actions are irreversible: You can't unscramble an egg (the second law of thermodynamics). Stocks and flows (accumulations) and long time delays often mean doing and undoing have fundamentallydifferent time constants: During the 50 years of the Cold War arms race the nuclear nations generated more than 250 tons of weapons-grade plutonium (239Pu)T. he half life of 239Pu is about 24,000 years.

- **Self Organizing**

  The dynamic of systems arise spontaneously from their internal structure. Often, small, random pertubations are amplified and molded by feedback structure, generating patterns in space and time and creating path dependence.The pattern of stripes on a zebra, the rhythmic contraction of your hearth, the persistent cycles in the real estate market, and structures such as sea shells and markets all emerge spontaneously from the feddbacks among the agents and elements of the system.

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- **Adaptive**

  The capabilities and decision rules of the agents in complex systems change over time. Evolution leads to selection and proliferation of some agents while others become extinct. Adaptation also occurs as people learn from experience, especially as they learn new ways to achieve their goals in the face of obstacles. Learning is not always beneficial, however.

- **Counterintuitive**

  In complex systems cause and effect are distant in time and space while we tend to look for causes near the events we seek to explain. Our attention is drawn to the symptoms of difficulty rather than the underlying cause. High leverage policies are often not obvious.

- **Policy resistant**

  The complexity of the systems in which we are embedded over whelms our ability to understand them. The result: Many seemingly obvious solutions to problems fail or actually worsen the situation.

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- **Characterized by trade-offs**

  Time delays in feedback channels mean the long-run response of a system to an intervention is often different from its short-run response. High leverage policies often cause worse-before-better behavior, while low leverage policies often generate transitory improvement before the problem grows worse.

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2.4 Pertanyaan Terhadap Perilaku (Fenomena)

(a) Berapakah nilai (angka) besaran itu pada suatu titik waktu yang akan datang? **[point prediction]** (**prakiraaan**, **prediksi masa depan**)

(b) Mengapa perubahan besaran tersebut seperti itu? **(*why* ?)** Dan dengan cara bagaimanakah mengubahnya? **(*how* ?) [behavior prediction]** (menyusun strategi dan memformulasikan kebijakan, **analisis kebijakan** atau ***policy analysis***)

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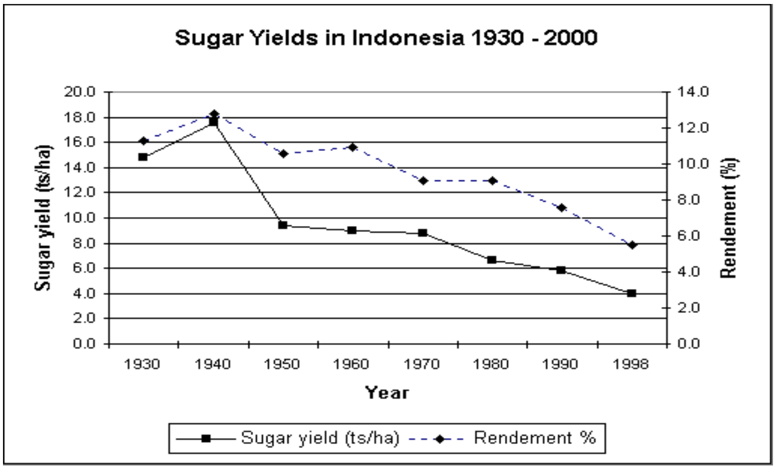
Contoh: Dinamika Produksi Gula di Indonesia



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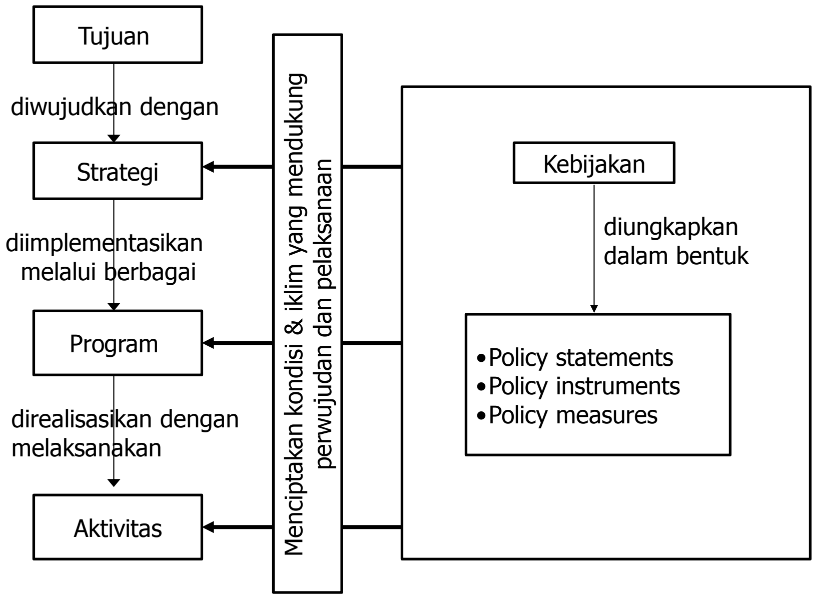
2.5 Strategi dan Kebijakan



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- **Strategi (*strategy*)**
  Sebuah rencana (metode) aksi untuk mencapai suatu tujuan tertentu [*a plan (method) of action to achieve a particular goal (aim)*]

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Kebijakan

Petunjuk-petunjuk (*directives*) yang dikeluarkan dan disebarluaskan (oleh pemerintah) dengan tujuan:

- menciptakan serta membangun iklim dan kondisi yang perlu untuk mendukung (*to facilitate*) pelaksanaan strategi;
- memberikan kepastian kepada unsur-unsur dunia usaha, masyarakat luas, dan peyelenggara pemerintahan; tentang arah, ruang lingkup, dan tingkat keleluasaan masing-masing di dalam memilih upaya yang berkaitan dengan strategi tersebut.

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Pelaksanaan Kebijakan

Untuk melaksanakan kebijakan, setelah mengeluarkan kebijakan (pernyataan), *policy measures* harus dibentuk:

- bentuk, rumuskan, dan keluarkan instrumen-instrumen kebijakan (hukum, peraturan, petunjuk-petunjuk);
- bentuk dan dirikan badan-badan administratif dan prosedur-prosedur untuk mencatat (*to administer*) kegiatan-kegiatan yang berkaitan dengan pelaksanaan kebijakan; dan
- alokasikan sumberdaya (dana, manusia, fasilitas) untuk mendukung badan administratif di atas.

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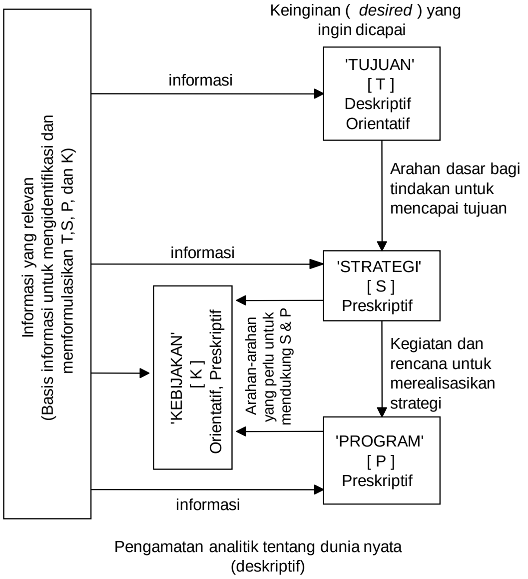
Proses Pendekatan Perumusan Kebijakan



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Kebijakan Publik

[Wibawa, Samodra (2011), Politik Perumusan Kebijakan Publik, Graha Ilmu – Yogyakarta]

Kebijakan publik adalah keputusan suatu “sistem politik” negara, provinsi, kabupaten dan desa, atau RW dan RT untuk/dalam/guna mengelola suatu masalah (persoalan) atau memenuhi suatu kepentingan publik, di mana pelaksanaan keputusan itu membutuhkan dikerahkannya sumberdaya milik semua warga (publik) sistem politik tersebut.
[UUD, Keppres, Permen, Perdes (Peraturan desa), ataupun peraturan RT (Rumah Tangga)]

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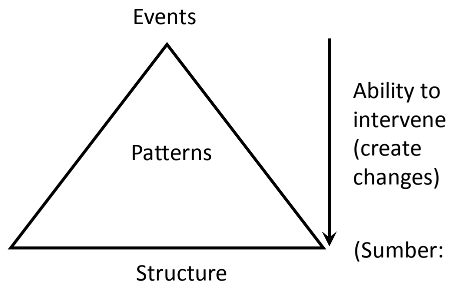
2.6 Logical framework (approach)

- **Fenomena Gunung Es (*The Iceberg Phenomenon*)**

Fenomena gunung es (the iceberg) ini menggambarkan bahwa **sturktur yang sistematis merupakan fondasi terbentuknya suatu pola (*patterns*) dan kejadian (*events*)**. Namun struktur sistematis tersebut sulit untuk dilihat. Sering kali kita hanya melihat kejadiannya saja (puncak dari gunung es), dan hal tersebut menjadi dasar pengambilan keputusan. Padahal kejadian (events) hanyalah merupakan akibat (hasil) suatu struktur. **Sehingga keputusan yang dibuat berdasarkan kejadian (events) tidak akan menyelesaikan suatu persoalan.**



(Sumber: Innovation Associates)

- **Tingkatan Pemahaman (*Levels of understanding*)**

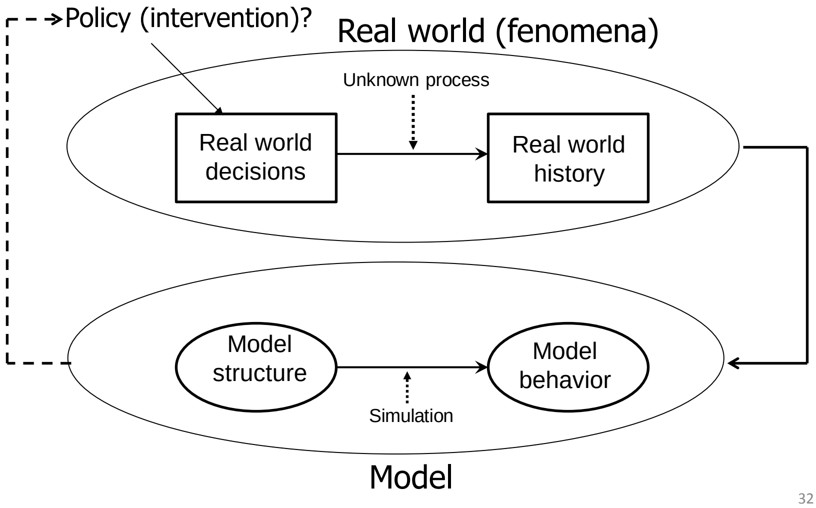
	Tindakan	Waktu	Cara Pemahaman	Pertanyaan yang dapat diajukan
Kejadian	Reaktif	Saat ini	Mengamati kejadian	"Bagaimana cara tercepat untuk merespon kejadian ini?"
Pola	Adaptif		Mengamati pola perubahan kejadian	"Seperti apa kecenderungan dan pola dari kejadian tersebut, apakah terdapat pengulangan?"
Struktur	Perubahan	Masa depan	Causal loop diagrams dan metode systems thinking lainnya	"Struktur seperti apakah yang menyebabkan terbentuknya pola tersebut?"

Sumber : Anderson, Virginia and Lauren Johnson, 1997: *Systems Thinking Basics: From Concepts to Causal Loops*, Pegasus Communications, Inc. MA USA.

2.7 Model Untuk Analisis Kebijakan

Kerangka Pemikiran (Pendekatan)

- **Pemodelan kebijakan (*policy modelling*)**



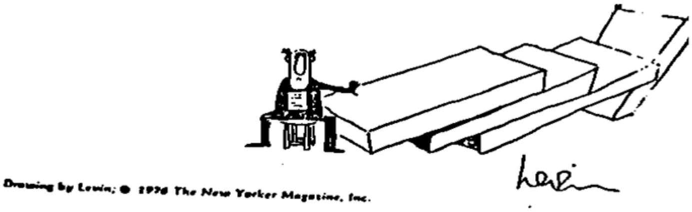
- Model suatu fenomena adalah deskripsi (penjelasan atau gambaran) struktur fenomena tersebut yang dinyatakan (diungkapkan) menggunakan bentuk-bentuk media yang dapat dikomunikasikan.
- *Iconic model* (patung dan maket), *graphical model* (grafik dan gambar), *mathematical model* (persamaan matematik), *tabular model* (tabel input-output/tabel I-O yang menyatakan transaksi antar-industri dalam suatu perekonomian), dan *computer model* (model matematik yang dapat dioperasikan atau disimulasikan).

33

- Setiap manusia secara naluriah menggunakan suatu model untuk membuat suatu keputusan (kebijakan), **model mental**. Model mental tidak lengkap dan kabur. Konsep sistem dan interpretasi terhadap hubungan-hubungan yang ada di dalam sistem, tidak kita miliki secara lengkap. Selanjutnya, model mental sering kali tidak adaptif terhadap konsekuensi-konsekuensi dinamis yang muncul.
- "....... *the human mind is not adapted to interpreting how social systems behave. Our social systems belong to the class called multiloop nonlinear feedback systems*." (Forrester, 1970)

34

Keputusan berdasarkan model mental,



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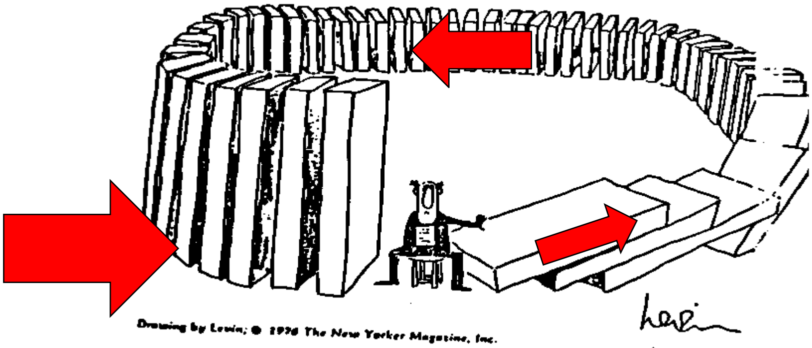
hasil yang tidak diharapkan!



Dibutuhkan suatu model eksplisit ???

36

Prinsip-Prinsip Pemodelan Kebijakan

- Model yang memenuhi syarat dan mampu dijadikan sarana analisis untuk merumuskan (merancang) kebijakan haruslah merupakan suatu wahana untuk menemukan jalan dan cara intervensi yang efektif dalam suatu sistem (fenomena).
- Melalui jalan dan cara intervensi inilah perilaku sistem yang diinginkan dapat diperoleh (perilaku sistem yang tidak diinginkan dapat dihindari).
- Model yang dibentuk untuk tujuan seperti di atas haruslah memenuhi syarat-syarat berikut:

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- karena efek suatu intervensi (kebijakan), dalam bentuk perilaku, merupakan suatu kejadian berikutnya; maka untuk melacaknya, unsur (elemen) waktu perlu ada (*dynamic*);
- mampu mensimulasikan bermacam intervensi dan dapat memunculkan perilaku sistem karena adanya intervensi tersebut;
- memungkinkan mensimulasikan suatu intervensi yang efeknya dapat berbeda secara dramatik: (1) dalam konteks waktu (efek jangka pendek vs jangka panjang, *trade offs in time*), dan (2) dalam konteks sektoral (efek memperbaiki *performance* suatu sektor yang berakibat memperburuk *performance* sektor yang lain, *trade offs between sectors*); disebut dengan istilah *dynamic complexity* (kompleksitas dinamik);
- perilaku sistem di atas dapat merupakan perilaku yang pernah dialami dan teramati (historis) ataupun perilaku yang belum pernah teramati (pernah dialami tetapi tidak teramati atau belum pernah dialami tetapi kemungkinan besar terjadi); dan
- mampu menjelaskan mengapa (*why*) suatu perilaku tertentu (transisi yang sukar misalnya) dapat terjadi.

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Prinsip-Prinsip Membuat Model Dinamik (Sterman, 1981)

- Keadaan yang diinginkan dan keadaan yang terjadi harus secara eksplisit dinyatakan dan dibedakan di dalam model;
- Adanya struktur stok dan aliran dalam kehidupan nyata harus dapat direpresentasikan di dalam model;
- Aliran-aliran yang secara konseptual berlainan cirinya harus secara tegas dibedakan di dalam menanganinya;
- Hanya informasi yang benar-benar tersedia bagi aktor-aktor di dalam sistem yang harus digunakan dalam pemodelan keputusan-keputusannya;
- Struktur kaidah pembuatan keputusan di dalam model haruslah sesuai (cocok) dengan praktek-praktek manajerial; dan
- Model haruslah *robust* dalam kondisi-kondisi ekstrem.

39

Kesahihan (*validity*) Model

- Dalam hubungannya dengan kesahihan (*validity*) model, suatu model haruslah sesuai (cocok) dengan kenyataan empirik (realitas) yang ada.
- Model merupakan hasil dari suatu upaya untuk membuat tiruan kenyataan tersebut (Burger, 1966).
- Upaya pemodelan haruslah memenuhi (sesuai dengan) metode ilmiah. Saeed (1984) telah melukiskan metode ilmiah ini berdasarkan kepada konsep penyangkalan (*refutation*) Popper (1969).
- Metode ini menyaratkan bahwa suatu model haruslah mempunyai banyak titik kontak (*points of contact*) dengan kenyataan (*reality*) dan pembandingan yang berulang kali antara model dengan dunia nyata (*real world*) melalui titik-titik kontak tersebut haruslah membuat model menjadi *robust*.

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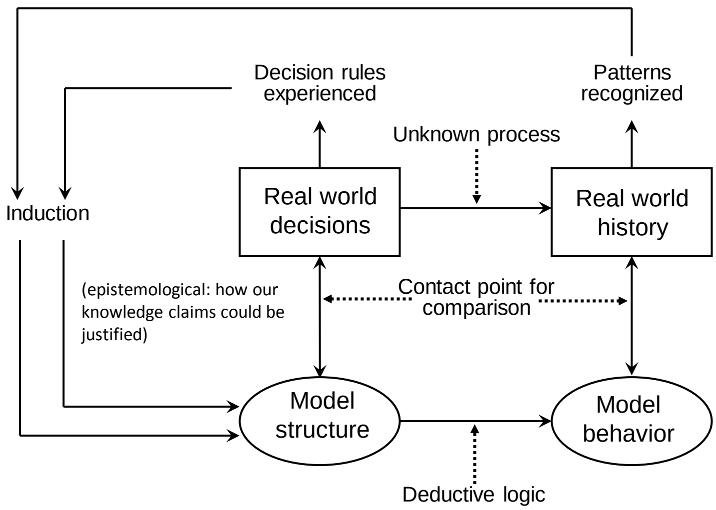
Metode Ilmiah (Saeed, 1984)

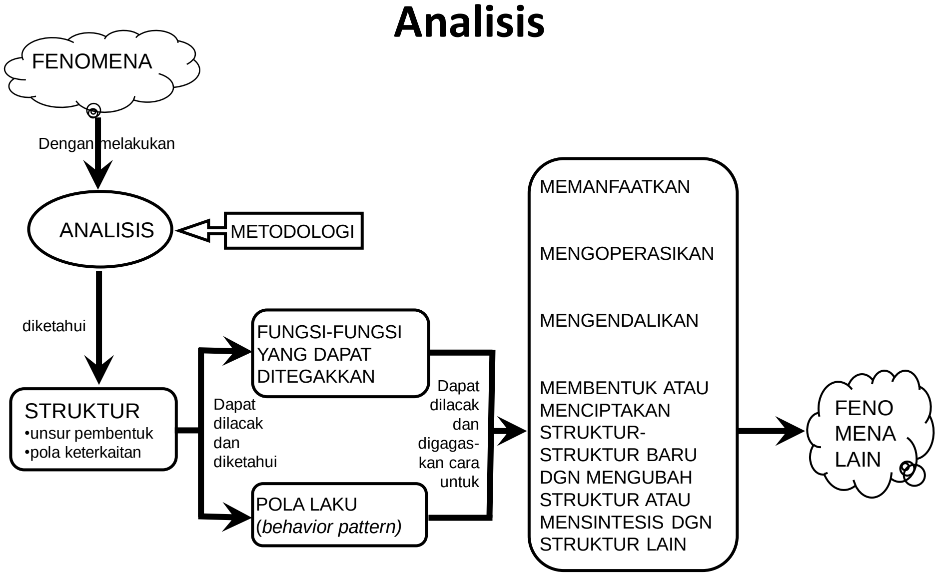


41

Usaha pertama dari penyelidikan ilmiah adalah **upaya untuk memahami bagaimana suatu perilaku dunia nyata muncul dari strukturnya**. Karena tidak ada cara langsung yang dapat digunakan untuk mengetahuinya, suatu model yang mewakili struktur dunia nyata itu harus dikonstruksikan dan perilakunya kemudian diperoleh melalui logika deduktif. **Struktur model ini didapat melalui suatu proses induksi yang didasarkan kepada pengetahuan empirik tentang dunia nyata tersebut**. Pembandingan-pembandingan baik struktur maupun perilaku model dengan struktur dan perilaku dunia nyata akan menegakkan kepercayaan dalam model, dan pada gilirannya kepercayaan itu akan menjadi dasar kesahihan model tersebut (Kemeny, 1959).

42

Analisis



Sumber: Sasmojo (2000)

43

Dua (2) kesukaran:

1) menentukan batas-batas model (model boundary); dan
2) menentukan struktur pembuatan keputusan.

Saeed (1982):

- Pendekatan kotak hitam (*black box approach*), hubungan-hubungan struktural biasanya dicari melalui suatu proses deduksi dari data historis tentang perilaku sistem. Penentuan variabel-variabel yang penting yang harus masuk dalam model ditentukan melalui pengujian-pengujian statistik berdasarkan data historis perilaku sistem tersebut.

  Menurut Black (1982), pendekatan ini sering menimbulkan kesalahan-kesalahan spesifikasi dan identifikasi struktur sistem; karena adanya penyimpangan (bias) data.

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Alternatif lain adalah memodelkan struktur proses pembuatan keputusan aktor-aktor dalam sistem (fenomena) berdasarkan struktur informasi sistem yang di dalamnya terdapat aktor-aktor, sumber-sumber informasi, dan jaringan aliran informasi yang menghubungkan keduanya.

- analogi fisik, sumber informasi merupakan suatu tempat penyimpanan (*storage*/*stock*), sedangkan keputusan merupakan aliran yang masuk ke atau keluar dari tempat penyimpanan itu.
- analogi matematik, sumber informasi dinyatakan sebagai variabel keadaan (*state variable*), sedangkan keputusan merupakan turunan (*derivative*) variabel keadaan tersebut.

