KAEMaRT

Knowledge Aided Engineering,
Manufacturing and Related Technologies

Open Innovation Platform
University - Enterprise
Collaboration

Introduction to Technology Forecasting

OIPEC Workshop at VISU
November 14, 2016

Gaetano Cascini

Co-funded by the
Erasmus+ Programme
of the European Union

Short Resume – Gaetano Cascini

- 1999 : PhD in Machine Design
- 1999 – 2008 : Assistant Professor at University of Florence
- 2008 – 2014 : Associate Professor at Politecnico di Milano
- 2014 – current : Full Professor at Politecnico di Milano

- Past:
  - 2003-2005 : Founder and first President of Apeiron, the Italian TRIZ Association
  - 2005-2009 : Founder and Vice-Chair of the IFIP 5.4 Working Group (Computer-Aided Innovation)
  - 2006-2009 : President of the European TRIZ Association (ETRIA)
  - 2009-2013 : Publications and Events Officer of TC-5 Committee (Computer Applications in Technology) of IFIP
  - 2012-2015 : Coordinator of the EU Marie Curie Project IAPP (PIAP-GA-2011-286305): **FORMAT (FOrecast and Roadmapping for MAnufacturing Technologies)**
- Currently:
  - Coordinator of the **EU project SPARK**: Spatial Augmented Reality as a Key for co-creativity (Horizon 2020 – ICT)
  - Coordinator of the **EU project OIPEC**: Open innovation Platform for university-Enterprise Collaboration: new product, business and human capital development (Erasmus+ – Capacity Building in Higher Education)
  - Member of the Editorial Board of: Research in Engineering Design, Journal of Integrated Design & Process Science, International Journal of Design Creativity and Innovation
  - Member of the **ETRIA** (European TRIZ Association) Executive Board
  - Co-Chair of the **Design Creativity** SIG and member of the Advisory Board of the Design Society
  - Chair of the Training WG of **CEPIUG** (Confederacy of European Patent Information User Groups)
  - Author of **120+ papers** presented at International Conferences and published in authoritative Journals
  - Author of **13 patents**

Goals and Outline

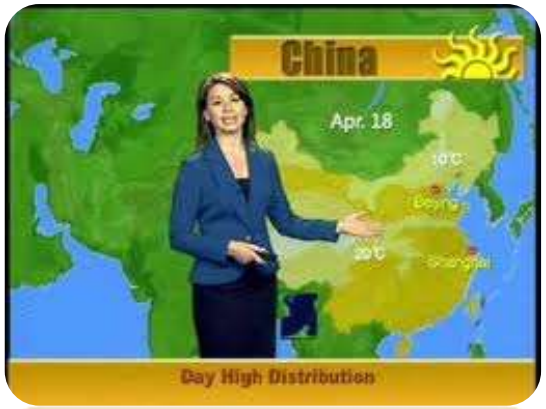
- Goals
  - Share a common vision about innovation, opportunities and threats
  - Realize that it is possible to forecast the evolution of technology to support R&D and investment decisions

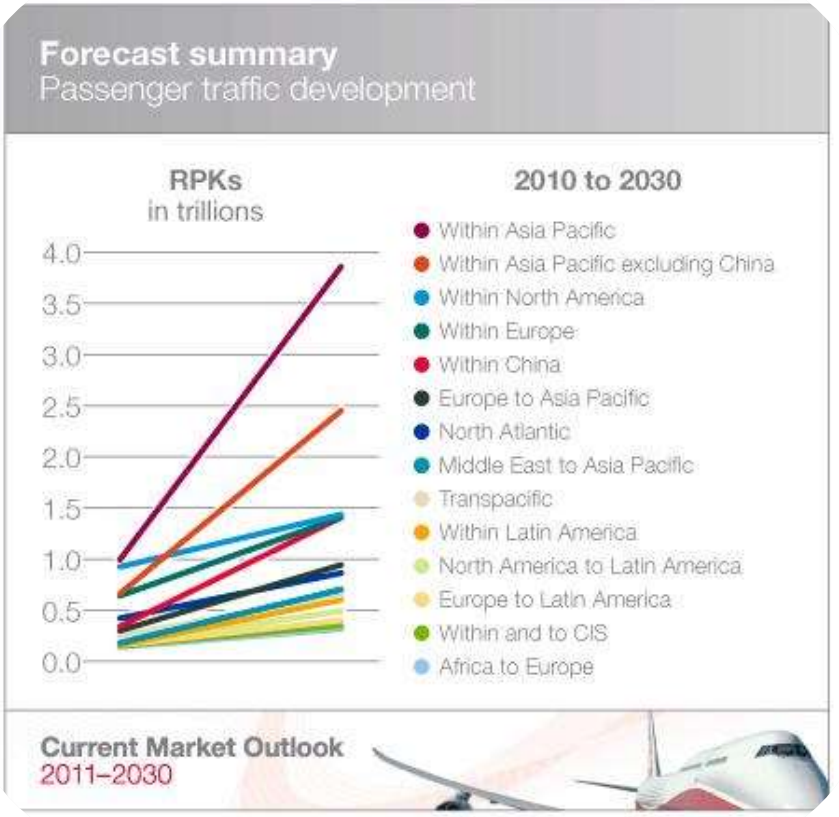
- Outline
  - Technology Forecasting – What? Why? Who? How?
    - Learning about the Future
  - Introduction to Technology Forecasting approaches:
    - Leveraging Experts' Knowledge
    - Trend extrapolation
    - Analogical reasoning and envisioning through evolutionary patterns
  - FORMAT methodology
    - Reference models
    - Stages and gates
  - Industrial Case studies
    - Consumer products
    - Industrial processes

Technology Forecasting

What? Why? Who? How?

