

# CompAVI Summary

Quizlet: <https://quizlet.com/ch/1137870186/managing-complexity-innovation-in-aviation-compavi-flash-cards/?i=dgqxd&x=1jqt>

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# Principles of Innovation I

## Macro vs. Micro

Macro	Aggregate view – entire state, economy, industry, system at large e.g. BIP (Bruttoinlandprodukt)
Micro	Individual actor, firm, component

## Complicated vs. complex

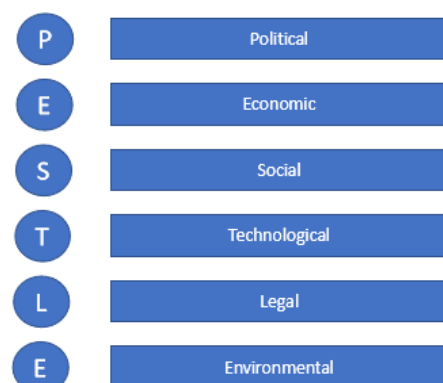
Complicated	Complex
<ul style="list-style-type: none"> <li>• Hard to understand</li> <li>• Solvable through analysis</li> <li>• Expert knowledge required</li> </ul>	<ul style="list-style-type: none"> <li>• Multi-layered</li> </ul>
	<p>A system composed of a <b>large number of interacting components without central control, whose emergent “global” behaviour</b> – described in terms of dynamics, information processing, and/or adaptation is <b>more complex than can be explained or predicted</b> from understanding the sum of the behaviour of the individual components.</p> <p>Complex systems are generally capable of adapting to changing inputs/environment and in such cases sometimes referred to as complex adaptive systems.</p>

## Invention vs. innovation

Invention	Innovation
<ul style="list-style-type: none"> <li>• sth brand new</li> <li>• IP (intellectual property = patent)</li> </ul>	<ul style="list-style-type: none"> <li>• successful commercial execution of ... (processes, etc.)</li> </ul>

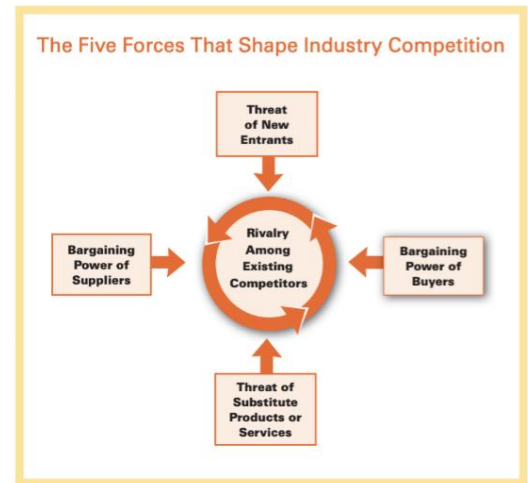
## PESTLE Factors

exogenous factors, used for system analysis



## Porter's Five Forces Framework

1. Buyers – Driven by price, will buy based on lowest fare
2. Suppliers – want to be paid more and deliver less. Powerful suppliers will use clout to raise prices or set more favourable terms, e.g. fuel suppliers.
3. Substitutes – may come from other industries, e.g. railways
4. New entrants – e.g. Low-cost carriers (LCC) forced competition to reduce costs
5. Existing Rivals – intense competition affects everyone's rivalry.



## Principles of Innovation II - Growth

- important factor

Definition: “Sign of progress and embodiment of hope in human affairs

Technological Growth (technical advancements)	Economic Growth (= prosperity)
<ul style="list-style-type: none"><li>• new energy sources</li><li>• level &amp; reliability of food supply</li><li>• new materials</li><li>• new industries (e.g. bike, car, plane, etc.)</li></ul>	<ul style="list-style-type: none"><li>• tangible material gains</li><li>• private possessions to enrich lives</li></ul>

### Challenges

- controlling growth (acceleration, moderation, ending)
- forecasting outputs & performance

### Quantifying growth

How do you measure growth?

- Quantitative:
  - physical units: length, mass, time, electric current, temperature, amount of substance, luminous intensity
  - derivatives: volume, speed, energy, power, ...
  - compare two points in time = result
- Qualitative:
  - growth of economies: GDO, GNI
  - average living space per family
  - possessions of household appliances
  - destructive power of stockpiled missiles

### GDP – Gross Domestic Product

$$GDP = C + I + G + NX$$

- C = private-consumption expenditures by households and nonprofit organizations
- I = refers to business expenditures (investments) by businesses and home purchases by households, government spending
- G = denotes expenditures on goods and services by the government
- NX = net exports = a nation's exports minus its imports.

## Fathers of innovation – Schumpeter & Drucker

Schumpeter's theories	<ul style="list-style-type: none"> <li>• how does capitalism work?</li> <li>• capitalist “equilibrium” misleading: constant change &amp; innovation are key traits</li> <li>• innovation in specific industries creates growth (= economic expansions)</li> <li>• <b>innovation requires continuous disequilibrium</b></li> <li>• difficulties: resistance and uncertainties of sth that has not been done before</li> <li>• <b>Credit creation is essential</b></li> <li>• <b>entrepreneurs are the agent of innovation &amp; destruction.</b> → their projects lead to new jobs, higher incomes, and general economic progress</li> </ul>
Drucker's principles of Innovation	<p>5 Do's:</p> <ol style="list-style-type: none"> <li>1. Purposeful, systematic innovation begins with the <b>analysis of the opportunities.</b></li> <li>2. Innovation is both <b>conceptual and perceptual.</b></li> <li>3. An innovation, to be effective, has to be <b>simple</b> and it has to be <b>focused.</b></li> <li>4. Effective innovations <b>start small.</b></li> <li>5. But ... a successful innovation <b>aims at leadership.</b></li> </ol> <p>3 Don'ts:</p> <ol style="list-style-type: none"> <li>1. Try not to be clever.</li> <li>2. Don't diversify, don't splinter, don't try to do too many things at once.</li> <li>3. Don't try to innovate for the future. Innovate for the present!</li> </ol> <p>3 Conditions</p> <ol style="list-style-type: none"> <li>1. <b>Innovation is work.</b> It requires knowledge. It often requires ingenuity.</li> <li>2. To succeed, innovators must <b>build on their strength.</b></li> <li>3. Innovation is an effect in <b>economy and society.</b></li> </ol> <p>7 Sources of Innovation</p> <ol style="list-style-type: none"> <li>1. Unexpected occurrences</li> <li>2. Incongruities (incompatibilities)</li> <li>3. Process Needs</li> <li>4. Industry &amp; Market Changes</li> <li>5. Demographic changes</li> <li>6. Changes in Perception</li> <li>7. New Knowledge</li> </ol>

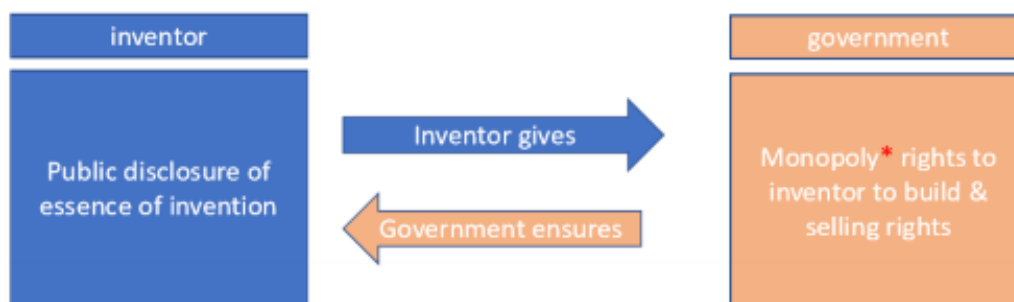
## Academic vs. Corporate R&D

- **Academic research** is driven by “Publish or Perish.”
- **Corporate R&D** adds “Patent” to this – “Patent, Publish or Perish.”
  - Corporations organize R&D teams to improve or create products, often to **combat competitors' innovations.**

- Patents play a strategic role by **protecting inventions** and securing **temporary monopolies**.

## Patents (IP)

- A **patent** is a **contract between the inventor and the government**:
  - The **inventor discloses** the invention publicly.
  - The **government grants** exclusive rights (usually for 20 years) to make, use, and sell it.



## Three Swiss Patent Requirements:

1. **Novelty** – not previously known (no prior art).
2. **Inventiveness** – not obvious to a skilled professional.
3. **Industrial Applicability** – must be usable and reproducible in industry.

→ **Not patentable**: abstract ideas, scientific theories, medical procedures, plant/animal breeds, and inventions contrary to public policy.

## Alternative to Patents

- **Copyrights** – protect the *expression* of ideas (e.g., written works, art).
- **Trademarks** – protect *symbols and signs* that distinguish products.
- **Trade Secrets** – oldest form of IP; rely on secrecy and confidentiality, not registration.
  - Advantage: unlimited duration, no fees.
  - Risk: others may independently discover or patent the same innovation.
  - Example: 2019 case of Russian and Italian nationals charged with stealing **GE Aviation trade secrets**.
- **Other incentives**:
  - Government R&D funding, national labs, and innovation prizes as alternatives to patent-based systems.

## Patents in Aviation

- Between **1900–1970**, aviation saw a **surge in patent activity**, reflecting:
  - Rapid technological advancement.
  - Increased industrial R&D investment.
  - The growing economic and political power tied to aerospace innovation.
- Aviation patents exemplify how **legal protection and public disclosure** fostered global progress in aeronautics.

## Problem & Solution

### Trivial Problems

#### Trivial problems:

- Well-defined, with clear goals, known variables, and procedures (e.g. solving a utility equation).

#### Non-trivial problems:

- Complex, uncertain, and dynamic — like the **Traveling Salesman Problem (TSP)**.
- Adding new elements changes the entire solution; cannot be optimized analytically.

These concepts show that **real-world innovation** deals with **ill-defined, non-trivial problems** requiring creative and iterative exploration.

### *Evolutionary and Iterative Problem-Solving*

- Borrowing from **evolutionary optimization** (mutation, selection, recombination), innovation improves through cycles of testing and refinement.
- The **principle of successive refinement**: begin with broad exploration and progressively fine-tune.
- Random deviations and failures are essential for discovering better solutions

## Multiple and Conflicting Optimization Criteria

- Real problems involve competing goals — e.g., cost vs. performance or individual vs. societal needs.
- There is rarely a “perfect” solution, only **balanced trade-offs**.
- Thucydides’ quote (“the strong do what they can, the weak suffer what they must”) is used to highlight how **power and imbalance** often shape outcomes in problem-solving and innovation.

## Simple vs. Complex Problems/ Well-defined vs ill-defined

- **Simple:** few criteria, low interdependence → clear, optimal solutions.
- **Complex:** multiple, interrelated criteria → unpredictable, emergent solutions (“frustrated systems”).
- **Well-defined** problems can be solved by computers; **ill-defined** ones need human mediation and creativity.

### *The Law of Unintended Consequences (Robert K. Merton)*

- Actions often lead to outcomes that are **unexpected or contrary** to intentions.
- “Cui bono?” — who benefits?
- Includes **self-fulfilling prophecies**, where beliefs shape outcomes (e.g., bank runs, consumer panics, Amazon’s drone delivery hype).
- Example: child-restraint regulations on airplanes unintentionally increased car travel risks.

### *Problem Solving Cycles (PSC)*

Steps:

1. Define objectives and problem.
2. Search for creative solutions.
3. Evaluate and select the best alternative.
4. Implement the chosen solution.
5. Review results and iterate if necessary.  
→ In practice, many “good” solutions coexist — innovation is a process of balancing trade-offs, not finding perfection.

Linked to Lindblom’s “**Muddling Through**” theory — progress through incremental, limited adjustments rather than grand, optimal solutions.

## Disruptive Technologies

Explains why strong companies fail:

1. Dependence on existing customers discourages disruptive ideas.
2. Large firms avoid small, early-stage markets.
3. Emerging markets lack reliable data for investment.
4. New tech often underperforms initially but improves over time.

**Disruptive technologies** are simpler, cheaper, and initially unattractive to major customers, but grow to transform industries.

**Managerial advice:** create small, independent teams, embrace failure as learning, and iterate patiently.

### *Henry Chesbrough – Open Innovation*

Firms should use **external and internal knowledge flows** to accelerate innovation. Instead of relying solely on in-house R&D, companies should collaborate, license, and share technology to expand markets and speed up progress.

### *Jim McKelvey – The Innovation Stack*

Innovation is a **chain reaction** of solving interconnected problems. Success arises when these stacked innovations create a unique, self-reinforcing system (e.g., Southwest Airlines' low-cost model). Reflects Schumpeter's view of entrepreneurs as creative disruptors driving systemic change.

## Evaluation of Technologies

TRA: Technology Readiness Assessment, systematic, evidence-based process that evaluates the maturity of technologies (hardware, software, processes) critical to the performance of a larger system or the fulfilment of the key objectives of an acquisition program, including cost and schedule.

TRL: Technology Readiness Levels, Higher TRL = closer to implementation.

Other forms of readiness

- manufacturing readiness Levels (MRL)
- Integration readiness level (IRL)
- System readiness levels (SRL)

### *Applications in Aviation*

- TRL concepts adapted to **Feedstock Readiness Level (FSRL)** for aviation biofuels.
- Shows how readiness assessments reduce risk of time and budget overruns in aerospace innovation.
- Contrasts **commercial** and **defence** TRL systems, showing differing approaches to maturity, testing, and cost control.

## Principles of Innovation III

### Nasa Technology Roadmaps

NASA's Technology Roadmaps outline 14 areas of focus, distinguishing between **“push” and “pull” technologies for long-term missions**. Similarly, Airbus uses a technology roadmap to align business goals with technology strategies over short and long terms.

- 14 Technology Areas covering all aspects of NASA Missions
- Differentiation between mission “Push” and “Pull” technologies \*
  - Pull: “needed to support the increased capabilities demanded by future planned NASA missions”
  - Push: “could meet NASA’s long-term strategic challenges.”
- Not budget driven or constrained, no prioritisation (at this stage)

### Technology Roadmap:

helps prioritise product features and align business activities with technology strategies. Used as a mechanism to define future budgets, collaborations, prioritisations. Visualisation through Technology Area Strategic Roadmap & Breakdown Structure.

Time is a dimension (unlike NASA TR above) to address

- Short-term goals
- Long-term goals

4 factors mapped:

- Market drivers (customer need, business need, tech. advances, env. Awareness, economical)
- Product features
- Technology
- Resources

### Example Airbus – Single-aisle program

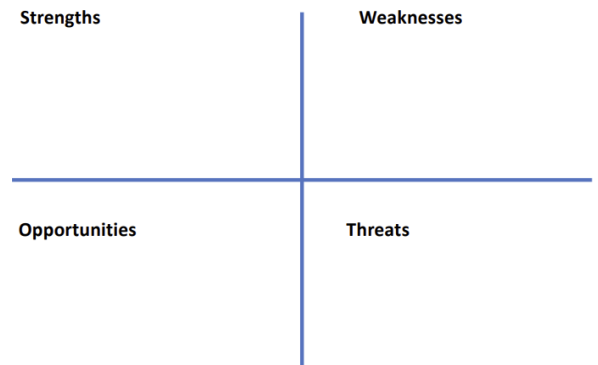
Key Inputs / Assumptions:

- 4.4% growth in air traffic
- Demand driven by demographics and wealth creation (income growth)
- Industry growth projection: 0.3% (global revenue)
- Competitive landscape: duopoly

### SWOT Analysis/Matrix

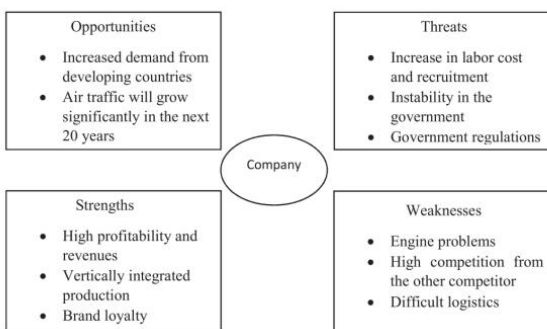
SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) helps firms identify internal and external factors influencing success, often accompanied by PESTLE analysis.

- Identify future opportunities and risks (threats)
- Strengths & Weaknesses (Inward looking, “today”)
- Opportunities & Threats (outward looking, “future”)
- Time dimension - this is only a snapshot:
  - Over time, categories can shift into other quadrants



## Examples

### Single-Aisle Program



SWOT analysis of the company's position.

NB: sequence of quadrants not the same!

### South African Civil Aviation Authority (SACAA)

#### 6.5 SACAA Functional Capability – SWOT Analysis

The strategic review process was preceded by a consultative SWOT analysis with the following results, and these will be applied in the organisational review and development of objectives.

SWOT ANALYSIS	
<p><b>STRENGTHS</b></p> <ul style="list-style-type: none"> <li>• Smart and talented employees</li> <li>• Reputable international standing</li> <li>• Independently acknowledged operational excellence</li> <li>• Financial strength</li> <li>• Category 1 status in terms of the ICAO 8 Critical Elements</li> <li>• ICAO recognition for SA leading role in Armed in Africa as a centre of excellence</li> </ul>	<p><b>OPPORTUNITIES</b></p> <ul style="list-style-type: none"> <li>• Alignment of organisational structure and role accountabilities to the optimal business process</li> <li>• Building stronger industry relationships</li> <li>• Effective stakeholder engagement</li> <li>• Use of TETA funds for pilot training</li> <li>• Industry transformation through aviation training schools</li> <li>• Leadership in regional aviation safety oversight integration</li> <li>• Consolidation of the UAV industry</li> </ul>
<p><b>WEAKNESSES</b></p> <ul style="list-style-type: none"> <li>• Sub-optimal business processes</li> <li>• Less than optimum infrastructure and capability</li> <li>• Inadequate talent management &amp; career pathing</li> <li>• Wavering staff morale due to a high turnover of Director of Civil Aviation</li> <li>• Working in silos</li> <li>• Sub-optimal human resources management processes</li> <li>• SACAA remuneration not attractive to potential employees</li> <li>• Lack of rigorous performance management and productivity measurement</li> <li>• Sub-optimal revenue model</li> </ul>	<p><b>THREATS</b></p> <ul style="list-style-type: none"> <li>• Lack of technical aviation skills across the board</li> <li>• Unethical employee behaviour (unknown conflict of interest)</li> <li>• Information security risk due to manual record-keeping</li> <li>• High reliance on Passenger Safety Charge</li> <li>• Integration of UAV into civil airspace</li> <li>• IT Security (Inherent risk)</li> <li>• African safety record</li> </ul>

## Project Management Triangle

Project Management Objectives:

- Deliver results with the 3 given constraints
- Optimise the resources allocated
- Start & complete the project



## BCG Growth Share Matrix

- Companies should have a healthy mix (portfolio diversification) of products with variety of growth rates and cash flows (market share).
- Use as a method to understand the lifecycle of a product
- Technology-driven enterprises accelerate movement through the matrix

4 categories of growth:

- Stars – “assure the future”
- Cash Cows - “fund future growth”
- Question Marks – “need to be converted to stars with added funds”
- Pets (a.k.a. dogs) – Divest



## Ansoff Matrix

The Ansoff Matrix uses the BCG matrix as an input by outlining four growth strategies—Market Penetration, Market Development, Product Development, and Diversification.

### 4 Growth Alternatives

#### 1. Market penetration

- a. increase sales without changing original product-market strategy.
- b. Increase volume sales or find new customers

#### 2. Market Extension / Development

- a. adapt product line (incremental) for new missions
- b. e.g. passenger aircraft for cargo use

#### 3. Product Development

- a. Maintain mission
- b. Develop new products or existing with new characteristics

#### 4. Diversification

- a. Depart from product line and mission
- b. Horizontal, vertical or lateral shift

## Biomimetrics

Biomimicry applies nature’s designs to engineering.

- copying from nature
- inspiring from nature

- Self-replication
- Reconfigurability
- Self-healing
- Balancing content of various chemicals, temperature, pressure
- Durability
- Multi-functionality



### Human’s Benefits

- Food
- Clothing
- Comfort
- Construction
- Energy
- ...