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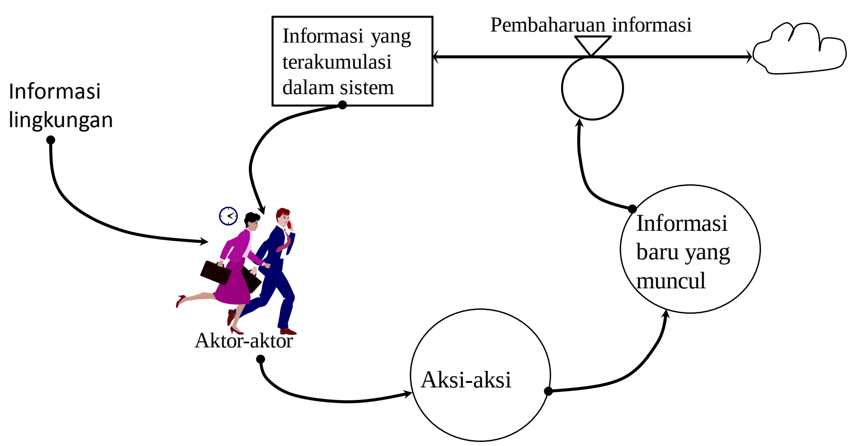
Proses Pembuatan Keputusan



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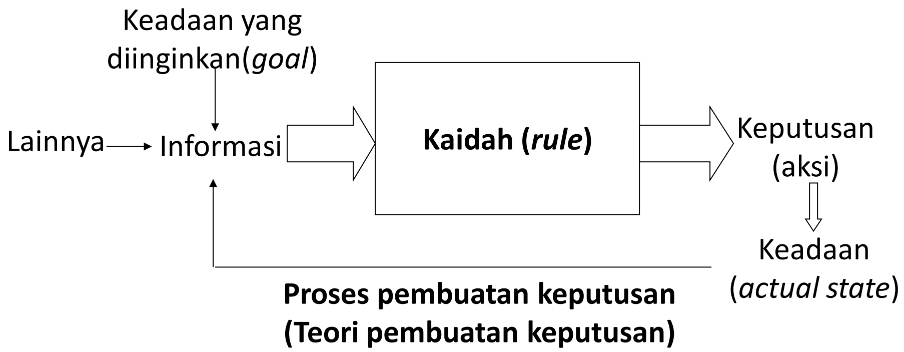
Struktur: (1) pembuatan Keputusan; dan (2) fisik.

Struktur pembuatan keputusan ⇐ **Proses pembuatan keputusan**



Struktur fisik ⇐ **Hukum alam**

47

Struktur fisik dan struktur pembuatan keputusan

Proses pembuatan keputusan menyangkut fenomena-fenomena yang dinamis. Fenomena dinamis ini dimunculkan oleh adanya struktur fisik dan struktur pembuatan keputusan yang saling berinteraksi.

- Struktur fisik dibentuk oleh akumulasi (stok) dan jaringan aliran orang, barang, energi, dan bahan.
- Struktur pembuatan keputusan dibentuk oleh akumulasi (stok) dan jaringan aliran informasi yang digunakan oleh aktor-aktor (manusia) dalam sistem yang menggambarkan kaidah-kaidah proses pembuatan keputusannya.

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Sesi 3
Inventory Simulation Game

Outcomes

Memahami bahwa struktur (fisik dan pengambilan keputusan) menentukan perilaku

3.1 The Inventory Game (1)

- The Inventory Game is one of a number of management simulators developed at MIT's Sloan School of Management for these purposes. The game was developed by Sloan's System Dynamics Group in the early 1960s as part of Jay Forrester's research on industrial dynamics. Its has been played all over the world by thousands of people ranging from high school students to chief executive officers and government officials.
- The game is played by teams of at least four players, often in heated competition, and takes from one to one and a half hours to complete. A debriefing session of roughly equivalent length typically follows to review the results of each team and discuss the lessons involved.

3

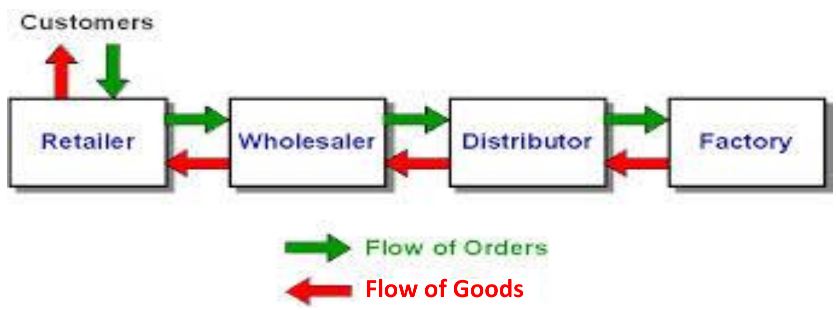
The Inventory Game (2)

- The purpose of the game is to understand the distribution side dynamics of a multi-echelon supply chain used to distribute a single item. The aim is to meet customer demand of goods through the distribution side of a multi-stage supply chain with minimal expenditure on back orders and inventory.
- Players can see each other's inventory but only one player sees actual customer demand. Verbal communication between players is against the rules so feelings of confusion and disappointment are common.
- Players look to one another within their supply chain frantically trying to figure out where things are going wrong. Most of the players feel frustrated because they are not getting the results they want.
- Players wonder whether someone in their team did not understand the game or assume customer demand is following a very erratic pattern as backlogs mount and/or massive inventories accumulate.

4

The Inventory Game (3)

- Suatu ilustrasi yang memperlihatkan bahwa perilaku suatu fenomena (sistem) ditentukan terutama oleh struktur internalnya.



5

- Setiap *policy-maker* mempunyai kebebasan sepenuhnya untuk menentukan *ordering policy* dalam aturan-aturan sebagai berikut ini.
  1. Pengiriman barang harus memenuhi semua order, sepanjang stok barang dalam *inventory* memungkinkan untuk keperluan itu.
  2. Diberlakukan struktur biaya (*cost)*:
     - *Carrying cost* adalah $ 0.50 per unit/period; dan
     - *Out-of stock costs* adalah $ 2.00 per unit/period.

- Agar biaya total minimum, setiap sektor dalam sistem harus berupaya menjaga agar stok dalam *inventory*-nya seminimum mungkin, tetapi cukup untuk dapat memenuhi permintaan yang boleh jadi berubah.

- Bila stok lebih kecil dari kebutuhannya, order harus lebih besar dari tingkat penjualan (pengiriman) rata-rata. Sebaliknya, bila stok lebih besar dari kebutuhannya, order harus lebih kecil dari penjualan (pengiriman) rata-rata.

6

- Setiap *policy-maker* harus dapat menjawab 2 (dua) pertanyaan berikut ini.
  1. Apakah stok yang dimiliki dalam *inventory* cukup untuk memenuhi permintaan? (kenyataan)
  2. Berapa banyak barang yang harus dipesan ke pemasok dan cukup untuk menghindari terjadinya *out-of-stock*? (kebijakan atau *policy*)

3.2 Langkah-Langkah Permainan

Langkah 1

a. Kirim barang dari *inventory* ke sektor sebelah kiri, sesuai dengan permintaan yang tertera di order backlog. Barang diletakkan pada bagian kanan *shipping delay* sektor sebelah kiri. Bila barang yang harus dikirim tidak tersedia simpan secarik kertas sebagai penanda. (Untuk sektor retailer simpan barang terkirim pada *customers decks*, sedangkan sektor *factory* kirim seluruh barang yang berada di *inventory* ke *distributor*).

b. Jika pengiriman sesuai dengan permintaan, buang catatan pesanan dari order backlog. Jika pengiriman tidak sesuai dengan permintaan, catat kekurangan pengiriman dengan menambahkannya pada *order backlog*.

Langkah 2: Catat jumlah *inventory* dan *order backlog* pada formulir yang telah disediakan.

Langkah 3: Pindahkan barang-barang pada bagian kirim *shipping delay* ke *inventory*.

Langkah 4: Pindahkan barang-barang dari sebalah kanan ke sebelah kiri dari *shipping delay* [termasuk memindahkan barang pada sektor *factory*: 4(a) and 4(b)].

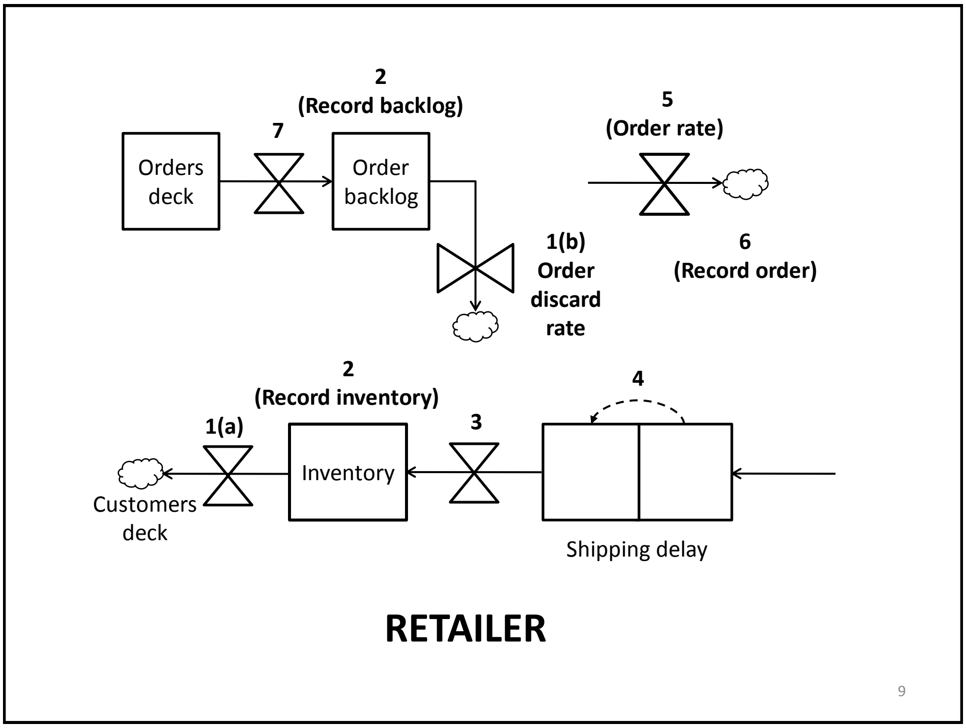
Langkah 5:Tentukan jumlah barang yang akan dipesan, dan simpan pada bagian kiri dari *mail box* di sektor sebelah kanan.

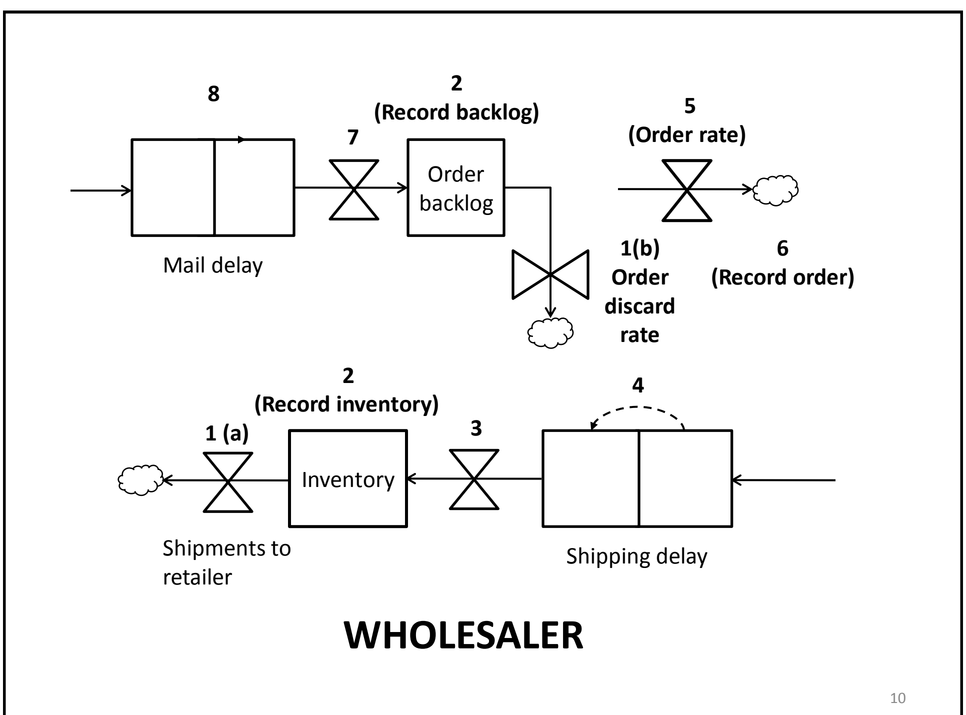
Langkah 6: Catat pesanan pada formulir yang disediakan.

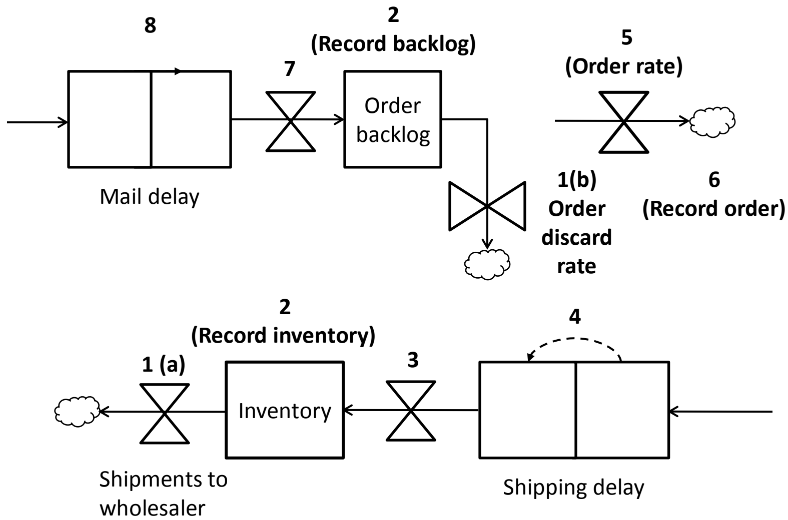
Langkah 7: Ambil pesanan di *mail box*, tambahkan dengan jumlah yang tertera di *order backlog*. (Sektor *retailer* ambil pesanan dari *orders deck*, sedangkan sektor *factory* langsung memproduksi barang sesuai dengan permintaan dan simpan pada bagian atas dari kotak *goods in process*).

Langkah 8: Pindahkan slip order dari kiri delay bagian kanan *delay mail box*.

Langkah 9: Kembali ke langkah pertama.

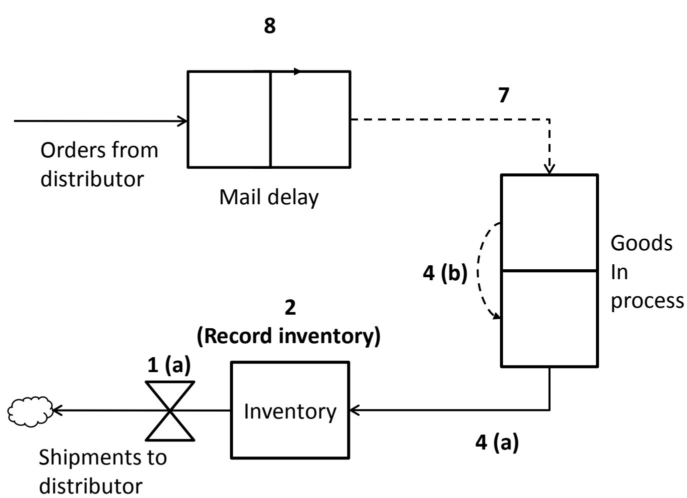

2
(Record backlog)
7
Orders deck
Order backlog
5
(Order rate)
1(b)
Order discard rate
6
(Record order)
2
(Record inventory)
4
1(a)
3
Inventory
Customers deck
Shipping delay
RETAILER
9


8
2
(Record backlog)
5
(Order rate)
7
Order backlog
Mail delay
1(b)
Order discard rate
6
(Record order)
2
(Record inventory)
4
1 (a)
3
Inventory
Shipments to retailer
Shipping delay
WHOLESALER
10



DISTRIBUTOR

11



FACTORY

12

Sesi 4
Systems Thinking
&
System Dynamics

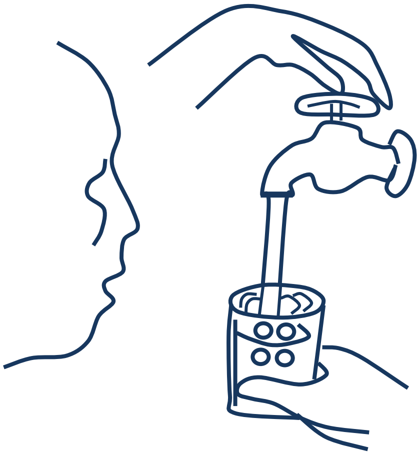
Outcomes

Pada akhir sesi ini, peserta dapat:

- mengenali hubungan sebab akibat;
- memahami metodologi pemodelan *system dynamics.*

Pengisian air ke dalam gelas sampai penuh

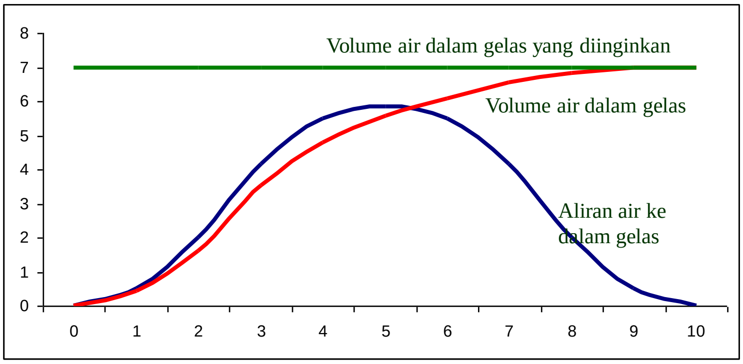
(Sumber: “The Fifth Discipline”, Peter M. Senge, 1990)



3

Kemungkinan Perilaku

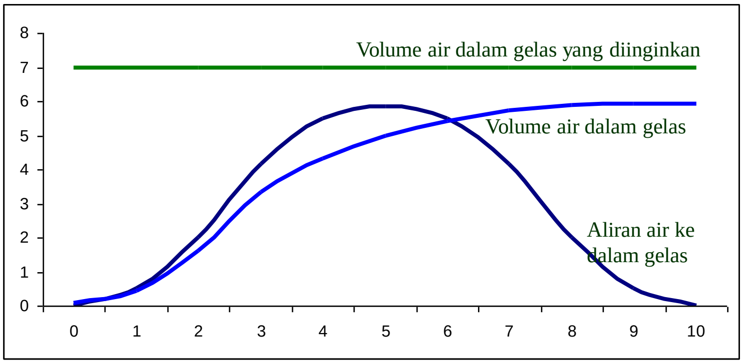
A. Jika sumber air mencukupi



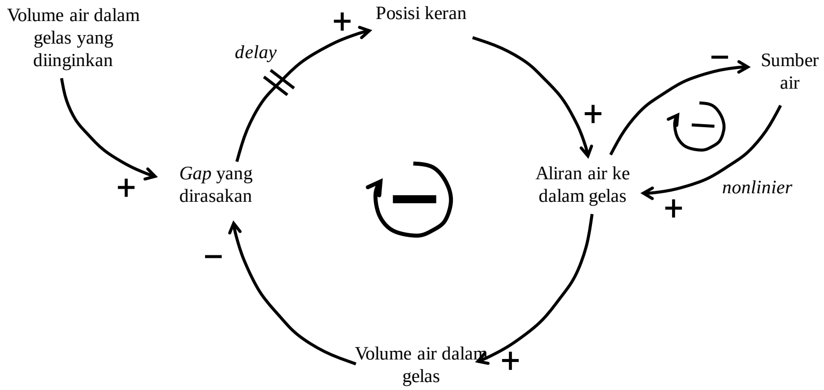
4

Kemungkinan Perilaku

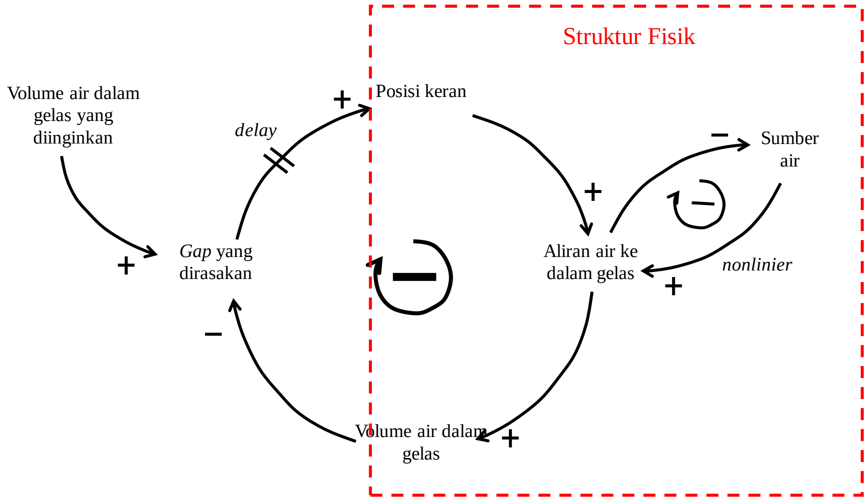
B. Jika sumber air terbatas



Struktur Fenomena



Struktur Fenomena



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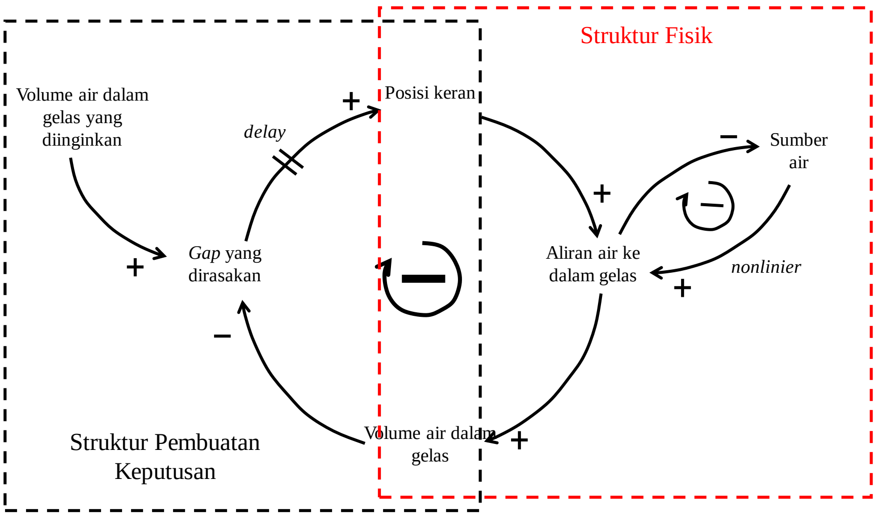
Struktur Fenomena



8

Metodologi Pemodelan

Systems Thinking dan *System Dynamics*

Struktur ⇨ Perilaku

- **unsur pembentuk**
- **pola keterkaitan antar unsur :**

(1) *feedback* (*causal loop*)
(2) *stock* (*level*) dan *flow* (*rate*)
(3) *delay*
(4) *nonlinearity*

(ontological: *the ways reality itself could be*)

Pendekatan Struktural
Systems Thinking
System Dynamics

9

4.1 System Dynamics Methodology

10

A. Source:
System Dynamics Home Page.htm

System Dynamics Methodology

- System dynamics is a methodology for studying and managing complex feedback systems, such as one finds in business and other social systems.
- In fact it has been used to address practically every sort of feedback system.
- While the word system has been applied to all sorts of situations, feedback is differentiating descriptor here.
- Feedback refers to the situation of X affecting Y and Y in turn affecting X perhaps through a chain of causes and effects.
- One cannot study the link between X and Y and, independently, the link between Y and X and predict how the system behave. Only the study of the whole system as a feedback system will lead to correct results.

What is the relationship of Systems Thinking to System Dynamics?

- Systems thinking looks at the same type of problems from the same perspective as does system dynamics.
- The two techniques share the same causal loop mapping techniques.
- System dynamics takes the additional step of constructing computer simulation models to confirm that the structure hypothesized can lead to the observed behavior and to test the effects of alternative policies on key variables over time.