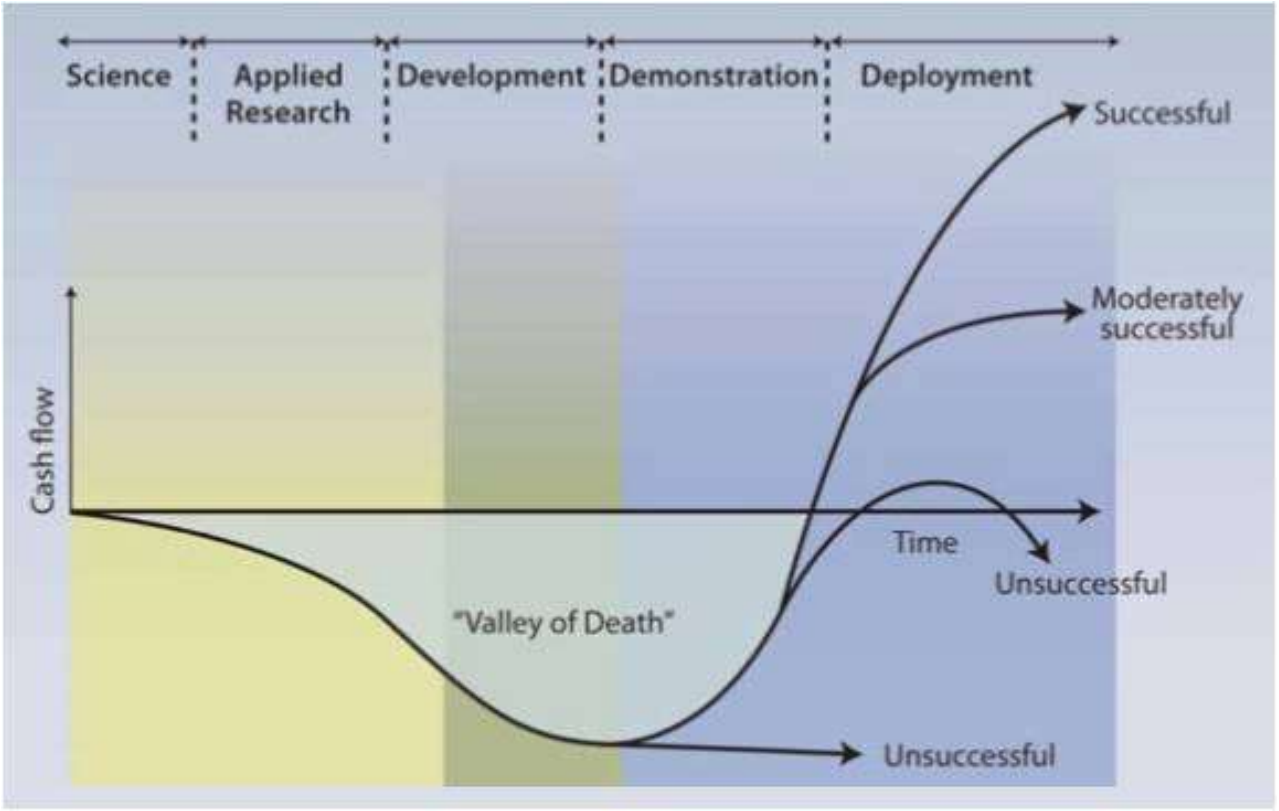
Introduction to Technology Forecasting





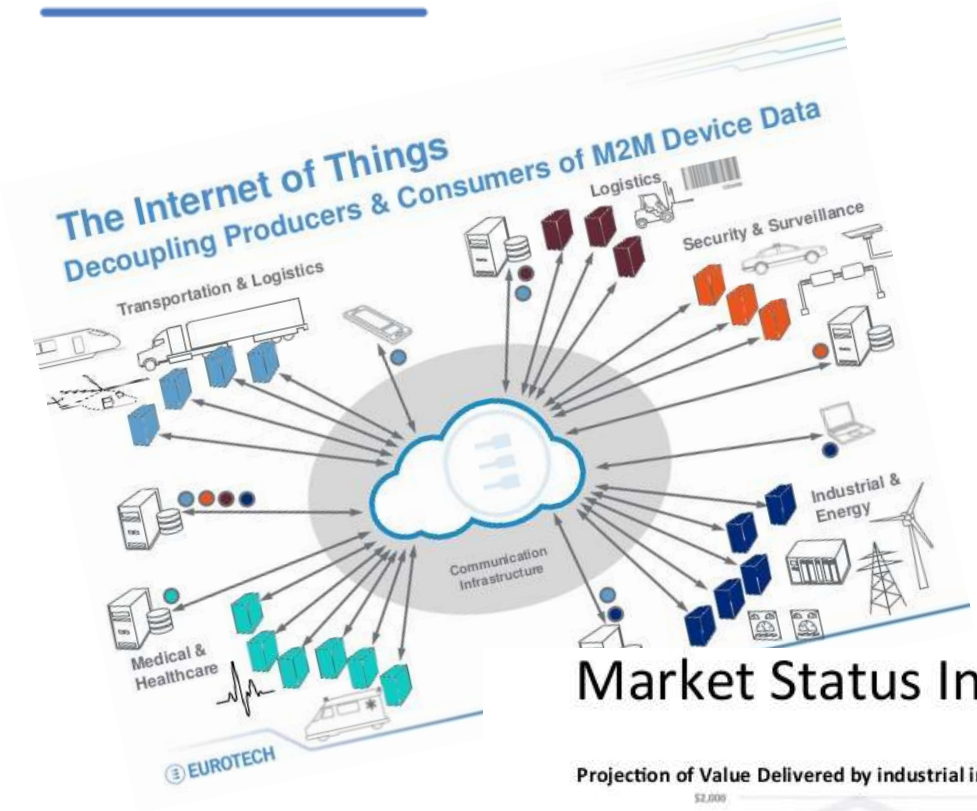
Introduction to Technology Forecasting

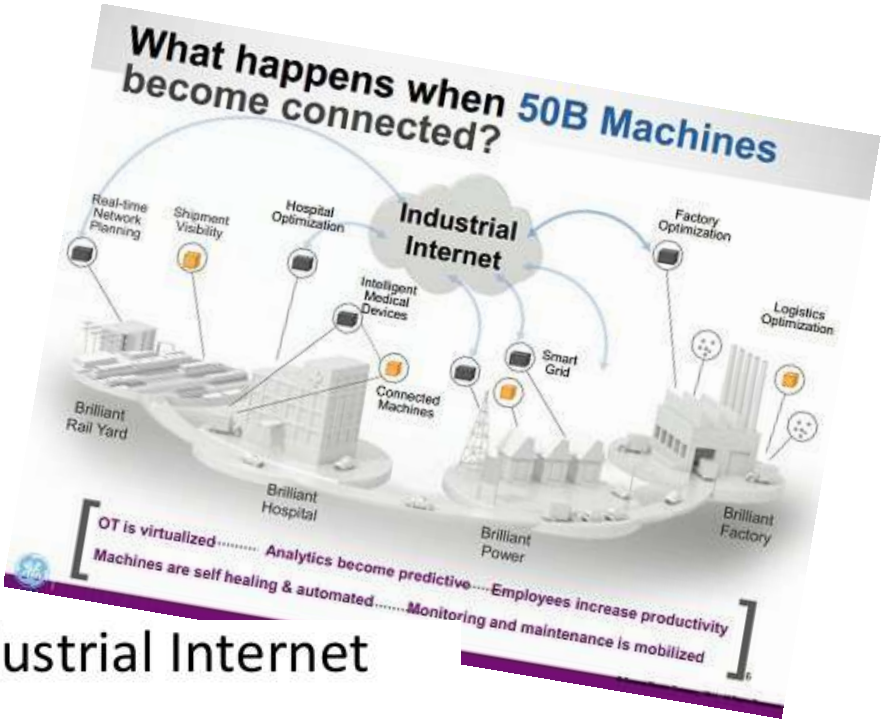
- Innovation, opportunities and threats
  - From research to market



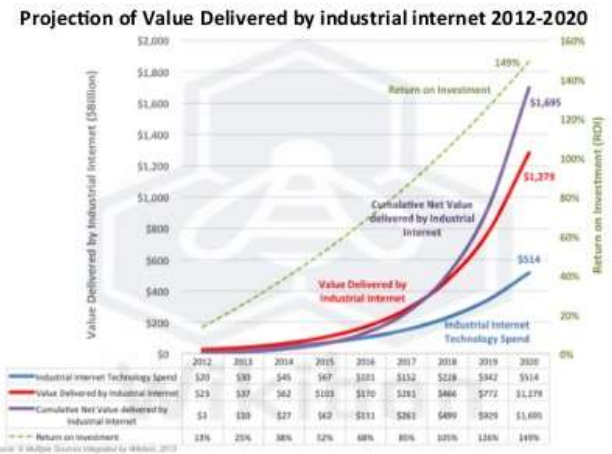
source: ca.gov

Introduction to Technology Forecasting





Market Status Industrial Internet



Projected value by 2020:

€1.57 Trillion

Current US value:

€57.3 Billion

Introduction to Technology Forecasting

- Technology Forecasting: what for?
  - Provide support to decision-makers (entrepeneurs, administrators, researchers) for the identification of the right strategy to pursue

  ✓whether to invest on a certain technology;

  ✓how to identify the proper competences to keep/improve competitiveness;

  ✓select the right partner or supplier;

  ✓focus R&D investments;

  ✓…

Introduction to Technology Forecasting

- **forecast = knowledge**

  - *Those who have knowledge, don't predict.*
    Those who predict, don't have knowledge.
    -Lao Tzu

  - The goal of forecasting is not to predict the future but to tell you what you need to **know to take meaningful action** in the present.
    -Paul Saffo

  - Innovation leaders regularly scrutinize/challenge the future validity of their past strategies and success formula
    -Jean-Philippe Deschamp

Introduction to Technology Forecasting

Louis XVI (23 August 1754 – 21 January 1793)

From Louis' journal:
14 Juillet 1789
"…rien…"

source: R. Santolamazza

Introduction to Technology Forecasting

- An example Best Practice from IBM

Since 1982, IBM Research has marshaled the unique capabilities of its worldwide community of top scientists to create the Global Technology Outlook (GTO).

The GTO is a comprehensive analysis that looks three to ten years into the future seeking to identify significant, disruptive technologies that will change IBM and the world.

The completed GTO is used within IBM to define areas of focus and investment and is shared broadly with a range of IT influencers, including clients, academics, and partners, through education programs and client briefings.

GTO is not perfect: predicting is difficult

GTO is not speculative: driven by business

GTO is not ignored: 100M$+ investments based on GTO

Introduction to Technology Forecasting

It's all about Data

2012	2013	2014	2015
			
Volume Velocity Variety Veracity	Confluence of Social, Mobile, Cloud, Big Data, and Analytics	Systems of Insight Data Transforming Industries	Data will disrupt entire industries

IBM Global Technology Outlook 2015 - Do not Distribute

Introduction to Technology Forecasting

- An example Best Practice from Siemens

Since 2001, Siemens' Pictures of the Future magazine reports twice a year on major technology trends and looks at the latest research in the company's laboratories. The magazine includes scenarios of the future, features, reports on associated R&D activities at Siemens, and interviews with internationally-recognized experts.

Introduction to Technology Forecasting

Industry & Automation

Future of Manufacturing