### Examples

- Fur
- Leather
- Honey
- Wax
- Milk
- Silk

*Man-Made vs. Nature*

Man-Made	Nature
Processing with heat & pressure	Uses ambient conditions*
Synthetic Silk → Epidemic amongst silk-worms	* Bones, silk are made from organism's body with minimal waste, strong materials, biodegradable
Nylon → WWII use in parachutes (original use for toothbrushes & stockings)	

*Inspire-Abstract-Implement*

➔ bioinspired design paradigm

Examples

- structures built significantly larger than species building them
  - ants → anthill
  - bees → beehives
  - bird → bird nest
  - spider → spider web
- Honeycombs
  - bees' usage: efficient packing configuration for offspring & food storage, material: beeswax & propolis (resin)
  - aviation usage: efficient space filler parts which has low weight and high strength, material: paper, metals, ceramics, composites
- Velcro
  - velours (loop) and crochet (hook)
- The wheel
  - limitations such as complex terrains → better legged animals
- shark
  - shark skin technology
- flyability (EPFL spin-off)
  - heavily inspired by bio (insect) design

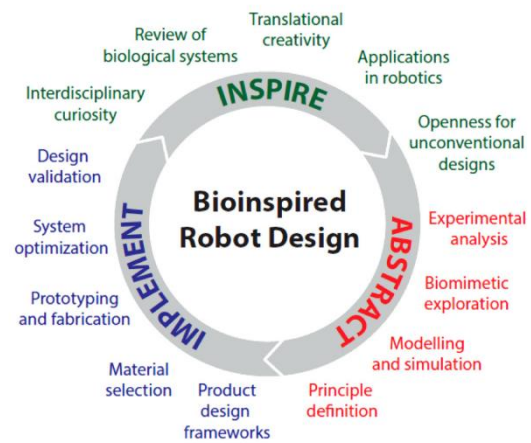


Figure 1: inspire-abstract-implement

A few more examples:

A few more examples:	Attributes
Dragon Fly	Flight performance, fly backwards, stopping & starting with a small body
Spider Silk	Toughness of silk, produced at room temperature & pressure conditions
Monarch Butterfly	Navigational ability, migrating to targeted locations which it never visited before. Information coded into genes.
Seashells	Strength of shells, despite being made of "soft material" – calcium carbonate (i.e. chalk)
Humans	Ability if identify people not seem for many years and whose appearances may have significantly changed

## Technological Determinism

- ➔ is an invention always used everywhere?
- ➔ “Technology is only an instrument, and man does not always know how to use it”  
– Fernand Baurdel (1902-1985)

### Examples

- Gun adoption in Japan
  - cultural digression: samurai class rejected gun
- The wheel
  - north Africa: camel was smarter use than a wheeled ox
- adoption of electricity
  - Sweden: light (=energy) for working class
  - South Africa: light (=energy) used for mineral extraction
  - UK: 1936 30% electricity in homes (rest gas)
  - USA: 1936 90% electrified households

## Prognostications: Prediction, Forecasting & Projections

Form of prognostication	Persons involved	Focus	Timeframe
Prediction	Inventors, utopian writers	Breakthrough inventions	Long term
Forecasting	Engineers, entrepreneurs	Innovations	< 10 years
Projection	Designers, marketers	New models	< 3 years

- ➔ predictions if done well become self-fulfilling prophecies

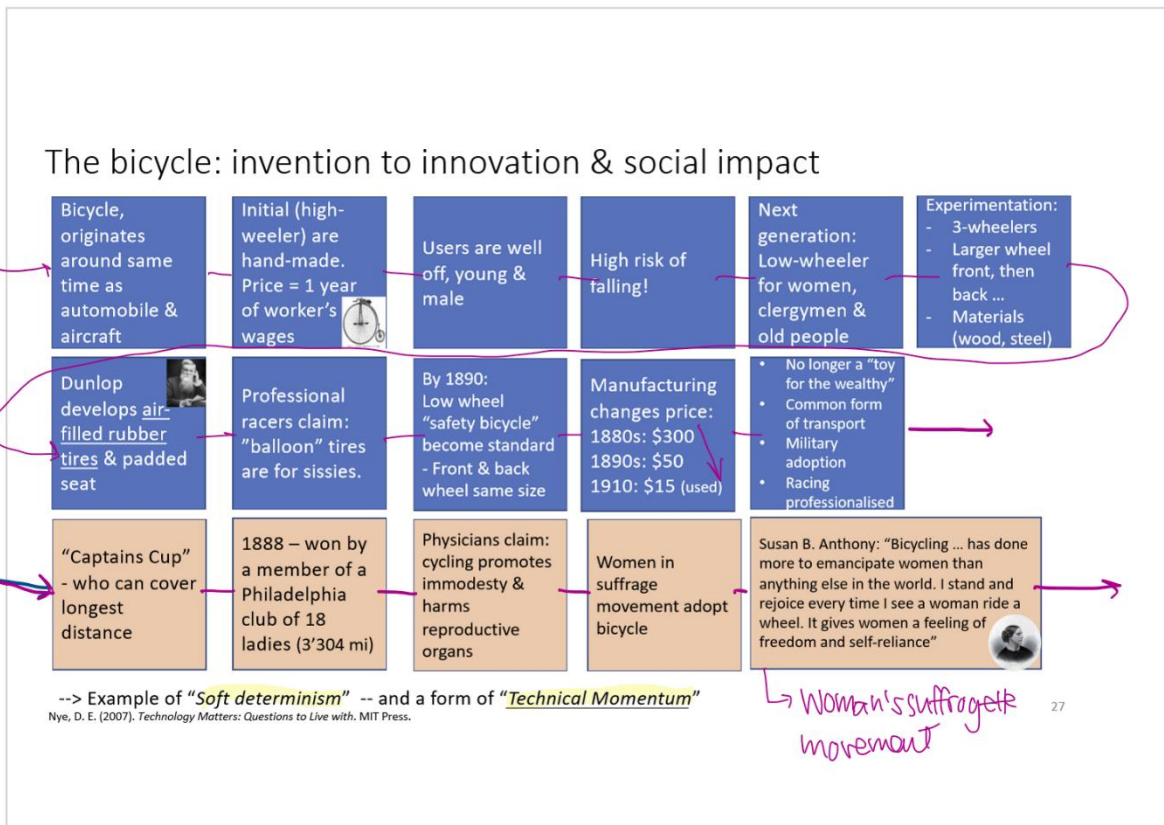
## Importance of technology

social vs. technical inventions by Werner Sombart (1863-1941)

- ➔ Coined term “creative destruction” (schöpferische Zerstörung) – Schumpeter builds upon the concept
- ➔ Cultures are more important with shaping events than technology
- ➔ e.g. Ancient Rome decline ➔ failure of cultural & political institution (not technology)
- ➔ Technology is important but culture and institutions as well

CASE STUDY: Women’s Suffrage  
Converging forces and influences (“**piling up process**”):  
mass production, urbanisation, adoption of typewriter, birth control, theory of natural rights

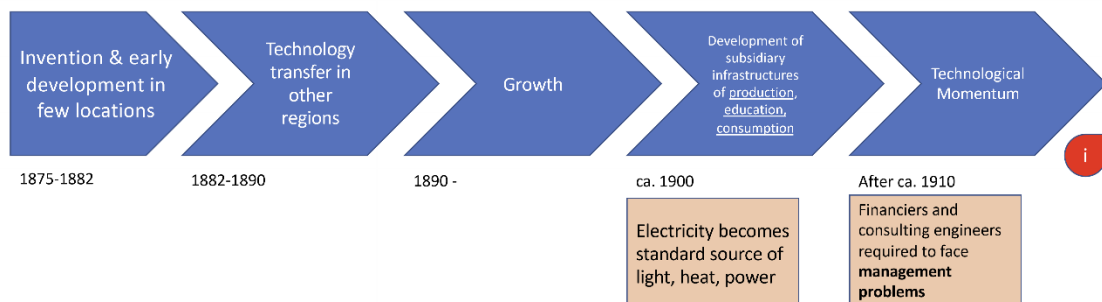
## The bicycle (=soft determinism)



## Technical Momentum (soft determinism)

- by Thomas Hughes (1923-2014)
- can be applied to explain "soft determinism"

### Example of electrification



# Principles of Innovation IV: Mission-Oriented Innovation Policy

## Structural Change and Mission Thinking

- ➔ Economic growth not only has a rate but also a direction
- ➔ How can we innovation-lead growth which is inclusive and sustainable?

## Characteristics of structural change

### 1. Uncertainty

- Odds of success/failure can not be calculated in advance
- Results unknown (may need to “muddle through”)
- Some failures are both (i) inevitable and (ii) essential part of innovation process

### 2. Cumulative

- “show patience” & ability to accumulate competencies and learn (long term)
- Appetite for long-term policy and investment horizons

### 3. Collective

- Innovation is collaborative & collective endeavour ... across multiple sectors & public agencies
- Risks (and rewards) are shared

## Key Market Participants

1. Public sector: Government
2. Private sector
3. Third sector: NGO's – Stiftungen & Verein
4. civil society: Public

## Missions

**Challenges:** “an area which a nation may identify as a priority” e.g. climate change, challenges of an aging society

**Mission:** “involves tackling specific problems” e.g. reduce carbon emissions of x by a period y.

➔ Requires multiple sectors involvement

- Climate change: not just energy sector, but also transport, nutrition, ...

➔ Requires consensus building in civil societies – esp. for bottom-up initiatives

## Mission oriented thinking

1. Industrial sectors
2. Broad challenges
3. Concrete problems that different sectors can address to tackle challenge

Innovation-driven change is uncertain, cumulative, and collective. Mission-oriented policies align industrial, societal, and environmental goals. Challenges (e.g., climate change) are broad, while missions (e.g., reducing emissions by X%) are specific and actionable.

### *Examples: Apollo Program & Energiewende*

The Apollo Mission demonstrated a top-down approach mobilizing multiple sectors for a clear goal. Germany's Energiewende represents a bottom-up, society-driven mission tackling climate change. Both involve public-private collaboration and long-term vision.

## Grand Challenges

Addressing major challenges:

- Social
- Environmental
- Economic
- Public health



similar to PESTLE

### **Wicked Problems:**

1. Complex
2. Systemic
3. Interconnected
4. Urgent

### **Example: Poverty**

- Nutrition
- Health
- Infrastructure
- Education
- ...

→ Mission-oriented policies seek to address grand challenges / wicked problems

Examples: SDGs



17 Goals  
169 Targets

### Market-Failure vs Mission-Oriented Frameworks

Market-Failure	Mission-Oriented
<div style="border: 1px solid black; padding: 10px;"> <div style="display: flex; justify-content: space-around;"> <div style="border: 1px solid blue; padding: 5px; background-color: #e6f2ff;"> <p><b>ex-ante analysis *</b></p> <p>Cost-benefit analysis - Incl. government failures</p> </div> <div style="border: 1px solid blue; padding: 5px; background-color: #e6f2ff;"> <p><b>ex-post analysis **</b></p> <p>Verifies if estimates were correct</p> </div> </div> <div style="text-align: center; margin: 20px 0;"> </div> <p style="text-align: center;">OK for firms, but <u>not</u> for mission challenges!</p> </div>	<ul style="list-style-type: none"> <li>• Requires continuous &amp; dynamic monitoring</li> <li>• Evaluation throughout innovation process</li> </ul> <p>cf. Lindbloom w.r.t. Muddling Through</p>

### Mission Oriented Policies

Mission Oriented Policies systemic public policies that draw on frontier knowledge to attain specific goals, or “by science deployed to meet big problems”

Common example is NASA’s to “put a man on the moon”

Today: aging populations, inequality, youth unemployment,

...

### Critical Success Factors:

1. Missions are well defined
2. Mission do not compromise of a single R&D or innovation project, but rather a portfolio (cf. BCG Matrix at a firm level)
3. Missions should result in a trickle-down effect

### Pragmatic Elements of Missions:

1. Be feasible
2. Draw on existing public and private resources
3. Be amenable to existing policy instruments
4. Command broad and continuous political support

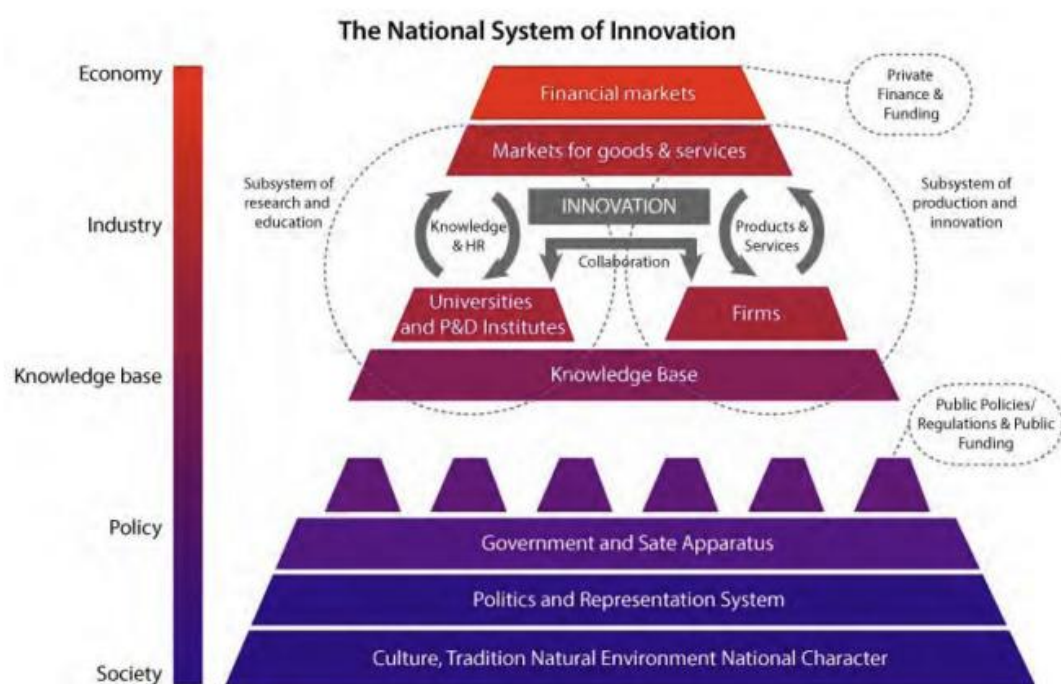
## Contemporary Missions:

### Characteristics of Contemporary Missions

1. diffusion of technologies
2. economic feasibility
3. shared sense of direction
4. decentralised control by public agencies
5. development of both radical and incremental innovations
6. enabling complementary policies.

Old: Defense, nuclear and aerospace	New: Environmental technologies and societal challenges
Diffusion of the results outside of the core of participants is of minor importance or actively discouraged	Diffusion of the results is a central goal and is actively encouraged
The mission is defined in terms of the number of technical achievements, with little regard to their economic feasibility	The mission is defined in terms of economically feasible technical solutions to particular societal problems
The goals and the direction of technological development are defined in advance by a small group of experts	The direction of technical change is influenced by a wide range of actors including government, private firms and consumer groups
Centralised control within a government administration	Decentralised control with a large number of agents involved
Participation is limited to a small group of firms due to the emphasis on a small number of radical technologies	Emphasis on the development of both radical and incremental innovations in order to permit a large number of firms to participate
Self-contained projects with little need for complementary policies and scant attention paid to coherence	Complementary policies vital for success and close attention paid to coherence with other goals

Figure 2: Maastricht Memorandum



Source: figure created by Mazzucato and Penna (2016) based on diagram prepared by the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT, 2002).

## The Entrepreneurial State

### Key elements of the Entrepreneurial State

1. Investment along the entire innovation chain, including demand side policies.
  - o government guaranteed loans
  - o tax reliefs on patent boxes

2. Decentralised nature of public mission-oriented organisations (not top-down).
3. Risk-taking and investment not only during the downside of the business cycle.
4. Long-term strategic finance.
  - tax incentives are an example of indirect investment
  - State Investment Banks
5. Equitable distribution of risk and rewards.

## Mission-Oriented Agencies "make markets" rather than "fixing them"

Agency **Mission Statements** help direct public funds in a more targeted way (as opposed to merely "helping all SMEs").



**NASA Mission Statement:**

to "[d]rive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth." (NASA 2014 Strategic Plan).



**DARPA Mission Statement:**

"Creating breakthrough technologies for national security is the mission of the Defense Advanced Research Projects Agency".



**NIH:**

to "seek fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to enhance health, lengthen life, and reduce illness and disability".

## Mission selection criteria

### 5 Criteria for Selecting Missions:

1. Bold, inspirational with wide societal relevance
2. A clear direction: targeted, measurable, and time-bound
3. Ambitious but realistic research and innovation actions
4. Cross-disciplinary, cross-sectoral, and cross-actor innovation
5. Multiple, bottom-up solutions

# Business Model Innovation & Design

## Fundamentals of Business Model Innovation

4 Dimensions:

1. The customer – who are our target customers?
2. The value proposition – what do we offer our customers?
3. The value chain – how do we produce our offerings?
4. The profit mechanism – why does it generate profit?



Figure 3: Magic Triangle BM

➔ General rule: Innovation of BM requires modifying at least 2 of the 4 dimensions

## BMI Challenges

1. Thinking outside one's own dominant industry logic – not invented here syndrome
2. Difficulty of thinking in terms of business models rather than technologies and products – e.g. PAYD insurance
3. Lack of systematic tools

## Examples innovative BM

1. Amazon – largest bookseller, yet no bookstores
2. Apple – largest music retailer, did not sell CDs
3. Pixar – 11 academy awards in 10 years, yet not a single actor in films
4. Netflix – Reinvented “video rental” (pre-streaming) without a single shop
5. Skype – largest telco, yet no network infrastructure
6. Starbucks – largest coffee retailer selling standard coffee at premium prices

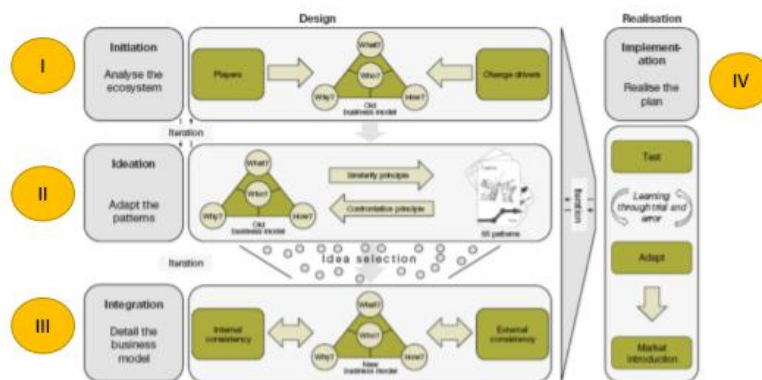
## BMI Myths

1. The Initial Ascent myth – first mover advantage not always relevant
2. The “Think Big” myth – giant leaps instead of incremental change
3. The Technology myth – the business application and use of a novel/nascent technology is “what makes the difference”
4. The Luck myth – planning & being systematic helps
5. The Einstein myth – Individual masterminds vs. interdisciplinary teams
6. The Size myth – “Established corporations can't do it, precisely because they have so many resources” – Joachim Schoss, founder of AutoScout24
7. The R&D myth – R&D departments are not the source of all important innovations

## The Business Model Navigator Framework

Developed by Gassmann et al. (2014), it outlines four phases:









- **Initiation:** Understand the ecosystem and current model.
- **Ideation:** Adapt existing business model patterns (55 total).
- **Integration:** Ensure internal and external consistency.
- **Implementation:** Overcome resistance, negotiate new partnerships, and launch.