13

B. Source:

Richardson, George P. & Alexander L. Pugh III (1981), *Introduction to System Dynamics Modeling with Dynamo*, MIT Press/Wright-Allen series in system dynamics.

14

Overview of the System Dynamics Approach

- The system dynamics approach to complex problems focuses on feedback processes. It takes the philosophical position that feedback structures are responsible for the changes we experience over time. The premise is that ***dynamic behavior is consequence of system structure*** and will become meaningful and powerful. At this point, it may be treated as a postulate, or perhaps as a conjecture yet to be demonstrated.
- As both a cause and a consequence of the feedback perspective, the system dynamics approach tends to look ***within*** a system for the sources of its problem behavior. Problems are not seen as being caused by external agents outside the system.

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- Inventories are not assumed to oscillate merely because consumers periodically vary their orders. A ball does not bounce merely because someone drops it. A pendulum does not oscillate merely because it was displaced from the vertical. The system dynamicist prefers to take the point of view that these systems behave as they do for reasons ***internal*** to each system. A ball bounces and a pendulum oscillates because there is something about their internal structure that gives them the tendency to bounce or oscillate.
- In practice, this internal point of view results in models of feedback system that bring external agents inside the system. Customers orders become endogenous to a production system, part of the feedback structure of the system. Orders affect production; production affects orders. Part and parcel with the notion of feedback, the endogenous point of view helps to characterize the system dynamics approach.

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- The are roughly seven stages in approaching a problem from the system dynamics perspective:

  (1) problem identification and definition;
  (2) system conceptualization;
  (3) model formulation;
  (4) analysis of model behavior;
  (5) model evaluation;
  (6) policy analysis; and
  (7) model use or implementation.

- The process begins and ends with understandings of a system and its problems, so it forms a loop, not a linear progression. Figure 4.1 shows these stages and the likely progression through them, together with some arrows that represent the cycling, iterative nature of the process. At a number of stages along the way one's understanding of the system and the problem are enhanced by the modeling process, and that increased understanding further aids the modeling effort.
- Figure 4.1 shows that final policy recommendations from a system dynamics study come not merely from manipulations with the formal model but also from the additional understandings one gains about the real system by iterations at a number of stages in the modeling process. Done properly, a system dynamics study should produce policy recommendations that can be presented, explained, and defended without resorting to the formal model. The model is a means to an end, and that end is understanding.

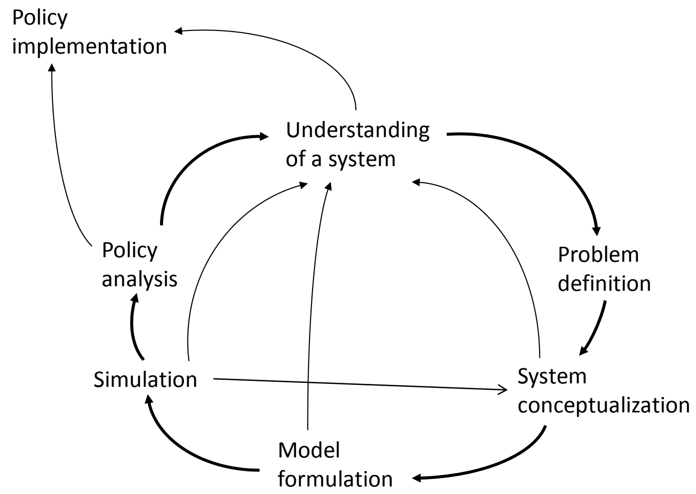


Figure 4.1 Overview of the system dynamics modeling approach

Guidelines for Causal-loop Diagrams

The apparent simplicity of causal-loop diagram is deceptive. It is easy for would-be modelers to go astray with them. The following suggestion may help to prevent the more common difficulties.

1. Think of variables in causal-loop diagrams as quantities that can rise or fall, grow or decline, or be up or down. But do not worry if you can not readily think of existing measures of them. Corollaries:
   a) Use nouns or noun phrases in causal-loop diagrams, not verbs. The actions are in the arrows (see Figure 4.2).
   b) be sure it is clear what is means to say a variable increases or decreases. (Not attitude toward crime", but "tolerance for crime".)
   c) Do not use causal-links to mean "and then….."

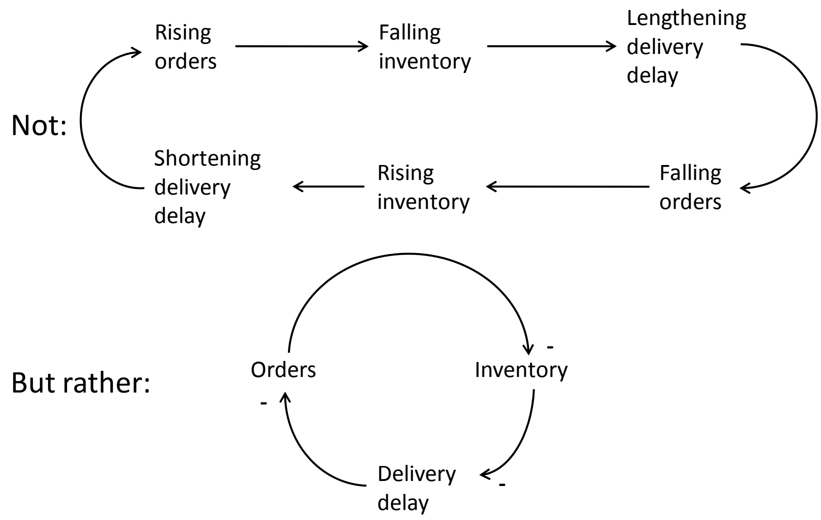


Figure 4.2 Loops illustrating that the action in causal-loop diagram is best left to the arrows

2. Identify the units of the variables in causal-loop diagram, if possible. If necessary, invent some: some psychological variables might have to be thought of in “stress units” or “pressure units”, for example. Units help to focus the meaning of a phrase in a diagram.
3. Phrase most variables positively (“emotional state” rather than “depression”. It is hard to understand what it to say “depression increases” when testing link and loop polarities.

4. If a link needs explanation, disaggregate it – make it a sequence of links. For example, a study of heroin-related crime claimed a positive link from heroin price to heroin-related crime. The link is clear if disaggregated as in Figure 4.3 into the sequence of positive links from heroin price to money required per addict, frequency of crimes per addict, and finally heroin-related crime. Some might feel a high price deters addict and so lowers the number of addicts as it well might, but that is another link (see Figure 4.3).
5. Beware of interpreting open loops as feedback loops. Figure 4.3, for example, does not show a feedback loop.

23

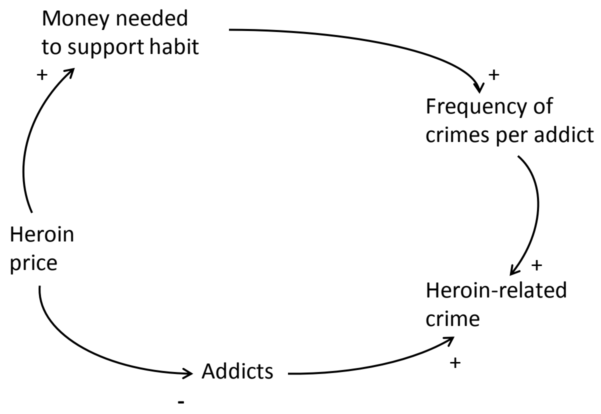


Figure 4.3 Links relating heroin price and crime

24

4.2 Systems Thinking

25

Systems Thinking

(Anderson, Virginia and Lauren Johnson, 1997: *Systems Thinking Basics: From Concepts to Causal Loops*, Pegasus Communications, Inc. MA USA)

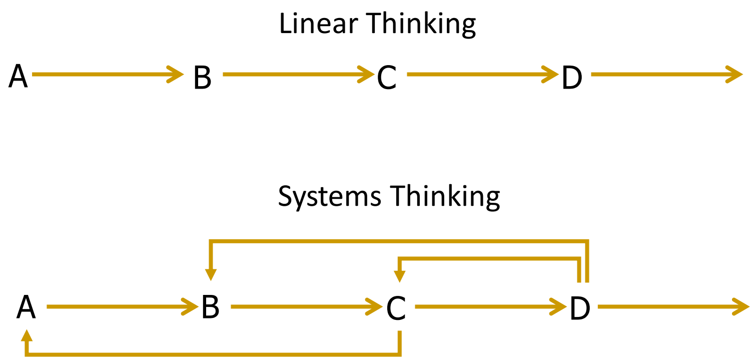
In general, systems thinking is characterized by these principles:

(1) thinking of the "big picture";
(2) balancing short-term and long-term perspective;
(3) recognizing the dynamic, complex, and interdependent nature of system;
(4) taking into account both measurable and non measurable factors; and
(5) remembering that we are all part of the systems in which we function, and that we each influence those systems even as we are being influenced by them.

26

Linear Thinking vs Systems Thinking

(Kim, Daniel H., 1997: *Introduction to Systems Thinking*, Pegasus Communications, Inc. MA USA)



27

Prinsip **systems thinking** (Senge, 1990) :

- To observe the interdependent relationship (influenced and influence or feedback or interdependent), not a direct cause-effect relationships;
- To observe the processes of change (the process continues, ongoing processes), not just portraits.

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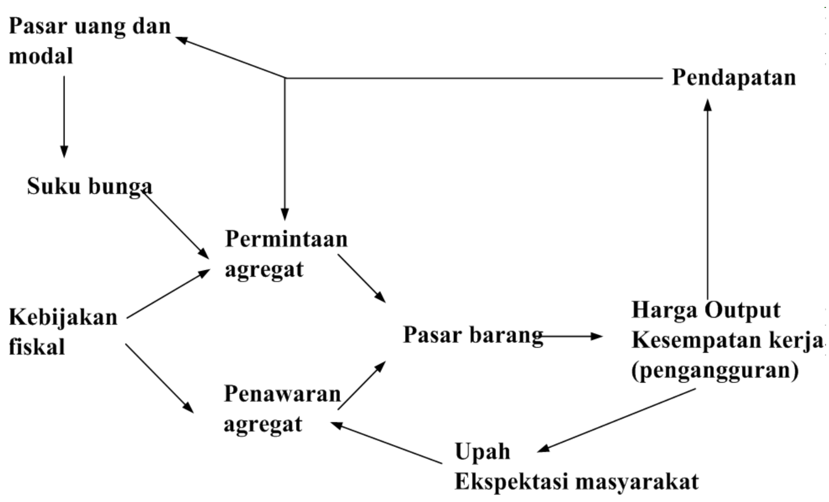
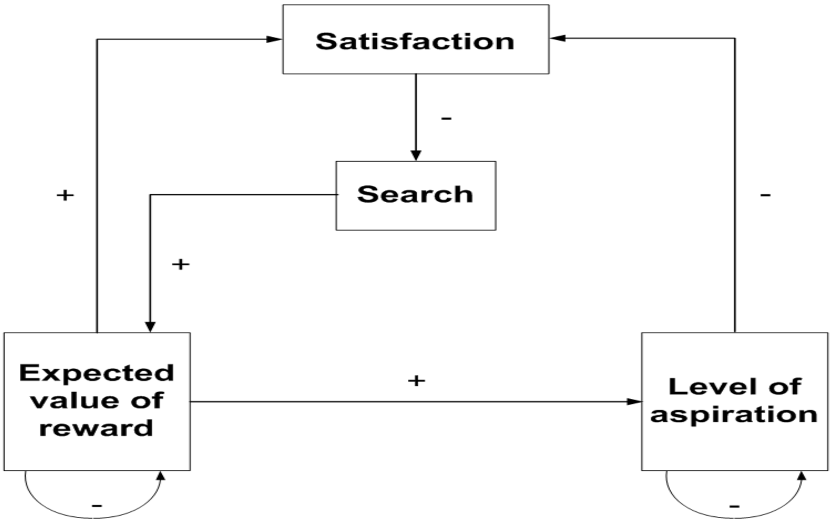
- Model yang dibangun melalui suatu analisis struktural (*structural analysis*), berdasarkan pendekatan *systems thinking*, dimungkinkan untuk mempunyai titik kontak yang banyak.
- Dalam paradigma *systems thinking*, struktur fisik ataupun struktur pengambilan keputusan diyakini dibangun oleh unsur-unsur yang saling-bergantung (*interdependent*) dan membentuk suatu lingkar tertutup (*closed-loop* atau *feedback loop*).
- Hubungan unsur-unsur yang saling bergantung itu merupakan hubungan sebab-akibat umpan-balik dan bukan hubungan sebab-akibat searah (Senge, 1990). Lingkar umpan-balik ini merupakan blok pembangun (*building block*) model yang utama.

29



PENDEKATAN DASAR TERHADAP MAKROEKONOMI

30



General model of adaptive motivated behavior
Source: March and Simon (1958, p. 49).

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4.3 Persediaan Dan Aliran

(Teori makroekonomi – edisi ke 5 oleh N. Gegori Mankiw, Harvard University – Penerbit Erlangga 2003, hal 18)

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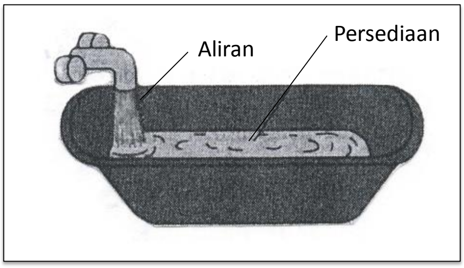
- Banyak variabel ekonomi mengukur jumlah sesuatu– jumlah uang, jumlah barang, dan seterusnya. Para ahli ekonomi membedakan antara dua jenis variabel jumlah: persediaan *(stocks)* dan aliran *(flows)*. ***Persediaan (stocks)*** adalah jumlah yang diukur pada titik waktu tertentu, sedangkan ***aliran (flow)*** adalah jumlah yang diukur per unit waktu.
- Bak mandi, ditunjukkan pada Gambar 4.3.1, adalah contoh klasik yang digunakan untuk menggambarkan persediaan dan aliran. Jumlah air di dalam bak adalah persediaan: yaitu jumlah air di bak mandi pada titik waktu tertentu . Jumlah air yang keluar dari kran adalah aliran: yaitu jumlah air yang sedang ditambahkan ke bak per unit waktu. Catat bahwa kita mengukur persediaan dan aliran dalam unit yang berbeda. Kita berkata bahwa bak mandi berisi 50 *galon* air, tetapi air yang keluar dari kran adalah 5 *galon per menit.*

Gambar 4.3.1



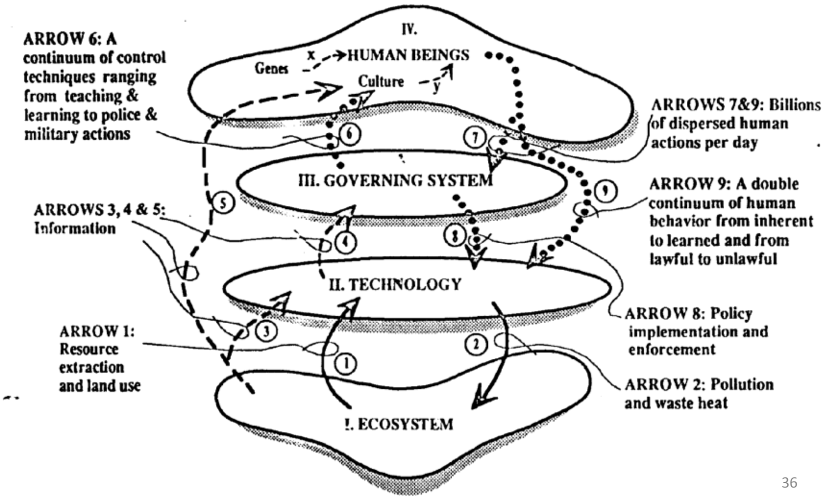
Persediaan dan Aliran

Jumlah air di bak mandi adalah persediaan: jumlahnya diukur pada titik waktu tertentu. Jumlah air yang keluar dari kran adalah aliran: jumlahnya diukur per unit waktu.

- GDP mungkin adalah variabel aliran paling penting dalam perekonomian: GDP menyatakan berapa banyak uang yang mengalir mengelilingi aliran sirkuler perekonomian per unit waktu. Ketika Anda mendengar seseorang berkata GDP AS adalah $10 triliun, Anda seharusnya mengerti, ini berarti bahwa GDP adalah $10 triliun *per tahun.* (Demikian pula, kita bisa mengatakan bahwa GDP AS adalah $17.000 per detik.)
- Persediaan dan aliran seringkali berkaitan. Dalam contoh bak mandi, hubungan ini jelas. Persediaan air di bak menunjukkan akumulasi dari aliran yang keluar dari kran, dan aliran air menunjukkan perubahan dalam persediaan. Ketika membangun teori untuk menjelaskan variabel-variabel ekonomi, seringkali berguna untuk menentukan apakah variabel-variabel itu adalah persediaan atau aliran dan apakah ada hubungan di antara keduanya.
- Inilah beberapa contoh persediaan dan aliran yang akan kita pelajari dalam bab-bab berikutnya:
  - Kekayaan seseorang adalah persediaan; pendapatan dan pengeluarannya adalah aliran.
  - Jumlah orang yang menganggur adalah persediaan; jumlah orang yang kehilangan pekerjaan mereka adalah aliran.
  - Jumlah modal dalam perekonomian adalah persediaan; jumlah investasi adalah aliran.
  - Utang pemerintah adalah persediaan; defisit anggaran pemerintah adalah aliran.

4.4 FOUR-SECTOR FEEDBACK MODEL OF HUMAN LIFE-SUPPORT SYSTEM

(Duncan, 1991)



- SECTOR I. ECOSYSTEM
  This is the earth's natural environment comprising all land, water, air, energy & material resources, plants and animals.
- SECTOR II. TECHNOLOGY
  This is the human industrial and consumption system comprising all technology used for agriculture, physical production, transportation, et cetera.
- SECTOR III. GOVERNING SYSTEM
  This is the social regulatory system comprising all human institutions and processes: economic, financial, governmental, judicial, military, educational, religious, et cetera.
- SECTOR IV. HUMAN BEINGS
  This is the global population comprising billions of individual human beings. Genes process hereditary information. Brains process cultural information.

- SOLID ARROW : Materials & energy flow
- DASHED ARROW : Information flow
- DOTTED ARROW : Human behavior or institutional action
- ARROW x : Genetic Influence
- ARROW y : Cultural Influence

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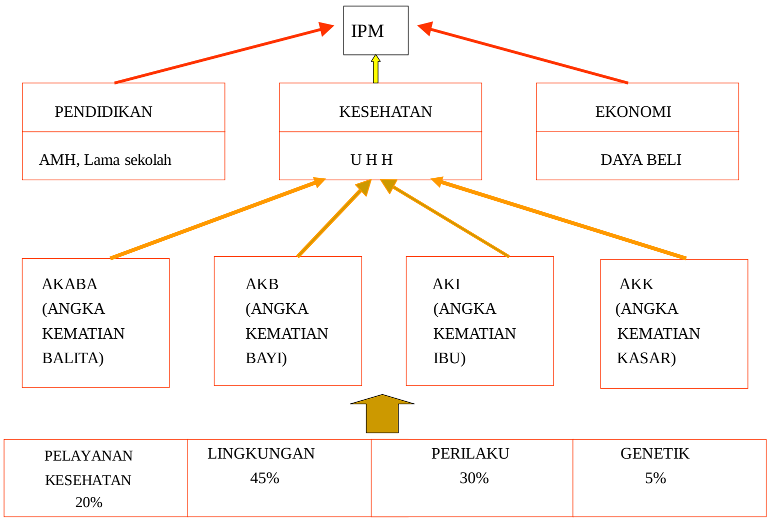
4.5 Indeks Pembangunan Manusia (IPM)



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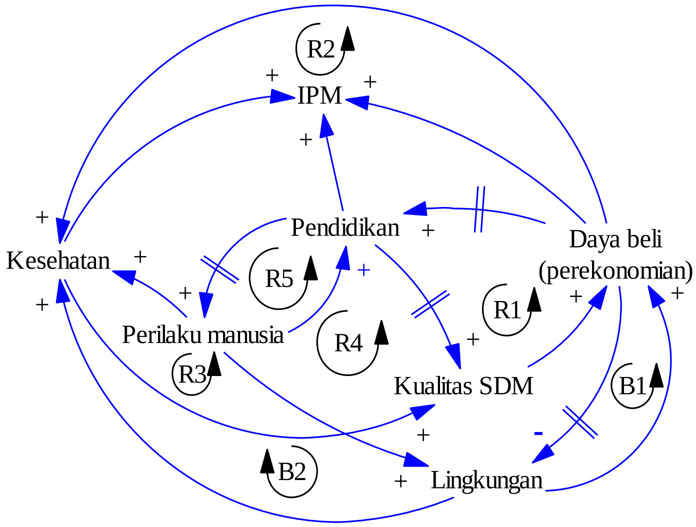
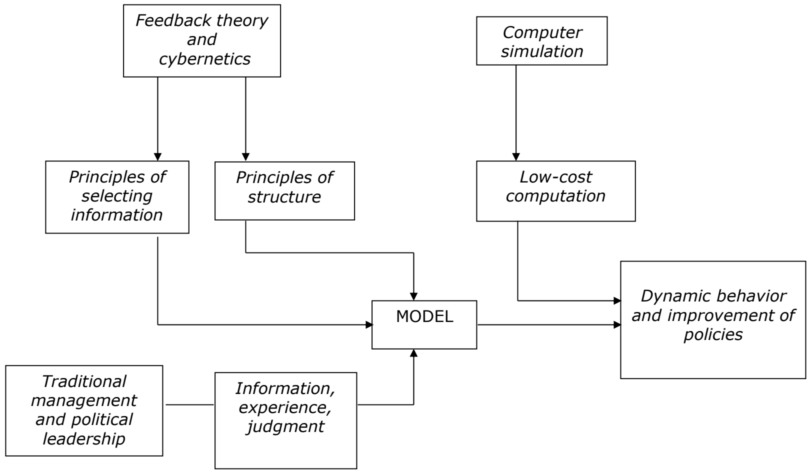


Causal loop diagram IPM

4.6 Peran beberapa bidang (*field*) dalam metodologi *system dynamics*



Manajemen tradisional (*traditional management*) beserta pengalamannya tentang dunia nyata merupakan sumber informasi yang mendasar untuk membuat struktur model suatu sistem. Karena semua informasi yang terkandung dalam suatu model mental tidak dapat dimasukkan ke dalam suatu model eksplisit, informasi itu perlu dipilih berdasarkan tingkat kepentingannya dalam fenomena atau gejala yang dianalisis.
Teori umpan-balik beserta sibernetika (*feedback theory* dan *cybernetics*) memberikan prinsip-prinsip untuk memilih informasi yang relevan dan menyingkirkan informasi yang tidak mempunyai hubungan dengan dinamika-dinamika persoalan.

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Sekali suatu model dapat diformulasikan, perilaku dinamisnya dapat dipelajari menggunakan simulasi dengan komputer. Simulasi ini sangat membantu dalam upaya kita untuk membandingkan struktur model beserta perilakunya dengan struktur dan perilaku sistem yang sebenarnya, yang pada gilirannya akan meningkatkan keyakinan kita terhadap kemampuan model di dalam mendeskripsikan sistem yang diwakilinya. Keyakinan ini menjadi dasar bagi kesahihan model. Bila kesahihan model telah dapat dicapai, simulasi selanjutnya dapat digunakan untuk merancang kebijakan-kebijakan yang efektif.

