IESR

Institute for Essential Services Reform

Dissemination Webinar on Indonesia's Transportation Decarbonisation Roadmap: Emission Reduction Projection and Policy Intervention in Modal Share and Electric Vehicles

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Pemodelan Dinamika Sistem (*System Dynamics*) Transportasi: Dekarbonisasi

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Prinsip Dasar Kebijakan Dekarbonisasi

Kebijakan dekarbonisasi harus terintegrasi dengan kebijakan pembangunan (kesejahteraan).

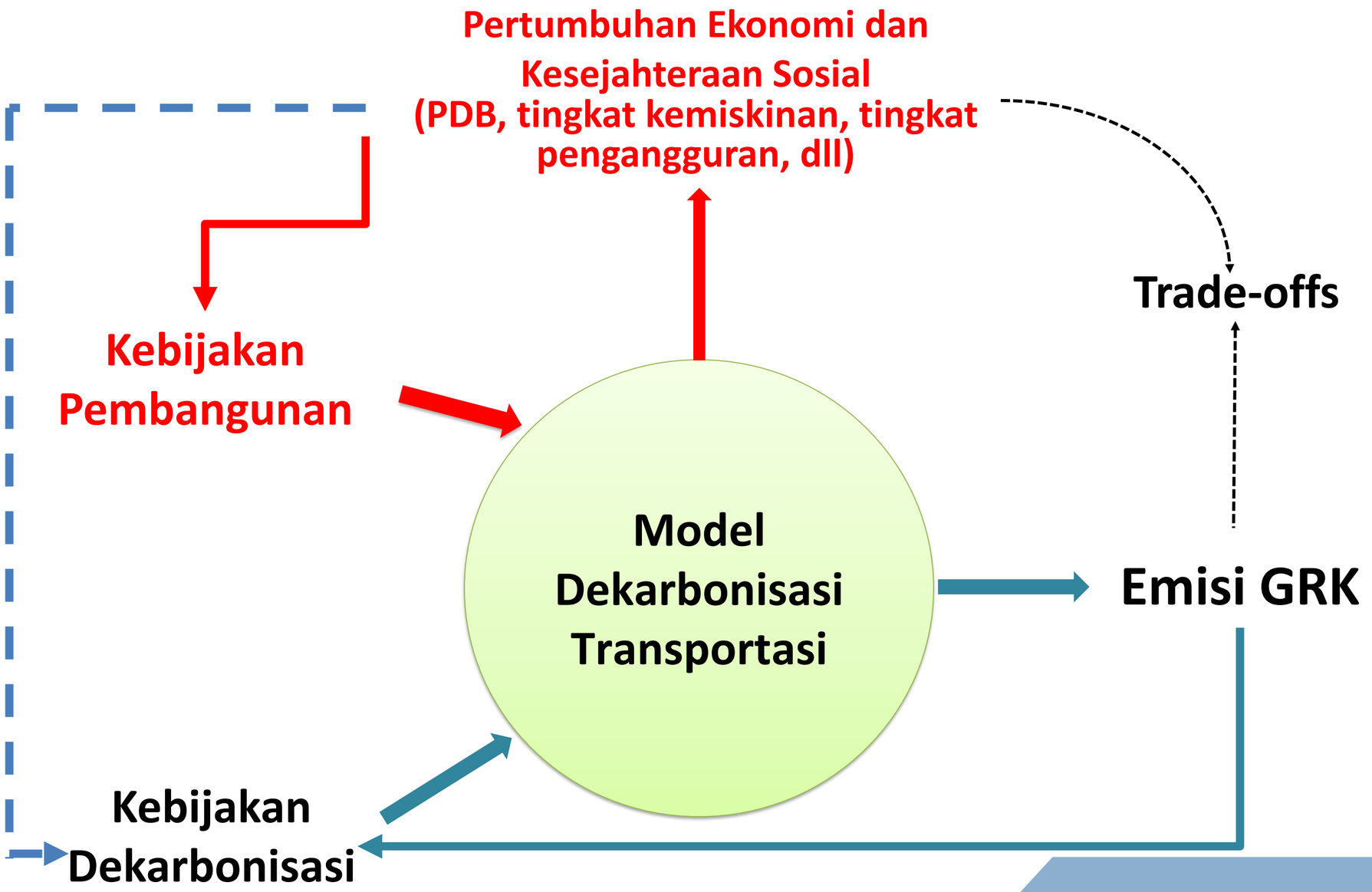
Article 3.4 of UNFCCC:

‘**policies** and measures to protect the climate system against human-induced … should be integrated with national development program…’