Seven Facts you have to know about the Fourth Industrial Revolution. >

21 January 2016

Introduction to Technology Forecasting

- An example Best Practice from ACARE

ACARE
Advisory Council for Aviation Research and Innovation in Europe

Introduction to Technology Forecasting

- An example Best Practice from ACARE

	2020	2035	2050
Customer-centric mobility	• Evolution of customer mobility expectation and profile understood • Market & societal opportunities and acceptance factors known • Customer-centric mobility system design • Planning, payment and single ticketing support for intermodal journey selection • Seamless transport processes defined • Legal framework for data privacy and availability	• Accountable door-to-door integrated journey planning, payment and single ticketing used for the majority of journeys • Automatic journey monitoring and disruption management for the majority of journeys • Seamless processes implemented • Indoor and outdoor route guidance • Robust, high-speed and secure personal communication and notifications links	• Door-to-door integrated journey planning, payment and single ticketing & accountability for over 90% of journeys • Automatic journey monitoring and disruption management for over 90% of journeys
Integrated transport	• Aviation at core of integration of transport modes • Level playing field for all modes of transport • Intermodal business models incentivise seamless travel integration • Mobility performance baselined • Intermodal transport architecture & standards • Interoperability data-sharing regulation • Collaboration on implementation & context at early stages of research	• Infrastructure planning and prioritisation based on contribution to mobility goal • Choices of transport modes based on fair and unbiased comparison • Resilient behaviour of the Air Transport Sociotechnical System and supporting policies in place • Strategic, tactical and real-time mobility modelling and simulation with forecasting functionality for integrated transport system • Mobility plans for large-scale disruptions • Optimised processes and interfaces between transport modes	• Fully integrated intermodal transport system • Mobility goals achieved • Various innovative mobility systems and services complementing each other based on their individual contribution • Infrastructure development in line with mobility needs
Aviation services	• Design of innovative passenger, baggage and freight processes • Integration of new air vehicles and services at airports • Advanced ATM functions introduced • Concepts to reduce impact of weather on air transport performance • Improved disruption management & recovery	• Innovative air vehicles and services fully integrated • Performance-based ICNS information platform • Optimised ATM services based on breakthrough ICNS technologies and services • Optimised airport infrastructure • Innovative services to airspace users	• Flights arriving within +/-1 minute of planned time • Win-win situation between aviation infrastructure and neighbours • Sustainable aviation ground infrastructure and operation • No congestion due to capacity shortfalls