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Pada mulanya Forrester menerapkan metodologi *system dynamics* untuk memecahkan persoalan-persoalan yang terdapat dalam industri (perusahaan). Model-model *system dynamics* pertama kali ditujukan kepada permasalahan manajemen yang umum seperti fluktuasi inventori, ketidakstabilan tenaga kerja, dan penurunan pangsa pasar suatu perusahaan (lihat Forrester 1961). Perkembangannya terus meningkat semenjak pemanfaatannya dalam persoalan sistem-sistem sosial yang sangat beragam, yang antara lain dapat disimak dari tulisan Forrester dan Hamilton (Forrester 1969, Hamilton et al. 1969, dan Forrester 1971).

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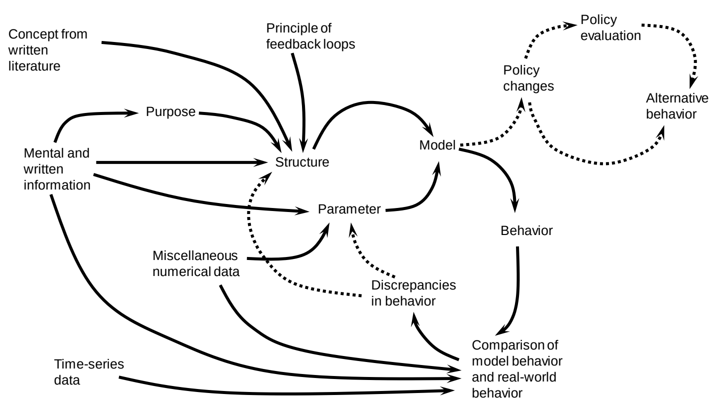
4.7 Perancangan suatu model *System Dynamics*



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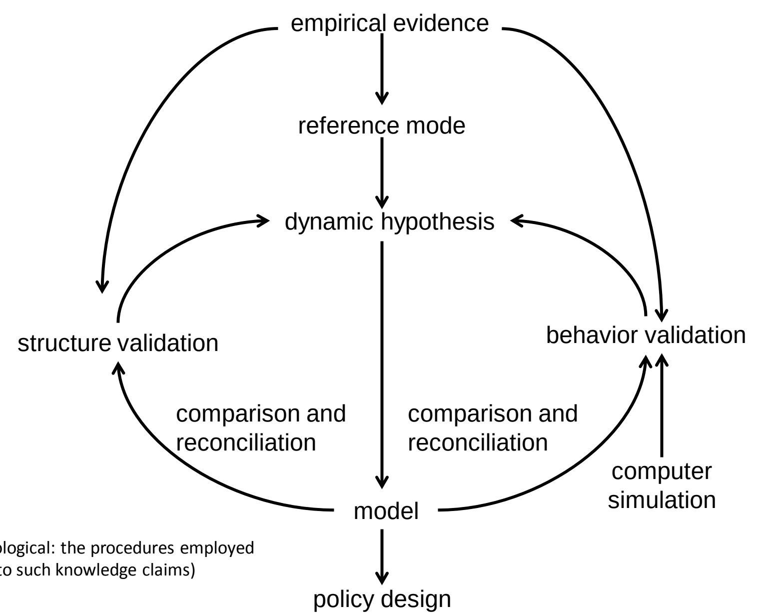

(methodological: the procedures employed to arrive to such knowledge claims)

4.8 Tests for Building Confidence in System Dynamics Model

(Forrester and Senge 1980, Richardson and Pugh 1981):

❑ Test of Model Structure

1. ***Structure Verification***
   (Is the model structure consistent with relevant descriptive knowledge of the system?)
2. ***Parameter Verification***
   (Are the parameters consistent with relevant descriptive [and numerical, when available] knowledge of system?)
3. ***Extreme Conditions***
   (Does each equation make sense even when its inputs take on extreme values?)
4. ***Structure Boundary Adequacy***
   (Are the important concepts for addressing the problem endogenous of the model?)
5. ***Dimensional Consistency***
   (Is each equation dimensionally consistent without the use of parameters having no real-world counterpart?)

Test of Model Behavior

1. ***Behavior Reproduction***
   (Does the model endogenously generate the symptoms of the problem, behavior modes, phasing, frequencies, and other characteristics of the behavior of the real system?)
2. ***Behavior Anomaly***
   (Does anomalous behavior arise if an assumption of the model is deleted?)
3. ***Family Member***
   (Can the model reproduce the behavior of other examples of the systems in the same class as the model?)
4. ***Surprise Behavior***
   (Does the model point to the existence of a previously unrecognized mode of behavior in the real system?)

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5. ***Extreme Policy***
   (Does the model behave properly when subjected to extreme policies or test inputs?)
6. ***Behavior Boundary Adequacy***
   (Is the behavior of the model sensitive to the addition or alteration of structure to represent plausible alternative theories?)
7. ***Behavior Sensitivity***
   (Is the behavior of the model sensitive to plausible variations in parameters?)
8. ***Statistic Character***
   (Does the output of the model have the same statistical character as the “output” of the real system?)

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- **Test of Policy Implications**

1. ***System Improvement***
   (Is the performance of the real system improved through use of the model?)
2. ***Behavior Prediction***
   (Does the model correctly describe the results of a new policy?)
3. ***Policy Boundary Adequacy***
   (Are the policy recommendations sensitive to the addition or alteration of structure to represent plausible alternative theories?)
4. ***Policy Sensitivity***
   (Are the policy recommendations sensitive to plausible variations in parameters?)

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4.9 Archetypal Structures (System Archetypes) in System Dynamics

(E. F. Wolstenholme: "Towards the definition and use of a core set of archetypal structures in system dynamics" in System Dynamics Review Vol. 19, No. 1, (Spring 2003): 7-26)

System archetypes are introduced as a formal and free-standing way of classifying structures responsible for generic patterns of behavior over time, particularly counter-intuitive behavior.

Such "structures" consist of **intended actions** and **unintended reactions** and recognize **delays** in reaction time.

System archetypes have an important and multiple role to play in systemic thinking.

System archetypes are first and foremost a communications device to share dynamic insights.

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4.10 System Dynamics for policy design in terms of System Archetypes

- ***System dynamics* consists of five (5) components of system "structure":**
  (1) processes, created using stock-flow chains;
  (2) information feedback;
  (3) policy;
  (4) time delays; and
  (5) boundaries.

(E. F. Wolstenholme: "Using generic system archetypes to support thinking and modeling" in *System Dynamics Review Vol. 20, No. 4, (Winter 2004): 341-356)*

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- **Boundaries in system archetypes**

1. Organisations are by definition very bounded entities in terms of disciplines, functions, accounting, power, and culture (the existence of boundaries as basic elements of organisational structure).
2. Boundaries are the one facet of organisations that are perhaps changed more often than any other.
3. They are often changed in isolation from strategy and process on the whim of a new top team or political party, usually to impose their own people.

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4. Different types of boundaries:

a) they may be between the organisation and its environment;
b) they may be very physical accounting boundaries between different functional parts of the same organisation; and
c) they may be between management teams or indeed mental barriers within individuals.

5. The existence and importance of boundaries within organisations, as a determinant of organisational evolution over time, has to be represented in system archetypes.

6. The superimposition of organisational boundaries on system archetypes helps explain why systemic management is so difficult.

a) Organisational boundaries highlight dramatically that action and reaction are often instigated from separate sources within organisation.
b) Organisational boundaries imply that reactions are often “hidden” from the “view” of the source responsible for the actions.
c) Organisational boundaries force system actors to actively confront the need to share information and collaborate to achieve whole system objectives.

4.11 The characteristics of a totally generic two-loop system archetype

- **The basic structure of a totally generic two-loop system archetype (Figure 4.11.1)**

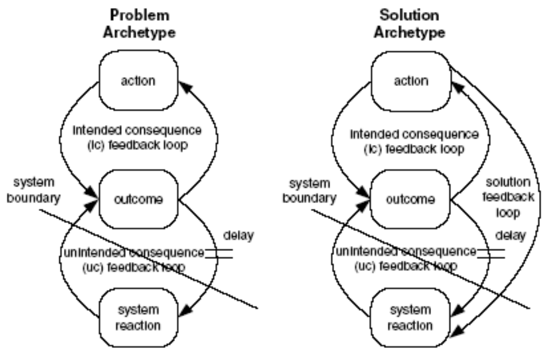

Figure 4.11.1 The basic structure of a totally generic two-loop system archetype

- **The characteristics of the archetype:**

1. It is composed of an *intended consequence* (*ic*) *feedback loop* which results from an *action* initiated in *one sector of an organisation* with an intended consequence over time in mind.
2. It contains an *unintended consequence* (*uc*) f*eedback loop*, which results from a *reaction within another sector of the organisation or outside*.
3. There is a *delay* before the unintended consequence manifests itself.
4. There is an *organisational boundary* that "hides" the unintended consequence from the "view" of those instigating the intended consequences.
5. That for every "*problem*" archetype, there is a "*solution*" archetype.

- **Problem archetypes:**

1. A *problem archetype* is one whose net behavior over time is far from that intended by the people creating the ic loop.
2. It should be noted that reactions can arise from the same system participants who instigate the original actions (perhaps due to impatience with the time taken for their original actions to have effect).
3. The reaction may also arise from natural causes.
4. It is more often the case that the reaction comes from other individuals, groups or sectors of the same organisation or from external sources.
5. Almost every action will be countered by a reaction in some other part of the system and hence no one strategy will ever dominate (systems are dynamic, self-organising, and adaptive).

- **Solution archetypes:**

1. The closed-loop *solution archetype* is to minimise any side effects (a generic two-loop solution archetype is also shown on Figure 4.11.1).
2. The key to identifying solution archetypes lies in understanding both the magnitude of the **delay** and the nature of the **organisational boundary** present.
3. Solutions require that system actors, when instigating a new action, should attempt to remove or make more transparent the organisational boundary masking the side effect.
4. Collaborative effort on both sides of the boundary can then be directed at introducing new “solution” feedback loops to counter or unblock the uc loop in parallel with activating the ic loop.
5. The result is that the intended action should be much more robust and capable of achieving its purpose.

4.12 Four generic problem/solution archetypes

- Initiating actions for change can be condensed down to one of two kinds.
- These are actions that attempt to improve the *achievement* of an organisation by initiating *reinforcing feedback* effects and those that attempt to *control* an organisation by introducing *balancing feedback* effects.
- Reactions can also be condensed to one of the same two kinds.
- There are only four totally generic two-loop archetypes possible, arising from the four ways of ordering the two basic types of feedback loops (balancing and reinforcing):

(1) *Underachievement*, intended achievement fails to be realised (Figure 4.12.1).

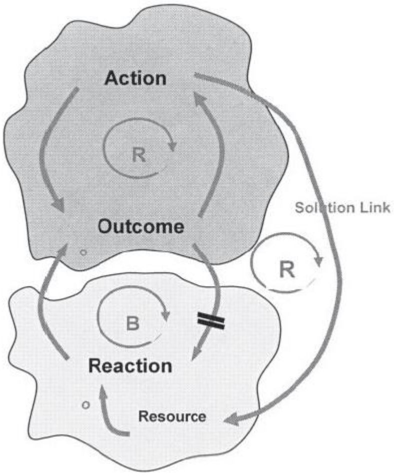

Figure 4.12.1 *Underachievement* archetype

(2) *Out of control*, intended control fails to be realised (Figure 4.12.2).

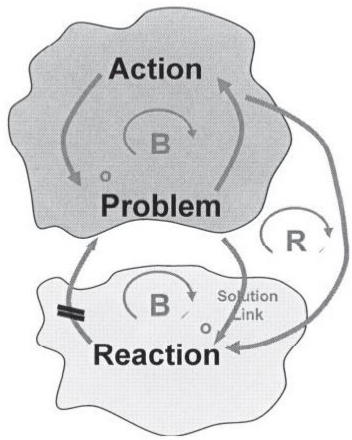

Figure 4.12.2 *Out of control* archetype

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(3) *Relative achievement*, achievement is only gained at the expense of another (Figure 4.12.3).

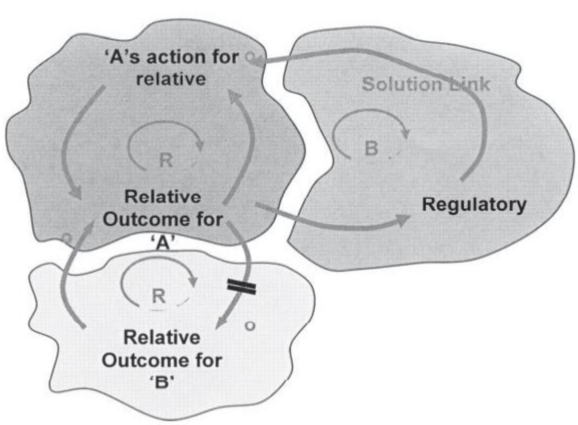

Figure 4.12.3 *Relative achievement* archetype

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(4) *Relative control*, control is only gained at the expense of others (Figure 4.12.4).

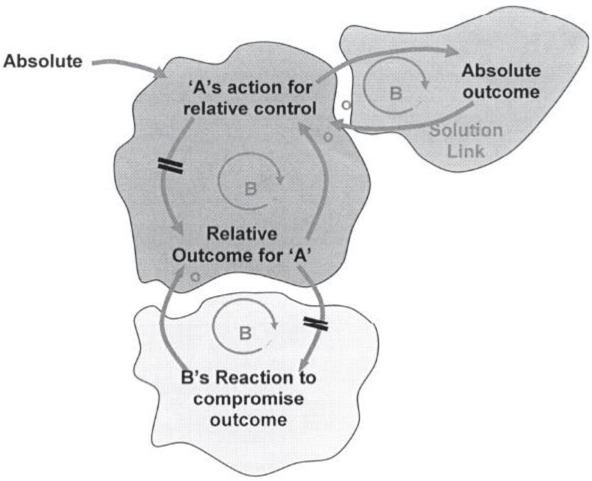
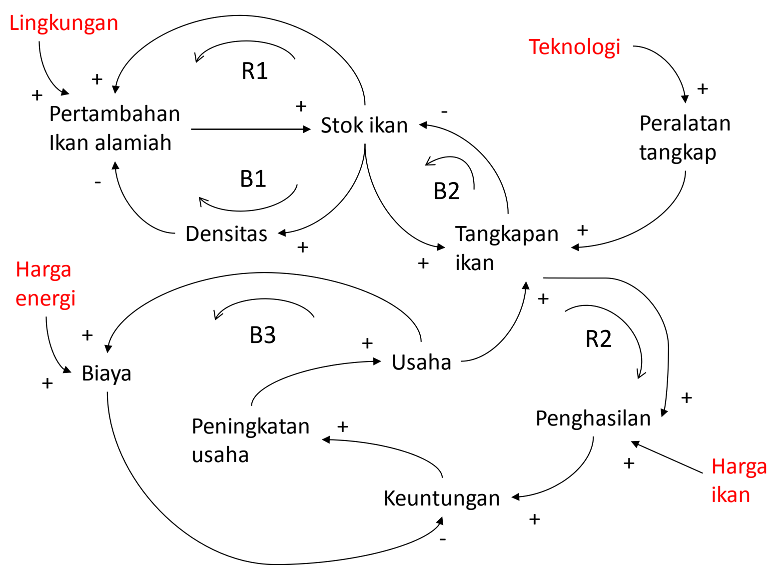


Figure 4.12.4 *Relative control* archetype

4.13 Mapping existing semi-generic problem archetypes onto four generic problem archetypes

- Semi-generic archetypes that can be mapped onto the generic *underachievement* archetype (Figure 4.12.1) are *Limits to success*, *Tragedy of the commons*, and *Growth and underinvestment*.
- Semi-generic archetypes that can be mapped onto the generic *out of control* archetype (Figure 4.12.2) are *Fixes that fail*, *Shifting the burden*, and *Accidental adversaries*.
- The semi-generic archetype which can be mapped onto the generic *relative achievement* archetype (Figure 4.12.3) is *Success to the successful*.
- The semi-generic archetypes which can be mapped onto the generic *relative control* archetype (Figure 4.12.4) are *Escalation* and *Drifting goals*.

4.14 Problem Sederhana: Tangkapan Ikan



Struktur fenomena penangkapan ikan

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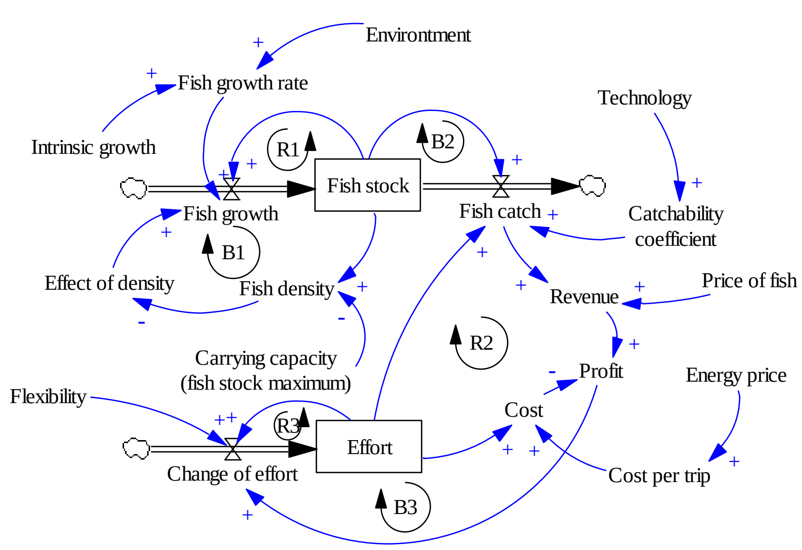

Fish stock dynamics

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Sesi 5
Feedback Loop, Delay, dan *Nonlinearity*

1

Outcomes

Pada akhir sesi peserta dapat:

- mengkonsepsualisasikan sebuah fenomena menggunakan *causal loop diagram* (CLD);
- memahami konsep *feedback loops* (positif dan negatif);
- memahami konsep *stock, flow, delay*, dan *nonlinearity;* dan
- menjelaskan teori-teori yang mendasari pembuatan CLD.

2

5.1 Hubungan Kausal (Sebab-Akibat)

- Suatu struktur umpan –balik harus dibentuk karena adanya hubungan kausal (sebab-akibat). Dengan perkataan lain, suatu struktur umpan-balik adalah suatu causal loop (lingkar sebab-akibat).
- Struktur umpan-balik ini merupakan blok pembentuk model yang diungkapkan melalui lingkaran-lingkaran tertutup. Lingkar umpan-balik (feedback loop) tersebut menyatakan hubungan sebab-akibat variabel-variabel yang melingkar, bukan manyatakan hubungan karena adanya korelasi-korelasi statistik.
- Hubungan sebab-akibat antar sepasang variabel (variabel sebab terhadap variabel akibat), dalam suatu fenomena, harus dipandang dengan suatu konsep bahwa hubungan variabel lainnya terhadap variabel akibat dianggap tidak ada.

3

Sedangkan suatu korelasi statistik antara sepasang variabel, dalam suatu fenomena, diturunkan dari data kedua variabel tersebut yang diperoleh dalam keadaan (kondisi) semua variabel yang terdapat dalam fenomena itu berhubungan satu dengan yang lainnya dan kesemuanya berubah secara simultan.

Ada 2 macam hubungan kausal, yaitu:

- hubungan kausal positif; dan
- hubungan kausal negatif.

Ada 2 macam lingkar umpan-balik, yaitu:

- lingkar umpan-balik positif (growth);dan
- lingkar umpan –balik negatif (goal seeking).

4

Hubungan kausal positif:

Kelahiran (sebab) —+→ **Populasi** (akibat)

Kelahiran menambah Populasi

Populasi (sebab) —+→ **Kelahiran** (akibat)

Populasi menigkat (menurun), kelahiran akan meningkat (menurun)
(aspek perubahan, searah)

5

Hubungan kausal negatif:

Kematian (sebab) —-→ **Populasi** (akibat)

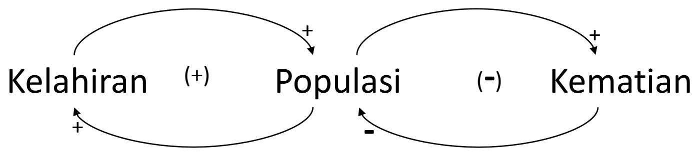
Kematian mengurangi Populasi

Harga (sebab) —-→ **Konsumsi** (akibat)

Harga menigkat (menurun), konsumsi akan menurun (meningkat)
(aspek perubahan, negasi)

6

Causal-loop diagram (CLD)



5.2 Level (Stock) dan Rate (Flow)

- Dalam merepresentasikan aktivitas dalam suatu lingkar umpan-balik, digunakan dua jenis variabel yang disebut sebagai *level* dan *rate*.
- *Level* menyatakan kondisi sistem pada setiap saat. Dalam kerekayasaan (*engineering*) *level* sistem lebih dikenal sebagai *state variable system*. *Level* merupakan akumulasi di dalam sistem.
- Persamaan suatu variabel *rate* merupakan suatu struktur kebijakan (*policy*) yang menjelaskan mengapa dan bagaimana suatu keputusan (*action*) dibuat berdasarkan kepada informasi yang tersedia di dalam sistem. *Rate* inilah satu-satunya variabel dalam model yang dapat mempengaruhi *level*.

(*rate* disebut juga sebagai *decision point*)

Level (Stock) and Rate (Flow)

- **Levels and rates as loop sub-substructure →** A feedback loop consists of two distinctly different types of variables, the levels (states) and the rates (actions). Except for constants, these two are sufficient for represent a feedback loop. Both are necessary.
- **Levels are integrations →** The level integrate (or accumulate) the result of action in a system. The level variables can not change instantaneously.
- **Level are changed only by the rates →** A level variable is computed by the change, due the rate variables, that alters the previous value of the level. The earlier value of the level is carried forward from the previous period. It's altered by rates that flow over the intervening time interval. The present value of a level variable can be computed without the present or previous values of any other level variables.
- **Levels and rates not distinguised by units of measure→** The units of measure of a variable do not distinguish between a level and a rate. The identification must recognize the difference between a variable created by integration and one that is a policy statement in the system.

9

Level (Stock) and Rate (Flow)

- **Rates not instantaneously measurable→** No rate of flow can be measured except as an average over a period of time. No rate can, in priciple, control another rate without an intervening level variable.
- **Rates dapend only on levels and constants→** No rate variable depends directly on any other rate variable. The rate equations (policy statements) of system are of simple algebraic form; they don't involve time or the solution interval; they are not dependent on their own past value.
- **Level variables and rate variables must alternate→** Any path through the structure of a system encounters alternating level and rate variables.
- **Levels completely describe the system condition→** Only the values of the level variables are needed to fully describe the condition of a system. Rate variables are not needed because they can be computed from the levels.