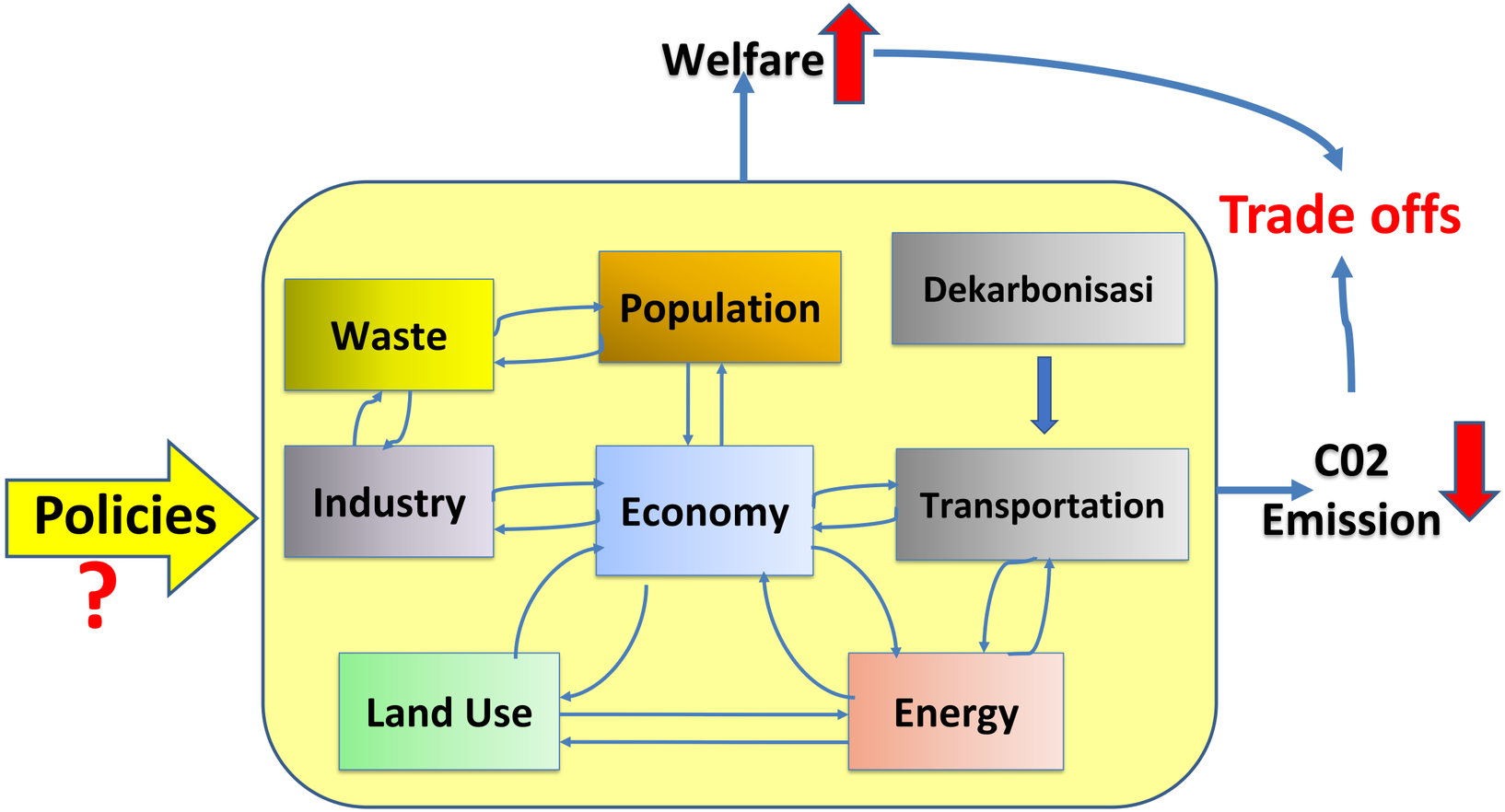
Model Analisis Kebijakan

(*Policy Modeling*)

Model Konseptual Dekarbonisasi Transportasi



Garis Besar Model



[Menganalisis kebijakan pembangunan dan lingkungan hidup terhadap *Economic and Social Performance* dan *Environment Performance* dapat memunculkan perilaku “trade-offs” **(Complex System).**]

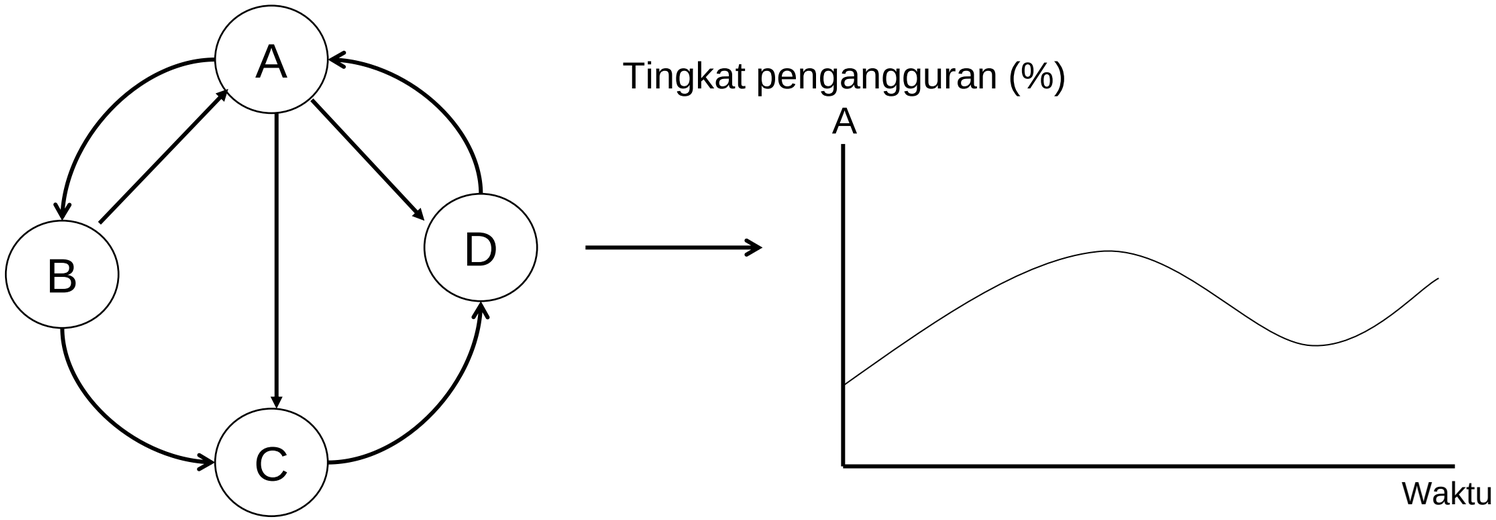
Konsep Kompleksitas

(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.

Dynamic complexity (kompleksitas dinamis)

Suatu fenomena yang strukturnya dibentuk oleh unsur-unsur yang saling bergantung, secara alamiah (*nature*) memiliki karakter kompleksitas dinamis (*dynamic complexity*).