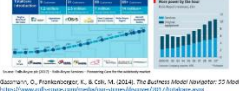


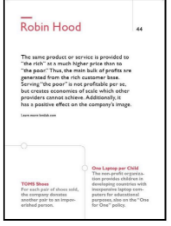



Phase	Description
Initiation	<p>understanding your ecosystem</p> <p>Understand your existing BM:</p> <ul style="list-style-type: none"> <li>• WHO – customers</li> <li>• WHAT – value proposition / problem being solved</li> <li>• HOW – value chain, resources required</li> <li>• WHY – profit mechanism</li> </ul> <p>Other Actors/Players: not only customers, also partners, competitors, ... Change Drivers: Technology, Mega Trends (e.g. demographics), Regulatory</p>
Ideation	<p>adapting patterns (55!)</p> <p>1. Similarity Principle:</p> <ul style="list-style-type: none"> <li>• Finding analogies in a structured way</li> <li>• Search for patterns to apply to the existing BM (e.g. in related industry)</li> </ul> <p>2. Confrontation Principle</p> <ul style="list-style-type: none"> <li>• Study extremes &amp; compared to existing BMs</li> <li>• Good for “hazy” / unknown problem statements</li> <li>• Ask questions like “how would Nestle Nespresso manage your business” (Razor &amp; Blade)</li> </ul> <p>Example: Could a steel company be confronted by Apple’s “Pay per use” model? YES: Adapt existing BM from “pay what is shipped” to “pay what is consumed” (unused steel shipped back)</p>

Integration	<p>Shaping your BM</p> <p>BM needs to meet company's internal requirements</p> <ul style="list-style-type: none"> <li>• <b>Internal Consistency</b> “presenting harmony between who-what-how-why dimensions</li> <li>• <b>External Consistency</b> “fit between your new BM and the company's environment” e.g. stakeholders' needs, competition ...</li> </ul>
Implementation	<p>realising your plans</p> <ul style="list-style-type: none"> <li>• Negotiate contracts with new collaborators</li> <li>• Create new sales channels</li> <li>• Specify go-to-market (GTM) strategy</li> <li>• Question existing assumptions</li> <li>• Push resistance from all angles (market, partners, employees)</li> </ul>

## 55 Patterns

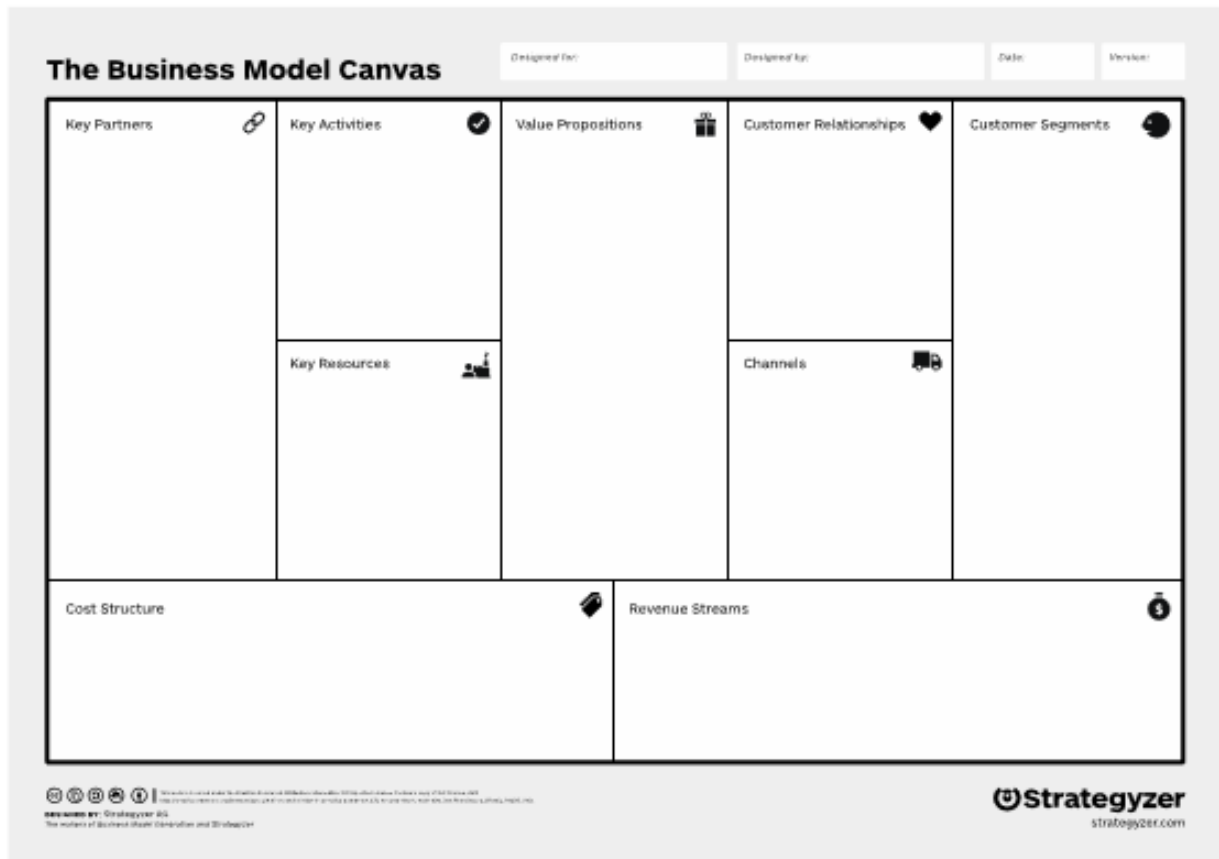
<p>1. Add-on – additional charges for extras</p> <p>Key Questions:</p> <ul style="list-style-type: none"> <li>• Can we provide a basic product to which customers can be price-sensitive and then add on services?</li> <li>• Can we lock our customers in so that they will buy the add-on product from us?</li> </ul>  <p><a href="https://www.easyjet.com/en/terms-and-conditions/fees">https://www.easyjet.com/en/terms-and-conditions/fees</a> <a href="https://www.nauli.com/ee/en/useful-info/help-centre/fees">https://www.nauli.com/ee/en/useful-info/help-centre/fees</a></p> <p><small>Gassmann, O., Frankenberger, K., &amp; Czik, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>	<p>3 - Aikido</p> <p>"I watch where the cosmetics industry is going and then walk in the opposite direction" – Anita Roddick</p> <p>Questions:</p> <ol style="list-style-type: none"> <li>1 – Do you have a lead customer who will follow, if aikido pattern is implemented?</li> <li>2 – Will others follow?</li> <li>3 – Can you overcome the obstacles to “change rules of the game”?</li> </ol>   <p><small>Gassmann, O., Frankenberger, K., &amp; Czik, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>
<p>4 - Auction</p>  <p><i>"for improvements to auction theory and inventions of new auction formats"</i></p>  <p><small>Gassmann, O., Frankenberger, K., &amp; Czik, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>	<p>6 – Cash Machine</p> <p>Run a negative cash conversion cycle</p> <p>Cash conversion cycle = Inventory conversion period + Receivables conversion period – Payables conversion Period</p> <p>1891 – First “American Express Travellers Cheque”</p> <p>→ <b>Receive payments as early as possible, pay your bills as late as possible.</b></p> <p>Question: Can you create a value to customer in this process? Example: <b>Dell's build-to-order (BTO) process</b></p>  <p><small>Gassmann, O., Frankenberger, K., &amp; Czik, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>
<p>10 – Customer Loyalty</p> <ul style="list-style-type: none"> <li>• Frequent Flyer Programs (AAAdvantage first, Miles&amp;More, ...)</li> <li>• Ecosystem around pattern (barter) – e.g. Loyallogic</li> </ul> <p>Questions:</p> <ul style="list-style-type: none"> <li>• Do you have suitable channels to engage with customers?</li> <li>• Can you give customer something back for their “loyalty”?</li> </ul>  <p><small>Gassmann, O., Frankenberger, K., &amp; Czik, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>	<p>15 – Flatrate - “all you can eat”</p> <p>Attempted for airline prices (American, JetBlue, Onego, ...), Norwegian, but never took off / commercially viable</p> <p>Questions: Is the average customer still in the calculated margin? Can you protect yourself from abuse?</p>  <p><small>Gassmann, O., Frankenberger, K., &amp; Czik, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>

<p><b>16 – Fractionalized ownership</b></p> <p>Timesharing for optimised utilisation of assets. Origins in 1960s in CH for <b>holiday homes, then Mobility ...</b> NetJets – first fractional ownership of aircraft</p> <p>Questions: Does dividing ownership make product more affordable? How easy is it to exit scheme?</p>   <p><small>Gasman, O., Frankeberger, K., &amp; Calk, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>	<p><b>21 – Hidden Revenue</b></p> <p>Primary source of revenue is a 3<sup>rd</sup>-party, who cross-finances the product. Examples: Google, Facebook, JCDecaux, ...</p> <p>Questions: Can you separate customers from revenue streams? Can you get away with being a dominant market participant (cf. Google, also pattern 52 on two-sided markets)</p>  <p><small>Gasman, O., Frankeberger, K., &amp; Calk, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>
<p><b>27 – Lock-in</b></p> <p>Forcing loyalty with high switching costs</p> <p>Examples: Lego, Nespresso (only while patent was valid), ...</p> <p>Questions: Do you have the legal, technical or economic means to retain customers? Can you implement lock-in pattern without damaging reputation and customer loss?</p>  <p><small>Gasman, O., Frankeberger, K., &amp; Calk, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>	<p><b>31 – No frills</b></p> <p>“Whatever, as long as it is cheap”</p> <ul style="list-style-type: none"> <li>- Origin: Ford Model T (1908)</li> <li>- LCCs, discount supermarkets, McD</li> </ul> <p>Questions: Where do you really need to differentiate? How can you eliminate cost/waste? Can processes be re-designed to reduce costs?</p>  <p><small>Gasman, O., Frankeberger, K., &amp; Calk, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>
<p><b>35 – Pay per use</b></p> <p>Pay-per-use (PPU) 1962: HP – “<b>payed by the hour</b>” (PPU) Google “pay per click” ads</p> <p>Questions: Will customer behaviour change as a result of this BM? How can billing process be adapted? What kind of data can be measured/collected/analyzed about the customer? Can we provide additional value from data collected? (e.g. Google/air maintenance) for B2B/PM</p>   <p><small>Gasman, O., Frankeberger, K., &amp; Calk, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>	<p><b>39 – Razor and blade</b></p> <p>“bait and hook” Origin in 1880s by Rockefellers selling cheap lamps to China which only worked with their (Standard Oil) paraffin. 1904 – Gillette – Cheap Razor / Expensive blade 1984 – HP: first consumer InkJet printer 1986 – Nestlé Nespresso</p> <p>Challenge: Can hard-to-imitate components prevent competitors from copying service or spare part business?</p>  <p><small>Gasman, O., Frankeberger, K., &amp; Calk, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>
<p><b>44 – Robin Hood</b></p> <p><b>“Take from the rich and give to the poor”</b></p> <p>Eye hospital in India offers free eye surgery for poor (2/3 of patients), while rich patients pay “full price”. TOM’S Shoes – For each pair sold through retail, one pair donated”. Margins: 100%</p>  <p><small>I report on poverty reduction via sometimes regressive – Mykalis, R., Mui, L., Calvo, L., Calverley, K., &amp; James, B. (2016). Moving the Children: The Impact of the 1000 Schools Program in Rural Sri Lanka. The World Bank Economic Review, 38(3), 717-752. <a href="https://doi.org/10.1016/j.econres.2016.05.002">https://doi.org/10.1016/j.econres.2016.05.002</a></small> <small>Gasman, O., Frankeberger, K., &amp; Calk, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>	<p><b>45 – Self-service</b></p> <p>Putting the customer to work. Can be enhanced with automation mechanisms. Aviation: check-in (kiosks, online, ...) IKEA: pick-up components, <b>self-assembly</b></p> <p>Questions: How to position against “full-service” players? How should self-service be priced? Is customer value (still) being delivered? Will customers take work as a positive experience? How can we trust customer’s work/input?</p>  <p><small>Gasman, O., Frankeberger, K., &amp; Calk, M. (2014). The Business Model Navigator: 55 Models That Will Revolutionize Your Business (1st Edition). FT Press.</small></p>

**Key Takeaways**


- Don’t reinvent the wheel
- A BM is not for a specific industry. Use it where not used already!
- Combine: Take 55 models to “create your own BM”
- Patterns not set in stone – will continue to recombine and evolve over time

## The Business Model Canvas



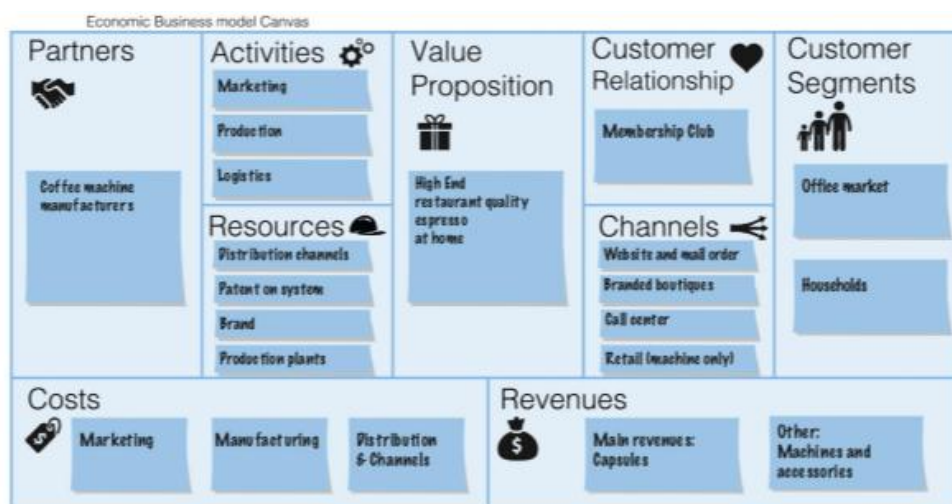
Nine building blocks: Customer Segments, Value Propositions, Channels, Customer Relationships, Revenue Streams, Key Resources, Key Activities, Key Partnerships, and Cost Structure. Used to visualize and test new models.

Segment	Description
CS – Customer Segments	<p>WHO do you want to reach</p> <p>Sample segment types:</p> <ol style="list-style-type: none"> <li>1. Mass Market</li> <li>2. Niche Market</li> <li>3. Segmented</li> <li>4. Diversified</li> <li>5. Multi-sided platforms/markets</li> </ol>
VP – Value Propositions	<p>Describes the bundle of products and services that create value for a specific Customer Segment</p> <p>Factors which can contribute to value creation:</p> <ol style="list-style-type: none"> <li>1. Newness</li> <li>2. Performance</li> <li>3. Customisation</li> <li>4. “Getting the job done” – Rolls-Royce (pay per hour)</li> </ol>

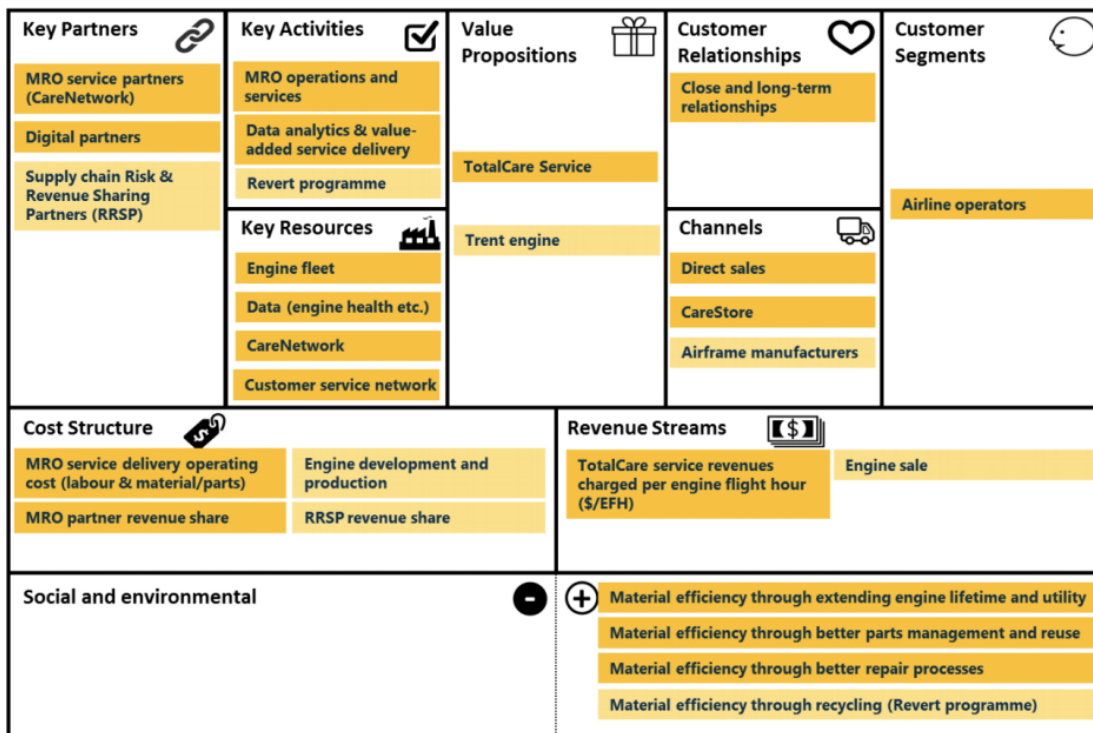
	<ol style="list-style-type: none"> <li>5. Design</li> <li>6. Brand/Status</li> <li>7. Price</li> <li>8. Cost Reduction</li> <li>9. Risk Reduction</li> <li>10. Accessibility (NetJets)</li> <li>11. Convenience/Usability</li> </ol>																			
<p>CH - Channels</p>	<p>describes how a company communicates with and reaches its Customer Segments to deliver a Value Proposition</p>  <table border="1" style="font-size: small; width: 100%;"> <thead> <tr> <th colspan="2">Channel Types</th> <th colspan="5">Channel Phases</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Own</td> <td>Direct</td> <td rowspan="5">1. <b>Awareness</b> How do we raise awareness about our company's products and services?</td> <td rowspan="5">2. <b>Evaluation</b> How do we help customers evaluate our organization's Value Proposition?</td> <td rowspan="5">3. <b>Purchase</b> How do we allow customers to purchase specific products and services?</td> <td rowspan="5">4. <b>Delivery</b> How do we deliver a Value Proposition to customers?</td> <td rowspan="5">5. <b>After sales</b> How do we provide post-purchase customer support?</td> </tr> <tr> <td>Own stores</td> </tr> <tr> <td rowspan="3">Partner</td> <td>Indirect</td> </tr> <tr> <td>Partner stores</td> </tr> <tr> <td>Wholesaler</td> </tr> </tbody> </table>	Channel Types		Channel Phases					Own	Direct	1. <b>Awareness</b> How do we raise awareness about our company's products and services?	2. <b>Evaluation</b> How do we help customers evaluate our organization's Value Proposition?	3. <b>Purchase</b> How do we allow customers to purchase specific products and services?	4. <b>Delivery</b> How do we deliver a Value Proposition to customers?	5. <b>After sales</b> How do we provide post-purchase customer support?	Own stores	Partner	Indirect	Partner stores	Wholesaler
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	Partner stores																			
	Wholesaler																			
<p>CR – Customer Relationships</p>	<p>describes the types of relationships a company establishes with specific Customer Segments</p> <p>Customer Relationship Segments:</p> <ol style="list-style-type: none"> <li>1. Personal assistance</li> <li>2. Dedicated personal assistance</li> <li>3. Self-service</li> <li>4. Automated Services</li> <li>5. Communities</li> <li>6. Co-creation</li> </ol>																			
<p>RS – Revenue Streams</p>	<p>Represents the cash a company generates from each Customer Segment (costs must be subtracted from revenues to create earnings)</p> <p>Types:</p> <ol style="list-style-type: none"> <li>1. Transactional - one-time payment</li> <li>2. Recurring – ongoing payments (e.g. for support)</li> </ol> <p>Sources:</p> <ol style="list-style-type: none"> <li>1. Asset sale</li> <li>2. Usage fee</li> <li>3. Subscription fees</li> <li>4. Lending/Renting/Leasing</li> <li>5. Licensing</li> <li>6. Brokerage fees (% commission)</li> <li>7. Advertising</li> </ol>																			
<p>KR – Key Resources</p>	<p>Describes the most important assets required to make a business model work</p> <p>Resource types:</p> <ol style="list-style-type: none"> <li>1. Physical</li> <li>2. Intellectual</li> <li>3. Human</li> <li>4. Financial</li> </ol>																			

<p>KA – Key Activities</p>	<p>describes the most important things a company must do to make its business model work</p> <p>Activity Categories</p> <ol style="list-style-type: none"> <li>1. Production</li> <li>2. Problem Solving</li> <li>3. Platform / Network</li> </ol>
<p>KP – Key Partnerships</p>	<p>Describes the network of suppliers and partners that make the business model work</p> <p>Types of partnerships</p> <ol style="list-style-type: none"> <li>1. Strategic alliances between non-competitors</li> <li>2. Coopetition: strategic partnerships between competitors</li> <li>3. Joint ventures to develop new businesses</li> <li>4. Buyer-supplier relationships to assure reliable supplies</li> </ol> <p>Motivation for Partnerships</p> <ol style="list-style-type: none"> <li>1. Optimisation and economies of scale</li> <li>2. Reduction of risk &amp; uncertainty</li> <li>3. Acquisition of particular resources and activities</li> </ol>
<p>CS – Cost Structure</p>	<p>describes all costs incurred to operate a business model</p> <p>2 classes of cost structures:</p> <ol style="list-style-type: none"> <li>1. Cost-driven (LCCs)</li> <li>2. Value-driven</li> </ol> <p>Cost structure characteristics:</p> <ol style="list-style-type: none"> <li>1. Fixed cost</li> <li>2. Variable cost</li> <li>3. Economies of scale</li> <li>4. Economies of scope</li> </ol>

Example BM Canvas – Nespresso



Toward Sustainable BM



Source: R2PI Project analysis, company interviews

# Regulation & Standards

## Standards

### Types of Standards

1. **Fundamental standards** - which concern terminology, conventions, signs and symbols, etc.
2. **Test methods and analysis standards** - which measure characteristics such as temperature and chemical composition.
3. **Specification standards** - which define characteristics of a product (product standards), or a service (service activities standards) and their performance thresholds such as fitness for use, interface and interoperability, health and safety, environmental protection, etc.
4. **Organization standards** - which describe the functions and relationships of a company, as well as elements such as quality management and assurance, maintenance, value analysis, logistics, project or system management, production management, etc.

### Categories of standards

1. **De-facto standards**

A de-facto standard is one that is widely accepted and used, but lacks formal approval by a recognised standards organisation or organisations” “Generally results from widespread consensus on a particular product or protocol that has a large market share” e.g. QWERTY Keyboard vs. Dvorak Keyboard

2. **Regulatory standards**

Supported/defined by regulatory agencies, not driven by market forces

3. **Consensus Standards**

Voluntary standards developed/used by voluntary consensus bodies

### Regulatory Standards

Used by regulators for conformity or as an Acceptable Means of Compliance (AMC) to a specific regulation

- **Mandatory:** CE Marking (conformity assessment) for UAS (Commission Delegated Regulation (EU) 2019/945)
- **AMC:** EASA standard in continuing airworthiness (Commission Regulation (EU) 1321/2014). Alternative Means of Compliance (AltMoC) are possible.

It can happen that the content is directly written in regulation, i.e. drone operators’ registration (EU 2019/947, Article 14) or its annexes.

## Industry Standards

Voluntary use of a standard by a group of industry stakeholders.

- Example: TCP/IP (open standard)
- Doc file or mp3 (proprietary standard) The regulator often waits for industry standards to emerge rather than prescribing them.

Some standards can be both regulatory or voluntary, depending on circumstances, i.e. ISO 9001.

## Compliance, certification & inspection

### *Compliance & certification*

Compliance/Conformity can sometimes be done by the company itself (i.e. CE marking for most electronics) or through approved third parties.

The Swiss Accreditation Service (SAS) accredits entities such as

- Testing laboratories
- Reference material producers
- Inspection bodies
- ...