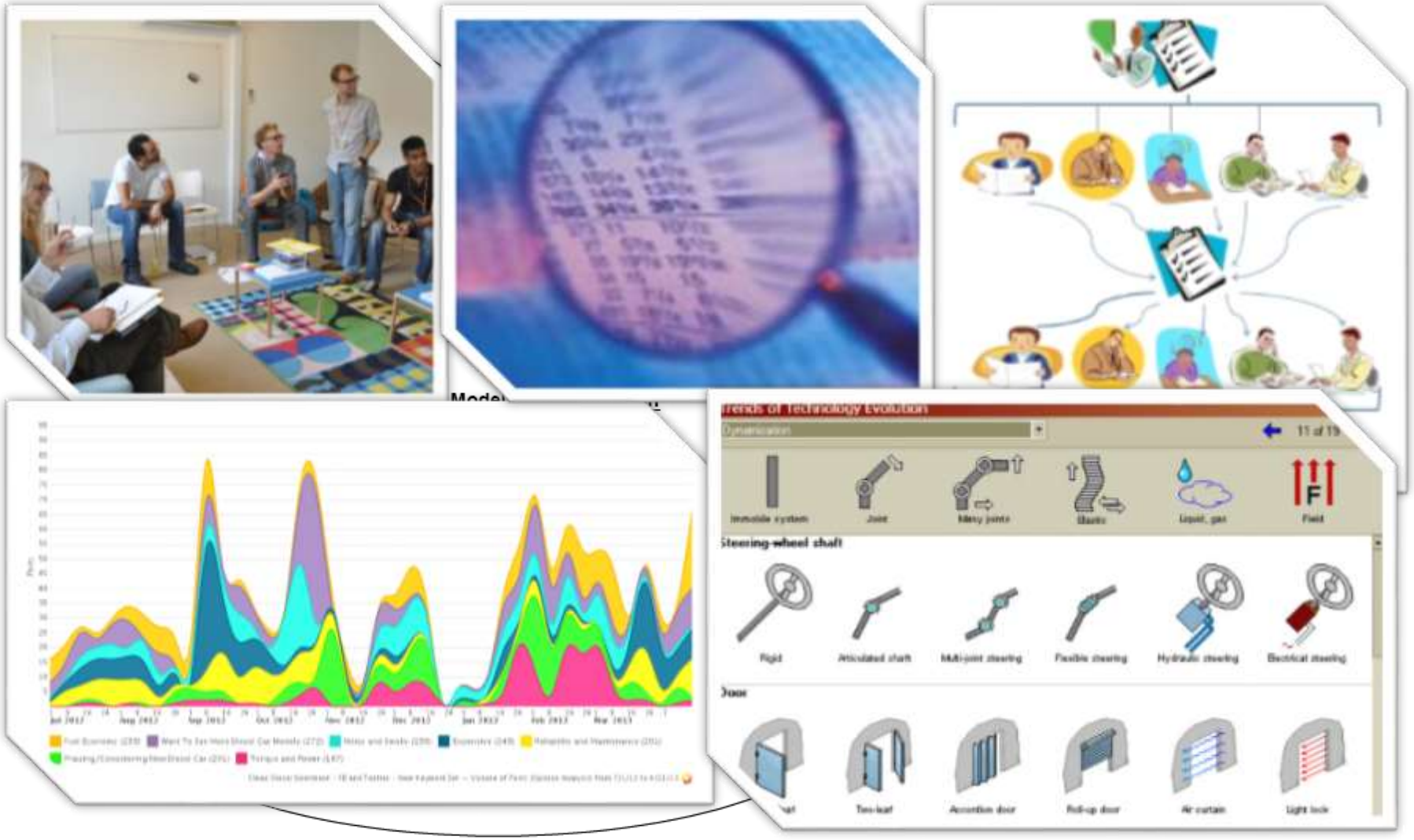
Definitions and Scopes

- **Technological forecast:**
  - a comprehensible description of emergence, performance, features, and impacts of a technology in a particular place of a particular point of time in the future
  - **(What? When? Where? Why?)**