Kompleksitas dinamis dicirikan oleh:

- kenyataan yang sering kali dijumpai yang memperlihatkan gagalnya kebijakan-kebijakan yang diyakini dapat menanggulangi suatu persoalan, atau bahkan memperburuk situasi yang ada (*policy resistant*) (Sterman 2004);
- adanya suatu keputusan yang dapat menghasilkan dinamika sesuai dengan yang diinginkan hanya dalam jangka pendek saja, dalam jangka panjang keputusan tersebut menghasilkan perilaku yang tidak diinginkan, atau sebaliknya (*tradeoffs in time*);
- adanya suatu keputusan yang dapat memperbaiki perilaku suatu sektor tertentu sesuai dengan tujuannya, akan tetapi keputusan itu memperburuk perilaku sektor yang lainnya (*sectoral tradeoffs*).

Kompleksitas dinamis muncul karena fenomena mempunyai karakteristik:

- **Dynamic**

  Heraclitus said, “All is change.” What appears to be unchanging is, over a longer 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.”

- **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

- **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 fundamentally different 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 perturbations 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 seashells and markets all emerge spontaneously from the feedbacks among the agents and elements of the system.

- **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 overwhelms our ability to understand them. The result: Many seemingly obvious solutions to problems fail or actually worsen the situation.

- **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.

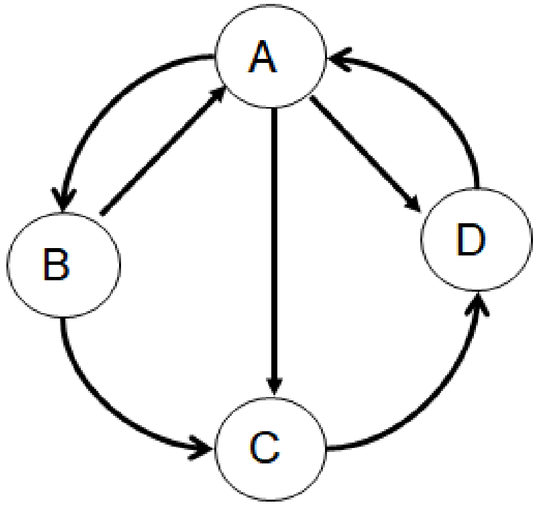
Fenomena Transportasi di Jakarta

[Suatu fenomena (*a phenomenon*) adalah sesuatu yang dapat kita lihat, alami, rasakan atau *something experienced: a fact or occurrence that can be observed.*]

Suatu fenomena menyangkut 2 hal (aspek):

(1) Struktur (*structure*)

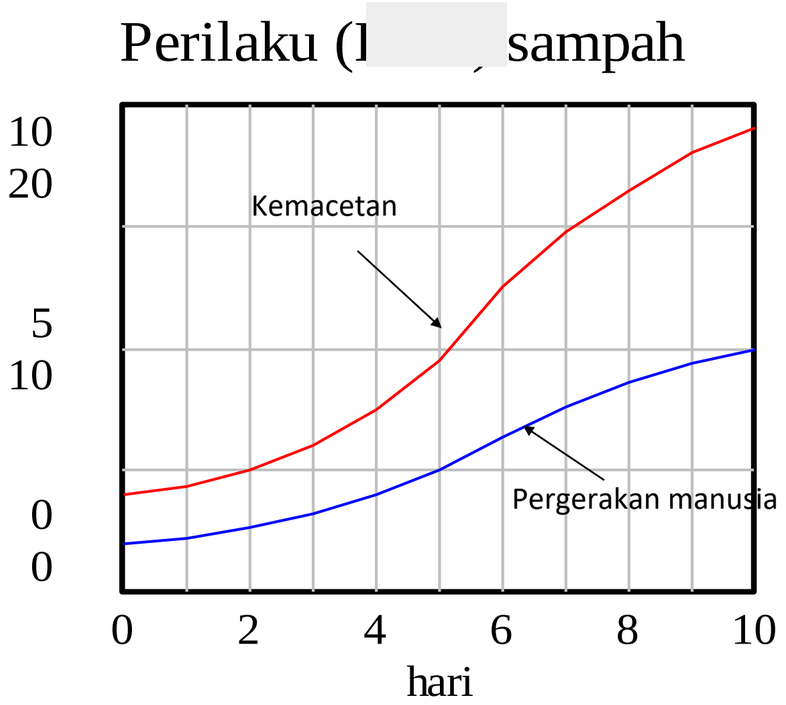
(**unsur** pembentuk fenomena dan pola **keterkaitan** antar unsur tersebut)



Fenomena sosial:
struktur fisik; dan
struktur pembuatan keputusan.

Perilaku (*behavior*) (2) - BOT

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



Pemahaman hubungan struktur dan perilaku sangat diperlukan dalam menyusun strategi dan memformulasikan kebijakan.

Tiga (3) Pertanyaan yang Perlu Dijawab
dalam
Analisis Kebijakan

- Apa-apa sajakah kebijakan (strategi)-nya?

  ***What* ???**

- Seberapa besarkah (angka/nilai) kebijakan-kebijakan tersebut?

  ***Magnitude* ???**

- Bagaimanakah penjadwalan kebijakan-kebijakan tersebut?

  ***Timing* ???**

Kerangka Pemikiran (Pendekatan)

[untuk memahami hubungan struktur suatu fenomena terhadap perilakunya]

Perilaku ditentukan oleh interaksi-interaksi antar unsur-unsur pembentuk fenomena (organisasi) dan antara fenomena (organisasi) dengan lingkungannya.