### *Inspection*

In order for an aircraft to be listed in the Swiss Aircraft Register, it must be inspected for compliance with the applicable airworthiness requirements. The airworthiness requirements are based on international and/or national regulations, depending on the aircraft. EUROCAE ED-112-A is an AMC to EU 965/2012 related to Airborne Recorder Systems is applicable to on board crash protected recorders, ancillary equipment and their installation in civil aircraft.

## Anti-Trust/Competition laws

➔ Do not use standards as a means to collude or exclude participants

Questions to ask (Carl Shapiro):

1. Do the firms in the proposed standards coalition have market power?
2. Does the coalition have open or closed membership?
3. Do members of coalition possess blocking patents or other IPR?
4. Are royalties required to adhere to the standard?
5. Is coordination critical to the launch of the product?
6. What ancillary restraints are placed on members of the standards coalition?

➔if answered with yes = collusion

Not all forms of collusion are illegal e.g. Eurovision Song Contest Voting (neighbour countries)

## Lobbying

Lobbying: “lobbying” means **promoting specific interests** by communication with a public official as part of a structured and organised action aimed at influencing public decision making

Objectives of regulating lobbying:

- Promote transparency of lobbying
- Regulate lobbying activities (who & what)
- Not infringe on democratic right of individuals to
  - Express opinions and petition public officials
  - Campaign for political change and change in legislation, policy, ...
- Transparency of activities performed
- Public register of lobbyists
- Standards of ethical behaviour for lobbyists (principles of openness, transparency, honesty and integrity)
- Sanctions for non-compliance
- Integrity of public sector officials (revolving doors, “cooling off periods”)
- Oversight of the above

## Dual-Use Regulation

### Export Controls

Wassenaar Arrangement (WA): On Export Controls for Conventional Arms and Dual-Use Goods and Technologies

- **“Related to the spread of conventional weapons and dual-use goods and technologies”**
- **For details, see EU’s dual-use list of technologies:**
  - **Category 7 - Navigation and avionics**
  - **Category 9 - Aerospace and propulsion 24**

State Secretariat for Economic Affairs (SECO) responsible for Swiss Export Controls

“Dual-use goods can **be used for military and civilian purposes**. They include, for example, machine tools, chemicals and unarmed military training aircraft. Switzerland is one of the six countries that export the most dual-use goods. A licence is required to export such goods.”

# Failures, Frauds & Fiascos

## Frauds

### Fraud Classification by Charles Babbage

1. Hoaxing: humours or malicious deceit (time limit), ridicule those who credit/fall for hoax

2. Forging: Recording observations never made to acquire reputation → falsified data/results

3. Trimming: for m of falsification, clipping of little bits here and there to gain a reputation for extreme accuracy → outliers (not mentioned)

4. Cooking: to give to ordinary observations the appearance and character of those of the highest degree of accuracy

Science Classification:

FFP: Fabrication – Falsification - Plagiarism

**Table 1: Percentage of scientists who say that they engaged in the behaviour listed within the previous three years (n = 3,247)**

Top ten behaviours	All	Mid-career	Early-career
1. Falsifying or 'tinkering' research data	0.3	0.2	0.5
2. Ignoring major aspects of human-subject requirements	0.3	0.3	0.4
3. Not properly disclosing involvement in items whose products are based on one's own research	0.3	0.4	0.3
4. Relationships with students, research subjects or clients that may be interpreted as questionable	1.4	1.3	1.4
5. Using another's ideas without obtaining permission or giving due credit	1.4	1.7	1.0
6. Unauthorized use of confidential information in connection with one's own research	1.7	2.4	0.8***
7. Failing to present data that contradict one's own previous research	6.0	6.5	5.3
8. Circumventing certain minor aspects of human-subject requirements	7.6	9.0	6.0**
9. Overstating others' use of flawed data or questionable interpretation of data	12.5	12.2	12.8
10. Changing the design, methodology or results of a study in response to pressure from a funding source	15.5	20.6	9.5***
<b>Other behaviours</b>			
11. Publishing the same data or results in two or more publications	4.7	5.9	3.4**
12. Inappropriately assigning authorship credit	10.0	12.3	7.4***
13. Withholding details of methodology or results in papers or proposals	10.8	12.4	8.9**
14. Using inadequate or inappropriate research designs	13.5	14.6	12.2
15. Dropping observations or data points from analyses based on a gut feeling that they were inaccurate	15.3	14.3	16.5
16. Inadequate record keeping related to research projects	27.5	27.7	27.3

Note: significance of  $\chi^2$  tests of differences between mid- and early-career scientists are noted by \*\* ( $P < 0.01$ ) and \*\*\* ( $P < 0.001$ ).

Figure 4: Examples from Science

→ Challenge of fraud classification is to determine the level of malicious intent (cannot be measured).

### Examples Frauds & Failures

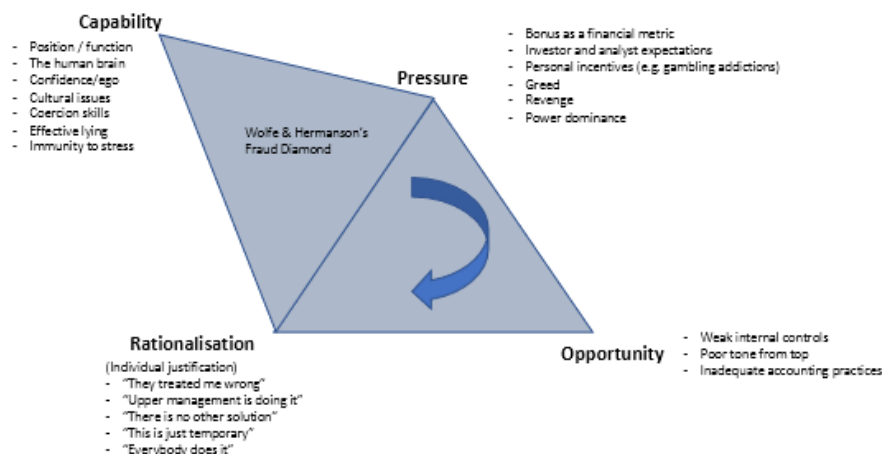
- Theranos: Silicon Valley's biggest Fraud, lab-on-a-chip, did not work. Inventor (Elizabeth Holmes) knew this.
- de Havilland Comet: first commercial jetliner, did not serialise their production, never had a prototype, positive: air accidents investigations progress
- Concorde: high fuel consumption, only prototypes built, excessive maintenance, exceeding Mach 1 costs 3x as much, Megalomania
- Hoover: **sloppiness**, poor planning, poor lawyers, poor campaigns, not using common sense.
- Wright Brothers Church: not intentional fraud but simple carelessness → Follow the money principle (FTM) for white collar crimes

## Fraud Triangle (Motivation to commit fraud)

### [Corporate, Financial] Fraud Triangle



Donald Cressey  
(1919 – 1987)



## Fraud Risk Rating



## Counterfeit

### Counterfeit

Counterfeit parts are defined as a product produced or altered to resemble a product without authority or right to do so, with the intent to mislead or defraud by presenting the imitation as original or genuine. (AIA)

→ Definition varies across industries.

Examples for counterfeit in aviation:

- runway lighting, maybe less good quality from counterfeit parts

### Why counterfeit in aviation?

- attractive in aviation industry due to the long lifespan of parts & usage
- As parts may not be available from original component manufacturer (OCM), original equipment manufacturer (OEM), authorized aftermarket manufacturer or through franchised or authorized distributors or resellers.

- 70% of counterfeiting is from China (reports by US air defence, SASC)

### Index for counterfeiting

- GTRIC-e: General Trade-Related Index of Counterfeiting for **economies**
- GTRIC-p: A general trade-related index of counterfeiting and piracy of **products**

15% of seized values for counterfeiting in air transport, GTRIC-p: =0 since parts are not easily counterfeited due to certification process, etc.

## Whistleblowing

**Whistleblowing:** The disclosure by organization members (former or current) of illegal, immoral and illegitimate practices under the control of their employers to persons and organizations that may be able to effect action.

**Motivation:**

- altruistic
- motivational/psychological
- rewards (financial)

**Risks:**

- Attack the messenger (smokescreens)
- Poor appraisals
- Threaten into silence
- Isolation / humiliation
- Set-up for failure
- Prosecute
- Eliminate jobs, ruin career prospects

<b>Category</b>	<b>Constituents</b>
Stealing	Stealing of federal funds, stealing of federal property, accepting bribes/kickbacks, use of official position for personal benefit, unfair advantage to contractor, and employee abuse of office.
Waste	Waste by ineligible people receiving benefits, waste by a badly managed program, and waste of organizational assets.
Mismanagement	Management's cover-up of poor performance and making false projections of performance.
Safety Problems	Unsafe or non-compliant products and Unsafe working conditions.
Sexual Harassment	Unwelcome sexual advances/requests for sexual favors and verbal/physical contact of sexual nature.
Unfair Discrimination	Discrimination based on race, sex, religion, etc.
Legal Violations	Violation of law, etc.
<i>Source: Near et al. (2004)</i>	

## Not all whistleblowers are treated equally

Protection of whistleblowers differs across jurisdictions and industries.



No law protecting whistleblowers per-se in Switzerland. Separate laws governing public and private law.



3 stage process:



Exception in CH:  
[Bradley Birkenfeld](#)  
\$104 M reward

<https://www2.deloitte.com/ch/en/pages/forensics/articles/swiss-law-whistleblowing.html>  
OECD (2016), Committing to Effective Whistleblower Protection, OECD Publishing, Paris. <http://dx.doi.org/10.1787/9789264252639-en>

## National Innovation Systems & Aviation Policies

Mission-oriented innovation requires innovation agencies welcoming:

- Uncertainty
- Explorative capacity

### National Innovation System (CH, 2006)

A key element of the NIS is the interaction between the funding from the (government) administration and the methods for technology transfer (WTT\*)

\* WTT = Wissen und Technologie Transfer

#### Success Factors of Swiss Model

##### Competitive & Innovative Firms

- 3.4% of GDP spent on R&D (2/3rds from private sector)

##### Education System

- University System (Federal, Cantonal, FHs ...)
- Duale Bildung / Apprentice system

##### Efficient Research & Innovation Promotion

- Competitive SNF grants

##### General environment factors

- High quality infrastructure
- Flexible labour laws

### Challenges & Opportunities of Swiss Model

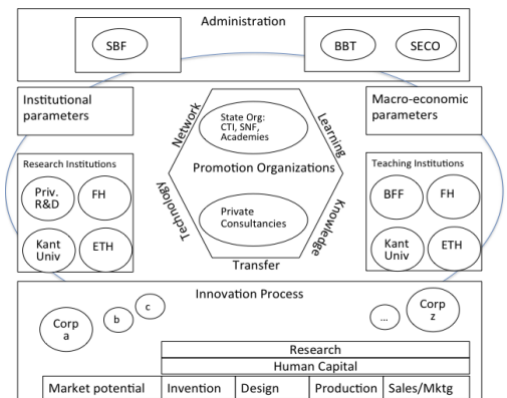
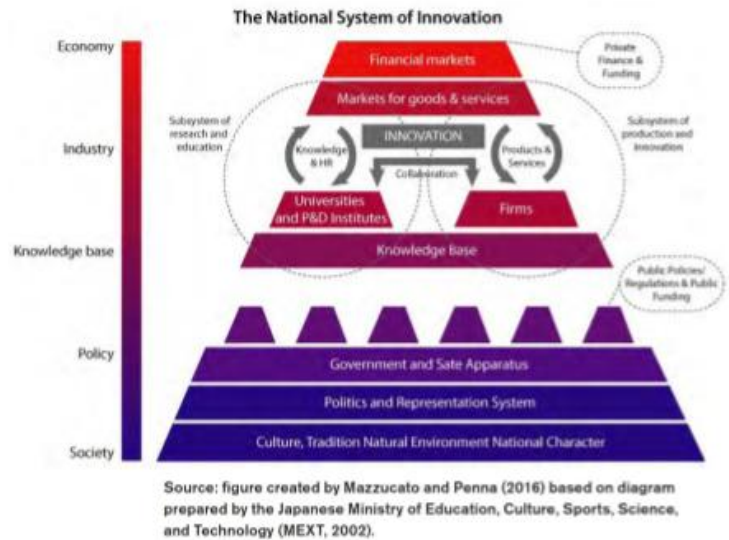
#### Preparation for Digitisation

- Across all societal aspects
- Impacting all demographics
- Unintended Consequences (cf. Merton)

#### Knowledge & Technology Transfer (WTT)

- Proximity of universities to private sector (in terms of collaboration & geography)

R&D in 99% of companies (i.e. SMEs) has been in decline since 2000 Regulatory barriers



- Especially in finance and health

#### Support of Start-ups

- 300 Hi-tech start-ups p.a. (vs. 40'000 overall)

#### Integration to International Research & Innovation Programs

- e.g. EU joint funding programs (Horizon Europe, ...)

Switzerland is not mission-oriented

- UK started post-Brexit an ARPA (Advanced Research Projects Agency) Germany started Agentur für Sprunginnovationen (2019)

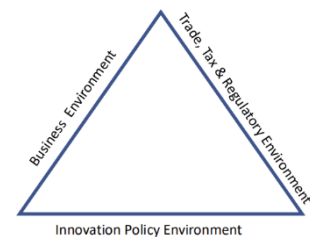
“If you can't measure it, it's not important”

- Measurement of Swiss model for Research & Innovation system's effectiveness requires more targeted data collection and analysis

## US NIS “Innovation Success Triangle”

Robert D. Atkinson (b. 1954)

Founder & President of Information Technology and Innovation Foundation (ITIF)



### *I. Business Environment*

#### 1. Market & Firm Structure & Behaviour

- Managerial “talent”
- Time horizon & Risk appetite of firms (short-termism / quarter-driven)
- ICT adoption

#### 2. Business Financing System

- VC / Risk Capital
- Firm finance (debt & equity)

#### 3. Cultural Factors

- (Domestic) customer demand
- Risk taking / entrepreneurship
- Attitudes towards science & technology
- Collaborative culture (inc. “coopetition”)
- Time horizon & willingness to invest in the future (mixed picture in terms of R&D spend)

### *II. Tax, Trade & Regulatory Environment*

#### 1. Regulatory Environment

- Industry structure & Nature of competition (anti-trust policy)
- Regulatory system for entrepreneurship (starting business, laying off labour)
- Role & Form of Regulation (cf. FAA approvals)
- Transparency and Rule of law

## 2. Tax, Trade and Economic Policy

- Macroeconomic environment (e.g. inflation, USD as reserve currency)
- Tax policy - R&D tax credits, no VAT
- Trade Policy – WTO, Tariffs ...
- Intellectual Property - incl. protection of overseas IPR
- Standards – see prev. lecture

## *III. Innovation Policy Environment Research & Technology*

### 1. Support of research in universities & research labs/institutes

- Overall mixed picture w.r.t. funding
- Federal funding (2013) ca. \$140 bln in R&D activity (2010: 0.78% GDP to 0.88% 2013)
- Since 2000, NIH funding down 25%
- Defence R&D ↑ (0.285% of GDP)

### 2. Federal Labs

- 80 – 100 funded labs
- Emphasis on defence, energy & health

### 3. University Research

- Funding mission goals of DOD, DOE, NIH
- Non-mission / basic research funding by NSF (cf. Vannevar Bush)

### 4. Technology Transfer Systems (from Univ. to federal labs / marketplace)

- Some NSF and NIH funding tied to commercialisation outcomes

### 5. Supporting research in business

- Tax credits for r&d investments
- Federal govt does not fund business r&d, unless related to defence missions

## *Systems of Knowledge Flows*

### 1. Innovation Clusters

- Silicon Valley, Research Triangle Park (RTP), Boston Rte 128

### 2. Industry collaboration systems (with academia & research institutes)

### 3. Acquiring foreign technology, exporting US technology

- FDI<sup>1</sup> policy
- Monitoring acquisitions by foreign entities (CFIUS<sup>2</sup> reviews)
- China National Aero-Technology Import and Export Corporation forced by CFIUS in 1990 to sell Mamco

### 4. Technology diffusion and adoption

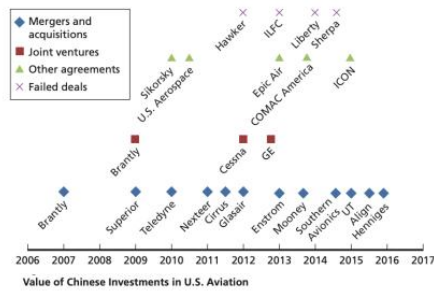
- Origins in agriculture policy (1957 – Hybrid Corn)

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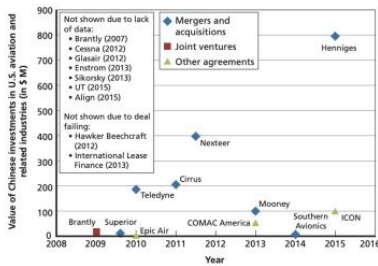
<sup>1</sup> FDI – Foreign Direct Investment

<sup>2</sup> CFIUS – Committee on Foreign Investment in the United States

Timeline of Chinese Investments in U.S. Aviation



Value of Chinese Investments in U.S. Aviation



reuters.com/article/us-global-eagle-ent-m-a-hna-group-idUSKBN1AB0BE  
INDUSTRY, MATERIALS & UTILITIES JULY 26, 2017 / 5:55 AM / UPDATED 3 YEARS AGO

U.S. regulatory scrutiny scuppers deal for unit of China's HNA

By Sumeet Chatterjee, Diane Bartz

5 MIN READ

HONG KONG/WASHINGTON (Reuters) - HNA Group Co Ltd's \$416 million investment in U.S. in-flight services firm Global Eagle Entertainment Inc ENT.O has been abandoned after failing to clear a U.S. national security panel, adding to uncertainty over Chinese deals with U.S. companies.

ainonline.com/aviation-news/business-aviation/2020-03-18/one-aviation-earns-cfius-approval-sale

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**One Aviation Earns CFIUS Approval for Sale**  
by Bob Fildes - March 18, 2020, 11:28 AM

Abuquerque, New Mexico-based One Aviation recently cleared a significant hurdle in its plan to emerge from Chapter 11 bankruptcy, though when that emergence will occur remains up in the air. The Committee on Foreign Investment in the United States (CFIUS) this month provided clearance for Clicking International US to acquire One Aviation, according to the law firm of Paul Hastings that represented the company in the matter.

Clicking, a U.S. entity backed by Chinese investors, has financially supported One Aviation's service operations for Eclipse 500 and 550 very light jets since the company filed for bankruptcy in October 2016. At that time, all parties aimed for an expedited trip through Chapter 11; however, those hopes were soon dashed by several factors.

"The bankruptcy process is unbelievably difficult to navigate," One Aviation CEO Alan Klappmeyer told AIN. "The process for certifying an aircraft is much more reasonable; after this experience, I'm really looking forward to working with the FAA again."

A short diversion into technology diffusion

1957 – Griliches looks at adoption of Hybrid Corn

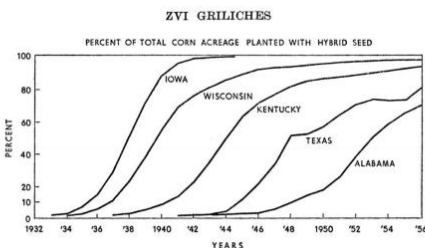
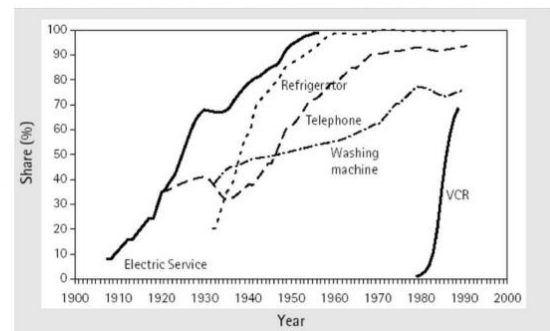
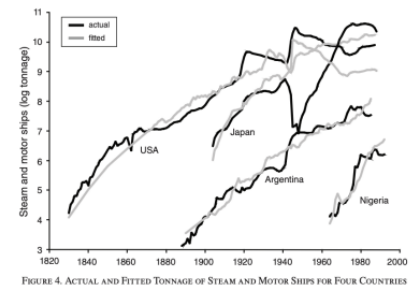
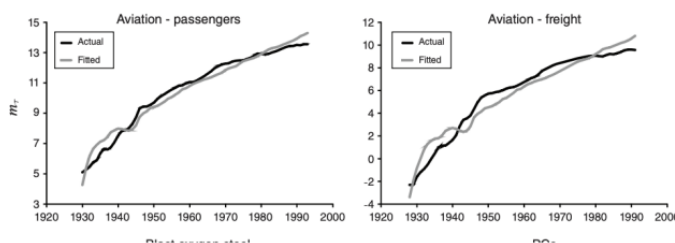


FIGURE 1.—Percentage of Total Corn Acreage Planted with Hybrid Seed. Source: U.S.D.A., Agricultural Statistics, various years.



➔ S-curve noticeable

Comin and Hobjin developed models testing technology diffusion across multiple technologies over space and time



**Aviation-Passengers:** Civil aviation passenger-kilometres travelled on scheduled services by companies registered in the country concerned. Invention year: 1903; the year the Wright brothers managed the first successful flight.

**Aviation–Freight:** Civil aviation ton-kilometres of cargo carried on scheduled services by companies registered in the country concerned. Invention year: 1903; same as aviation–passengers.

What leads to an adoption of an innovation?