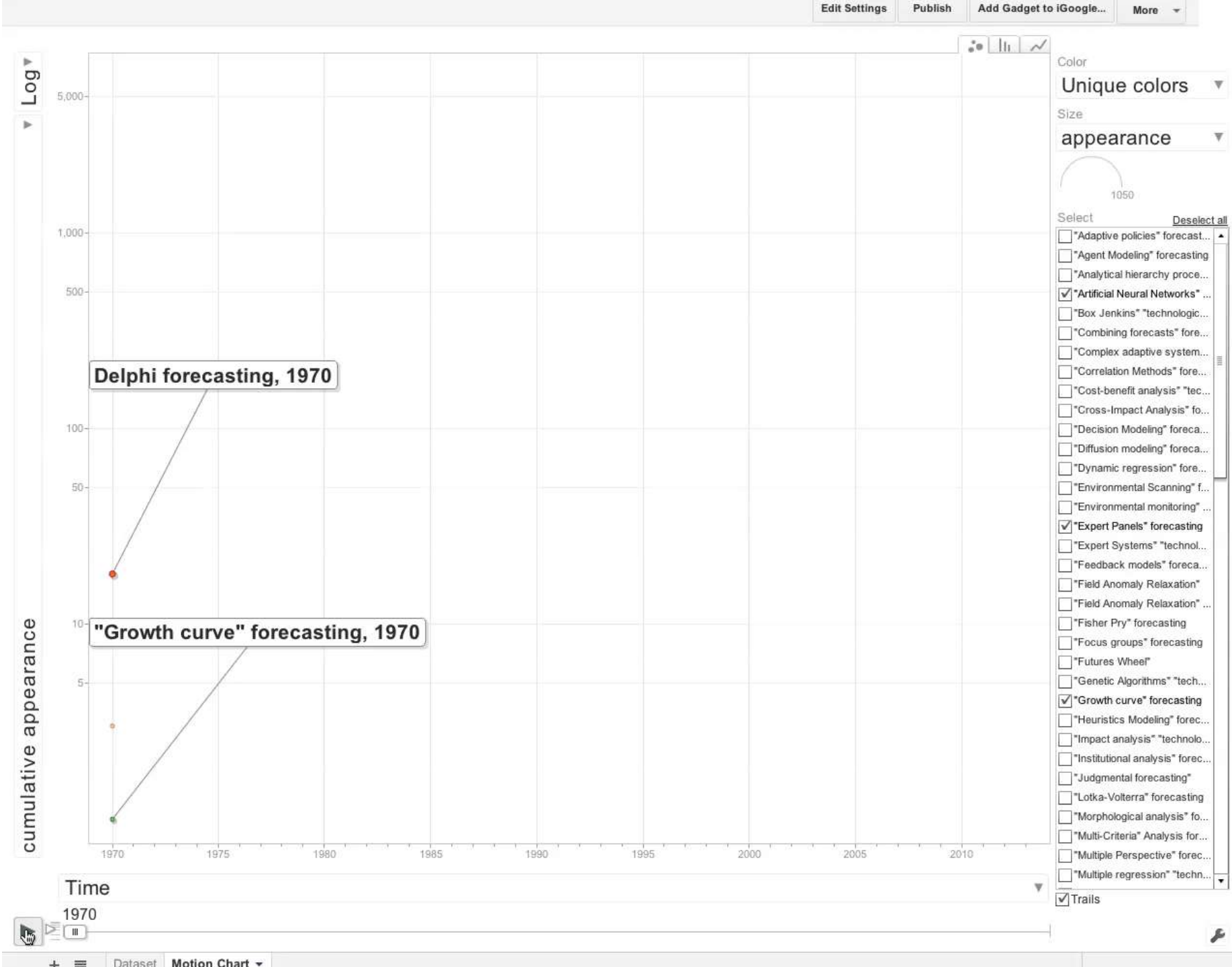
- **Prediction:**
  - a statement made about the future, anticipatory vision or perception. This statement is mostly qualitative
  - **(What? Why?)**

Source: Dmitry Kucharavy

Technology Forecasting Approaches



Source: Phillips, Heidrick, Potter


Edit Settings
Publish
Add Gadget to iGoogle...
More
Log
cumulative appearance
5,000
1,000
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Delphi forecasting, 1970
"Growth curve" forecasting, 1970
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2000
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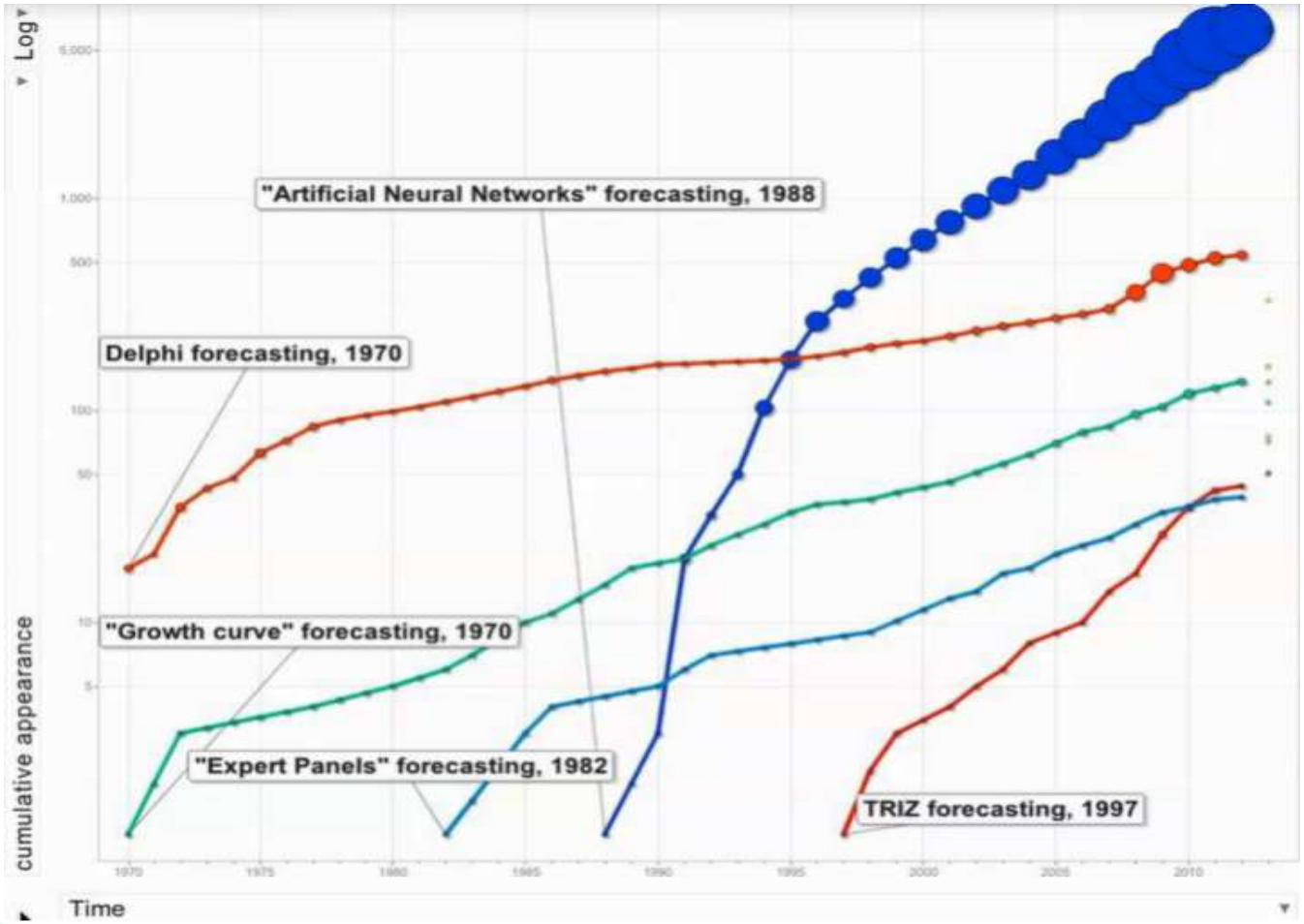
2010
Time
1970
Color
Unique colors
Size
appearance
1050
Select
Deselect all
"Adaptive policies" forecast...
"Agent Modeling" forecasting
"Analytical hierarchy proce...
"Artificial Neural Networks" ...
"Box Jenkins" "technologic...
"Combining forecasts" fore...
"Complex adaptive system...
"Correlation Methods" fore...
"Cost-benefit analysis" "tec...
"Cross-Impact Analysis" fo...
"Decision Modeling" foreca...
"Diffusion modeling" foreca...
"Dynamic regression" fore...
"Environmental Scanning" f...
"Environmental monitoring" ...
"Expert Panels" forecasting
"Expert Systems" "technol...
"Feedback models" foreca...
"Field Anomaly Relaxation"
"Field Anomaly Relaxation" ...
"Fisher Pry" forecasting
"Focus groups" forecasting
"Futures Wheel"
"Genetic Algorithms" "tech...
"Growth curve" forecasting
"Heuristics Modeling" forec...
"Impact analysis" "technolo...
"Institutional analysis" forec...
"Judgmental forecasting"
"Lotka-Volterra" forecasting
"Morphological analysis" fo...
"Multi-Criteria" Analysis for...
"Multiple Perspective" forec...
"Multiple regression" "techn...
Trails
Dataset
Motion Chart