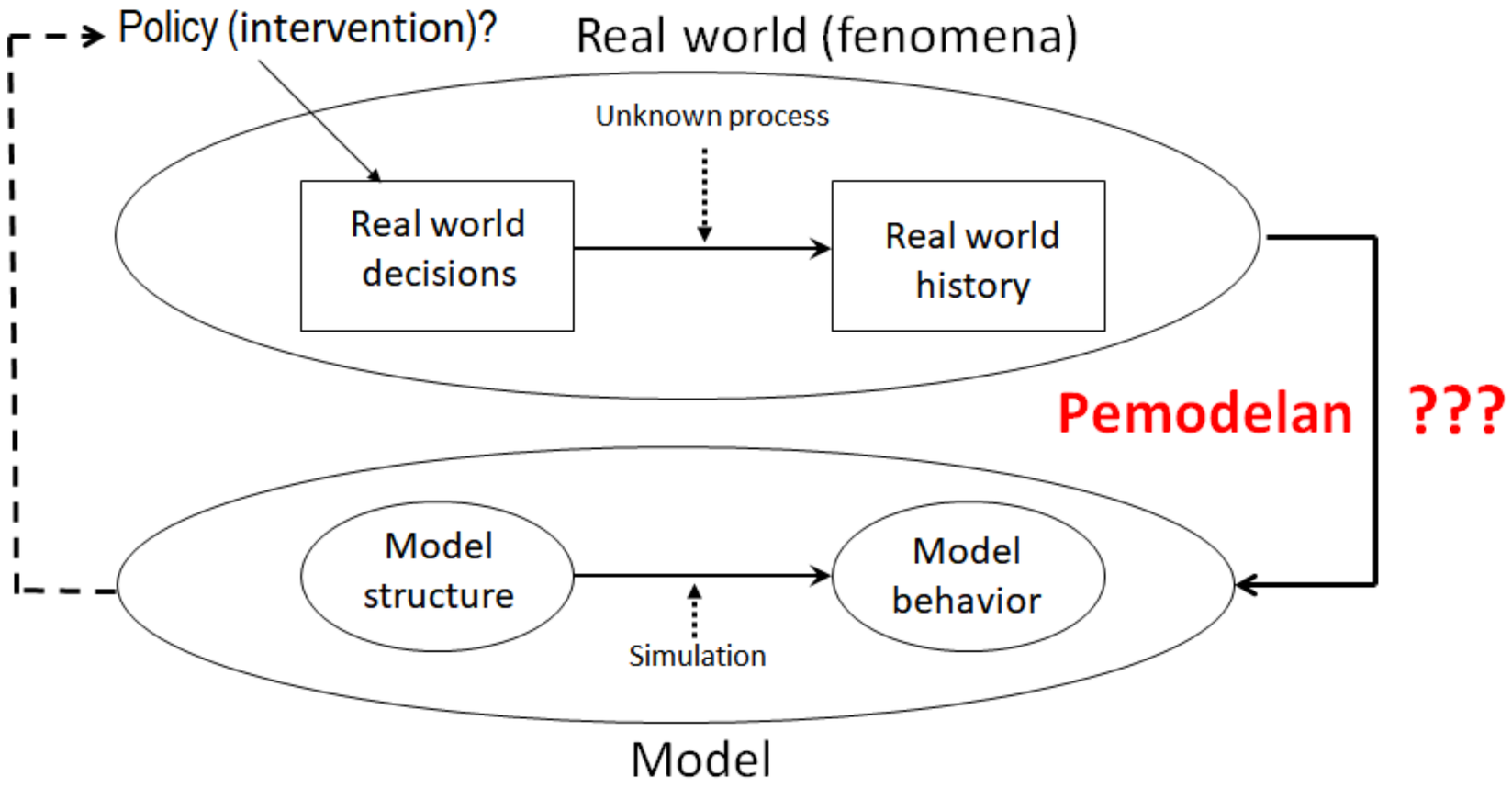
Interaksi-interaksi tersebut cederung lebih penting dari pada unsur-unsur tersebut.

Implikasi-implikasi jangka panjang boleh jadi berbeda dengan implikasi jangka pendek (kompleksitas dinamik).

Dibutuhkan suatu cara untuk melengkapi intuisi dan pengalaman (model mental) yang dapat memberikan pemahaman yang lebih baik tentang hubungan antara struktur dengan perilaku (menangani interaksi-interaksi tersebut dan memperkirakan strategi dan kebijakan dan efek-efeknya baik dalam jangka panjang maupun jangka pendek).

Kerangka Pemikiran (Pendekatan)

Membuat suatu model simulasi (pemodelan, *modeling*): pemodelan kebijakan (*policy modeling*)



Model suatu fenomena adalah deskripsi (penjelasan atau gambaran) struktur fenomena tersebut.

SYSTEM DYNAMICS METHODOLOGY (METODOLOGI DINAMIKA SISTEM)

System Dynamics Methodology

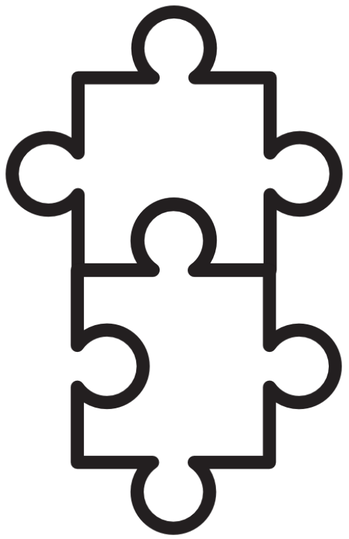
[Source: System Dynamics Home Page.htm]

- 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

[Source: System Dynamics Home Page.htm]



- 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.

Model *System Dynamics*

Struktur ⟹ **Perilaku**

(fisik & pembuatan keputusan)

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

(1) *feedback loop* (*causal loop*, sebab-akibat [bukan korelasi]);
(2) *stock* (*level*) dan *flow* (*rate*);
(3) *delay*; dan
(4) *nonlinearity*.