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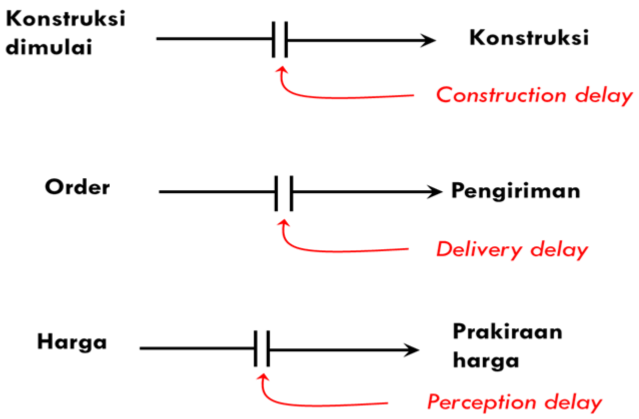
5.3 Delay



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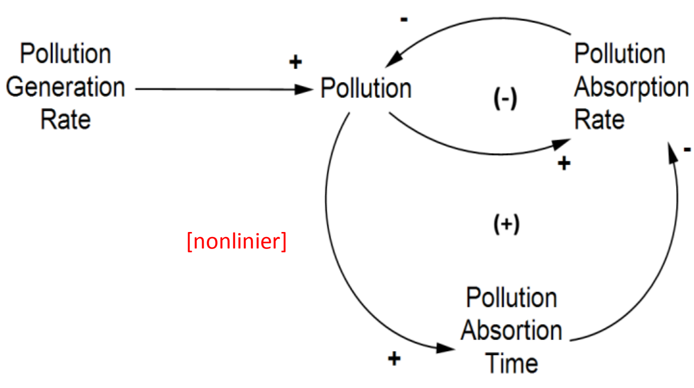
5.4 Nonlinearity



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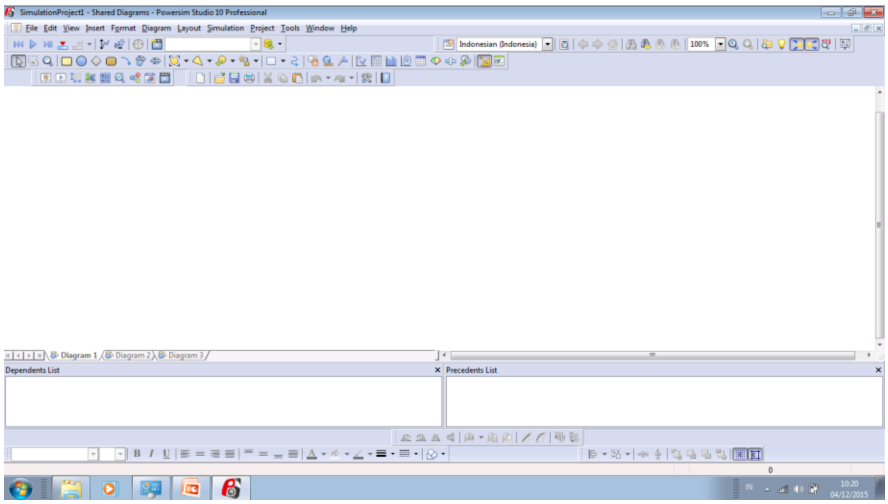
Sesi 6
Simulation Software: Powersim Studio

Outcomes

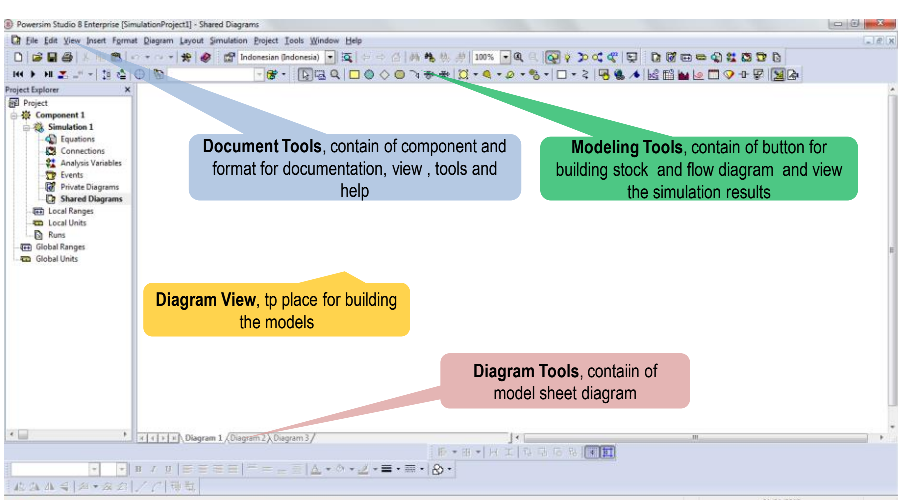
At the end of this session, participants will be able to:

- construct flow diagram based on a CLD
- simulate the model using Powersim Studio software **(Saving Model).**

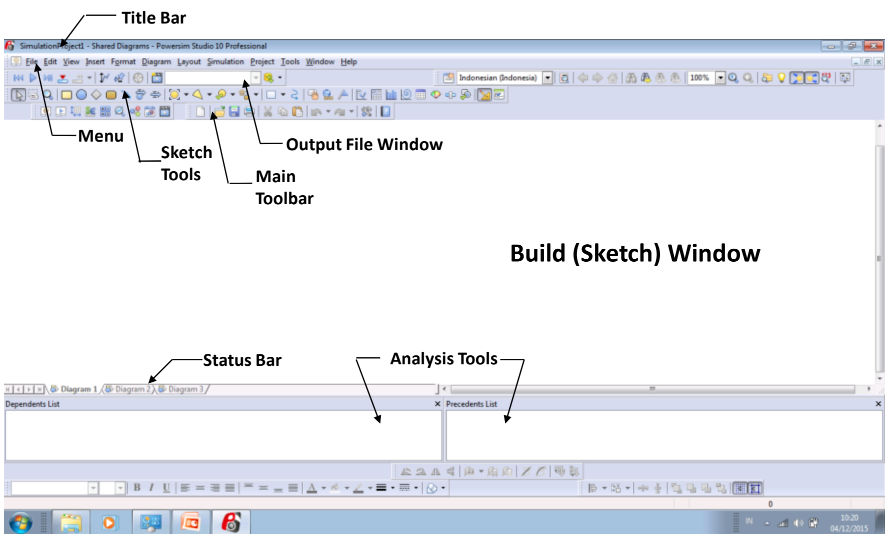
6.1 Powersim Studio Windows



Powersim Studio General View



Powersim Studio Ready to be Used



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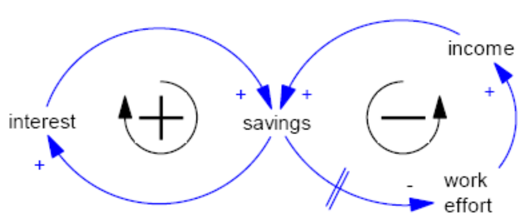
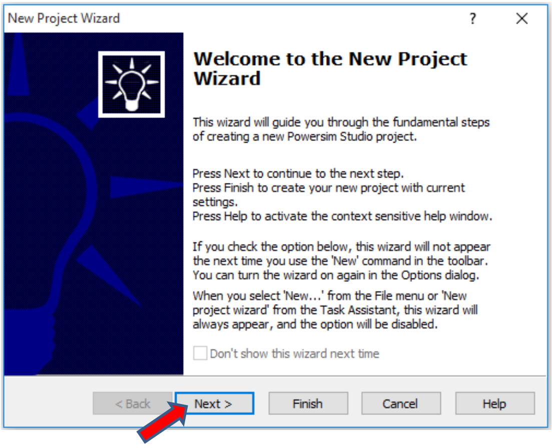
6.2 Causal Loop Diagram Saving Model



6

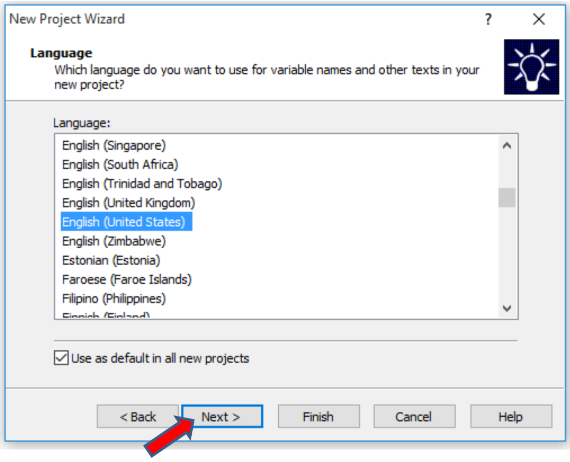
6.3 Model Building
Step 1

1. Open Powersim Studio, and click "**New Model**" in *Main Toolbar*.
2. Click **next** button in the **new project wizard** window



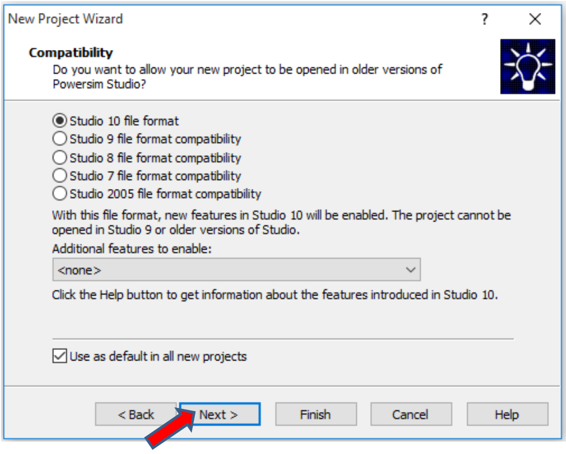
Step 2

3. Choose the language, then click **next**



Step 3

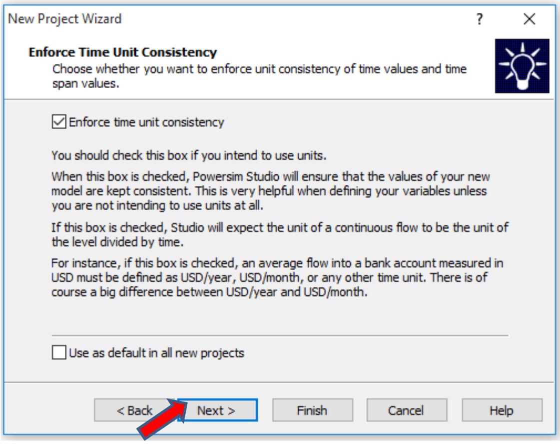
4. Choose Studio 10 file format, then click **next**



9

Step 4

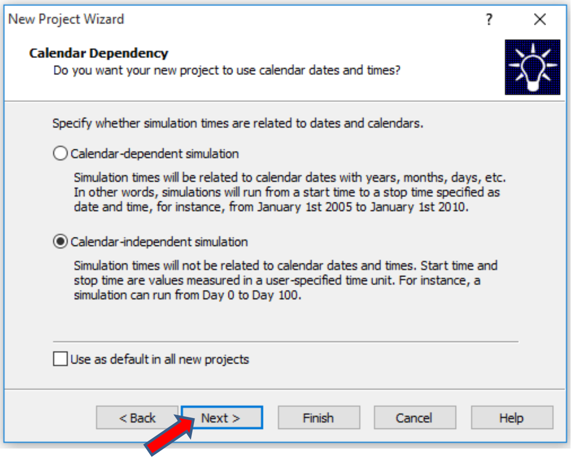
5. Choose **Enforce Time Unit Consistency,** then click **next**



10

Step 5

6. Choose **calendar interdependent simulation**, then choose **next**



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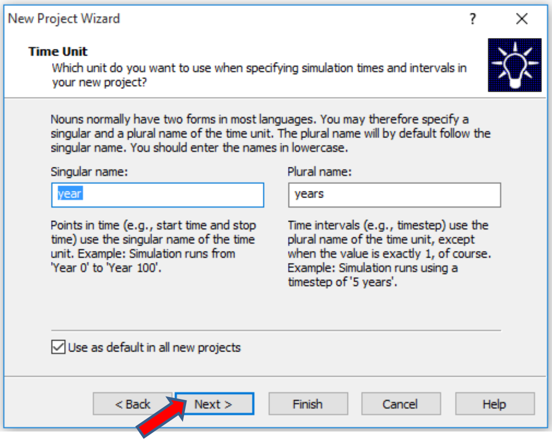
Step 6

7. Choose **use as default in all new projects**, then click **next**



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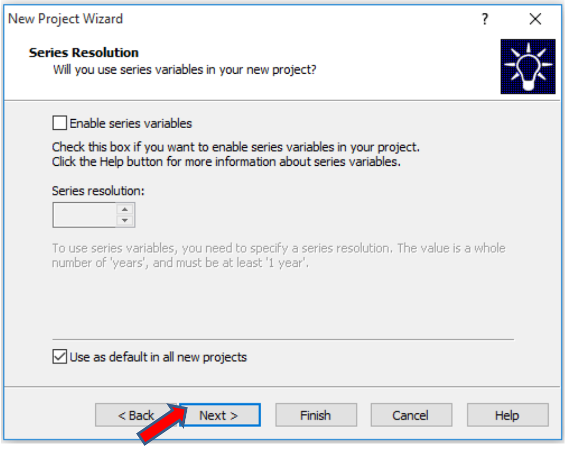
Step 7

8. Choose **Use as default in all projects**, then click **next**



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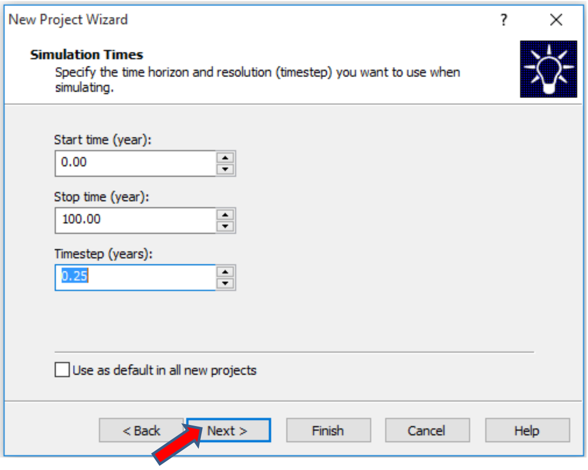
Step 8

9. Choose time step **0.25**, then click **next**



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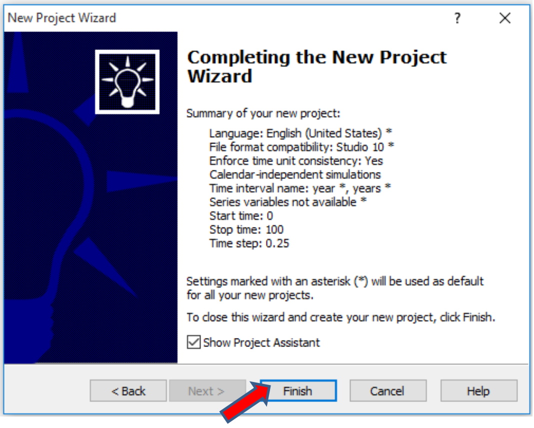
Step 9

10. Click **Finish**, so ready to build model flow diagram



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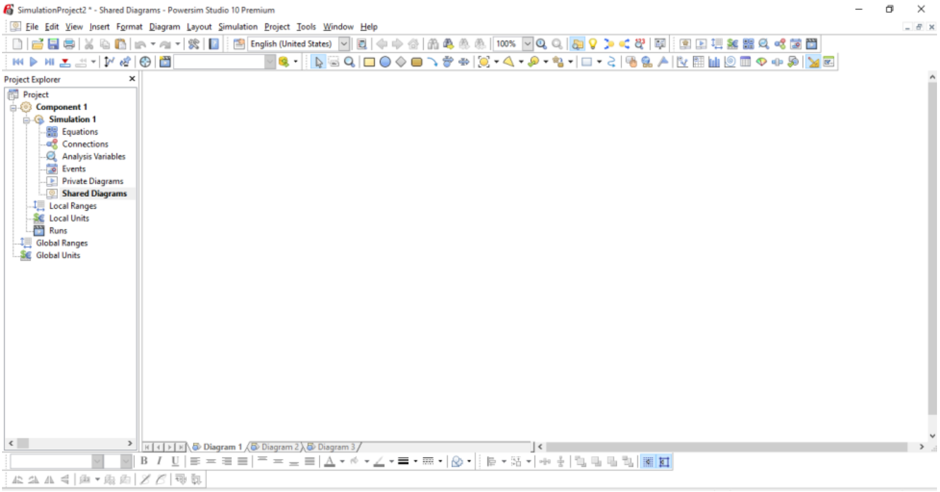
Step 10

11. Ready to Build **Saving Model Flow Diagram**



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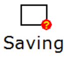
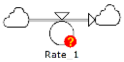
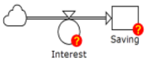
6.4 Building Saving Model

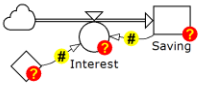
- Sketch tools 
- Activate tools for creating a **level** from *sketch tools*, than put in the *sketch window* or *diagram view,* 

- Type the name of the level ➔ **Saving** in *editing box,* then **enter,** 

- Activate tools for creating a Flow with Rate, 

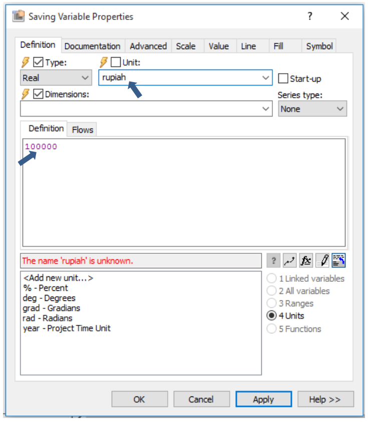
- than connect it to the “saving” level and naming it **Interest,** 

- Activate tools for creating a Constant and naming it **Interest Rate,** 

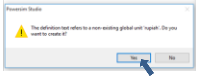
- Activate tools for creating a Link and link the savang level and Interest Rate constant to the Interest auxilary, 

6.5 Inputting Model Equations (1)

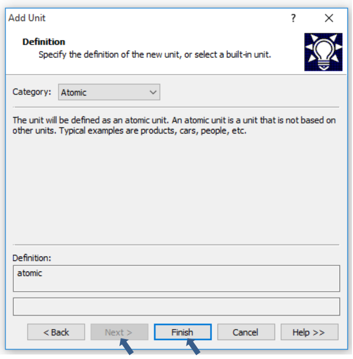
- Double click the **Saving** level
- input **100000** in definition windows
- input **rupiah** for the unit measure
- Click **apply**, then **ok**



- If **rupiah** not yet defined this message will appear, and click **yes**

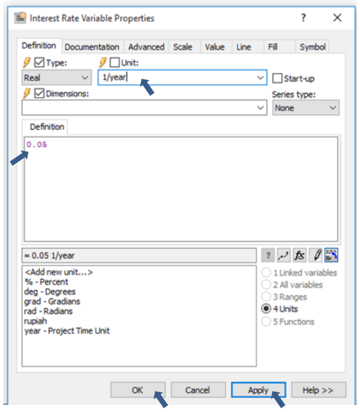


- click **next**, then **apply** and **finish**

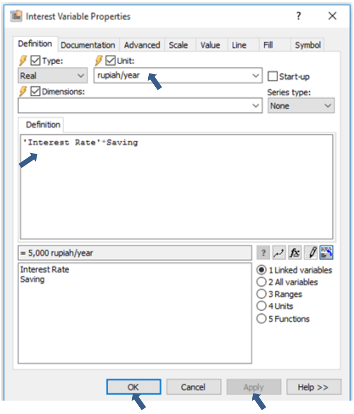


6.5 Inputting Model Equations (2)

- Double click the **Interest Rate** constant
- input **0.05** in definition windows
- input **1/year** for the unit measure
- Click **apply**, then **ok**

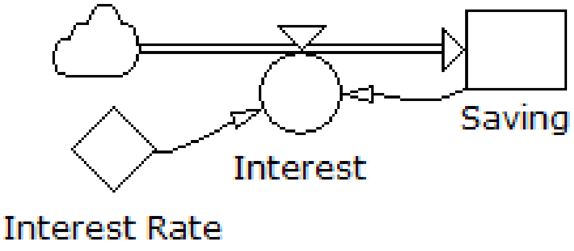


- Double click **Interest** auxiliary
- input equation **Interest Rate*Saving**
- **Activate** unit measure **v**
- Click **apply,** then **ok**



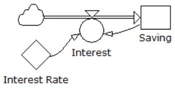
Saving Model Flow Diagram

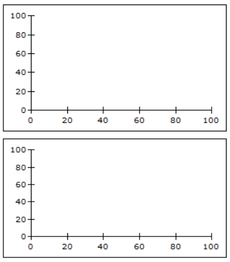
- **Saving Model** ready to be simulated



6.6 Model Simulation (1)

- Activate tool for creating a **Time Graph** for simulating the **saving** and **interest** behavior. 
- Activate tool for creating a **Time Table** for simulating the **saving** and **interest** behavior. 



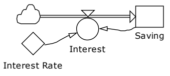


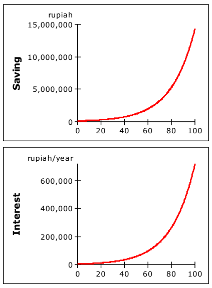
year	
0	
20	
40	
60	
80	
100	

year	
0	
20	
40	
60	
80	
100	

6.6 Model Simulation (2)

- Drag **Saving** level to the **Time Graph** and **the Time Table**
- Drag **Interest** rate to the **Time Graph** and **the Time Table**
- Click the simulation button to run the **Saving Model simulation** 





year	Saving (rupiah)
0	100,000.00
20	270,148.49
40	729,802.09
60	1,971,549.35
80	5,326,110.88
100	14,388,408.35

year	Interest (rupiah/year)
0	5,000.00
20	13,507.42
40	36,490.10
60	98,577.47
80	266,305.54
100	719,420.42

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Sesi 7
Latihan Simulasi

Outcomes

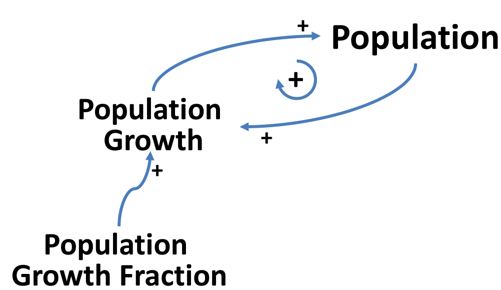
At the end of this session, participants will be able to:

- Develop Stock and flow diagram based on Causal Loop Diagram;
- Simulate the Model Using Powersim Studio (*positive feedback, negative feedback, non linearity*, **Population model, investment model, and inventory model**).