Forecasting Methodologies

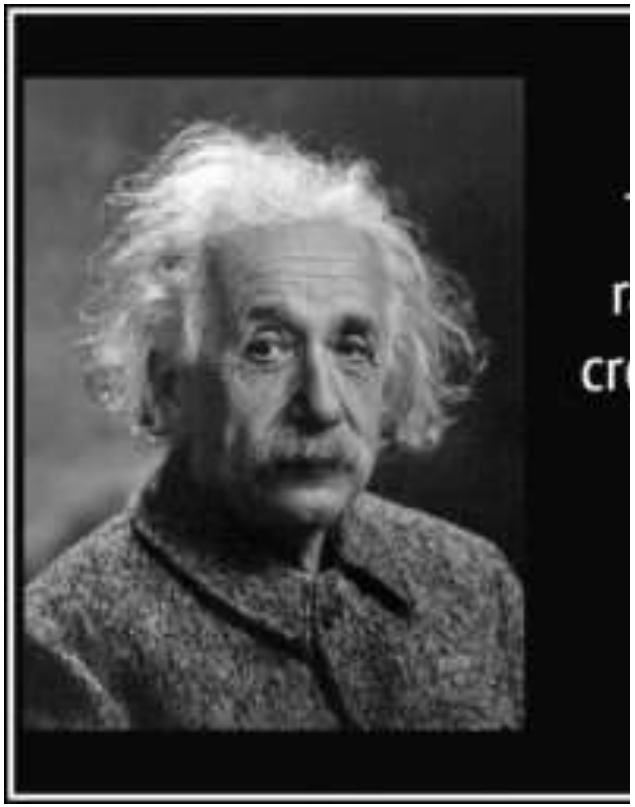
- Types of forecast: cumulative appearance of articles



Technology Forecasting

Based on Experts Tacit Knowledge

Technology Forecasting based on experts tacit knowledge



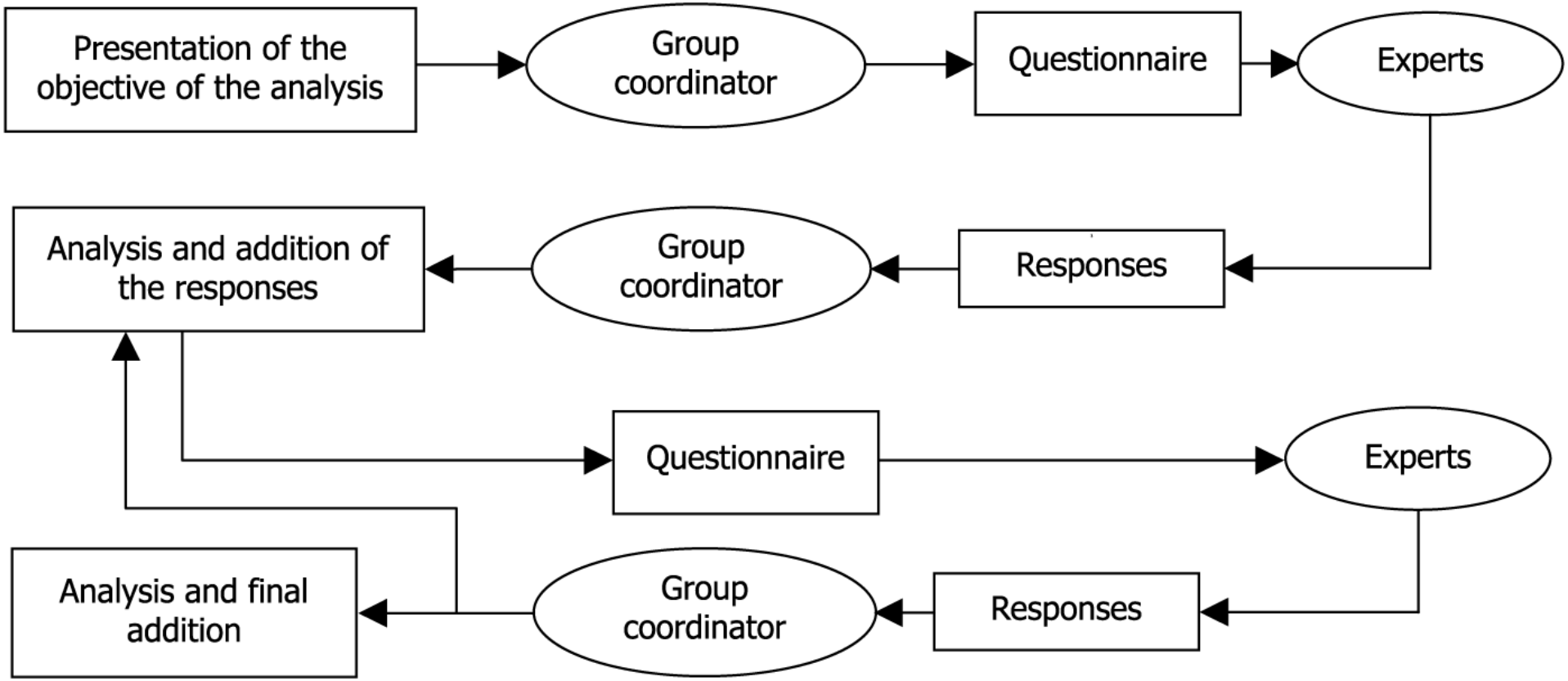
"WHILE DOING THE RESEARCH, KEEP IN MIND THERE ARE ONLY TWO KINDS OF FACTS... THOSE THAT SUPPORT MY POSITION... AND INCONCLUSIVE."