(ontological: the ways reality itself could be)

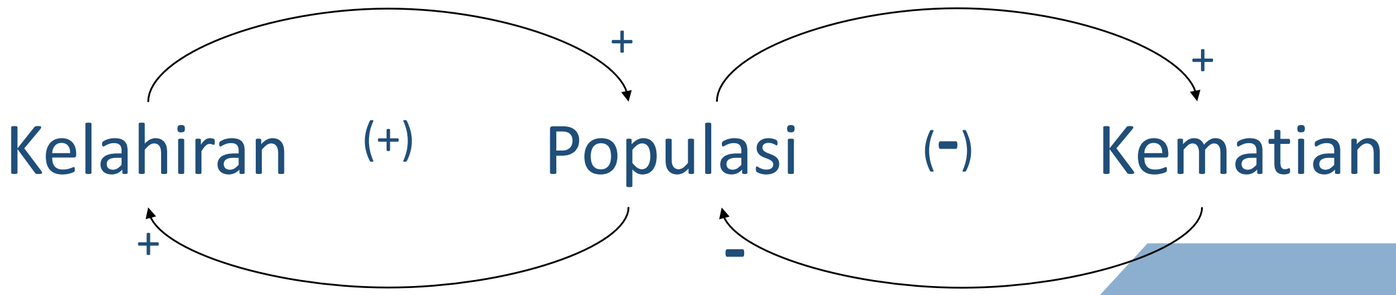
Struktur suatu Model *System Dynamics*

Hubungan sebab-akibat (kausal) beberapa pasangan variabel dapat membentuk suatu lingkaran tertutup (lingkar umpan-balik, *feedback loop*, atau *causal loop*).

Ada 2 macam lingkar umpan-balik, yaitu:

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

Causal Loop Diagram (CLD) populasi

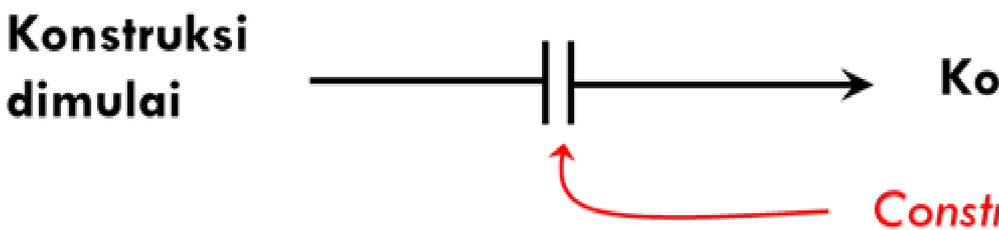


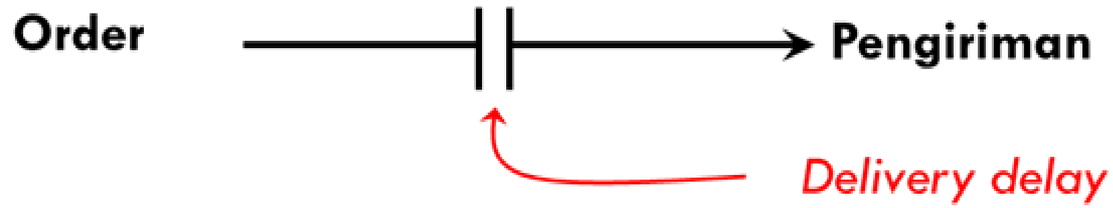
Level (Stock) dan Rate (Flow)

- 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*.

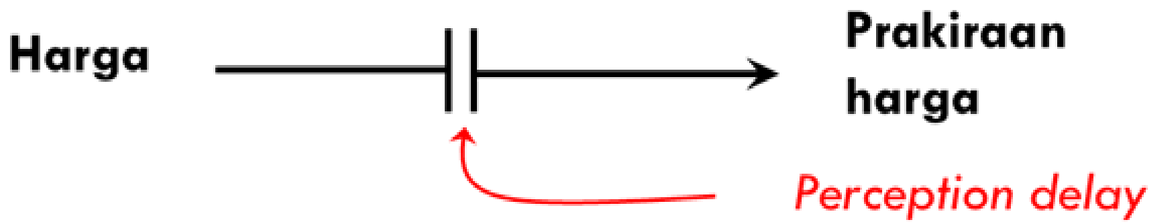
  (*rate* disebut juga sebagai *decision point*)