7.1 Positive Model (Population)

3

Causal Loop Diagram Population



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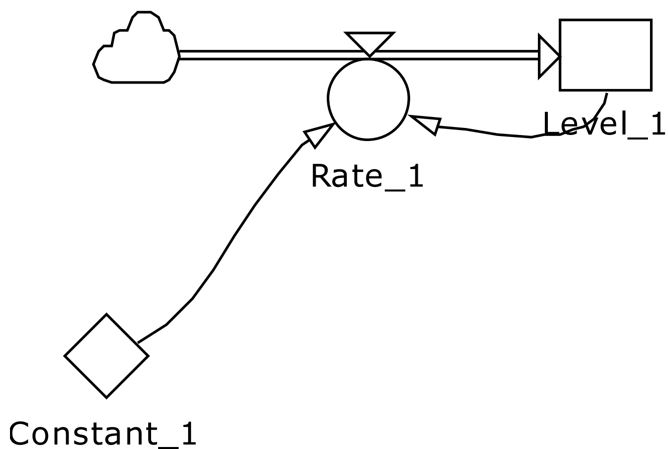
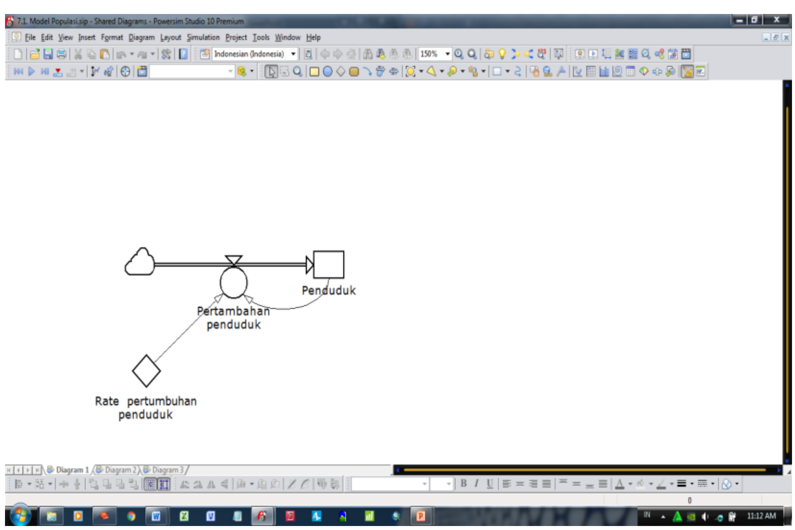
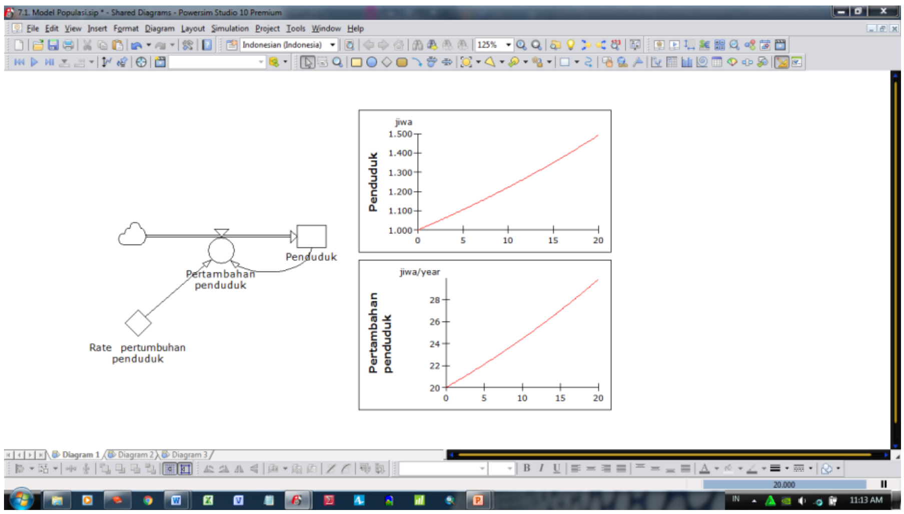
Population Model



Population Model



Population Model Behaviour



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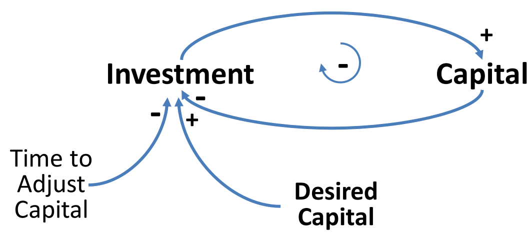
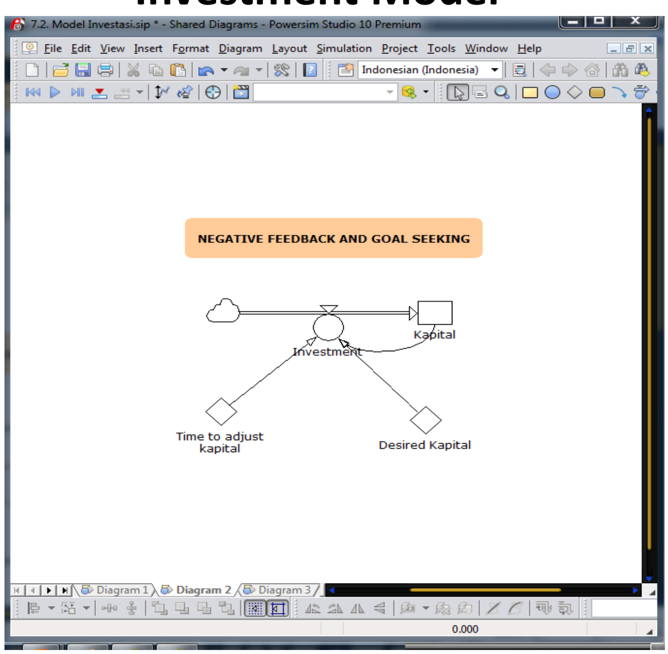
7.2 Negative Feedback (Investment Model)

8

Causal Loop Diagram Investment Model

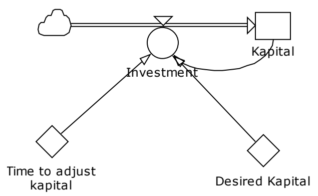


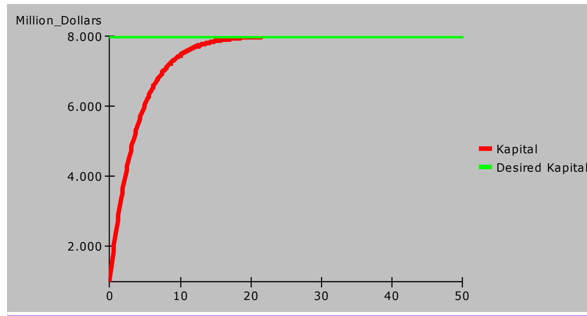
Investment Model

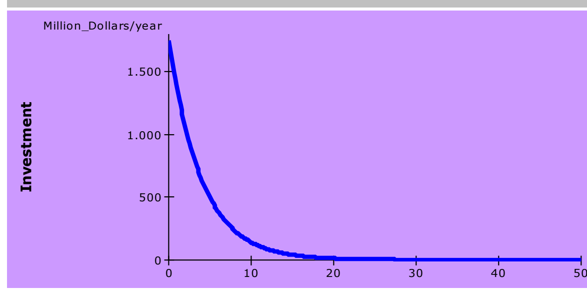


Investment Model Behaviour

NEGATIVE FEEDBACK AND GOAL SEEKING

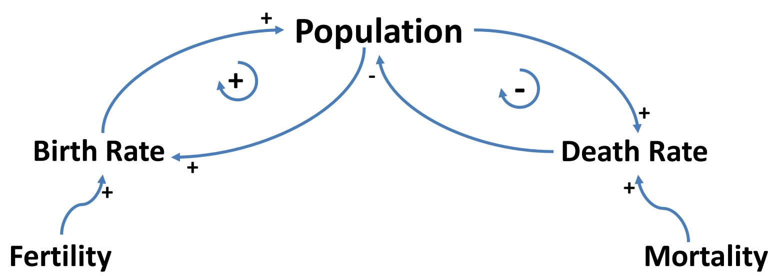




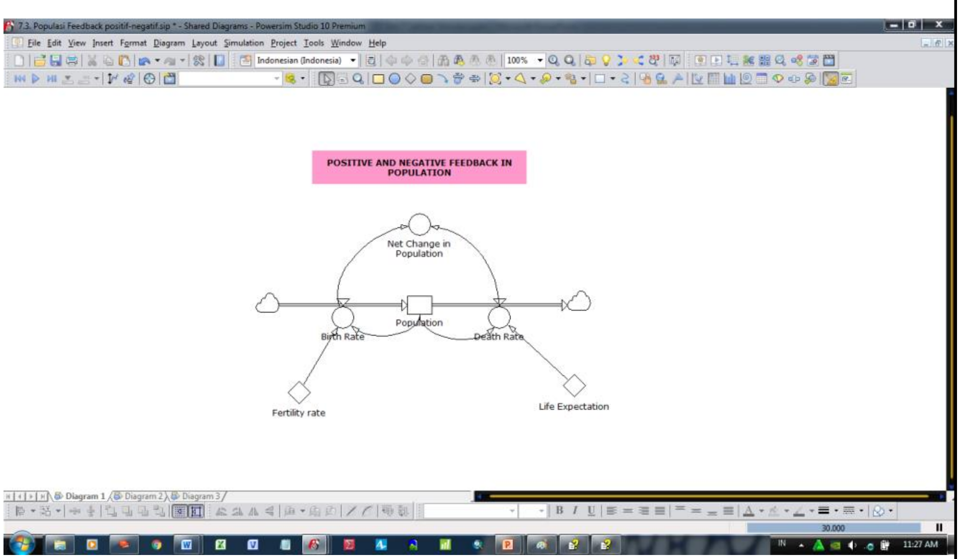


7.3 Positive and Negative Feeback (Population Model)

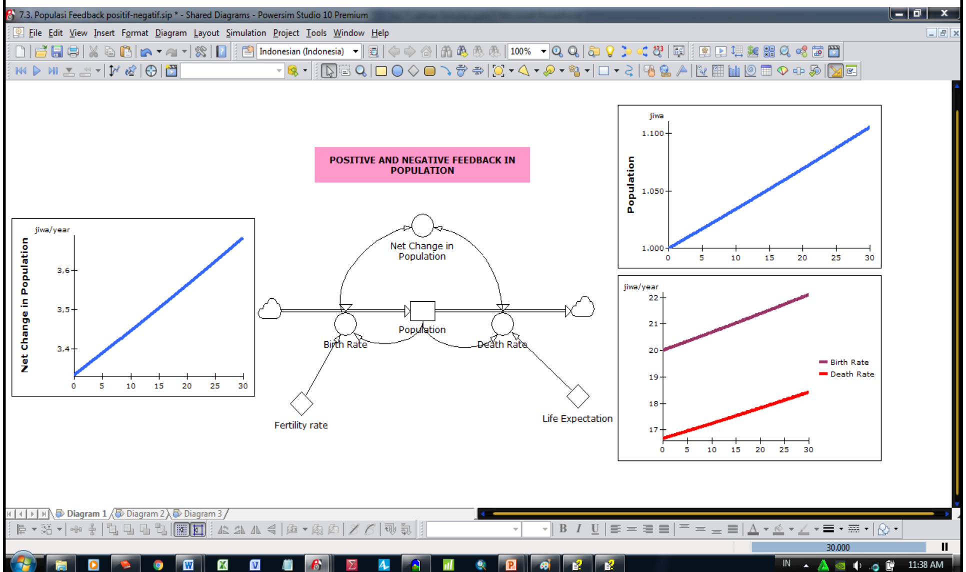
Causal Loop Diagram Population Model



Population Model



Population Model Behaviour



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7.4 Delay (Employee Model)

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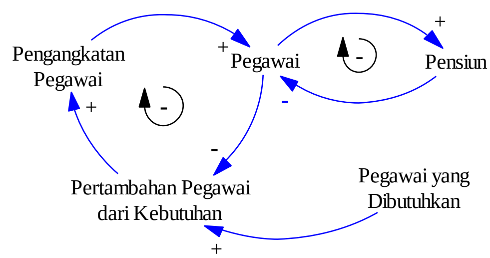
• **CLD Without Delay**



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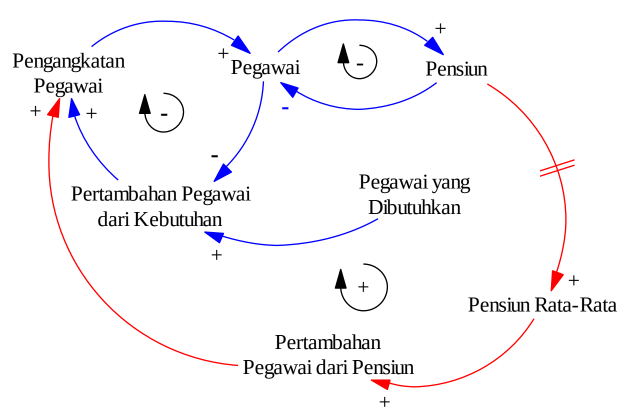
• **CLD Dengan Delay**



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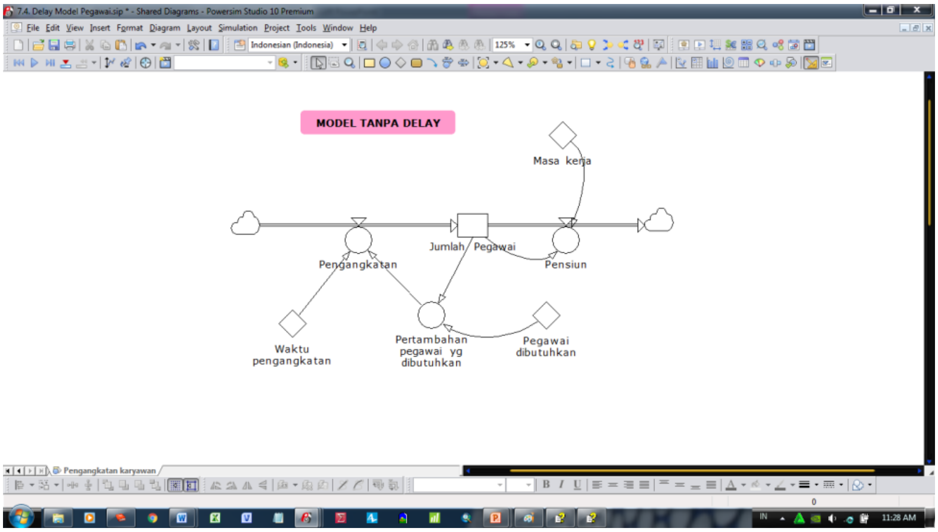
- **Non-Delay Employee Model**



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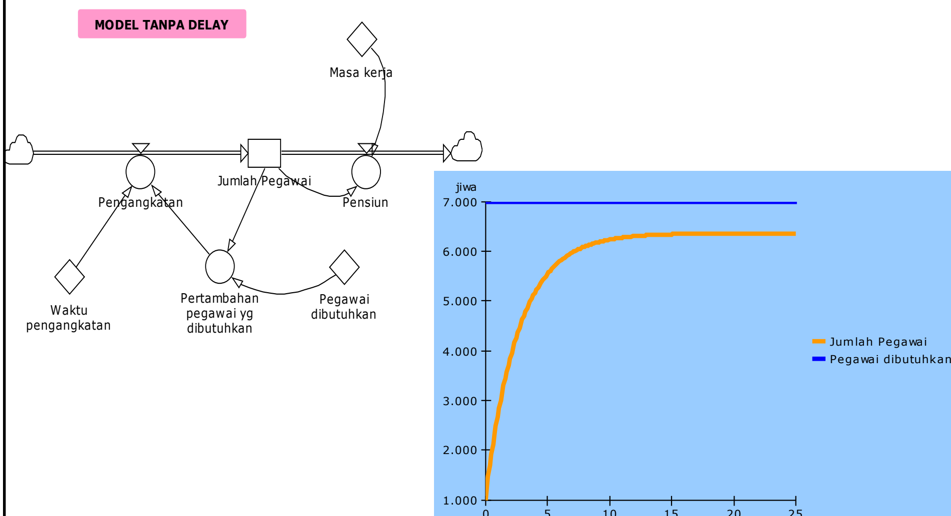
- **Non-Delay Employee Model Behaviour**



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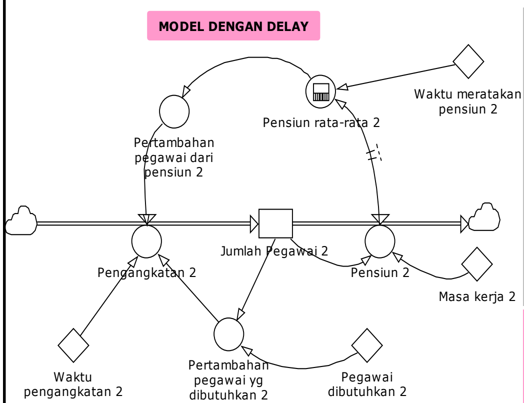
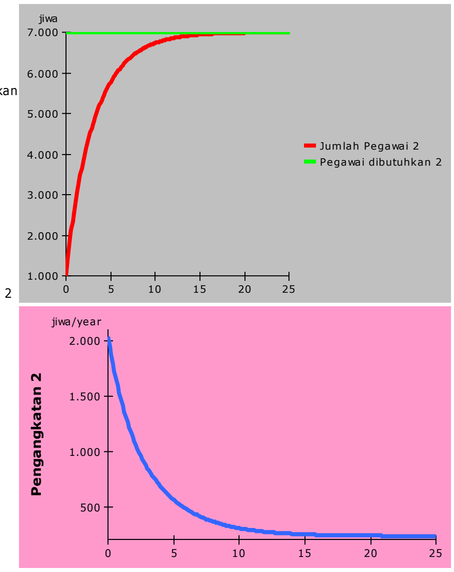
• Delayed Employee Mode Behaviour





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7.5 Nonlinearity (Pollution Model)

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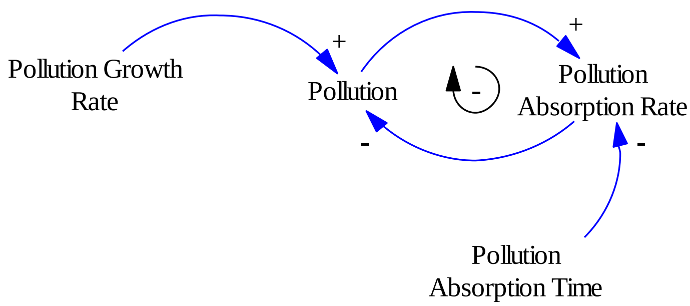
- **Linear CLD**



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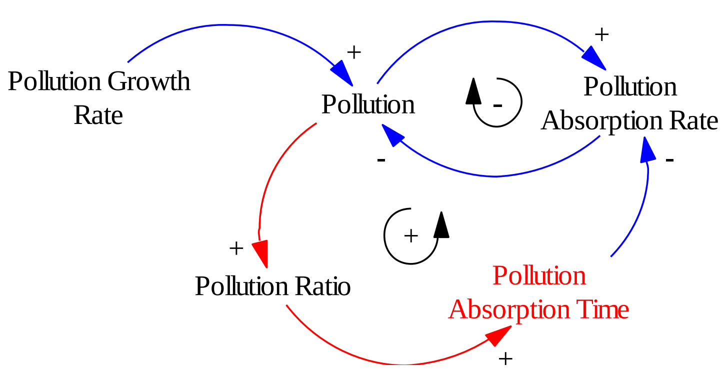
- **Non-Linear CLD**



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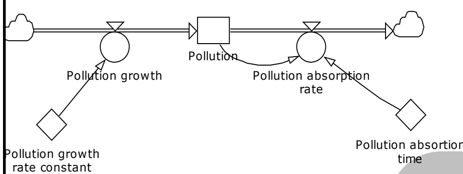
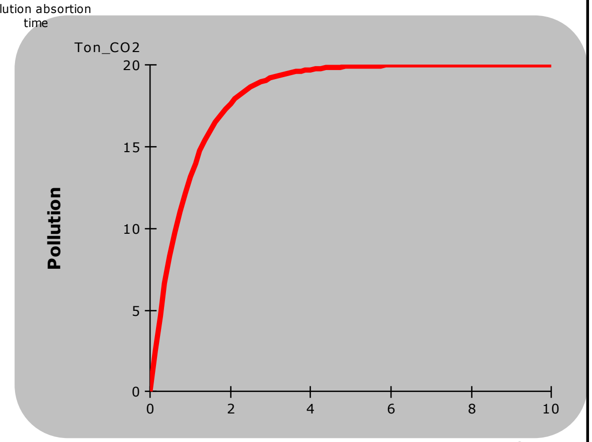
- **Linear Pollution Model**





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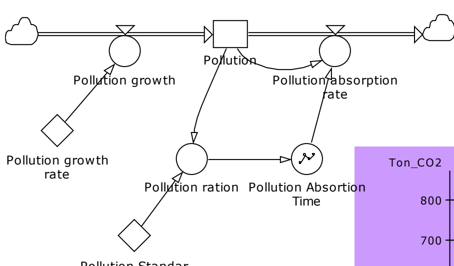
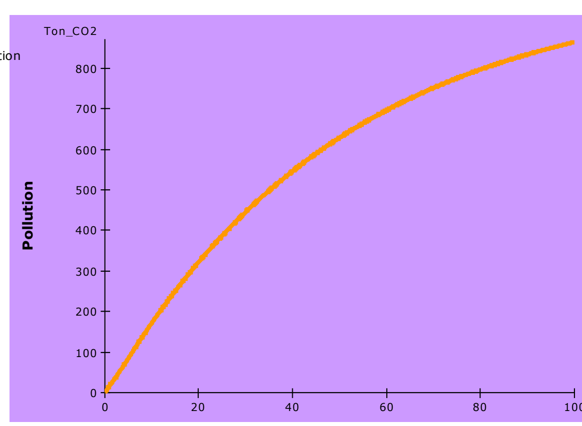
- **Non Linear Model**





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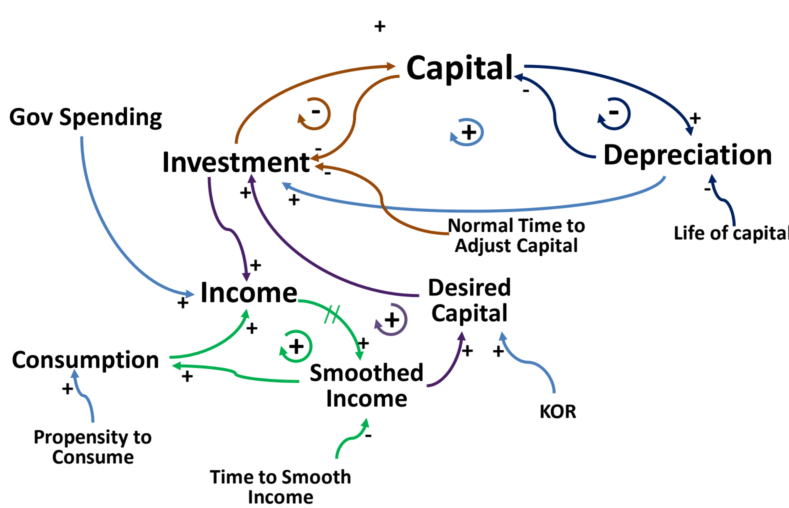
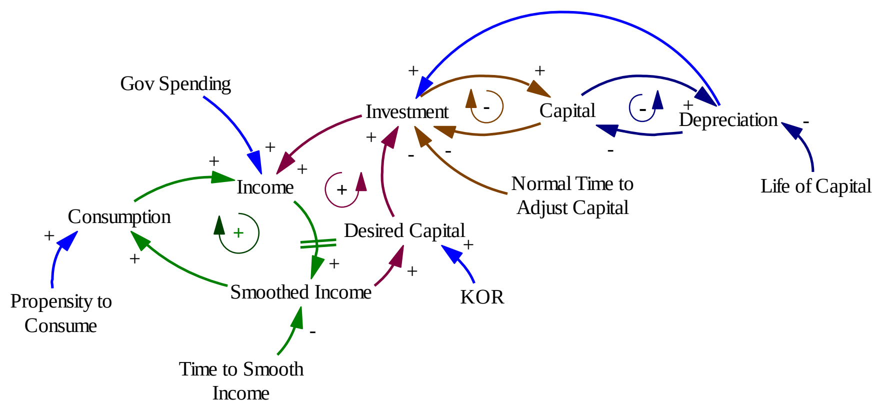
7.6 Investment Model