Forecasting Methodologies

- **Well known methods (1):**
  - **Delphy surveys (Explorative/Normative, Soft, Expert Opinion)**
    - Consensus based method: this method seeks to rectify the problems of face-to-face confrontation in the group, so the responses and respondents remain anonymous.
    - The classical technique proceeds in well-defined sequence. In the first round, the participants are asked to write their predictions. Their responses are collated and a copy is given to each of the participants. The participants are asked to comment on extreme views and to defend or modify their original opinion based on what the other participants have written. Again, the answers are collated and fed back to the participants. In the final round, participants are asked to reassess their original opinion in view of those presented by other participants.
    - The Delphi method generally produces a rapid narrowing of opinions. It provides more accurate forecasts than group discussions. Furthermore, a face-to-face discussion following the application of the Delphi method generally degrades accuracy.

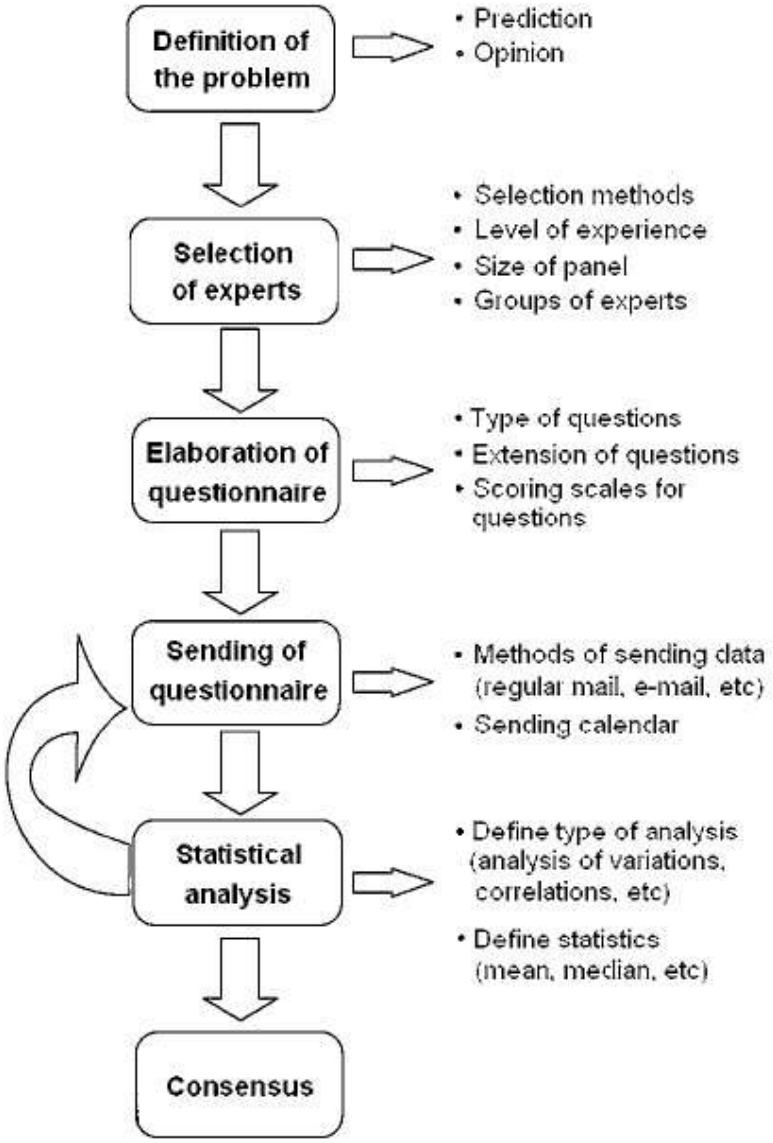
Source: David S. Walonick

Forecasting Methodologies



Source: Adapted from Landeta (1999)

Forecasting Methodologies



Forecasting Methodologies

- **Delphy surveys**
  - **Define the problem**
    - Identify the problem that you want to work on, writing it down in a clear way that is easy to understand. This can be in various forms, from a questionnaire to a broad and open question.
    - You can work on one problem and you can work on several problems at once. The constraint is usually the bandwidth and expertize of the people in the Delphi group.
  - **Give everyone the problem**
    - Recruit people to the Delphi group. This includes anyone who has been selected to contribute thinking on this project. There is seldom a meeting needed for Delphi work, making it ideal for virtual teams.
    - Delphi thinking can be done with a small group and it can be done with hundreds of people. Around 20 people is a fairly common size.
    - Send the problem or problems to everyone who is in the group and ask them respond. You will have to handle a lot of feedback, so asking for short bullet-points will make things much easier to deal with than rambling text.
  - **Collate the responses**
    - Take the responses that people send back to you and collate these into a single anonymous list or sets of lists.
    - Make this as easy as possible for the people to read when you send it back out again, but be aware of causing inappropriate bias. For example you may group responses into appropriate headings, but with the caution that this might presuppose particular thinking.
    - On the other hand, if you are seeking creative ideas you may deliberately mix up the answers.
  - **Give everyone the collation**
    - Send the collation back out to everyone with the request to score each item on a given scale (typically 1 to 5). You may also allow them to add further items as appropriate.
    - Remember to include the original problem at the top of the page, along with instructions on what to do. You can also make responding easier by putting the items in a table with space for the score.
  - **Repeat as necessary**
    - The process may now be repeated as many times as is deemed appropriate. If you are seeking consensus and there was a wide range of responses, then this may require several iterations. In particular at least a second round to see how others have scored can be very useful.
    - In analysing the scores, one method used in Delphi analysis for smaller groups and especially when percentage scores are used is to use the formula: (lowest score + highest score + 4 x average score) / 6. This gives more weight to the average whilst also allowing some influence from outliers.