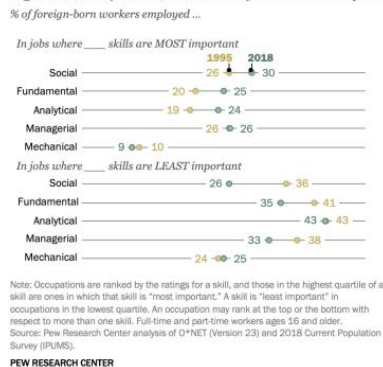
→by Everett Rogers

1. The relative advantage of the innovation
2. Its compatibility (for the adopter on how s/he gets things done today)
3. The complexity of the innovation
4. Triability, how easily can the innovation be tested
5. Observability, how easily can innovation be evaluated after the trial

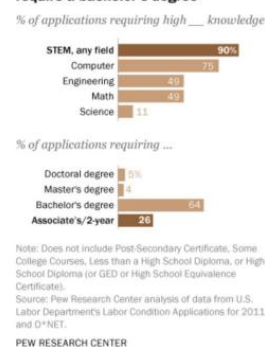
### Human Capital Systems

1. Education/Training (K-12)
2. Higher Education
3. Skill/Technical Training
4. Immigration policy
  - 15 – 26% of US high-tech companies founded by immigrants (past 20 yrs)
  - H-1B employment visa program for high-skilled jobs

#### Foreign-born workers made significant gains in high-skill occupations, moved away from low-skill jobs



#### Most H-1B applications seek STEM knowledge, but one-in-four don't require a bachelor's degree



### What about subsidies?

US Direct Payments<sup>3</sup> (1918-1998) to air carriers' industry & general aviation: \$155 bln

- 1930s: Funding of air mail delivery. Requires passengers to be carried as well (implicit)! Expenses exceeded revenues.
- 1934: Collusion of pricing detected fatal accidents
- 1938: Formation of Civil Aeronautics Authority (now NTSB). Airline passengers travel explicit.
- 1950s: Direct subsidies to airlines for postal mail phased out
- 1957-83: – Guaranteed loan scheme for air carriers to purchase aircraft. Rationale: reduce direct subsidies to carriers. 12 airlines default on 23 loans (worth \$128m). Total guarantees: \$924m
- 1925 – 70: Federal Airways Expenditures (non-regulatory expenses): \$9.1 bln
- 1953-70: Federal Airport Expenditures: \$1 bln --- seen as a form of employment generation (construction jobs)
- 1977 -98: National Weather Service (for aviation industry) - \$672k

<sup>3</sup> Direct Payment = subsidy

# Benchmarking NIS across Europe

**Table 3: Indicators used in the international comparison**

FRAMEWORK CONDITIONS	DATA SOURCE	YEAR
<b>HUMAN RESOURCES</b>		
1.1.1 New doctorate graduates per 1000 population aged 25-34	OECD - Education at a Glance	2017
1.1.2 Population aged 25 or above completed tertiary education	OECD - Education at a Glance	2018
<b>ATTRACTIVE RESEARCH SYSTEMS</b>		
1.2.1 International scientific publications per million population	Scopus*	2019
1.2.2 Scientific publications among the top 10% most cited publications worldwide	Scopus*	2017
<b>INNOVATION-FRIENDLY ENVIRONMENT</b>		
2.1.1 R&D expenditure in the public sector (percentage of GDP)	OECD (LIS)	2018
2.1.2 R&D expenditure in the business sector (percentage of GDP)	OECD (LIS)	2018
<b>FINANCE AND SUPPORT</b>		
3.1.1 SMEs introducing product or process innovations (% share)	Scopus*	2016
3.1.2 Public-private co-publications (per million population)	Scopus*	2019
<b>LINKAGES</b>		
3.2.1 Innovator SMEs collaborating with others (% share)	Scopus*	2016
3.2.2 Public-private co-publications (per million population)	Scopus*	2019
3.2.3 Private co-publications (per million population)	Scopus*	2019
<b>INTELLECTUAL ASSETS</b>		
5.1.1 ICT patent applications	Patents, OECD	2017
5.1.2 Trademark applications (per billion GDP)	World Bank - WIPO	2018
5.1.3 Design applications (per billion GDP)	World Bank - WIPO	2018
<b>IMPACT</b>		
<b>EMPLOYMENT IMPACTS</b>		
6.1.1 Medium and high-tech product exports (share of total product exports)	United Nations	2018
6.1.2 Knowledge-intensive services exports (share of total services exports)	United Nations, OECD	2018

**Table 4: Core/soft+ indicators in the international comparison**

Indicator	Period	Source
<b>PERFORMANCE AND STRUCTURE OF THE ECONOMY</b>		
GDP per capita, PPP (international \$)	Average 2014-2018	World Development Indicators*
Average annual GDP growth (%)	2014-2018	World Development Indicators*
Employment share in Agriculture (%)	Average 2014-2018	World Development Indicators*
Employment share in Industry (%)	Average 2014-2018	World Development Indicators*
Employment share in Services (%)	Average 2014-2018	World Development Indicators*
Manufacturing - share in total value added**	Average 2014-2018	UNIDO
<b>BUSINESS AND ENTREPRENEURSHIP</b>		
Total early-stage Entrepreneurial Activity (TEA) (%)	Average 2017-2019	Global Entrepreneurship Monitor
FDI net inflows (% GDP)	Average 2017-2019	World Development Indicators*
Top R&D spending firms per 10 million population	Average 2017-2019	EU Industrial R&D Investment Scoreboard
The R&D spending intensity, average R&D spending (million Euros)	Average 2017-2019	EU Industrial R&D Investment Scoreboard
Number of startups - start-up rate of all	All active enterprises (per 1000)	OE Insights**
Start-up rate (0-1 to 7 best)	Average 2017-2019	World Economic Forum
<b>GOVERNANCE AND POLICY FRAMEWORK</b>		
Ease of starting a business (0 to 100 best)	Average 2017-2019	Doing Business*
Basic school entrepreneurial education and training (0 to 5 best)	Average 2017-2019	Global Entrepreneurship Monitor
Government procurement of advanced technology products (0 to 7 best)	Average 2017-2019	World Economic Forum
Rate of law (1-5 to 2.5 best)	Average 2014-2018	Worldbank Governance Indicators*
<b>TECHNOLOGY</b>		
Population size (million)	Average 2014-2018	World Development Indicators*
Average annual population growth (%)	2010-2018	World Development Indicators*
Population density (population/km2)	Average 2014-2018	World Development Indicators*

\*Data source for Scopus (1996 to end of year) is from European Commission (EC Research and Innovation) \*\* World Development Indicators

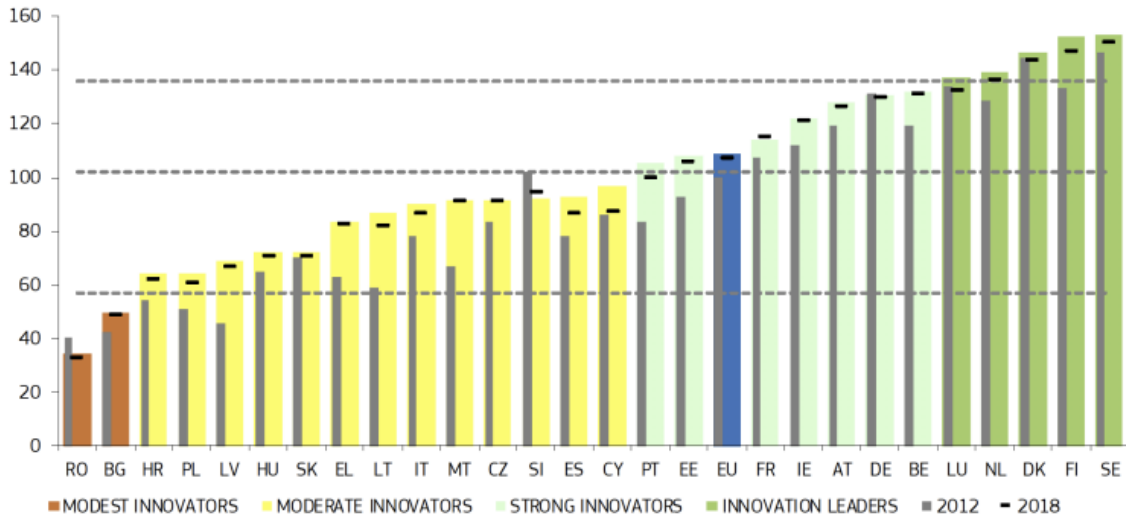
↳ look at it  
European innovation scoreboard 2020 - main report, (2020), European Commission. <https://ec.europa.eu/docsroom/documents/42981>

\*\* Data source for the World Bank - "Data assist does not use in the international comparison & both"

Uni.com  
Sinn-Pflege: especially unique  
Knowledgeable buyer (informed)

## Performance across member states

Figure 3: Performance of EU Member States' innovation systems



Coloured columns show countries' performance in 2019, using the most recent data for 27 indicators, relative to that of the EU in 2012. The horizontal hyphens show performance in 2018, using the next most recent data, relative to that of the EU in 2012. Grey columns show countries' performance in 2012 relative to that of the EU 2012. For all years, the same measurement methodology has been used. The dashed lines show the threshold values between the performance groups.

### Korea, Canada vs EU

Performance in 2012 and 2019 relative to the EU in 2012	South Korea	2012	2019	2012-2019
Doctorate graduates	7350	796	2219	
Tertiary education	1775	1802	2219	
International co-publications	9139	914	226	
Most cited publications	61.1	768	46	
R&D expenditure public sector	1074	1151	77	
R&D expenditure business sector	2165	2196	34	
Product and/or process innovations	5119	766	261	
Marketing and/or organisational innovations	404	1047	309	
Innovation collaboration	573	563	68	
Public-private co-publications	1164	1148	48	
Private co-funding public R&D expenditures	98.3	1221	218	
ICT patent applications	99.2	3028	1006	
Trademark applications	2419	252	28	
Design applications	2001	228	28	
Medium & high-tech product exports	1287	1171	111	
Knowledge-intensive services exports	91.7	85.7	66	

Performance in 2012 and 2019 relative to the EU in 2012	Canada	2012	2019	2012-2019
Doctorate graduates	749	463	224	
Tertiary education	1571	1600	219	
International co-publications	1069	1043	46	
Most cited publications	3366	1165	100	
R&D expenditure public sector	1134	1061	78	
R&D expenditure business sector	750	946	491	
Product and/or process innovations	1054	1144	248	
Marketing and/or organisational innovations	154	1006	48	
Innovation collaboration	79	49	19	
Public-private co-publications	1161	1077	15	
Private co-funding public R&D expenditures	106.2	96.4	119.2	
ICT patent applications	276	3023	51	
Trademark applications	2119	2688	43	
Design applications	647	70	14.8	
Medium & high-tech product exports	64.2	36.4	3.9	
Knowledge-intensive services exports	102.6	95.1	-7.5	

Structural differences	KR	EU
Performance and structure of the economy		
GDP per capita, PPP (international \$)	38,700	41,800
Change in GDP %	2.5	2.2
Employment share in Agriculture	4.9	4.7
Employment share in Industry	25.1	20.0
Employment share in Services	70.0	75.3
Manufacturing - share in total value added	38.4	15.8
Business and entrepreneurship		
Total Entrepreneurial Activity (TEA)	7.4	6.7
FDI net inflows (% GDP)	6.9	2.3
Top R&D spending firms per million population	118	252
average R&D spending, million Euros	3063	2216
Number of Startups	10	27
Start-up rate (0-1 to 7 best)	3.26	3.73
Government procurement of advanced technology products	1.98	1.50
Rate of law (1-5 to 2.5 best)	1.10	1.06
Population size, million	51	61
Change in population %	0.1	0.1
Share of population aged 15-64	72.9	65.0
Population density (population/km2)	527.7	105.3

### Australia, Japan vs EU

Performance in 2012 and 2019 relative to the EU in 2012	Australia	2012	2019	2012-2019
Doctorate graduates	1146	153	216	
Tertiary education	2274	1411	17	
International co-publications	1850	1060	190	
Most cited publications	1301	151	17	
R&D expenditure public sector	1136	206	41	
R&D expenditure business sector	96.7	661	311	
Product and/or process innovations	1592	1242	55	
Marketing and/or organisational innovations	125.1	1178	27	
Innovation collaboration	75.2	1196	466	
Public-private co-publications	90.2	94.0	1.9	
Private co-funding public R&D expenditures	88.9	41.4	1.7	
ICT patent applications	3031	2095	19	
Trademark applications	2043	2046	47.7	
Design applications	85.6	99.5	13.8	
Medium & high-tech product exports	15.5	13.5	-2.1	
Knowledge-intensive services exports	52.8	53.6	-1.2	

Performance in 2012 and 2019 relative to the EU in 2012	Japan	2012	2019	2012-2019
Doctorate graduates	6746	651	225	
Tertiary education	1624	157.5	4.5	
International co-publications	765	710	46	
Most cited publications	67.8	362.6	50	
R&D expenditure public sector	95.6	87.4	84	
R&D expenditure business sector	196.6	1984	178	
Product and/or process innovations	280	1174	514	
Marketing and/or organisational innovations	94.4	284	169	
Innovation collaboration	256	1192	303	
Public-private co-publications	115.1	98.7	-10.8	
Private co-funding public R&D expenditures	31	303	19	
ICT patent applications	3015	3554	109	
Trademark applications	956	1874	303	
Design applications	880	96.2	8.2	
Medium & high-tech product exports	122.1	118.7	3.5	
Knowledge-intensive services exports	122.5	108.1	-16.4	

Structural differences	AU	EU
Performance and structure of the economy		
GDP per capita, PPP (international \$)	49,500	41,800
Change in GDP %	0.9	2.2
Employment share in Agriculture	2.6	4.7
Employment share in Industry	18.6	20.0
Employment share in Services	77.8	75.3
Manufacturing - share in total value added	31.1	15.8
Business and entrepreneurship		
Total Entrepreneurial Activity (TEA)	11.4	6.7
FDI net inflows (% GDP)	3.78	2.3
Top R&D spending firms per million population	56	252
average R&D spending, million Euros	2176	2216
Number of Startups	8	27
Start-up rate (0-1 to 7 best)	1.97	3.73
Government procurement of advanced technology products	1.92	1.50
Rate of law (1-5 to 2.5 best)	1.72	1.06
Population size, million	24.6	61.1
Change in population %	1.6	0.1
Share of population aged 15-64	65.5	65.0
Population density (population/km2)	5.2	105.3

## USA, China vs EU

Performance in 2012 and 2019 relative to the EU in 2012				Performance in 2012 and 2019 relative to the EU in 2012			
	India	2012-2019		China	2012-2019		2012-2019
Doctorate graduates	779	81.5	11	17.8	11.1	-1.6	
Tertiary education	1201	127.9	7.8	796	109	16.5	
International co-publications	1144	1106	-3.9	347	638	9.2	
Most cited publications	1533	1318	-15.5	684	101.9	33.3	
R&D expenditure public sector	1035	1101	6.4	99.7	68.5	9.4	
R&D expenditure business sector	1490	1414	-7.6	106.2	114.8	8.6	
Product and/or process innovations	675	198.8	89.8	794	109	16.5	
Marketing and/or organisational innovations	764	194	-74.4	664	109	16.5	
Innovation collaboration	764	194	-74.4	664	109	16.5	
Public private co-publications	1091	1388	30.2	175	358	10.5	
Private co-funding public R&D expenditures	55	32.7	-2.2	114.5	107.1	-7.2	
ICT patent applications	387	105.2	6.7	67.4	97.0	30.8	
Trademark applications	601	638	8	2506	1035	10.5	
Design applications	475	685	138	2001	2120	10.8	
Medium & high-tech product exports	82	78.1	-2.2	99.7	99.7	0	
Knowledge-intensive services exports	1021	107.2	-4.9	91.9	96.4	4.5	

Best three and worst three indicators highlighted

Structural differences			Structural differences		
	US	EU		CN	EU
Performance and productivity (EU=100)	60,800	41,800	Performance and productivity (EU=100)	18,900	41,800
GDP per capita, PPP (international \$)	60,800	41,800	GDP per capita, PPP (international \$)	18,900	41,800
Change in GDP %	1.2	2.2	Change in GDP %	6.2	2.2
Employment share in Agriculture	1.4	4.7	Employment share in Agriculture	26.9	4.7
Employment share in Industry	19.8	25.0	Employment share in Industry	28.4	25.0
Employment share in Services	78.6	70.3	Employment share in Services	44.7	70.3
Manufacturing - share in total value added	11.4	15.8	Manufacturing - share in total value added	51.5	15.8
Government procurement of advanced technology products	15.6	6.7	Government procurement of advanced technology products	1.4	6.7
Top R&D spending firms per million population	1.91	26.5	Top R&D spending firms per million population	1.48	26.5
Top R&D spending firms per million population	1.91	26.5	Top R&D spending firms per million population	1.48	26.5
Number of Unions	2.2	2.2	Number of Unions	2.2	2.2
Buyer sophistication 1-7 (best)	5.02	5.75	Buyer sophistication 1-7 (best)	4.43	5.75
Ease of starting a business	85.7	76.5	Ease of starting a business	72.4	76.5
Government procurement of advanced technology products	2.37	1.93	Government procurement of advanced technology products	2.17	1.93
Rate of law 1-2.5 to 2-5 (best)	1.57	1.05	Rate of law 1-2.5 to 2-5 (best)	0.27	1.05
Population size, million	524.9	446.1	Population size, million	1,385.9	446.1
Change in population %	0.7	0.2	Change in population %	0.6	0.2
Share of population aged 15-64	69.7	69.0	Share of population aged 15-64	71.7	69.0
Population density (population / km2)	35.5	105.3	Population density (population / km2)	147.6	105.3

## Brazil / Russia vs EU

Performance in 2012 and 2019 relative to the EU in 2012				Performance in 2012 and 2019 relative to the EU in 2012			
	Brazil	2012-2019		Russia	2012-2019		2012-2019
Doctorate graduates	764	109	16.5	764	109	16.5	
Tertiary education	1144	1106	-3.9	1144	1106	-3.9	
International co-publications	41.0	49.6	5.4	46.2	52.7	6.5	
Most cited publications	31.4	34.1	3.1	13.1	27.8	17.7	
R&D expenditure public sector	684	101.9	33.3	540	65.6	16.6	
R&D expenditure business sector	1035	1101	6.4	481	30.5	-38.8	
Product and/or process innovations	1054	1034	-0.5	1141	1328	6.5	
Marketing and/or organisational innovations	75	25	-6.4	75	25	-6.4	
Innovation collaboration	75	25	-6.4	75	25	-6.4	
Public private co-publications	1091	1388	30.2	84	101	18.8	
Private co-funding public R&D expenditures	55	32.7	-2.2	694	76.0	4.1	
ICT patent applications	387	105.2	6.7	105	105	0	
Trademark applications	601	638	8	135	135	0	
Design applications	475	685	138	443	503	14.8	
Medium & high-tech product exports	82	78.1	-2.2	184	30.1	-31.3	
Knowledge-intensive services exports	1021	107.2	-4.9	94.2	98.7	-4.5	

Best three and worst three indicators highlighted

Structural differences			Structural differences		
	BR	EU		RU	EU
Performance and productivity (EU=100)	15,700	41,800	Performance and productivity (EU=100)	25,800	41,800
GDP per capita, PPP (international \$)	15,700	41,800	GDP per capita, PPP (international \$)	25,800	41,800
Change in GDP %	1.9	2.2	Change in GDP %	0.8	2.2
Employment share in Agriculture	9.6	4.7	Employment share in Agriculture	6.2	4.7
Employment share in Industry	20.5	25.0	Employment share in Industry	26.0	25.0
Employment share in Services	69.9	70.3	Employment share in Services	67.8	70.3
Manufacturing - share in total value added	11.0	15.8	Manufacturing - share in total value added	15.0	15.8
Government procurement of advanced technology products	20.5	6.7	Government procurement of advanced technology products	14.2	6.7
Top R&D spending firms per million population	0.4	16.2	Top R&D spending firms per million population	0.1	16.2
Number of Unions	2.2	2.2	Number of Unions	0	2.2
Buyer sophistication 1-7 (best)	5.51	5.75	Buyer sophistication 1-7 (best)	1.56	5.75
Ease of starting a business	57.6	76.5	Ease of starting a business	77.4	76.5
Government procurement of advanced technology products	2.96	1.93	Government procurement of advanced technology products	3.33	1.93
Rate of law 1-2.5 to 2-5 (best)	0.24	1.05	Rate of law 1-2.5 to 2-5 (best)	1.06	1.05
Population size, million	207.8	446.1	Population size, million	144.4	446.1
Change in population %	0.8	0.2	Change in population %	0.1	0.2
Share of population aged 15-64	69.7	69.0	Share of population aged 15-64	68.1	69.0
Population density (population / km2)	249	105.3	Population density (population / km2)	88	105.3

## India, S Africa vs EU

Performance in 2012 and 2019 relative to the EU in 2012				Performance in 2012 and 2019 relative to the EU in 2012			
	India	2012-2019		South Africa	2012-2019		2012-2019
Doctorate graduates	387	36.0	-7.7	114	14.1	-2.8	
Tertiary education	1201	127.9	7.8	796	109	16.5	
International co-publications	1144	1106	-3.9	347	638	9.2	
Most cited publications	1533	1318	-15.5	684	101.9	33.3	
R&D expenditure public sector	1035	1101	6.4	99.7	68.5	9.4	
R&D expenditure business sector	1490	1414	-7.6	106.2	114.8	8.6	
Product and/or process innovations	675	198.8	89.8	794	109	16.5	
Marketing and/or organisational innovations	764	194	-74.4	664	109	16.5	
Innovation collaboration	764	194	-74.4	664	109	16.5	
Public private co-publications	1091	1388	30.2	175	358	10.5	
Private co-funding public R&D expenditures	55	32.7	-2.2	114.5	107.1	-7.2	
ICT patent applications	387	105.2	6.7	67.4	97.0	30.8	
Trademark applications	601	638	8	2506	1035	10.5	
Design applications	475	685	138	2001	2120	10.8	
Medium & high-tech product exports	82	78.1	-2.2	99.7	99.7	0	
Knowledge-intensive services exports	1021	107.2	-4.9	91.9	96.4	4.5	

Best three and worst three indicators highlighted

Structural differences			Structural differences		
	IN	EU		SA	EU
Performance and productivity (EU=100)	2,200	41,800	Performance and productivity (EU=100)	13,800	41,800
GDP per capita, PPP (international \$)	2,200	41,800	GDP per capita, PPP (international \$)	13,800	41,800
Change in GDP %	4.2	2.2	Change in GDP %	4.5	2.2
Employment share in Agriculture	17.5	4.7	Employment share in Agriculture	36.5	4.7
Employment share in Industry	24.5	25.0	Employment share in Industry	23.5	25.0
Employment share in Services	58.0	70.3	Employment share in Services	39.8	70.3
Manufacturing - share in total value added	16.9	15.8	Manufacturing - share in total value added	12.4	15.8
Government procurement of advanced technology products	11.9	6.7	Government procurement of advanced technology products	10.9	6.7
Top R&D spending firms per million population	0.2	16.2	Top R&D spending firms per million population	0.5	16.2
Number of Unions	2.2	2.2	Number of Unions	2.2	2.2
Buyer sophistication 1-7 (best)	4.56	5.75	Buyer sophistication 1-7 (best)	3.96	5.75
Ease of starting a business	66.5	76.5	Ease of starting a business	66.3	76.5
Government procurement of advanced technology products	4.14	1.93	Government procurement of advanced technology products	3.02	1.93
Rate of law 1-2.5 to 2-5 (best)	0.00	1.05	Rate of law 1-2.5 to 2-5 (best)	-0.01	1.05
Population size, million	1,385.9	446.1	Population size, million	57.0	446.1
Change in population %	0.1	0.2	Change in population %	1.4	0.2
Share of population aged 15-64	66.5	69.0	Share of population aged 15-64	65.6	69.0
Population density (population / km2)	460.1	105.3	Population density (population / km2)	470	105.3

## Regulations are more than those defined by Civil Aviation Authorities (CAAs)

- Civil liberties
  - Privacy, property rights
- Serving national interests:
  - Economic (jobs, growth ...)
  - National safety & security
  - Environmental
- Managing scarce resources & infrastructure
  - Air space, spectrum, ...