Delay

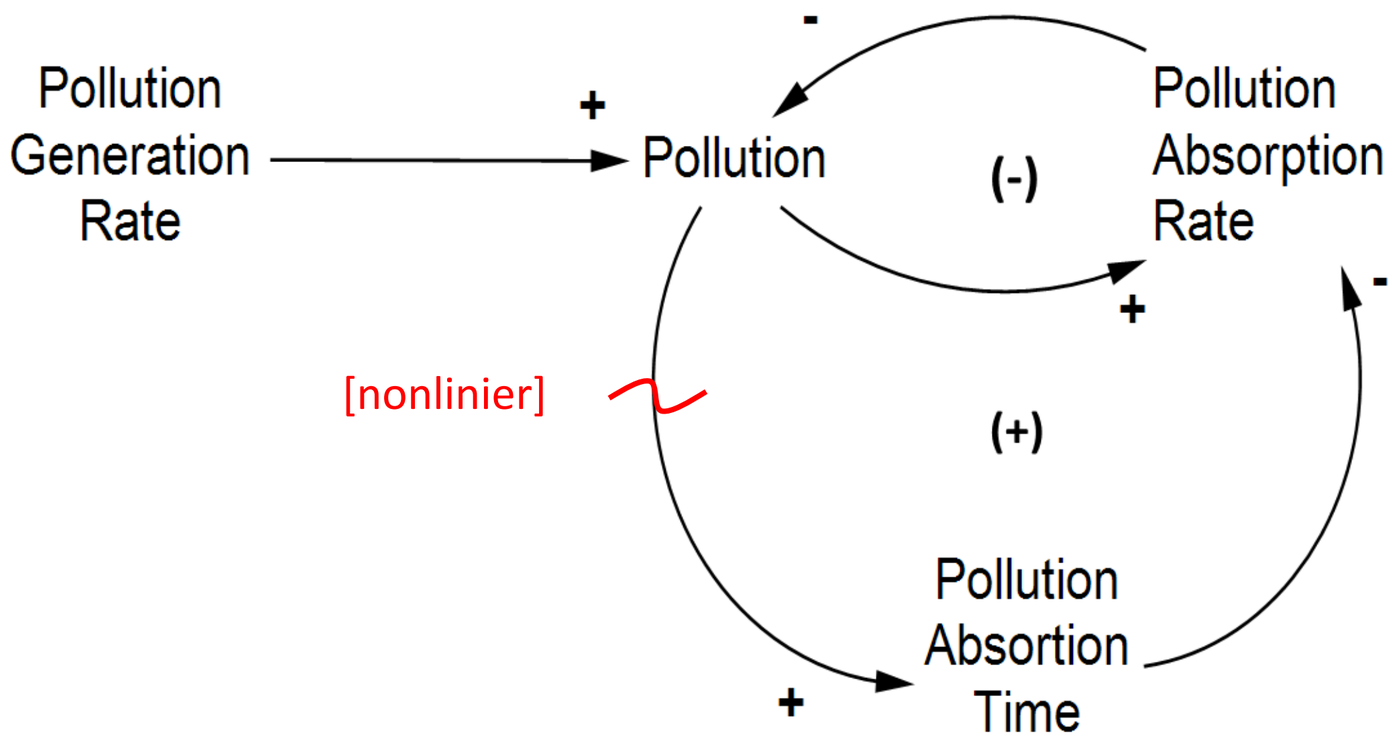




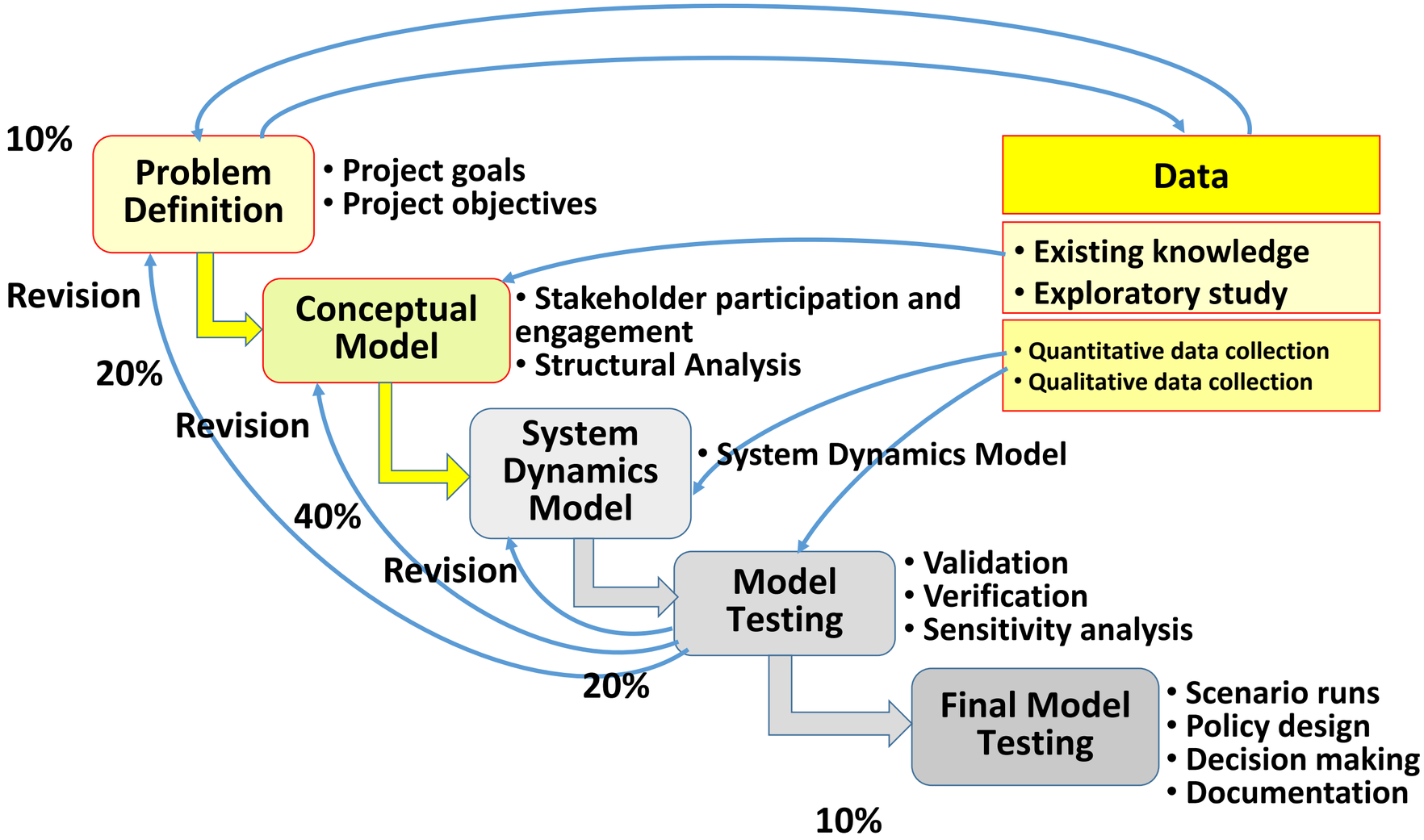
Information smoothing/averaging, perceived



Nonlinearity



Development Phase of System Dynamics Modeling



Data dalam Pemodelan
System Dynamics

Data

[Jay W. Forrester: Policies, decisions and information sources for modeling, *European Journal of Operational Research 59 (1992) 42-63 North-Holland*]

- Information for modeling is available from many different sources (Forrester, 1980). Figure 6.1 suggests three kinds of data bases: mental, written and numerical.
- Those working with statistics may think of data as always coming in measured, numerical form. But Webster's Third Unabridged Dictionary gives **no hint that data are restricted to numerical information**.