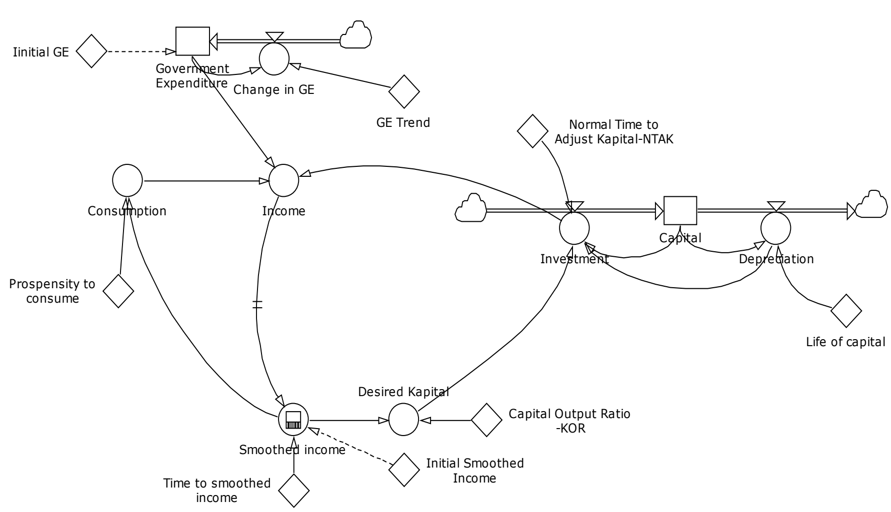
Causal Loop Diagram Investment



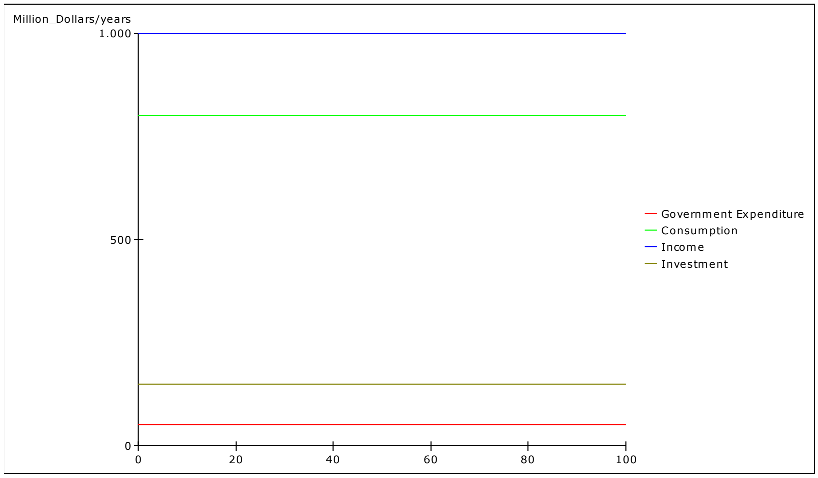
Causal Loop Diagram Investment Model



Investment Model



Investment Model Behaviour (Equilibrium)



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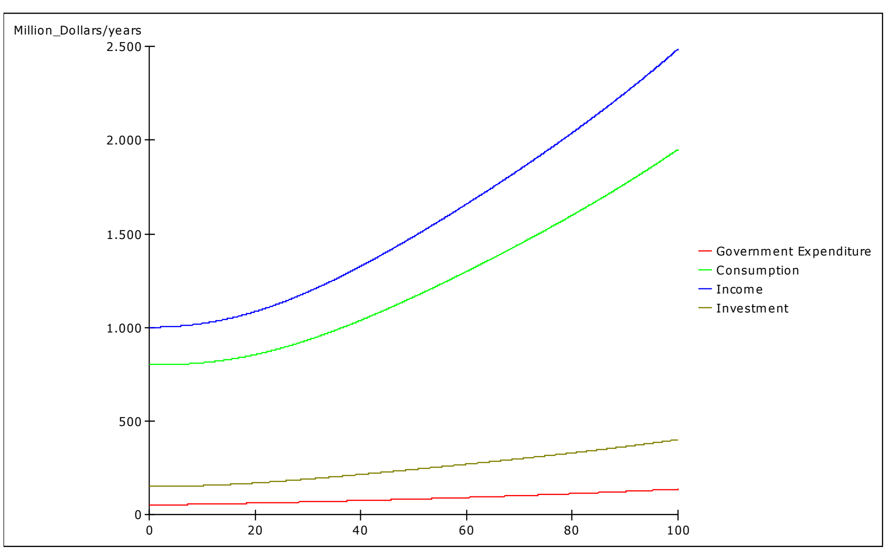
Investment Model Behaviour (GE Growth 1 %/year)



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7.7 Model Inventory

ABC Manufacturing Inventory (1)

SCENARIO

- ABC Manufacturing would like to use simulation to **better understand** the **interaction** between **the amounts of merchandise** the public **orders** and their own **inventory** and **production levels**.
- Since the company often experiences oscillations in their inventory and production levels, they think the first step in solving this problem is to **build a model that would explain the relevant interactions.**
- They know that their **production policy concists** of two components **increasing or decreasing the inventory** to match an optimal or **desired level of inventory** and keeping inventory **high enough to cover** what they expect their **demand** will be in **the future**.
- To be safe, they like to **keep four times** as much **inventory on hand** as they think will be needed to cover demand.
- In addition**, production** is set so that **one-sixth** of the **discrepancy between** the **desired and actual inventory** is corrected **every week.**

ABC Manufacturing Inventory (2)

- Their assumptions about **future demand** are based on the **current order rate**.
- The current order rate constitutes the **real demand** that the company faces.
- Their policy formulating their expected demand is simple.
- They want to **correct one-eighth** of the difference between their real and expected demands **every week.**
- When their beliefs about future demand change, this affects their desired level of inventory and the rate at which they produce widgets, according to the production policy described above.

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ABC Manufacturing Inventory (3)

- When widgets are produced, they go straight to warehouse to be stored as inventory.
- No Product can go from the production line straight to the customer; it must go into the inventory first.
- Shipments are made only from inventory. Because the company keeps **four times** as much inventory as they think they will need at any time, they believe they are able to ship the necessary products to fulfill every order.
- Therefore, they are not now concerned with backlogs and their effects (although a negative inventory while meaningless in reality, can here be constructed to represent a backlog).

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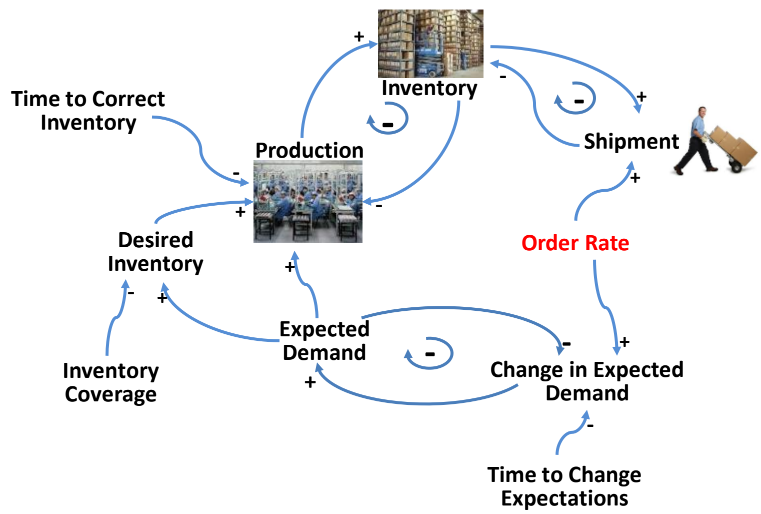
CLD Inventory Model



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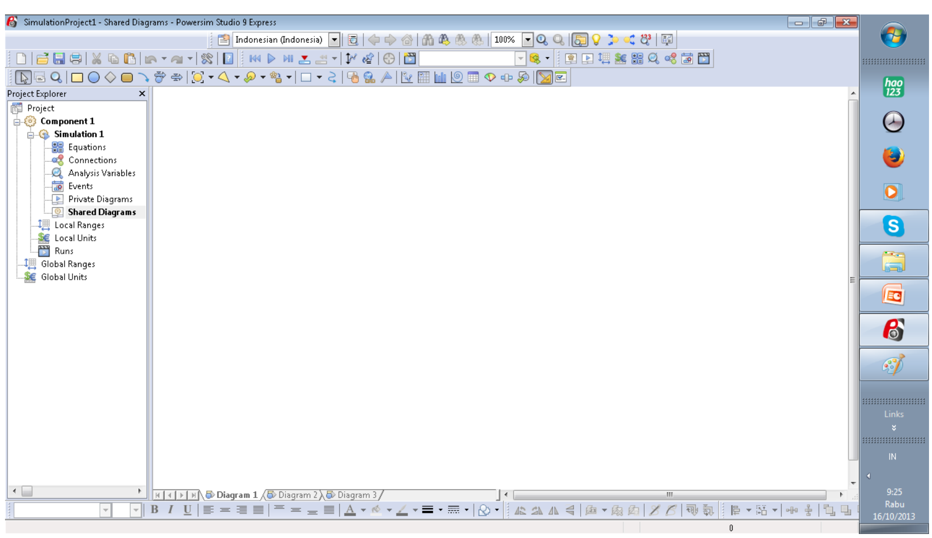
Powersim Studio



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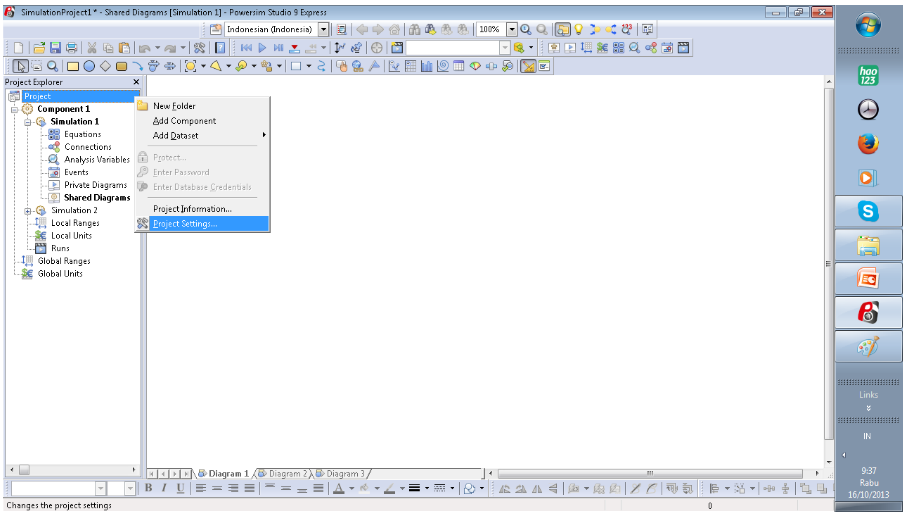
Setting The Simulation Time (1)



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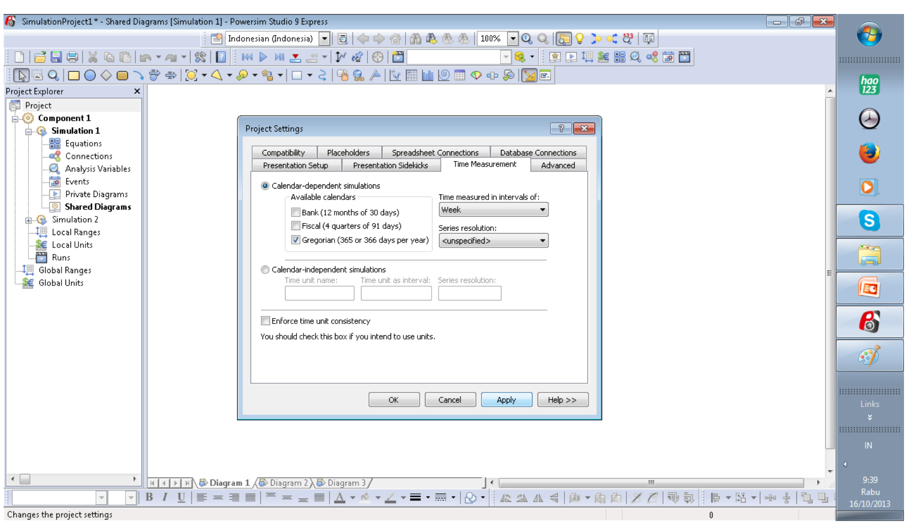
Setting The Simulation Time (2)



40

Model Building (1)

Modeling Inventory as a Level

An inventory represents an accumulation of items, in this case widgets. It should be modeled using a level, so you should place a level on the workspace and give it the name 'Inventory'. Also, the unit of measurement should obviously be 'wdg'. To create the level, follow these steps:

1. Click **Level** on the toolbar.
2. In the workspace, click where you want to position the new level.
3. While the level is selected, you can type the name directly. Type *Inventory* and hit `Enter` .

The '?' (question mark) that appears on the inserted variable indicates that the variable is not given a proper definition. We will address this later.

The level named 'Inventory' forms the starting point of our simulation model.

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Model Building (2)

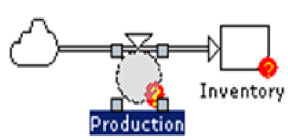
Modeling Production and Shipments as Flows

Inventory must be increased and decreased in some way. Production is a flow of widgets that adds to the inventory, while shipments drain the inventory. Let's add these two flows to the model.

To connect a production flow to the level:

1. Click **Flow** on the toolbar.
2. Align the cursor to the left of the 'Inventory' level, and click once.
3. Once you start moving the mouse, a cloud symbol with a double-lined arrow appears.
4. Drag the flow into the level, and click once inside the level.
5. Select the flow rate 'Rate_1'. Type *Production* and hit Enter.

The model now looks like the figure below.



The production adds to the inventory, and is therefore modeled as a flow into the level.

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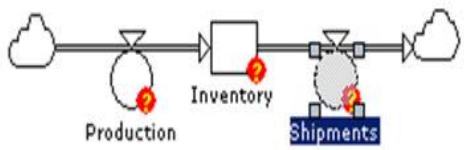
Model Building (3)

To connect a shipment flow that drains the level:

1. Again, select **Flow** on the toolbar.
2. With the mouse cursor inside the 'Inventory' level symbol, click the mouse. You will see a small box on the outline of the level symbol that indicates the starting position of the flow.
3. Once you start moving the mouse, a cloud symbol with a double-lined arrow pointing to it, appears.
4. Drag the flow a little distance to the right, and double-click to end the flow.
5. Select the flow rate 'Rate_1'. Type *Shipments* and hit Enter.

The model now has two flows, and looks something like the model below.



Shipments drains the inventory, and is therefore modeled as a flow out of the level.

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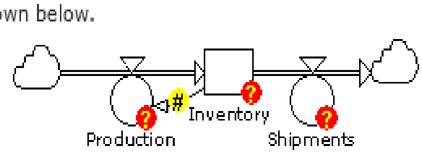
Model Building (4)

Making Production Depend on Inventory

From the information about the company that was given above, we know that production depends on several factors, including the difference between the actual inventory and the desired inventory. Since the 'Production' flow rate is dependent on the 'Inventory' level, we need to create an information link that shows this relationship.

1. Click **Link** on the toolbar.
2. Position the cursor inside the 'Inventory' symbol. A box appears on the outline of the symbol to indicate the starting position of the information link.
3. Click once, and drag the link to the 'Production' flow rate variable.
4. Click once again inside the 'Production' variable symbol (the circle, not the double flow arrow or the name symbol of the variable).

The model structure is shown below.



The rate of production is dependent on the amount of units already in inventory. This dependency is modeled by an information link from 'Inventory' to 'Production'.

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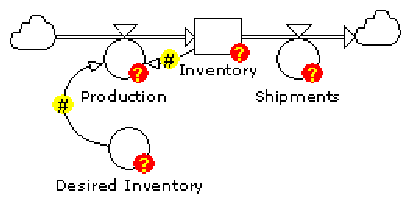
Model Building (5)

Adding the Concept of Desired Inventory

To represent the difference between inventory and desired inventory in the production equation, we need a new variable. Desired inventory is not an accumulation of inventory, but rather a value that is determined by the ordering manager based on the current inventory. An auxiliary is therefore the best representation for it in the model.

1. Click **Auxiliary** on the toolbar.
2. Position the cursor below the 'Production' flow rate, and click once to create the new auxiliary.
3. Type *Desired Inventory* and hit `Enter` to rename the auxiliary.
4. Connect the auxiliary to 'Production' using a new link, as described in the previous step.

The model we have built this far is shown below.



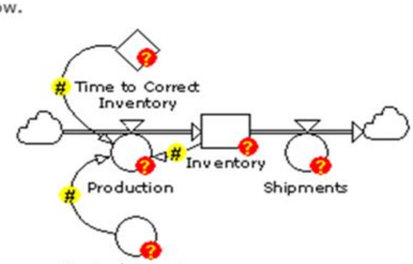
The desired level of inventory is used to decide the rate of production. It is included as an auxiliary and linked to 'Production' by an information link. The yellow mark on the two information links indicates that 'Inventory' and 'Desired inventory' are not used in the definition of 'Production'. This will be done later.

Adding Production Time

The third component of production is the time it takes to refill the inventory. This time factor represents a delay in the system because in real life, production cannot instantly fill an inventory. It takes time to make the goods and physically transport them into a warehouse. In this case, one-sixth of the discrepancy between actual and desired inventory is corrected each week. So, when the desired level of inventory changes, it actually takes six weeks for the actual inventory to change accordingly. This time factor does not change throughout the simulation, so a constant should represent it in the model.

1. Click **Constant** on the toolbar.
2. Position the cursor above the 'Production' flow rate, and click once to create the new constant.
3. Type *Time to Correct Inventory* and hit `Enter` to rename the constant.
4. Connect the constant to 'Production' using a link.

The model is shown below.



There is a time delay involved when producing goods for the inventory. This time is modeled as a constant named 'Time to Correct Inventory', and linked to 'Production'.

Model Building (7)

Defining the Inventory

The model is obviously not finished yet, but we can start to define some of the variables present in the diagram. We will start by defining the 'Inventory' level.

1. Select the 'Inventory' level symbol, and double-click it to open the Properties dialog box.
2. Type *400*. This will be the initial amount of widgets in inventory. 'Widgets' is the unit of measurement we want to use for the content in Inventory.
3. Select the *Unit* box. In the multi-function list at the bottom of the tab, and all the defined units will appear.
4. The unit 'wdg' is not predefined, and has to be defined. Double click on <*Add new unit...*> .
5. Enter the name *'wdg'* for the new unit in the **Add Unit Wizard.**
6. If you want, you may also change the plural name of the unit.
7. Click **Finish**. The *'wdg'* unit is now defined.
8. Click **Apply** to apply the definition without closing the variable dialog box.

As an alternative, you can write <<wdg>> right after 400 in the 'Inventory' definition. If the unit is undefined, a text box will pop up when you click **Apply**, and you will be asked if you want to define the unit. If you click 'Yes', the **Add Unit Wizard** will appear, and you can do step 5 to 8 to define the unit.

The '?' (question mark) on the 'Inventory' symbol has now disappeared, since the variable is correctly defined. However, the question marks on the other variables and on the flows themselves are still present, since these need to be defined in a similar way.

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Model Building (8)

Documenting the Inventory Variable

It is always useful to document the variables as we work. The *Documentation* tab of the *Property* dialog box allows us to add documentation and notes for each variable in the model. The fields can contain anything that is necessary to explain the variable to someone who is not familiar with the model. Since the model consists of assumptions we have made, it is not obvious that other modelers should immediately understand it. The documentation becomes increasingly useful when the model is shared among people.

To add documentation to the 'Inventory' variable: (If you clicked **OK** in the last step and closed the *Property* dialog box, double-click 'Inventory' to open the dialog box again.)

1. Click the *Documentation* tab.
2. Type a short description in the *Documentation* box.
3. Type any notes you wish to include in the *Notes* box.
4. Click **OK** to save the documentation and notes and close the dialog box.

You are free to use the documentation and note fields in any way you find useful. However, it might be a good idea to use the Documentation field to document the model, and the Notes field to keep reminders for yourself as you develop your model.

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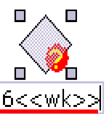
Model Building (9)

Defining the Time Constant

The time constant 'Time to Correct Inventory' has been explained previously. It represents the time it takes to adjust the actual inventory to equal the desired inventory. The delay for filling the inventory was six weeks, and the value of the time constant should therefore be '6 weeks'. In Studio we can enter the equation defining a variable directly in the name field, instead of in the Property dialog box. We can also include the variable's unit directly in the equation. This is especially useful when entering relatively simple definitions, as is the case for constant auxiliaries.

1. Select the 'Time to Correct Inventory' auxiliary symbol in the diagram.
2. Start typing the following expression: *=6<<wk>>*, as shown in the illustration below.
3. When you have typed the expression, hit `Enter`. The '?' (question mark) disappears to indicate that the variable is properly defined.



We can enter the variable equation directly in the variable's name symbol.

In this equation we have included both the numerical and unit part of the variable's definition.

> **Note!** To be able to enter the unit part, the numerical part is required. Thus, we are allowed to enter "6<<wk>>", but we are not allowed to enter only "<<wk>>".

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Model Building (10)

Temporarily Defining the Desired Inventory

Although we will refine the 'Desired Inventory' variable later, it can be useful to enter a temporary definition for it at this point, since this allows us to now define the 'Production Rate'. The 'Desired Inventory' is similar to 'Inventory', and should be defined as an initial number of widgets. At the start of the simulation everything is stable, and we can therefore set the value equal to the value of 'Inventory': 400 widgets.

We will define the variable in the same way as in the previous example.

1. Select the 'Desired Inventory' auxiliary symbol in the diagram.
2. Start typing the following expression: =400<<wdg>>.
3. When you have typed the expression, hit `Enter` .

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Model Building (11)

Defining the Production Rate

The variables 'Desired Inventory', 'Inventory', and 'Time to Correct Inventory' define the production rate 'Production'. We have already linked these variables to 'Production'. Since 'Production' should be defined as the difference between 'Inventory' and 'Desired Inventory' divided by the time it takes to fulfill the change the equation is expressed by:

('Desired Inventory' - Inventory)/'Time to Correct Inventory'

1. Double-click the 'Production' flow rate to open the *Property* dialog box.
2. Select the *Definition* box. The *Linked Variables* box at the bottom of the page shows a list of all the variables that are linked to the current variable.
3. In the *Definition* box, type a left parenthesis "(" from the keyboard.
4. Double-click 'Desired Inventory' in the *Linked Variables* box to insert it into the expression.
5. Type a minus sign "-" from the keyboard.
6. Double-click 'Inventory' in *Linked Variables.*
7. Type a right parenthesis ")" and a slash "/" from the keyboard.
8. Complete the equation by double clicking the 'Time to Correct Inventory' in *Linked Variables.*
9. Click **OK** to save the definition.

As soon as you click OK, Studio evaluates the equation. It immediately calculates the value of the variable as well as its unit of measurement, in this case 'wdg/wk'. The entire left-hand side of the diagram is now properly defined, and all the question marks have disappeared. The question mark on the flow itself has also disappeared. The reason for this is that a flow rate must always be defined per time. Since 'Inventory' has the unit 'wdg', 'Production' must have a unit expressed by 'wdg per time', which it has.

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Model Building (12)

Viewing the Values of Variables

There are several ways in Studio to view the value of a variable. First of all, the value will be visible on the Definition page of the Property dialog box. Second, if you point to the variable in the diagram, a tool tip containing the value and unit of the variable will appear after a short delay. Third, you can use an auto report to view the value.

To turn on an auto report for a variable:

1. Right-click the variable whose value you wish to view. By click right mouse
2. Select **Show Auto Report** from the shortcut menu.

An auto report showing the value and unit of the variable appears on the opposite side of the variable's name. An auto report can be deleted, hidden or shown, or shown as a different type. All these commands are available on the shortcut menus for both the auto reports and the variable symbols.

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Model Building (13)

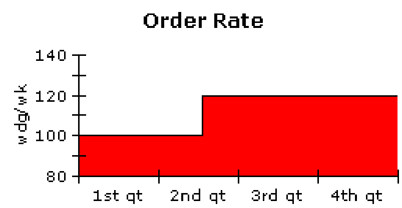
Adding an Order Rate

To be able to correctly define 'Shipments' and 'Desired Inventory', we need to add more variables to the model. The company fills every order by shipping items from inventory. Let us represent the order stream from the public using an auxiliary named 'Order Rate'.