→ not all CAAs are governed the same!

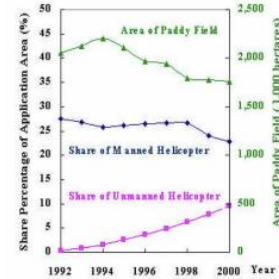
*FAA ≠ FOCA ≠ CAB*

*USA ≠ Switzerland ≠ Japan*

### Initial Commercial Drone usage in Japan

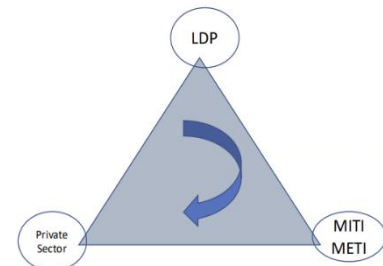
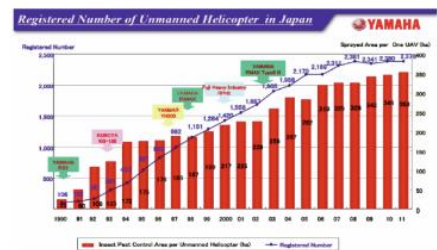
#### Why Japan & Commercial Drones?

1. Small-scale agriculture
  - avg size 5 acres
2. Highly protected agriculture
  - Gentan - 777% import duty on polished rice
3. Labour Shortage / Limited immigration
4. Iron Triangle (Amakudari) - see next slides



### Japan's Iron Triangle - Amakudari

The iron triangle, more commonly known as Amakudari (literally meaning to “descend from heaven”), is a type of revolving door and close collaboration between politics, bureaucrats and large industry. Amakudari is most commonly associated with the supporting of MITI, which is also responsible for regulating the Aviation Manufacturing Law.



#### Johnson's Definition:

“Maintaining coordination and cooperative interactions among the state and the public and private sectors—an aspect of what the Japanese call nemawashi (informal negotiation processes, literally translated as “preparing the groundwork”) and what others describe variously as consensual decision making or the interlocking directorate among the bureaucracy, the conservative party, and the business community”

- LDP – Liberal Democratic Party
- MITI – Ministry of International Trade and Industry
- METI - Ministry of Economy, Trade and Industry
- Private Sector – Japan's largest 100 corporations

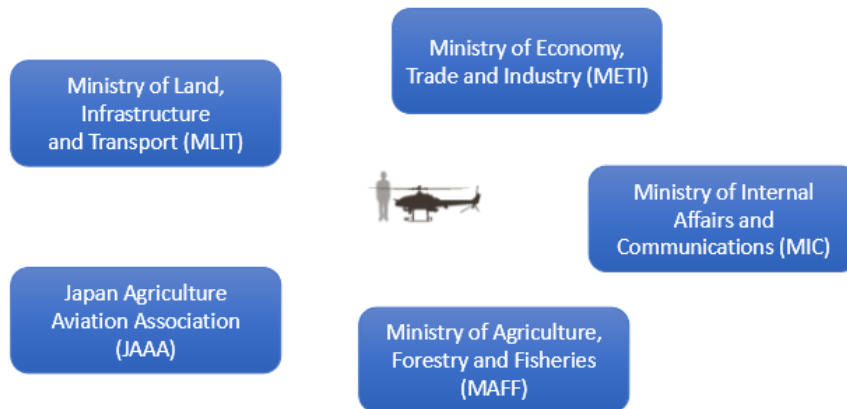
### Japan's Drone Logic

- Drivers: Economic & demographic
- Aviation Law<sup>4</sup>:
  - Aviation defines “the Aviation/Aircraft which a pilot can ride on/in such as an airplane, helicopter, glider an airship”

<sup>4</sup> Aviation law regulated by MLIT - Ministry of Land, Infrastructure and Transport

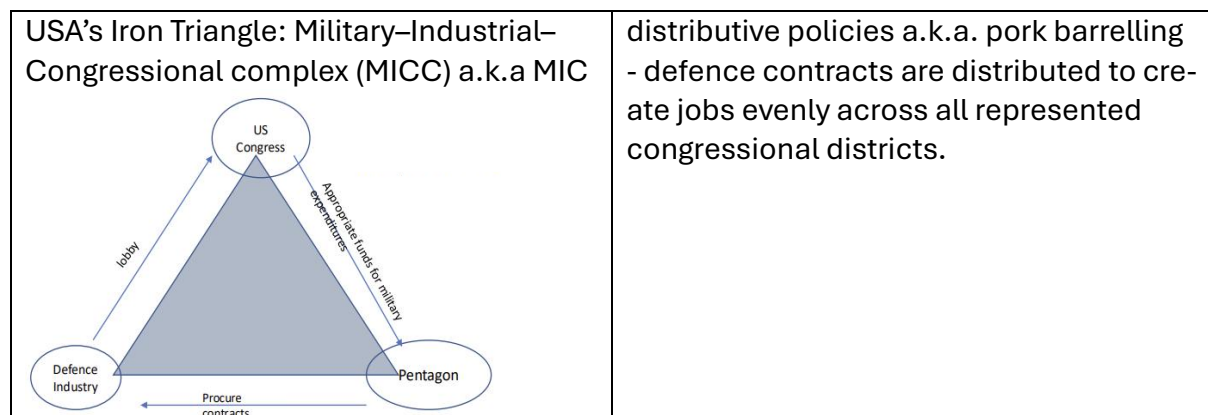
- Hence no MLIT-issued license is required to operate a UAV → not covered by aviation policy, since no pilot

### Interplay of Ministries (+Industry) goes beyond the CAA



### Iron Triangles – A definition

an iron triangle is a „political relationship that brings together three key participants in a clearly delineated area of policy making: The Federal bureaucracy, the key committees and members of Congress, and the private interest



## Vannevar Bush (1890-1974)



- 1919: Joins MIT faculty *as Prof.*
- 1922: Co-founder of Raytheon *now RTX, microwaves for AC company*
- 1932: Dean of MIT Engineering
- 1938: President, Carnegie Institution for Science – starts influencing US research policy
- 1940: Chairman of National Advisory Committee for Aeronautics (NACA) – “pre-NASA”; deputy George Mead
- 1940: Gets FDR to “OK” the creation of secret National Defense Research Committee (NDRC)  
“to coordinate, supervise, and conduct scientific research on the problems underlying the development, production, and use of mechanisms and devices of warfare”
- 1941: Gets FDR to “OK” the creation of Office of Scientific Research and Development (OSRD) –  
“unlimited funding”, civilian controlled  
– Radar, Proximity Fuze, Manhattan Project → *significant contributions*
- 1945: Publishes: “*Science, The Endless Frontier*” – Report to FDR  
Leads to creation of National Science Foundation (NSF) *in CH: SNF (almost)*
- 1946: Eisenhower publishes a **5-point memo** (a blueprint for MIC\*, penned by Edward Bowles – who also was instrumental in RAND Corporation)
  1. Army must have civilian assistance in military planning as well as for production of weapons
  2. Scientists and industrialists must be given the greatest possible freedom to carry out their research
  3. The possibility of utilizing some of our industrial and technological resources as *organic parts* of our military structure in time of emergency should be carefully examined
  4. Within the Army we must separate responsibility for research and development from the functions of procurement, purchase, storage and distribution.
  5. Officers of all arms and services must become fully aware of the advantages which the Army can derive from *close integration* of civilian talent with military plans and development

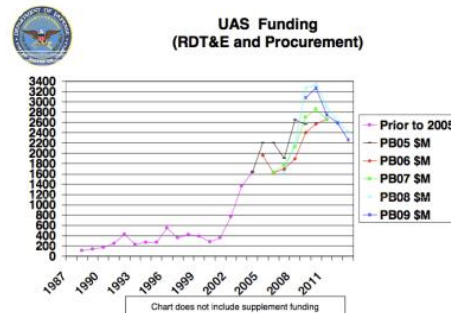
*research & development*

*How was Bush connected to 5-Point Memo: 5-point memo contributed by Bush. → BASIS for MICC/MIC*

\* Military-Industrial-Complex  
Zachary, G. P. (2018). *Endless Frontier: Vannevar Bush, Engineer of the American Century* (Reprint edition). Free Press.

➔ US Department of Defense (DoD) has an annual base budget of around \$585 billion dollars.

### Defense Spending as Share of the Economy (GDP)



Timescales of the DoD are impressive. Their Roadmap FY 2013-2038 is defined across three timescales: now, mid-term and long-term. As a result, R&D investments are made to address these three timescales. Organisations such as DARPA exist to “rethink complex military systems, recasting today’s approach with the intention of achieving far greater capabilities at lower cost”

### Innovation in National Aviation Policies (CH)

Luftfahrtpolitischer Bericht (“Lupo”) - Latest version published 2016

#### 1.1 Key Aspects of Swiss Aviation Policy

New Technologies: Der Bund ist gefordert, das Potenzial, aber auch die möglichen Sicherheitsrisiken derartiger Technologien frühzeitig zu erkennen und bei Bedarf ein günstiges regulatives Umfeld für deren Entwicklung und Verwendung zu schaffen und gleichzeitig die Sicherheitsrisiken tief zu halten.

### 3.4 Economic importance of Civil Aviation

Through serving nation's mobility needs, civil aviation it permits Switzerland to meet their needs of driving (domestic) innovation.

#### 4.2.1 Technical Safety Challenges

New Technical Possibilities .... bei der Einführung neuer Technologien ist der zusätzliche Nutzen gegenüber allfälligen neuen Sicherheitsrisiken abzuwägen. Dies gilt insbesondere auch für neue Fluggeräte im Luftraum, wie beispielsweise Drohnen. Ziel ist die laufende Verbesserung der technischen Interoperabilität der Systeme am Boden und in der Luft

#### 5.2.2 Civilian use of military airports

Transforming Dübendorf into an Innovation Park

#### 5.5 New Technologies

In den vergangenen zehn Jahren sind in der Luftfahrt verschiedene neue Technologien entwickelt worden. Diese verändern die Luftfahrtindustrie und werden sie zukünftig stark prägen. In der Schweiz sind zahlreiche neue, meist kleine und mittlere Unternehmen entstanden, die beispielsweise im Bereich der unbemannten Luftfahrt international eine führende Rolle einnehmen. Sie bieten hochqualifizierte Arbeitsplätze und haben ein grosses wirtschaftliches Potenzial. Es liegt im Interesse des Bundes, dieses Potenzial weiter zu entwickeln. Gemäss LFG fördert der Bund die Forschung und Entwicklung in den verschiedenen Sparten der Luftfahrt. Soweit auch Sicherheit oder Umweltschutz gefördert werden, kann der Bund Beiträge an entsprechende Projekte leisten

#### Australia's Future Aviation Sector

“Aviation is central to Australia's economy and quality of life. Aviation underpins Australian business: **transporting workers**, tourists and high value freight. The sector directly employed over 90,000 people and contributed \$20 billion to the economy before COVID-19. Furthermore, the sector indirectly enables the tourism, mining, manufacturing and higher education sectors”

Aviation key to tourism (6% of GDP, 4th largest export industry) Past 10 years, passenger growth: 75% Critical enabler of mining industry - transport for 60'000 FIFO (fly-in-fly-out) workers

**Government policy:** The Government will adopt aviation policies that create incentives for businesses to innovate, lower costs and provide better quality services. As technologies and market conditions change, businesses need flexibility to invest in services that meet the needs of Australian aviation users ...

Technology in the aviation sector is also evolving quickly. Growth in new emerging technologies such as remotely piloted aircraft systems (RPAS), alternative fuels, and electric propulsion and electric vertical take-off and landing (eVTOL) vehicles has the potential to catalyse important economic and social gains — where supported by an appropriate policy and legal framework.

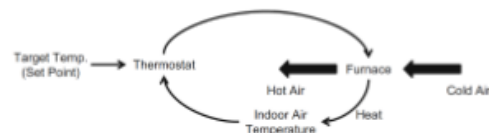
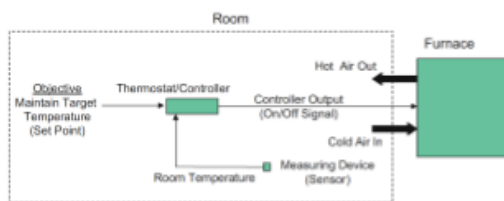
# Principles of Complexity I

## Definition

- Complexity
- An organized or connected group of things. A group or set of related or associated things perceived or thought of as a unity or complex whole.
  - A collection of artificial objects organized for a particular purpose, as components of a mechanism, roads, architectural features, etc.
  - A collection of natural objects, features, or phenomena considered as or forming a connected or complex whole.

→ Complex, Connected, Organized

## Flow of information vs. materials




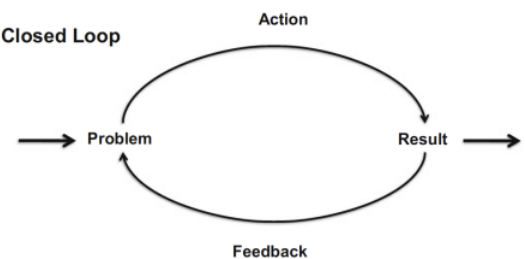
→ Thin arrow: flow of information  
 → Thick arrow: flow of material/energy

## Examples

Predator – Prey System	Controlling of Steel Thickness
<p>Predation controls the deer population</p> <p>Depletion of deer controls the wolf population</p>	<p>Objective: Desired Plate Thickness</p> <p>Feedback</p>
<ul style="list-style-type: none"> <li>• Wolf = predator, Deer = prey</li> <li>• Example of oscillation within the system</li> </ul>	<ul style="list-style-type: none"> <li>• Thickness dependent on:                             <ul style="list-style-type: none"> <li>• Temperature of heated slab</li> <li>• Clearance between rollers</li> <li>• Speed differences between roller pairs</li> </ul> </li> </ul> <p>CHALLENGE: Uniform steel thinness                      PROBLEM SOLVED: thru continuous feedback of thickness measurement to control final roller pair.</p>

	<p>Added outcome: Temperature &amp; clearance distance no longer that important!</p> <p>→ Took long time to solve (decades!), as engineers focussed on individual slab and not</p>
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### open vs. closed loops

Open Loop	Closed Loop
	
<p>OK when actions taken have negligible side effects. e.g. - Water management at a household level and ignoring impact on a community - Energy consumption for single car user and ignoring overall pollution/congestion to a community.</p>	<p>More realistic, but harder to focus on “whole system”, rather than individual parts.</p>

### Swiss Defence Industry

Unlike the United States, a DARPA program does not exist to fund research for military purposes. The defence budget is also much smaller. **While NATO members are being encouraged to spend 2%→5% of their GDP spend on their military, in Switzerland the level is presently at 0.7%**

Unlike in the US where the expenditure by the government leads to procurement for (US) domestic suppliers, the Swiss arms industry plays a significant role not only in serving the domestic demand, but also in terms of export income. In 2014, Switzerland was ranked 13th in terms of arms exports.

### Specialisation vs. reductionism

#### SPECIALISATION

- General trend towards narrow specialisation
- Increased compartmentalisation
- Neglects “big picture”

#### REDUCTIONISM

- Assumes a complex system can be understood/explained by reducing it to its fundamental parts.

Jacob Burckhardt (1818-1897): terrible simplificateur (terrible simplifiers)

→ Ignores interconnectedness

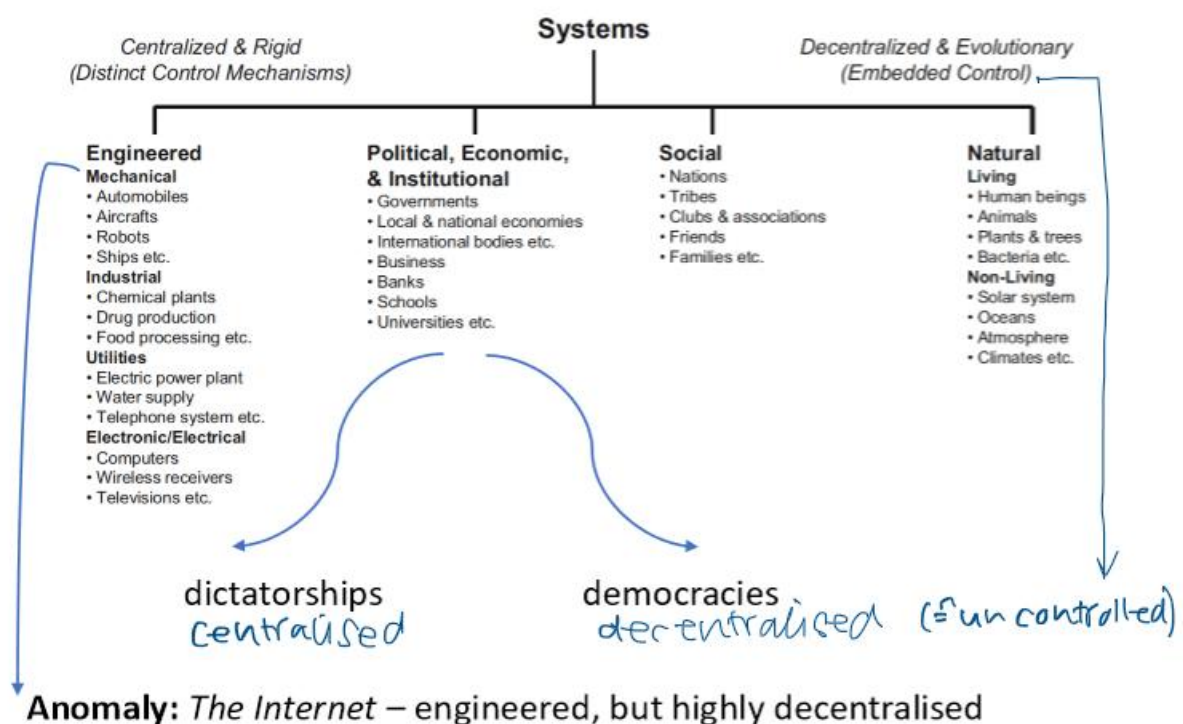
→ Impact on unintended consequences

SYSTEMS THINKING: Takes wider view on problem solving

### Systems View – why is it important?

- A system is more than (the sum) of its parts
- Let's you deal with complexities – permits (better) understanding of present and future behaviours
- Interactions with engineered systems – allows us to better understand and operate them
- Deal with systems over which we have limited control – better understand problems
- Improve systems we have some control over – e.g. eliminate or reduce bottlenecks
- Create sustainable systems – more efficient use of resources
- Avoid / manage unintended consequences