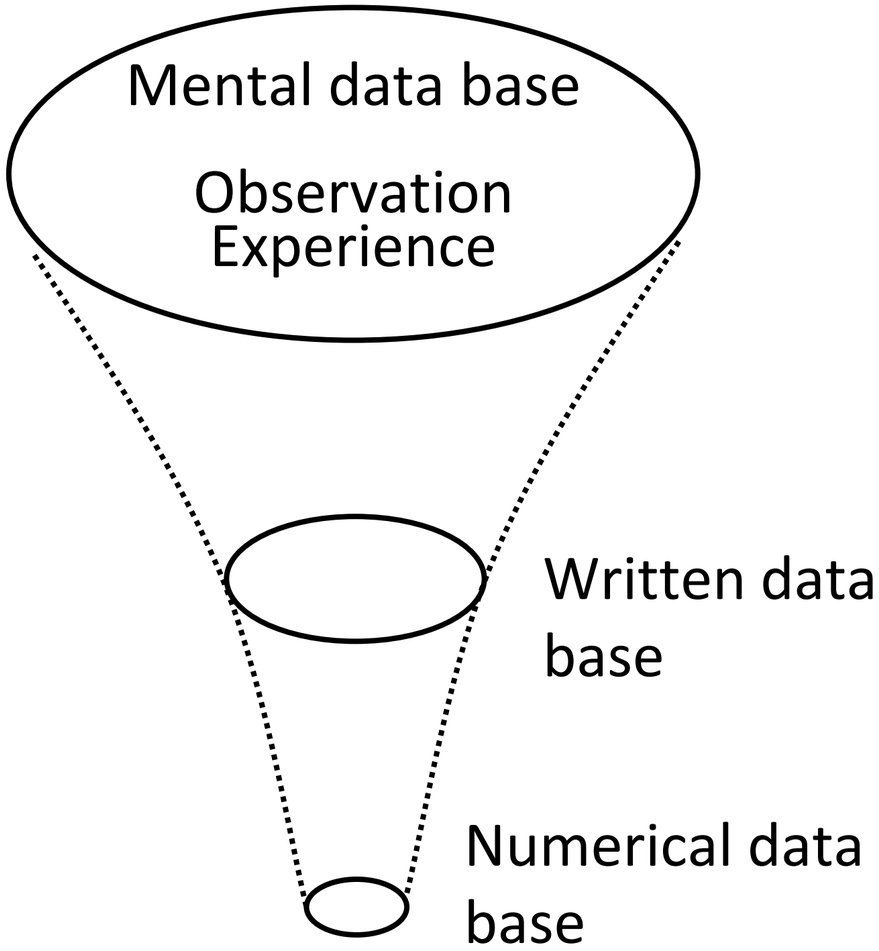


Figure 1 Mental data base and decreasing content of written and numerical data bases

- Webster's defines data as **"something that is given from being experientially encountered"** and **"material serving as a basis for discussion, inference, or determination of policy"** and **"detailed information of any kind"**. This broad definition must include **data stored mentally** in people's heads, **data stored descriptively in writing**, and **data available numerically**.

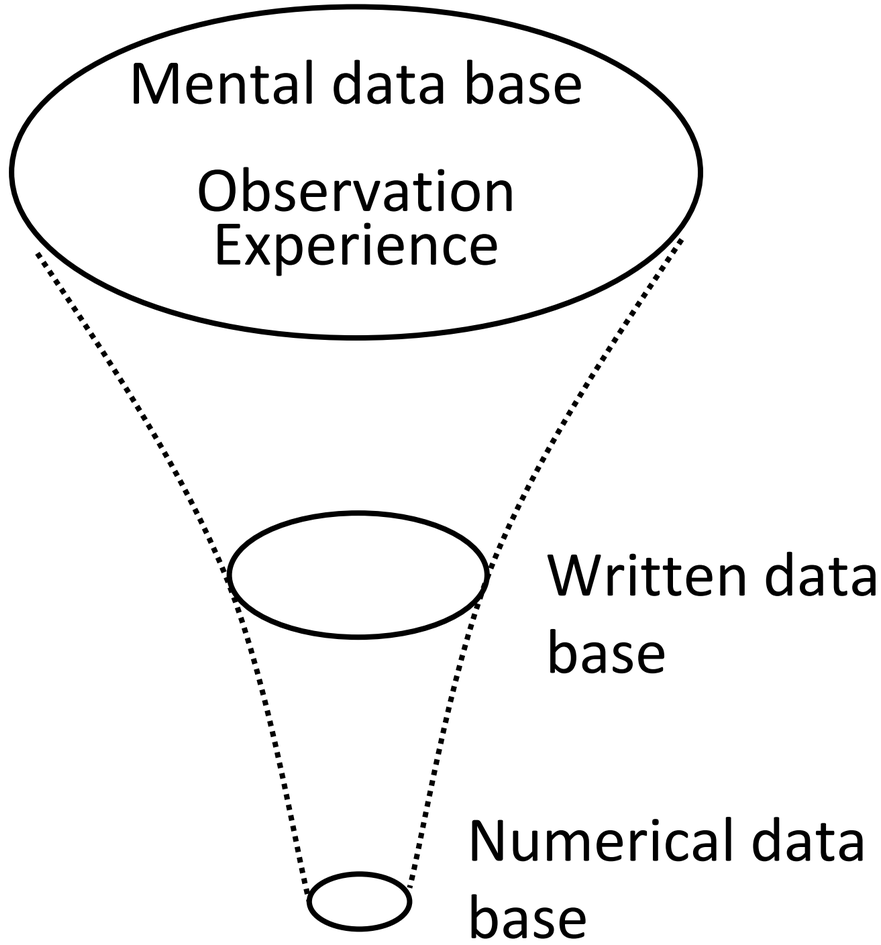


Figure 1 Mental data base and decreasing content of written and numerical data bases

As suggested by the figure, the amount of available information declines, probably by many orders of magnitude, in going from mental to written information and again by another similar large factor in going from written to numerical information.