This variable represents an outside influence on the model. As such, it can be used to "shock" the model to reveal its behavior under a simulated change in demand. The variable represents the number of widgets ordered per week. We can introduce a 20% increase in the demand with the following equation:

Order Rate = 100<<wdg/wk>> + STEP(20<<wdg/wk>>; StartTime + 20<<wk>>)

This equation uses a STEP function to increase the orders from 100 to 120 widgets after 20 weeks of the simulation. It is a simple representation of an order stream, but it gives us an idea of how the inventory reacts to changes in orders. The behavior of the equation over time is shown graphically below.



The rate of incoming orders increases suddenly after 20 weeks of the simulation.

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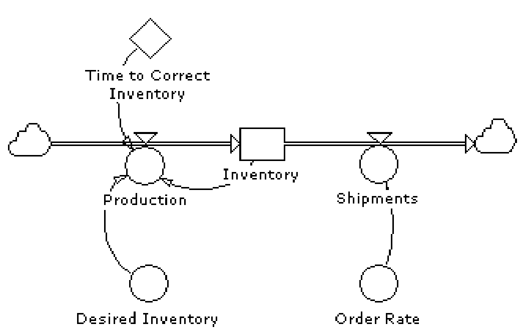
Model Building (14)

1. Create an auxiliary to the lower right of 'Shipments', and name it 'Order Rate' (see figure below).
2. Double-click 'Order Rate' to open the *Property* dialog box.
3. Type "100<<wdg/wk>> + " in the *Definition* box.
4. Click *fx Function Wizard (located to the lower right of the* Definition box).
5. In the *Function Wizard*, select *Time* in the *Categories* box.
6. In the *Functions* box, select *STEP*. The function parameters appear in the right of the wizard.
7. In the *Height* box, enter *20<<wdg/wk>>*.
8. In the First box, enter *STARTTIME + 20<<wk>>*.
9. Click **OK** in the *Function Wizard* to insert the function expression into the equation.
10. Click **Apply** to save the equation.



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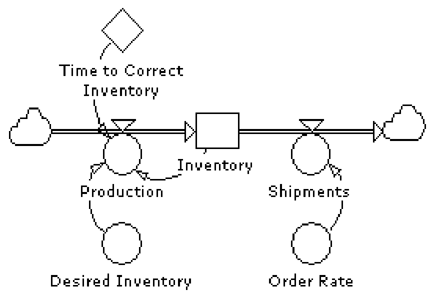
Model Building (15)

Defining Shipments

Because ABC Manufacturing fulfills all orders by shipping their products directly from inventory, 'Order Rate' must define 'Shipments' directly. Accordingly, we must connect 'Order Rate' to 'Shipments' by a link.

1. Double-click 'Shipments', and select the *Definition* box.
2. Double-click 'Order Rate' in the *Linked Variables* box.
3. Click **OK.**



The model now contains both a flow into the level ('Production') and a flow out of the level ('Shipments'). 'Shipments' is dependent on the 'Order Rate', which describes the behavior of the incoming orders from the market.

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Model Building (16)

Setting Up the Simulation

Although we are not completely finished with the model, we can already run the model to see how it behaves with the current definitions. To do this, however, we need to set up the simulation settings for the model. Since both 'Production' and 'Shipments' are measured in widgets per week, the time step of the simulation should be set to one week. The increase in 'Order Rate' occurs after 20 weeks, and a time horizon of two years should therefore be enough to gain some insight into the behavior of the model.

1. Select *Simulation Settings* on the *Simulation* menu.
2. Enter *7 da* in the *Time Step* field.
3. Leave the other boxes unchanged, and click **OK.**

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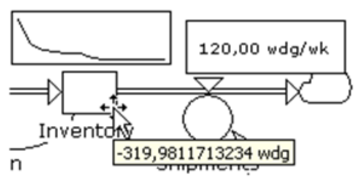
Model Building (17)

Performing a Test Run of the Model

By turning on auto reports for the key variables in the diagram, we can inspect their behavior and values. Since the 'Order Rate' increases after 20 weeks, we expect to see a decline in Inventory after this time. To view this decline in a better way, we can use a time graph auto report to view the outcome from the 'Inventory' level.

1. Right-click 'Production' and 'Shipments' respectively, and select **Show Auto Report** on the shortcut menu.
2. Right-click 'Inventory' and select the arrow next to **Show Auto Report**. On the submenu, select *Time Graph Auto Report*.
3. You can reposition the auto reports by drag and drop if they interfere with each other.
4. Click the **Play** button on the toolbar to run the simulation.

The simulation will run for one year, and the development of 'Inventory' will be shown in the auto report. Placing the mouse cursor over 'Inventory' will, after a short delay, present the value of the variable in a tool tip. At the end of the simulation, we have the situation shown below.



After 20 weeks, the inventory will start to drop. At the end of the simulation, we will have a negative inventory, since the production is not increased to compensate for the higher shipment.

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Model Building (18)

As we can see, 'Inventory' has decreased, and has now a negative value. Given the new rate of incoming orders, this is not surprising, since the value of 'Shipments' is higher than the value of 'Production' throughout most of the simulation. The reason for this behavior is simply that 'Desired Inventory' doesn't reflect the change in demand that occurs after 20 weeks. To be able to implement a sensitivity to demand in the model, we must introduce the concept of expected demand.

Adding the Concept of Expected Demand

Expected demand is an important part of this model because it translates changes in demand into changes in production. That is, it takes market information ('Order Rate') and converts it into action that controls how much the company produces. Demand is not a physical accumulation like inventory. It can seem like an abstract idea, with expectations about demand being even more abstract. However, the accumulations represented by levels do not have to be physical accumulations. Since we need to introduce a delay in the changes of expected demand, it is best to model it as a level.

1. Create a level in your model (position it as shown below) and name it 'Expected Demand'.
2. Define it with an initial value of *100<<wdg/wk>>*, which is equal to the initial rate of incoming orders.

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Model Building (19)

Flows are the only elements that change levels, so we need a flow to represent the change in 'Expected Demand'. We also need a time factor to indicate how long it takes to adjust expectations about demand into real demand.

1. Create a new flow and let it flow into 'Expected Demand'.
2. Name the new flow rate 'Change in Expected Demand'.
3. Add a constant named 'Time to Change Expectations'.
4. Link 'Order Rate', 'Time to Change Expectations' and 'Expected Demand' to 'Change in Expected Demand' using information links.

The variable 'Time to Change Expectations' represents the time it takes to adjust expectations about demand into real demand. This is a constant, and we estimate it to be 8 weeks.

To define the variables:

1. Double-click the variable 'Time to Change Expectations'.
2. In the *Definition* box, type *8<<wk>>*.
3. Click **Apply**.
4. In the diagram, select 'Change in Expected Demand'.
5. In the *Definition* box, enter the definition "('Order Rate' - 'Expected Demand')/'Time to Change Expectations' ".
6. Click **OK**.

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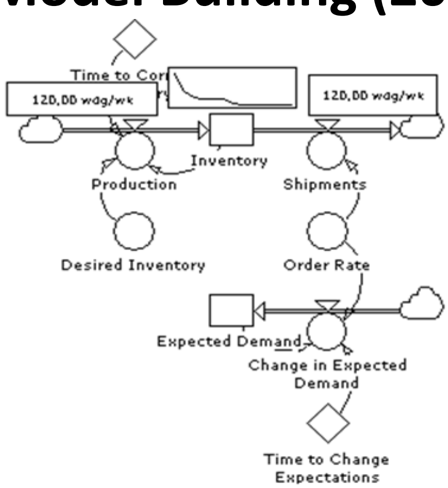
Model Building (20)



The model now contains a structure for finding the expected demand.

The model now contains a structure for evaluating the expected demand in the market. It is dependent on the current order rate and a time constant. This time constant represents the desired time for the company to change its opinion of the demand in the market. The structure is sensitive to change in demand. However, before we are finished, we need to couple this part of the model with the part of the model that controls the production rate.

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Model Building (21)

Letting Expected Demand Influence Production and Desired Inventory

What remains to do for this simple model is to show how 'Expected Demand' affects 'Production' and 'Desired Inventory'. Let us start by drawing the links.

1. Draw links from 'Expected Demand' to 'Production' and 'Desired Inventory'.

> **Note!** When you connect 'Expected Demand' to 'Production' with a link, a hash mark ('#') will appear inside the 'Production' symbol. This signifies an inconsistency in the diagram; that a linked variable is not used in the equation defining the target variable. The variable definition must be reformulated to maintain the consistency of the model.

The information about the company stated that they use production to cover desired inventory and that production should always reflect the expected demand. Therefore, we can simply add 'Expected Demand' to the equation for Production.

1. Double-click 'Production'.
2. Redefine the definition to look like this:
   'Expected Demand' + ('Desired Inventory' - 'Inventory')/'Time to Correct Inventory'
3. Click **OK.**

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Model Building (22)

We also know from the information given that the inventory the company wants to keep on hand should cover four weeks of expected demand. To reformulate the 'Desired Inventory' equation, we therefore need a constant representing this multiple of 'Expected Demand'. We call this constant 'Inventory Coverage'.

1. Create a new constant somewhere below 'Desired Inventory', and name it 'Inventory Coverage'.
2. Double-click 'Inventory Coverage'.
3. Enter the definition "4<<wk>>" in the *Definition* box.
4. Click **Apply.**
5. Draw a link from 'Inventory Coverage' to 'Desired Inventory'.
6. Select 'Desired Inventory'. Its definition will appear in the *Definition* box.
7. Replace the existing equation with the following:
   'Expected Demand' * 'Inventory Coverage'
8. Click **OK.**

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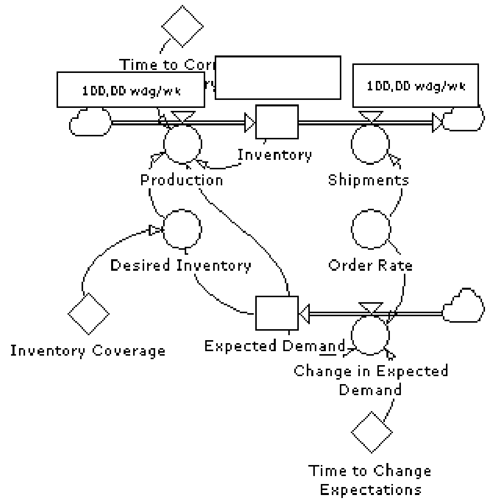
Model Building (23)

The figure below shows the finished model.



The finished model. 'Expected Demand' is connected to both 'Production' and 'Desired Inventory', and is taken into account when the level of production is decided.

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Model Building (24)

Running the Simulation

We have now finished the simulation model, and we can perform the first full-scale simulation run. To inspect the values of the variables, we need to add auto-reports to the key variables. It is a good idea to start with showing 'Inventory', 'Expected Demand, and 'Order Rate' as time graph auto reports, and showing 'Production', 'Shipments', and 'Desired Inventory' as number auto reports.

1. Turn on the auto reports for the different variables (as explained above).
2. Click ▷ **Play** on the toolbar to run the simulation.

Although the auto reports provide information about the values and behavior of the variables, it is difficult to compare results merely on the basis of auto reports. We will therefore add time graphs, sliders, and tables to create an interface for the simulation.

Presenting Simulation Results

Running simulations are not very useful unless we can present the simulation results in a useful manner. To enable us to create appealing simulation projects, Studio allows us to insert new diagrams and rename them to our liking. We will use this feature to create one diagram for the model and one diagram for presenting the simulation results.

1. Right-click the diagram tab at the bottom of the variable window.
2. Select *Rename,* and rename the current diagram to *Model.*
3. Right-click the diagram tab again, and select **Insert Constructor Diagram** on the shortcut menu. A new diagram will be inserted in the diagram book.
4. Right-click the new diagram tab, select **Rename** on the shortcut menu, and rename the tab to *Control Panel.*

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Model Building (25)

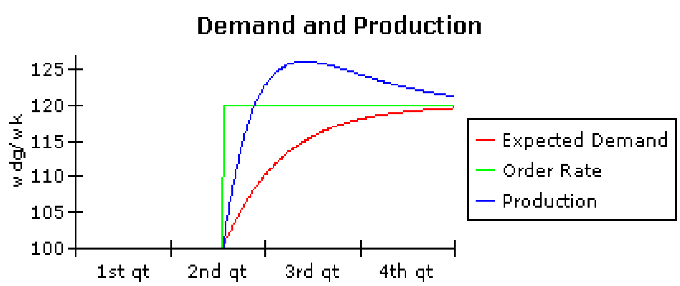
Comparing Demand and Production In a Time Graph

It is of great interest to be able to compare the time series of 'Expected Demand', 'Order Rate', and 'Production'. By comparing these, it is possible to see whether the decision policy we have modeled works the way we want it to. The best way to present these is through a time graph.

1. Click **Time Graph Control** on the toolbar.
2. Position the cursor where you want the control to appear in the diagram, and hold down the mouse button while dragging the control to the desired size. An empty time graph will appear in the diagram.
3. The time graph has no title by default. To add a title, simply right-click the time graph and select Show Title. In the edit field that appears, enter the new title. Let's name it *Demand and Production*.
4. Variables can be added to the time graph using drag and drop.
5. Activate the *Model* diagram again by clicking its tab in the diagram bar at the bottom of the window. Start dragging the 'Expected Demand' variable, let the mouse hover over the *Control Panel* diagram in the diagram bar to activate the target diagram, and then drop the variable on the time graph you just created. It will instantly appear in the graph.
6. In the same manner, drag 'Order Rate' and 'Production' to the time graph as well. To get the unit label along the value axis, right click the value axis, select **Unit Label** from the menu, and then select **Along Axis** from the list.
7. Start a new simulation run by clicking the **Play** button on the toolbar.

Model Building (26)

The results from the simulation run are shown below.



The behavior of 'Expected Demand', 'Order Rate', and 'Production' over the simulation run. The increase in 'Order Rate' forces delayed changes in both 'Production' and 'Expected Demand'.

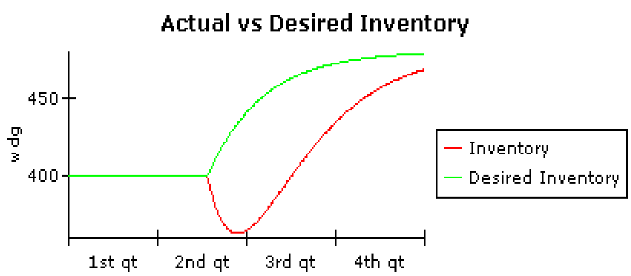
As we see, 'Order Rate' increases suddenly after 20 weeks. 'Expected Demand' follows slowly, and after a number of weeks it adjusts to the new level of orders. 'Production', however, increases suddenly as the 'Order Rate' increases. To get a good understanding of why 'Production' behaves as it does, we must also inspect the behavior of the two variables 'Inventory' and 'Desired Inventory'.

Model Building (27)

Comparing Inventory and Desired Inventory

1. Create another time graph, and set the title to "Actual vs. Desired Inventory".
2. Drag the variables 'Inventory' and 'Desired Inventory' onto the control.

The time graph of the new simulation run is shown below.



The graph shows (actual) 'Inventory' and 'Desired Inventory'. The desired inventory increases immediately when the 'Order Rate' increases, but due to the delay in 'Production', 'Inventory' decreases first before it increases and reaches the same level as 'Desired Inventory' at the end of the simulation.

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Model Behavior (1)

Let's examine and try to explain why the model behaves as it does. For the first 20 weeks of the simulation, all the variables are constant, indicating that the model is in equilibrium. However, after 20 weeks, the model is knocked out of equilibrium by 'Order Rate', which steps up from a steady rate of 100 to 120 widgets per week for the rest of the simulation. This behavior constitutes a "shock" to the model; it brings the model out of equilibrium and reveals its dynamic behavior. This behavior is seen in the graphs presented above.

The results of the shock can be seen in the behavior of the other variables. 'Expected Demand' can be seen to increase, but ever more slowly, until it reaches the new level of orders coming in. The rate at which it increases is slowing because the flow changes 'Expected Demand' according to the discrepancy between 'Order Rate' and 'Expected Demand'. This discrepancy is at its largest when the shock occurs. From then on, 'Expected Demand' is growing, making the discrepancy smaller and smaller, thus causing less to be added to the level each simulation period.

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Model Behavior (2)

'Production' rises above 'Order Rate' before settling into equilibrium again. Two elements; 'Desired Inventory' and 'Expected Demand' drive 'Production'. We have already seen that 'Expected Demand' is rising. 'Desired Inventory' is also rising (increasing the discrepancy between 'Desired Inventory' and 'Inventory') because it is simply a multiple of 'Expected Demand'. The equation that defined 'Production' adds to the 'Inventory' when 'Desired Inventory' and 'Expected Demand' are both rising. Intuitively, this makes sense, because a company would want to produce enough of their product to cover expected future demand as well as to keep a sufficient level of inventory on hand.

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Model Behavior (3)

The increase in 'Production' is also evident from the behavior of the 'Inventory'. In this company, 'Shipments' are always equal to the 'Order Rate', so the increase in 'Shipments' immediately starts to drain the 'Inventory'. This increases the discrepancy between 'Desired Inventory' and 'Inventory' even more, adding to the increase in 'Production'. When 'Production' reaches 'Order Rate' (thus reaching 'Shipments'), 'Inventory' reaches its minimum level. This occurs after approximately 25 weeks, a little before 7/1/2000. From then on, the 'Production' rate is higher than the 'Shipments' rate, so 'Inventory' is increasing. After 25 weeks, as the gap between 'Desired Inventory' and 'Inventory' closes and 'Expected Demand' reaches the 'Order Rate', 'Production' decreases until it is in equilibrium. After approximately 70 weeks, around 7/1/2001, the entire model is in equilibrium at the new, higher level of orders.

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Model Behavior (4)

So what does this mean in terms of business operations? The beauty of creating such a model of a system is that it allows us to investigate not only the structure of the system (how the levels and flows fit together) but also how changes to the structure change the system's behavior (here considered company performance). We have a tool that will help us understand the relationships among such important business variables as inventory, production, shipments, and expectations of demand.

We could refine and develop the model in many ways to make it even more accurate and more representative for ABC Manufacturing. We could add desired production rates, include structures that take into account the workforce of the company, and include yet other structures that affect the performance of the company.

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Model Behavior (5)

Although the example presented in this chapter is a rather simple one, it illustrates the potential of computer simulation models. The example illustrates how the model formalizes policies, and makes it easier to understand the relationships that control the company. It provides a laboratory where we can experiment with changes in incoming orders, time factors to react to changes, and so on.

The Powersim Studio installation contains several example models that you can study closely. In addition, the online help system also contains some more examples for you to run through if you wish to.

The model presented here is a simple example of a business model. However, it should give you a good idea of the potential that lies in this methodology in general and in the Powersim Studio software package in particular. Only your imagination will limit what models and simulators you can create using this tool. Good luck with your further modeling and simulator building aspirations.

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Conclusion

- The purpose of this session was to ilustrate how to build a simple model in Powersim Studio. Although the model is simple, it shows how to use Studio to create simulation models, and gives you a brief introduction to the technical aspect of modelling using the software.
- We recommend you to take a closer look at some of the other tutorials as well, and also to study the sample models. These shows various business cases as well as features in Studio. We would also encourage you to refer to Help for Studio, where you can find answers to a wide range of questions.

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Sesi 8
Model Ketersediaan (Availability)

1

Outcomes

At the end of this session, participants will be able to:

- understand some concepts of availability that are widely used in modeling using the system dynamics approach;
- understand the differences among the availability concepts; and
- build a model based on each of availability concepts using Powersim Studio software.

2

Simulation Objectives

- Participants are able to understand the concept of availability that was widely used in modeling using the system dynamics approach.
- Participants are able to build a model that is based on each of availability concepts using the software Powersim Studio.
- Participants are able to understand the differences among the availability concepts.

3

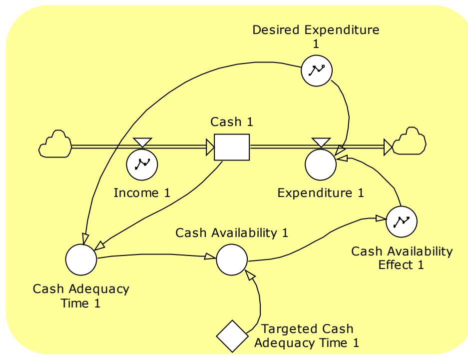
8.1 Availability Concept

- **Availability of a resource** means a resource that is committable, operable, or usable upon demand to perform its designated or required.
- If **Availability >= 1**, means **available**;
  if **Availability < 1** means **not available**
- Availability concept (cash)
  - **Cash Availability = Cash Adequacy Time /Targeted Cash Adequacy Time**
  - **Cash Availability = Cash/Desired Cash**
  - **Cash Availability = Maximum Outcome/Desired Outcome**
  - **Implicit Cash Availability;**
    Maximum Outcome = Cash/Targeted Cash Adequacy Time

4

Availability Concept 1

Availability Concept 1



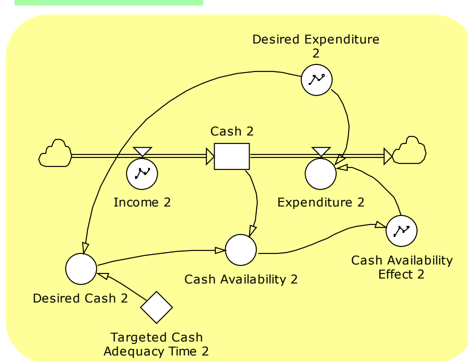
Cash Availability = Cash Adequacy Time / Targeted Cash Adequacy Time

Note: Can not be used when the desired expenditure is zero

5

Availability Concept 2

Availability Concept 2



Cash Availability = Cash / Desired Cash

Note: Can not be used when the desired expenditure is zero

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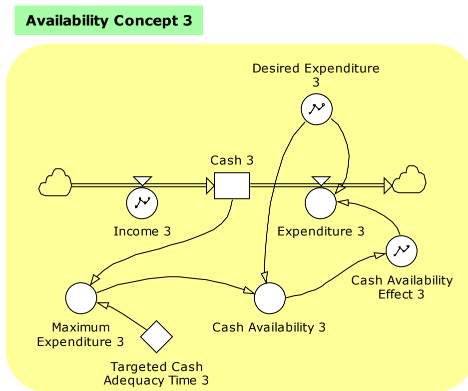
Availability Concept 3



Cash Availability = Maximum Expenditure / Desired Expenditure

Note: Can not be used when the desired expenditure is zero

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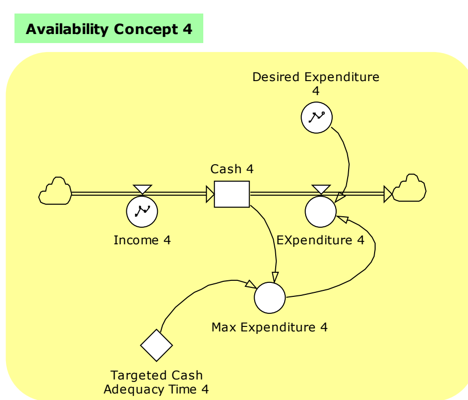
Availability Concept 4



(Implicit Cash Availability) Masimum Expenditure = Cash / Targeted Cash Adequacy Time

Note: Can be used when the desired expenditure is zero

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8.2 Simulation Results

- Although it is using the four different model structures but will produce the same dynamic behavior.