### Classification of Systems/ System Types



### ENGINEERED SYSTEMS:

- Tend to be man-made with control mechanisms (distinct from their functional parts)
- Controllers may be:
  - Mechanical
  - Electronic

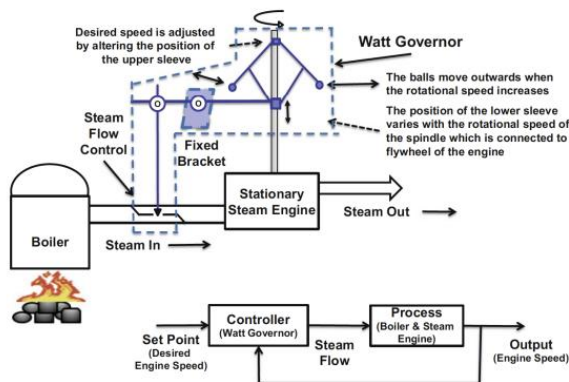
- Electromechanical
- Manual/Human (e.g. pilot)

NATURAL SYSTEMS

- Sophisticated control mechanism
- Non-Living Earth primarily based on laws of physics – but also human activities

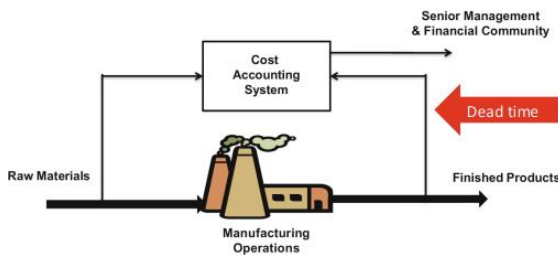
Examples

Watt governor – an early example of an engineered system with feedback

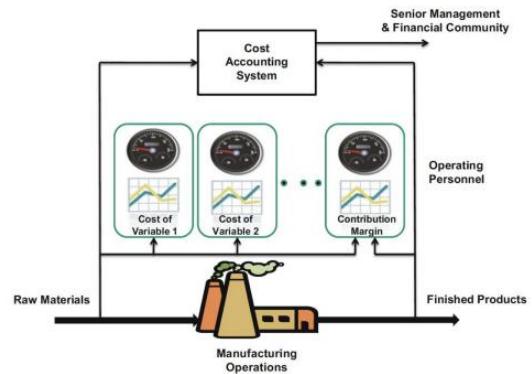


Dynamic performance measures (DPM)

➔ providing more timely (real-time?) feedback



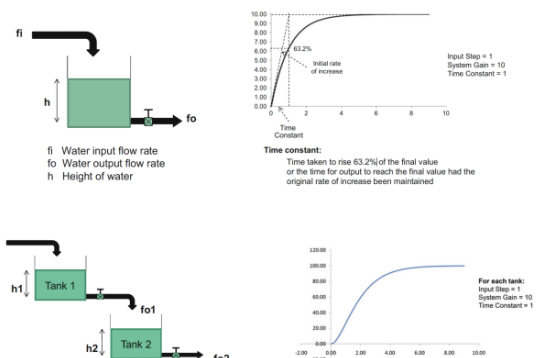
Traditional Cost Accounting



Dynamic Performance Measures (DPM)

Process Characteristics

- Instantaneous Response
- Delayed Response
- Dead time – finite amount of time before output responds due to change in input
- First Order Lag – Change immediate, but full effect takes time for significant manifestation (63.3%)

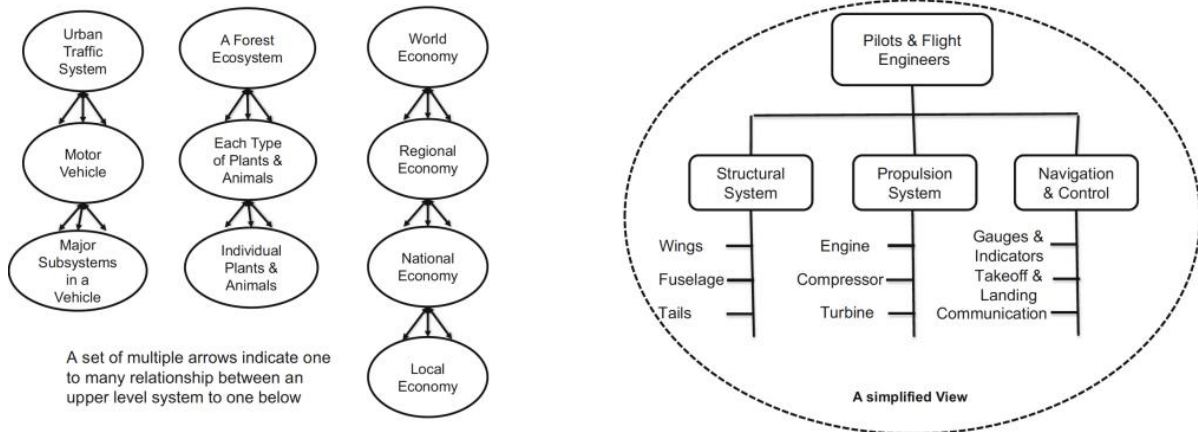


- Second Order Lag – two first order lags in series. Output represented by “S” curve

In Economic Systems:

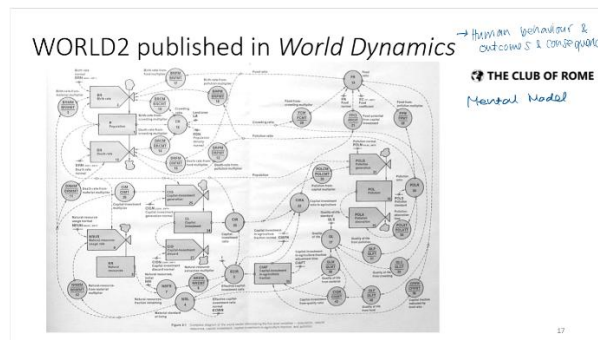
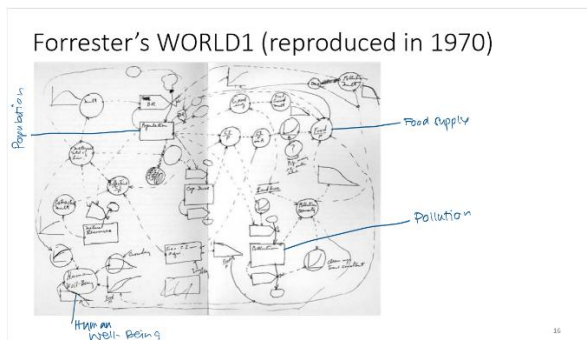
- Time to transfer money (dead time)
- Multiple permits to build factory (serial lags)

System Hierarchies

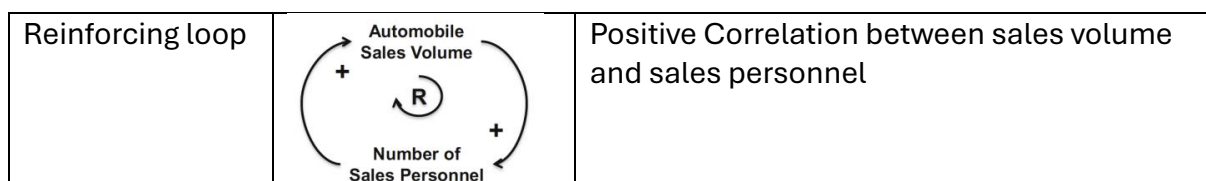


Example - Jay Forrester:

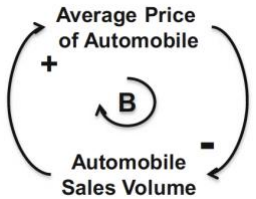
- Shifted 1956 from engineering to management (MIT Sloan):
  - Worked on GE’s 3-year oscillations between orders/inventory & staffing
  - Father of **Forrester (a.k.a. Bullwhip) effect**
- **Publishes Industrial Dynamics, Urban Dynamics, World Dynamics<sup>5</sup>**
  - 3 key topics: importance of feedback loops, simulation and expanding on “mental models”



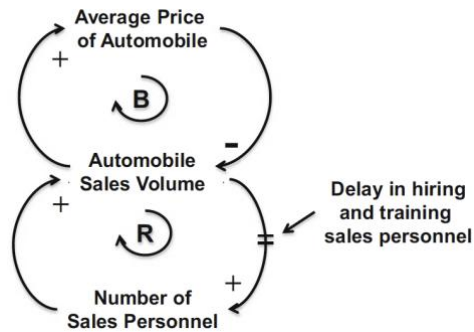
Causal loops



<sup>5</sup> Based on a 1970 visit to Bern (CH) with Club of Rome (based in Winterthur) where he was asked if systems dynamics could increase understanding of “the predicament of mankind”

Balancing loop		<ul style="list-style-type: none"> <li>- Negative Feedback: the two influences counteract</li> <li>- If the total of negative signs in a loop is an odd number, then that is a balancing loop.</li> </ul>
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*Multi Causal Loops (with delay)*



The “=” symbolises the delay.

*Limitations of causal loops*

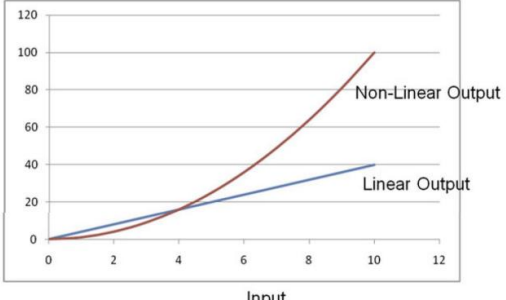
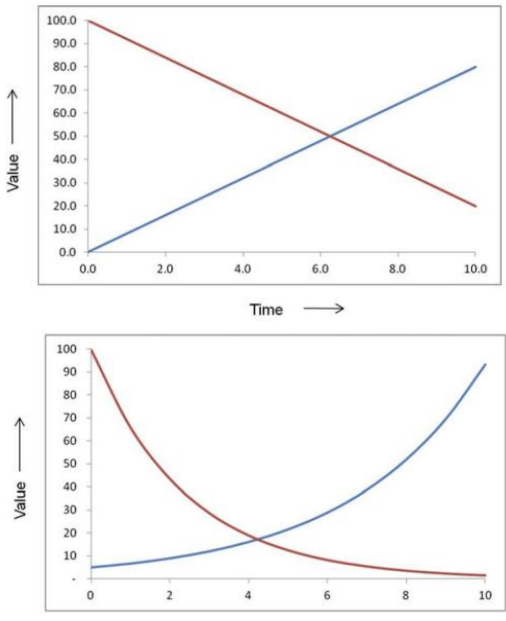
- Do not show numerical relationships
- Does not specify whether relationship is linear or not
- Does not show (or predict) an outcome at a given time (t=0, t+1, ...)

Additional guidelines on loops

	GUIDELINE	EXAMPLE
SELECTING VARIABLE NAMES	<b>1</b> Use nouns when choosing a variable name. Avoid verbs and action phrases, because the action is conveyed in the loop's arrows. For example, "Costs" is better than "Increasing Costs," because a decrease in Increasing Costs is confusing. The sign of the arrow ("s" for same or "o" for opposite) indicates whether Costs increase or decrease relative to the other variable.	
	<b>2</b> Use variables that represent quantities that can vary over time. It does not make sense to say that "State of Mind" increases or decreases. A term like "Happiness," on the other hand, can vary.	
	<b>3</b> Whenever possible, choose the more "positive" sense of a variable name. For example, the concept of "Growth" increasing or decreasing is clearer than an increase or decrease in "Contraction."	
LOOP CONSTRUCTION	<b>4</b> Think of the possible unintended consequences as well as the expected outcomes for every course of action included in the diagram. For example, an increase in "Production Pressure" may increase "Production Output," but it may also increase "Stress" and decrease "Quality."	
	<b>5</b> All balancing loops are goal-seeking processes. Try to make explicit the goals driving the loop. For example, Loop B1 may raise questions as to why increasing "Quality" would lead to a decrease in "Actions to Improve Quality." By explicitly identifying "Desired Quality" as the goal in Loop B2, we see that the "Gap in Quality" is really driving improvement actions.	
	<b>6</b> Distinguishing between perceived and actual states, such as "Perceived Quality" versus "Actual Quality," is important. Perceptions often change slower than reality does, and mistaking the perceived status for current reality can be misleading and create undesirable results.	
	<b>7</b> If a variable has multiple consequences, start by lumping them into one term while completing the rest of the loop. For example, "Coping Strategies" can represent many different ways we respond to stress (exercise, meditation, alcohol use, etc.).	
	<b>8</b> Actions almost always have different long-term and short-term consequences. Draw larger loops as they progress from short- to long-term processes. Loop B1 shows the short-term behavior of using alcohol to combat stress. Loop R2, however, draws out the long-term consequences of this behavior, showing that it actually increases stress.	
GENERAL TIPS	<b>9</b> If a link between two terms requires a lot of explanation to be clear, redefine the variables or insert an intermediate term. Thus, the relationship between "Demand" and "Quality" may be more obvious when "Production Pressure" is inserted between them.	
	<b>10</b> A shortcut to determining whether a loop is balancing or reinforcing is to count the number of "o's" in the loop. An odd number of "o's" indicates a balancing loop (i.e., an odd number of U-turns keeps you headed in the opposite direction); an even number or no "o's" means it is a reinforcing loop. CAUTION: After labeling the loop, you should always read through it to make sure the story agrees with your R or B label.	

Behavioural pattern

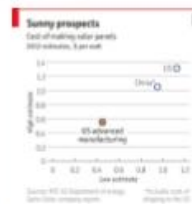
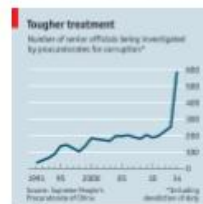
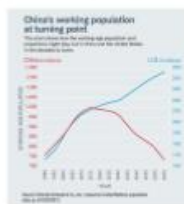
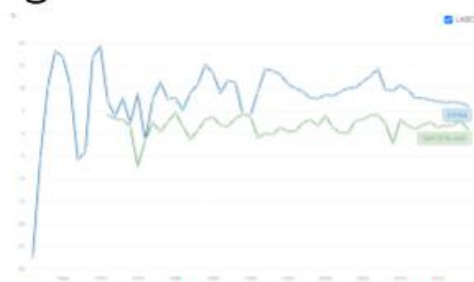
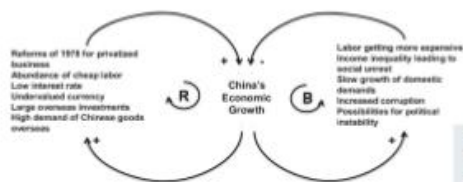
<p><b>Steady State (vs. dynamic state)</b></p> <p>A car travelling at a steady speed of 60 miles an hour</p>	<ul style="list-style-type: none"> <li>- Variables remain constant in recent past and immediate future.</li> <li>- Whether steady or dynamic depends on perspective.</li> <li>- Temporary instabilities can be seen as a transient state.</li> </ul>
<p><b>Linear &amp; Non-Linear, Time Variance</b></p>	<p>Linear – ratio of change of output due to change in input is constant</p> <p>Non-Linear – input/output relationship not as clear; optimisation more difficult</p>

	<p>Time Invariant – same response produced regardless of time. Generally, for mechanical systems.</p> <p>Time Variant – output varies over a period of time. Generally, for biological and social systems.</p>
<p><b>Linear &amp; Exponential Growth/Decay</b></p> 	<p>- Often happens when there is significant positive feedback and little/no negative feedback</p> <p>- Can not be sustained over longer periods of time – but “cost of inaction too high”</p>

Example China

Looking at China’s 10% growth rates

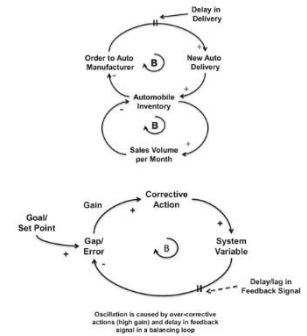
- Economy doubling every 7 years (at 10% p.a.)
- Not sustainable due to negative feedback loops



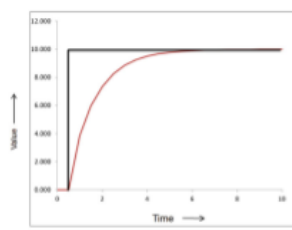
<https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=CN&text=1991>  
<https://www.economist.com/china/2012/04/21/the-boom-and-collapse>  
<https://www.economist.com/china/2013/02/20/the-draw-down>  
<https://www.marketwatch.com/story/china-shows-slow-growth-as-it-tries-to-reduce-its-dependence-on-exporting-2015-10-27>

## Oscillations

- Common where you have large or multiple lags
- Increased gain (amplitude) can lead to greater oscillations; lower gains may lead to decay/stabilisation
- Depending on the system studied, temporary oscillations may be more acceptable
- Economies vs. aircraft safety thresholds

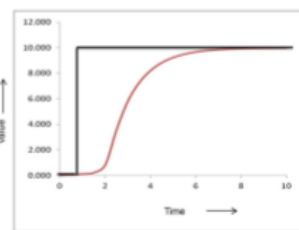


## Goal setting



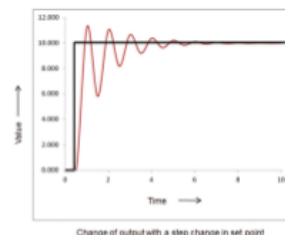
Change of output with a step change in set point

Goal seeking



Change of output with a step change in set point

Goal seeking with a lag



Change of output with a step change in set point

Goal seeking with oscillation

## Detail vs. Systems Complexity

Detail Complexity	Involves a large number of variables, but they don't change with time
Dynamic Complexity	Causes and effects are subtle, with effects significant over time

Example: Municipal Water Supply system – under “normal” conditions may be considered detailed complexity. However, a rupture could lead to observe system as dynamic (major flooding etc.)

## Initial conditions

Engineered/Mechanical Systems: rebooting/restarting can help

Non-engineered systems: much harder/impossible\* to reboot

\*There are exceptions:

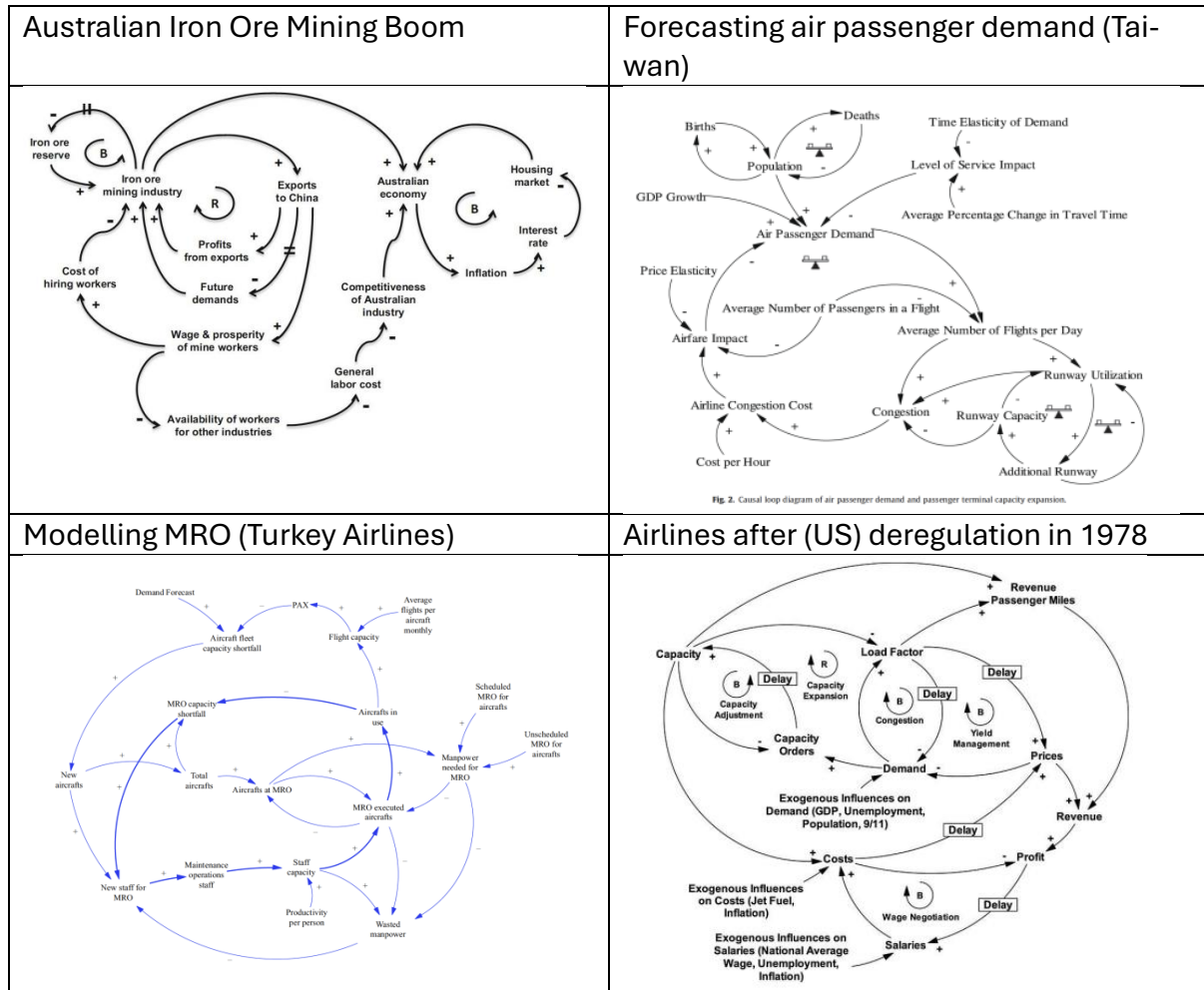
- Companies/Nations: Filing for bankruptcy, debt cancellation
- Forest Fires: Destruction of vegetation permitting new vegetation growth

## Ensuring stable and robust systems

- Reduce delay → less significant oscillations
  - Just-in-time delivery practices
- Decentralisation adds robustness
  - Failure in one part of system won't break entire system
- Add redundancy (also for safety)

- True also for non-engineered systems: e.g. branches on trees can be damaged, limbs on animals can get broken/amputated
- Promote continuous improvement (kaizen)
- Anticipate and reduce unintended consequences
- Cultivate a wholistic view

Examples



## Principles of Complexity III

### Complex system behaviour

1. Self-organising - into patterns (e.g. flocks of birds, schools of fish)
2. Chaotic Behaviour – Small initial conditions (ICs) produce later changes. (e.g. butterfly effect)
3. Fat-tailed Behaviour – Rare events occur more often than would be predicted by a (normal) bell curve.
4. Adaptive Interpretation – interacting agents modify their strategies in diverse ways as experience is accumulated (e.g. prisoner’s dilemma, markets)
5. Emergent Behaviour – see next slide

### *Understanding emergence through the “pile of sand” conundrum*

1. Start with a heap of sand
2. Take one grain away
3. Repeat step 2

Question: When is the pile no longer a heap?