Furthermore, the character of information content changes as one moves from mental to written to numerical information. In moving down the diagram, there is a progressively smaller proportion of information about structure and policies. Each kind of information can fill a different role in modeling a business or social system.

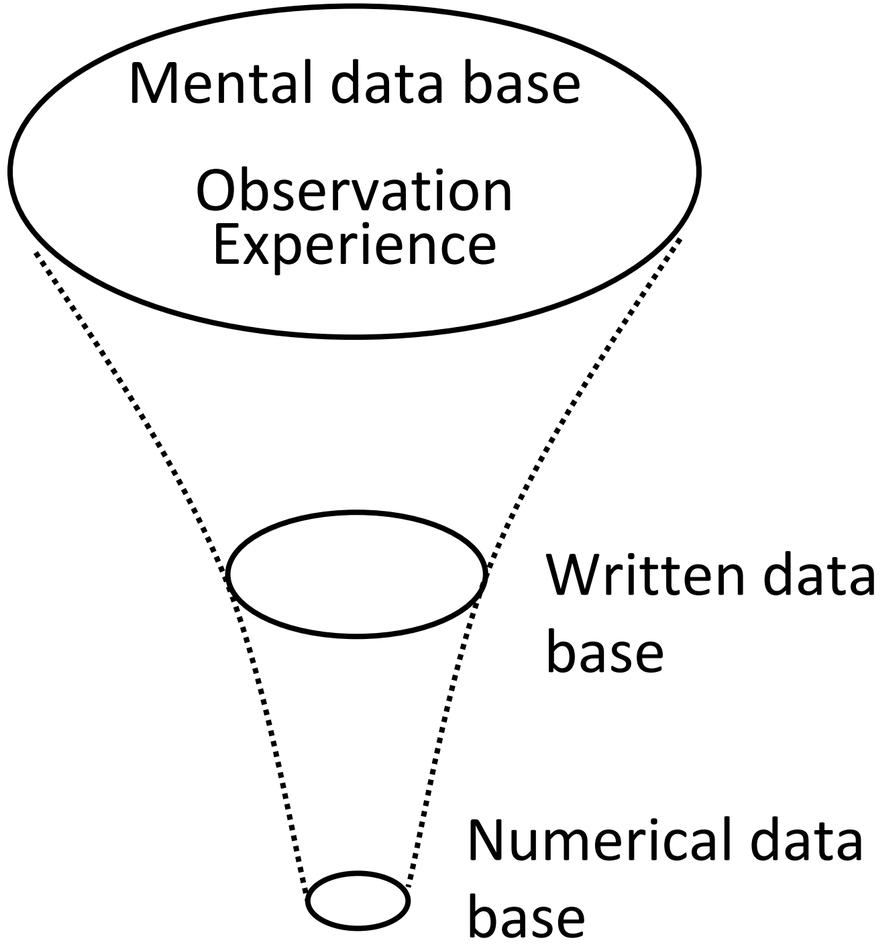


Figure 1 Mental data base and decreasing content of written and numerical data bases

Rujukan

1. Burger, Peter L., T. Lockman (1966), *The Social Construction of Reality*, Allen lane.
2. Dornbusch, Rudiger and Fischer, Stanley (1997). Mulyadi, Julius A. (Alih Bahasa). *Makro-ekonomi (Edisi Keempat).* Penerbit Erlangga.
3. Duncan, Richard C. (1991), "The Life-Expectancy of Industrial Civilization", *SYSTEM DYNAMICS '91 Proceedings of the 1991 International System Dynamics Conference, Bangkok-Thailand, August 27-30, 1991.*
4. Forrester, Jay W. (1961), *Industrial Dynamics*, Cambridge, Mass.: MIT Press.
5. Forrester, Jay W. (1969), *Urban Dynamics*, Cambridge, Mass.: MIT Press.
6. Forrester, Jay W. (1971), *World Dynamics*, Cambridge, Mass.: Wright-Allen Press.
7. Forrester, Jay W. and Peter M. Senge (1980), "Test for Building Confidence in System Dynamics Models", *TIMS Studies in the Management Sciences.*
8. Hamilton, H.R., et al. (1969), *Systems Simulation for Regional Analysis*, Cambridge, Mass.: MIT Press.
9. Kemeny, John G. (1959), *A Philosopher Looks at Science*, D.van Nostrand.
10. Parkin, Michael (1996). *Macroeconomics (third edition)*. Addison - Wesley Publishing Company, Inc..
11. Popper, Karl R. (1969), *Conjectures and Refutations*, Routledge and Kegan Paul.
12. Richardson, G.P. & A.L. Pugh III (1981), *Introduction to System Dynamics Modeling with Dynamo*, The MIT Press, Cambridge, Massachusetts.
13. Saeed, K. (1984), *Policy-Modelling and the Role of the Modeller*, Research Paper, Industrial Engineering & Management Division, Asian Institute of Technology, Bangkok.
14. Saeed K. 1994. *Development Planning and Policy Design: A System Dynamics Approach*. Avebury.
15. Sasmojo, Saswinadi (2004), *Sains, Teknologi, Masyarakat dan Pembangunan,* Program Pascasarjana Studi Pembangunan ITB.
16. Senge, Peter M. (1990), *The Fifth Discipline : the art and practice of the learning organization*, Doubleday/Currency, New York.
17. Sterman, John D. (1981*), The Energy Transition and The Economy: A System Dynamics Approach*, PhD Thesis, Cambridge : MIT.
18. Sterman, J.D. (2004), *Business Dynamics: Systems Thinking and Modeling for a Complex World,* Mc Graw Hill.