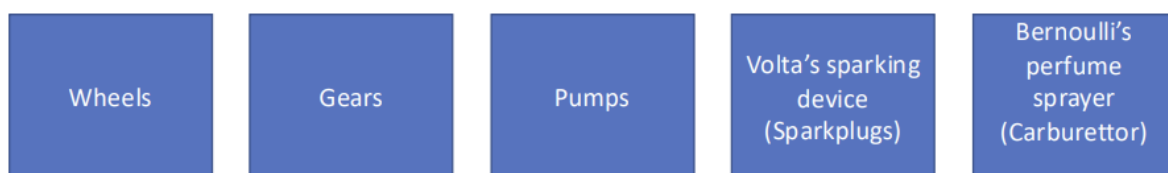
Answer: No sharp boundary

NB: Also works in reverse!

Other example: What is “wetness”? H<sub>2</sub>O at molecule level? - Aggregate of wetness emerging when molecules start interacting between each other

### *Building Blocks*

Example: Internal Combustion Engine, which had major impact on 20th century



Emergence is the non-additive interactions of the building blocks

### Measuring Complexity

It's hard to provide definitions for a “science” which is still under development.

Isaac Newton	Had no good definition of force, as it required magical “action of distance”; not allowed in mechanistic explanations of nature at the time
Biologists	Do not agree on definition of gene at a molecular level
Astronomers	95% universe is <i>dark matter and dark energy</i> . Yet no agreement what they consist of.
Psychologists	Don't agree on <i>idea and concept</i> – or how these are related to the brain!

3 dimensions to measure complexity of an object or process by Seth Lloyd

1. How hard is it to describe?
2. How hard is it to create?
3. What is its degree of organisation?

## Looking at Genomes

### Human Genome

- 3 billion base pairs (pairs or nucleotides)
- 25'000 genes (regions that code proteins)
- 2% of base pairs are parts of genes • 98% (rest) are non-coding regions
- Keep chromosomes falling apart
- Control workings of genes
- Some are “Junk” (no known purpose)

### Yeast Genome

- 12 million base pairs
- 6'000 genes

### *Measuring complexity as size*

- Humans (by base pairs) are ~ 250x as complex as yeast
- ... but only ~ 4x as complex when looking at number of genes!

### Looking at a few more genomes

Human Genome	Yeast Genome	Amoeba	Mustard
• 3 billion base pairs	• 12 million base pairs	• 225x as many pairs as humans	• ~ same number of genes as humans
• 25'000 genes	• 6'000 genes		

∴ humans are more complex than amoeba or mustard

... but genome size is not a good measure of complexity

→ Absolute #s of base pairs or genes do not give away complexity

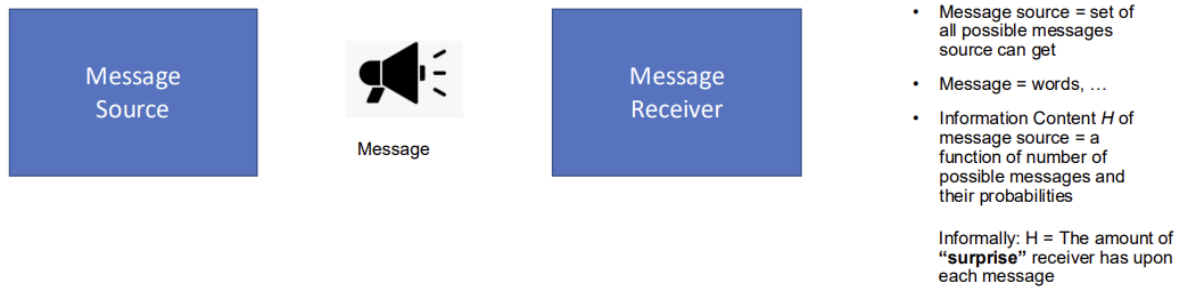
## Shannon's Information Theory

### Claude Shannon

- Worked at Bell Labs (AT&T), now Nokia Bell Labs (1916-2001)

Question: How to transmit signals most efficiently across telephone lines?

Built upon Boltzmann's theories / 2nd law of thermodynamics / entropy



### Complexity as entropy

Measure the Shannon entropy / amount of "surprise"

Example from genetics: A, C, G, T

A A A A A A A A → Highly ordered, easy to describe sequence → Entropy = 0

C A A T G A G C A → Maximum possible entropy

#### Limitations:

1. Object/process analysed has to be put in the form of "messages". Not always easy/possible
2. Highest entropy is achieved by a random set of messages. However, in genetics, this would be a non-functional genome!

→ Most complex entities are neither completely ordered nor completely randomised, but somewhere in between.

#### Complexity as algorithmic information content

Complexity of an object is measured by the size of the shortest computer program that could generate a complete description of the object.

String 1	AC AC AC AC AC AC AC AC AC AC AC	10x AC
String 2	TA CT TC GA AA CA TG CA GC AT	Pseudo-random
String 1	Print "AC" 10 times, compressible	
String 2	Print text "TA CT TC GA AA CA TG CA GC AT", not compressible	

∴ information context is higher for random objects than ones we consider complex (similar to Shannon entropy)

## Murray Gell-Mann & effective complexity



Murray Gell-Mann  
(1929 – 2019)

Gell-Mann proposed that “any given entity is composed of a combination of regularity and randomness”

**String 1**      Simple regularity

**String 2**      No regularity

Living Organisms (highly complex, we know that): some regularity combined with some randomness.

### Calculating effective complexity:

1. Determine best description of regularity of entity
2. **Effective complexity = amount of information contained in description** = algorithmic information content of the set of regularities

**String 1**      “Print AC ten times” – very predictable → low effective complexity

**String 2**      Random, no regularities → No information needed to describe regularities → effective complexity = 0

∴ we wish both **very ordered** and **very random** entities to have a **low effective complexity**

Mitchell, M. (2011). *Complexity: A Guided Tour* (1st edition). Oxford University Press.

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## Complexity as Logical Depth



Charles Bennett  
(b. 1943)

The *Logical depth* of an object is the measure of how difficult it is to construct that object.

“Logically deep objects ... contain internal evidence of having been the result of a long computation or slow-to-simulate dynamical process, and could not plausibly have originated otherwise”

**String 1**      and      **String 2**      Both are “easy to compute” – compared to DNA sequence of a real/viable organism

**Construction of an object = computation of objects with a string of 0s and 1s to encode object**

e.g.

A = 00

C = 01

G = 10

T = 11

∴ number of steps for a Turing Machine to construct a sequence output

Mitchell, M. (2011). *Complexity: A Guided Tour* (1st edition). Oxford University Press.

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## Complexity as Thermodynamic Depth

More complex objects are harder to construct

1. Determine most plausible scientifically determined sequence of events that lead to the thing itself
2. Measure the total amount of thermodynamic and informational resources required by the physical construction process

Example from human genome: Evolutionary genetic events (random mutations, recombination's, gene duplications, ...) lead to creation from "first creatures" to humans today.

Critiques:

1. Assumption that we can in practice list all events to lead to the creation of a particular object
2. How do you define an event?

### *Complexity as Computational Capacity*

Building upon the idea that both man-made and natural complex systems are based on computation:

Computational Capacity: Measure complexity in terms of the sophistication of what the system can produce.

Stephen Wolfram proposes: Systems are complex if their computational abilities are equivalent to those of a universal turing machine.

Charles Bennett is more subtle: Performing universal computation is not a sign of a complex system in itself. It is only when combined with machine code and inputs, do you produce a "sophisticated computation".

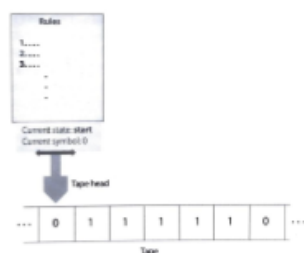
## The Turing Machine

3 Parts:

1. A tape, divided into cells (squares) with readable symbols. Read/Writeable. Length is indefinite in both directions.
2. Mechanical read/write tape head, at any time head is in one of a number of *states*
3. A set of rules that tell head what it has to do next



Alan Turing  
(1912-1954)



Rules tell:

1. Head what symbol to write on current tape cell (write over)
2. Shift head to left, right, stay put
3. Head's new state

When head state = **halt**, machine is done and stops

## Universal Turing Machine

“One can design a special universal Turing Machine (call it U) that can emulate the working of any other Turing Machine.”



Alan Turing  
(1912-1954)

Alan Turing's accomplishments:

- 1 – Defined notions of a definite procedure (i.e. what to **halt**)
- 2 – Turing Machine laid groundwork for invention of electronic programming computer
- 3 – There are limits to what can be computed.

### Complexity as Fractal Dimensions

#### Non-fractal objects

- As you magnify, eventually no more meaningful details are visible

#### Fractal objects

- Details visible, regardless how many times you magnify

∴ Fractal dimensions seen as a form of measuring complexity of real-world phenomena.

Fractal – is a geometric shape that has a fine structure at every scale

## Koch Curve – example of a “perfect fractal”

1. Start with a single line

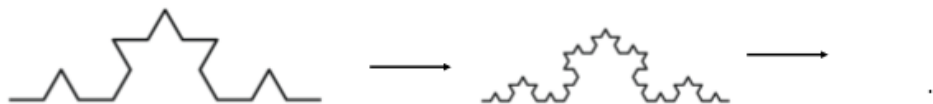


2. Apply Koch Curve rule:

For each line segment, replace its middle third by two sides of a triangle, each of length 1/3 of original segment



3. Apply the Koch Curve rule to the above figure. Continue indefinitely.



Notice self-similarity: all subshapes, their subshapes etc. have same overall curve

Mitchell, M. (2011). Complexity: A Guided Tour (1st edition). Oxford University Press.



Niels von Koch  
(1870 - 1924)

### Complexity as a degree of hierarchy

Complexity of system characterised by degree of hierarchy

“The complex system being composed of subsystems that, in turn, have their own subsystems, and so on”

Hierarchy

Body composed of organs → cells → cellular subsystems, ....

Near-  
decomposability

In hierarchical complex systems there are many more strong interactions within a subsystem than between subsystems.

e.g. Each cell in a living organism has a metabolic network that consists of large number of interactions among *substrates*, many more than between two different cells

→ Evolution can design complex systems in nature only if that can be put together like building blocks. i.e. hierarchical and nearly decomposable.

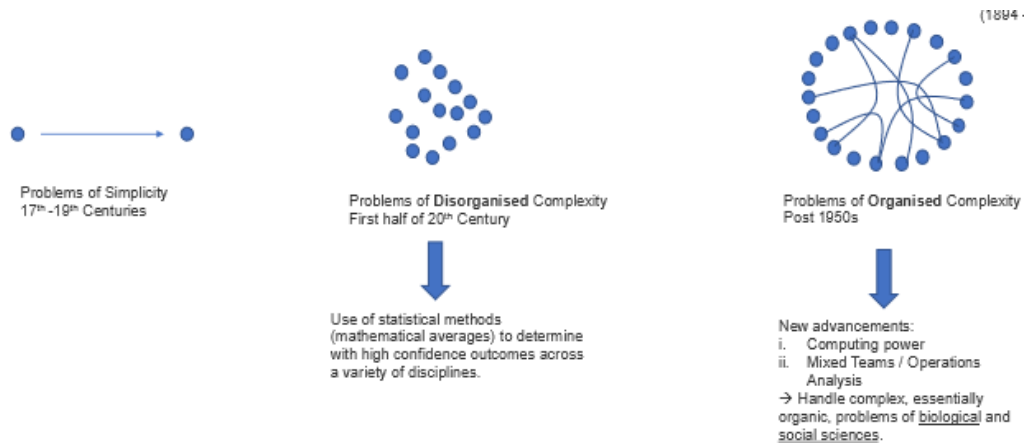
# Visualising Complexity

## Critiques/Limitations of “Trees”

1. Centralism/Centralisation – top-down hierarchy	Authoritarian
2. Finalism – everything flows towards a pre-determined final goal	Unidirectional
3. Essentialism – absolute understanding of the nature of being <ul style="list-style-type: none"> <li>• Every entity has a set of properties belonging to a precisely defined kind of group</li> </ul>	Stagnant

→ Trees don't embrace multiplicity / multilinearity

## Warren Weaver's 3 stages of Modern Science



## Rhizomatic Properties

1. Decentralisation
2. Emergence
3. Mutability
4. Non-linearity
5. Diversity

## Purposes of Network Visualisation

### 5 Functions

1. Document
  - Stimulates interest and awareness of subject matter
  - Opens door for further discovery / interpretations
2. Clarity
  - Makes system more understandable, intelligible, transparent
  - Objective: simplification
3. Reveal
  - Find “hidden patterns”, new insights
  - Focus on causality: disclose unidentified relationships & correlations
4. Expand

- Serve as a vehicle for other users / further exploration
5. Abstract
- Explore networked schema as a platform for abstract representation
  - e.g. for hypothetical expression based on non-existing data

### *Ben Fry's 8 Principles for network visualisation projects*

#### 1. Start with a question

- Identify question you wish to answer rather than data collected (no backward thinking)
- Collect data you require (vs. hoarding)

#### 2. Quest for relevancy

- Relevant = serves as an effective means to a particular purpose
- Relevant = if it increases the likelihood of achieving an underlying goal

If relevancy is high, this will increase possibilities of:

- Comprehension
- Assimilation
- Decision Making
- Transfer from information to knowledge

NB: ↑ processing effort → lower relevance

#### 3. Enable Multivariate Analysis

- Embrace complex data sets
- Provides additional information on the nature of nodes and their respective ties can expose causality patterns & relationships

Example: i. Map a river along cities / neighbourhoods it passes (nodes) ii. Now add colour & temperature of water, pollution levels, current speed, ... → Determine potential accidents, causes of water contamination, ...

#### 4. Embrace Time

- Networks evolve over time!
- Incorporating time is both conceptually complex and technically challenging

#### 5. Enrich your vocabulary

Two key elements in a network:

1. Nodes (vertices)
2. Links (edges)

Enhance above with use of colours, shapes, orientation, texture, value, position, ...

Example with My Muesli's radial visualisation:

Unexpected findings:

- Fruit are the most popular ingredient and are often combined with each other.
- Sweets and nuts, however, are rarely combined.
- Mango is often combined with coconut (Kokosnuß) or pineapple (Ananas), although these two don't tend to be used together.
- Goji berries with plantago seeds. Almonds (Mandeln) with fruit are also really popular. BUT: the strongest link almost disappears (raspberries (Himbeeren) to strawberries (Erdbeeren), because they are neighbours on the circle.

## 6. Expose Grouping

Showcase variables through spatial arrangements Grouping: combining several units of information into related chunks to: i. Reinforce relationships ii. Reduce complexity iii. Improve cognition

5 "Hat Racks" (from Richard Saul Wurman's *Information Anxiety*)

- Alphabetical order
- By time
- By location
- A given continuum/scale
- A given category

Gestalt Laws (from Gestalt psychology)

1. Law of Similarity (graphical treatment)

- Elements that are similar (colour, size, shape) are perceived more related than those dissimilar

2. Law of Proximity (spacial arrangement)

- Elements close to each other are perceived related

3. Law of Common Fate (motion)

- Elements move simultaneously in same direction and at same speed are perceived to be related

## 7. Maximise Scaling

Scaling fallacy: a representation that works at one scale will work at a larger/smaller one.

Consider 3 views of the network:

1 – Macro View (pattern) -- "synthesis"

- No detailed understanding of individual links and even less of nodes
- Bird's eye view into network

- Highlight certain clusters and isolated groups within structure
- Facilitate understanding of network's topology, structure of group as a whole
- Use of colour (within nodes/edges) and positioning (grouping) provides additional insights

## 2 – Relational View (connectivity) -- “analytics”

- Focuses on relationships of entities (nodes)

## 3 – Micro View (individual nodes)

- Focus on qualitative attributes
- Comprehensive & explicit
- Detailed information, facts, characteristics on single entity

## 8. Manage Intricacy

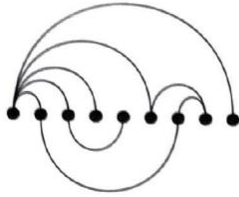
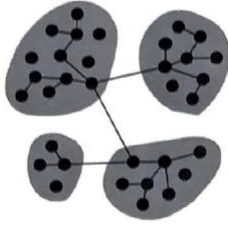

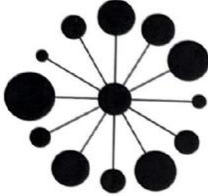
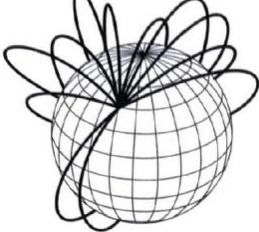
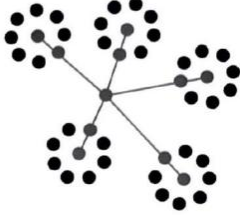
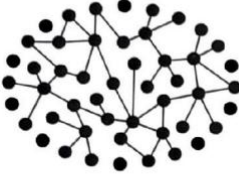


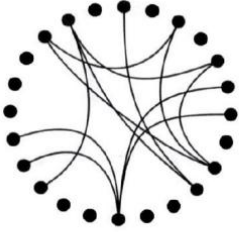
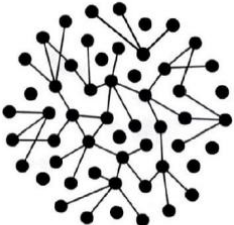
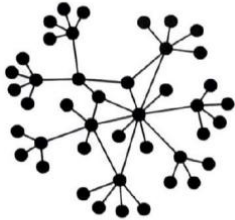

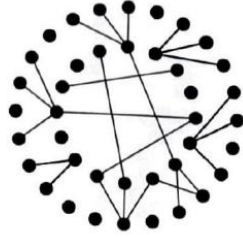
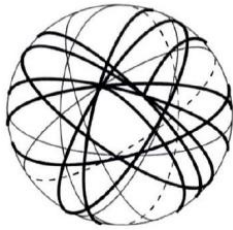
Ability to navigate through 3 views (above) effortlessly

Ben Schneiderman (1996): “Overview first, zoom and filter, then details-on-demand”

## Schneiderman's mantra

1. Adaptive zooming  
Provide progressive disclosure – see Google Maps
2. Overview & Detail  
Primary viewing area (detail)  
Accompanied by smaller macro view (overview)
3. Focus & Context – a.k.a. fish-eye view  
Simultaneous: detailed view (focus) & macro view (context) Often accomplished by enlarging the detailed view, while leaving the other nodes and edges to the periphery

Syntax for visualizing complex networks

 <p>Arc Diagram</p>	 <p>Area Grouping</p>	 <p>Centralized Burst</p>
 <p>Centralized Ring</p>	 <p>Circled Globe</p>	 <p>Circular Ties</p>
 <p>Elliptical Implosion</p>	 <p>Flow Chart</p>	 <p>Organic Rhizome</p>
 <p>Radial Convergence</p>	 <p>Radial Implosion</p>	 <p>Ramification</p>
 <p>Scaling Circles</p>	 <p>Segmented Radial Convergence</p>	 <p>Sphere</p>

*When to use tables and when to use graphs*

Use tables when

- The document will be used to look up individual values
- The document will be used to compare individual values
- Precise values are required
- The quantitative information to be communicated involves more than one unit of measure

Use graphs when

- The message is contained in the shape of the values
- The document will be used to reveal relationships among multiple values

*Rolf Hichert's SUCCESS Model*

**SAY** Convey a message

**UNIFY** Apply semantic notation

**CONDENSE** Increase information density

**CHECK** Ensure visual integrity

**EXPRESS** Choose proper visualization

**SIMPLIFY** Avoid clutter

**STRUCTURE** Organize content