Source: creatingminds.org

Technology Forecasting

Based on Trend Extrapolation

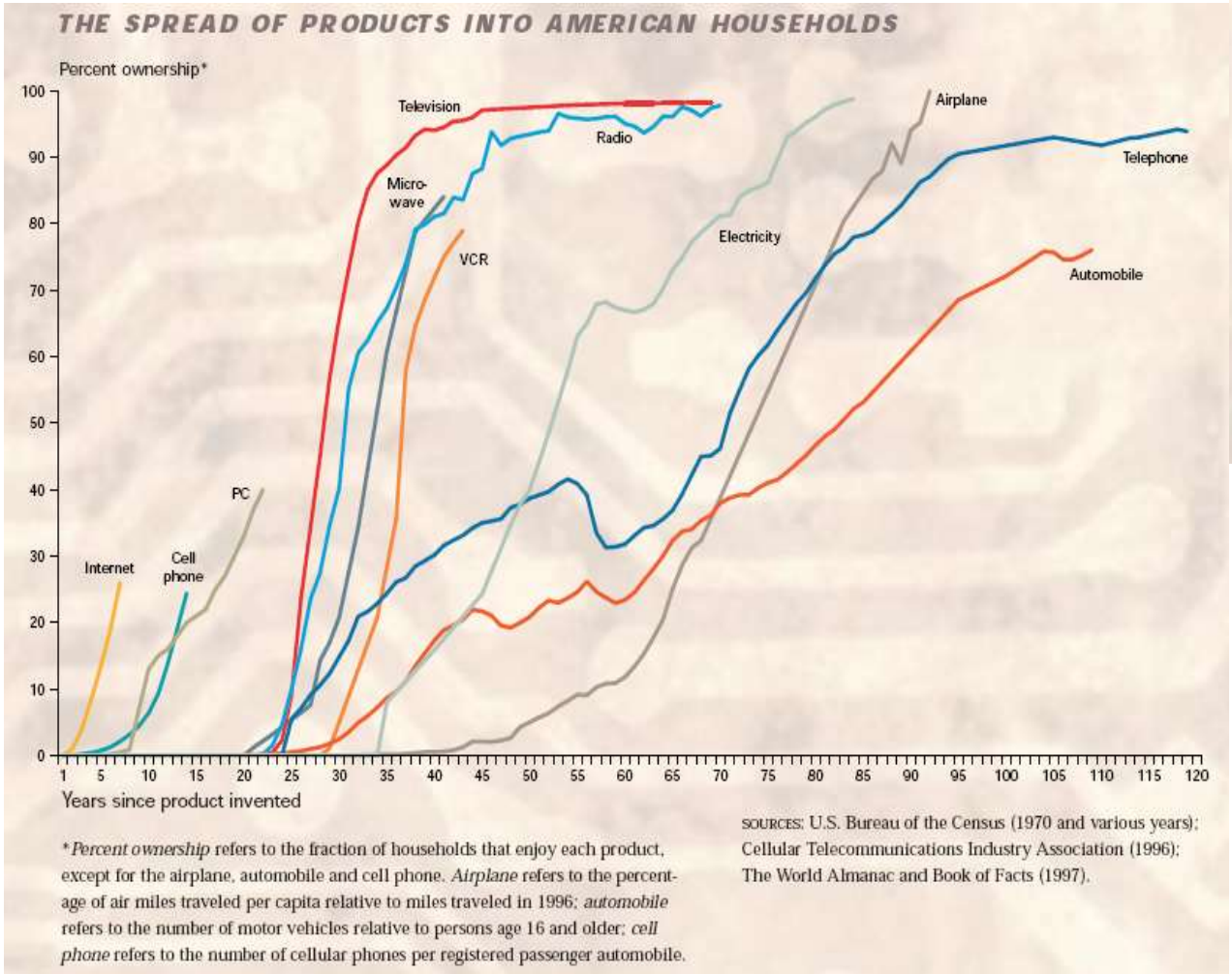
Forecasting Methodologies

- **Well known methods (2):**
  - **Trend extrapolation (Explorative, Hard, Trend Analysis)**
    - These methods examine trends and cycles in historical data, and then use mathematical techniques to extrapolate to the future. The assumption of all these techniques is that the forces responsible for creating the past, will continue to operate in the future. This is often a valid assumption when forecasting short term horizons, but it falls short when creating medium and long term forecasts. The further out we attempt to forecast, the less certain we become of the forecast.
    - The stability of the environment is the key factor in determining whether trend extrapolation is an appropriate forecasting model. The concept of "developmental inertia" embodies the idea that some items are more easily changed than others. Clothing styles is an example of an area that contains little inertia. It is difficult to produce reliable mathematical forecasts for clothing. Energy consumption, on the other hand, contains substantial inertia and mathematical techniques work well. The developmental inertia of new industries or new technology cannot be determined because there is not yet a history of data to draw from.
    - The common feature of these mathematical models is that historical data is the only criteria for producing a forecast. One might think then, that if two people use the same model on the same data that the forecasts will also be the same, but this is not necessarily the case. Mathematical models involve smoothing constants, coefficients and other parameters that must be decided by the forecaster. To a large degree, the choice of these parameters determines the forecast.

Source: David S. Walonick

Forecasting Methodologies

Trend extrapolation



SPREAD OF PRODUCTS TO A QUARTER OF THE POPULATION

Product	Year invented ▼	Years to spread
Electricity	1873	46
Telephone	1876	35
Automobile	1886	55
Airplane	1903	64
Radio	1906	22
Television	1926	26
VCR	1952	34
Microwave oven	1953	30
PC	1975	16
Cellular phone	1983	13
Internet	1991	7

The speed of technology adoption is determined by two characteristics p, which is the speed at which adoption takes off, and q, the speed at which later growth occurs. A cheaper technology might have a higher p, for example, taking off more quickly, while a technology that has network effects (like a fax machine, where the value of the item increases as others get it) may have a higher q.

Trend Extrapolation: logistic curve

Limitation of resources and logistic S-curve

Image source: www.cbsnews.com

$$N(t) = \frac{\kappa}{1 + e^{-\alpha t - \beta}}$$

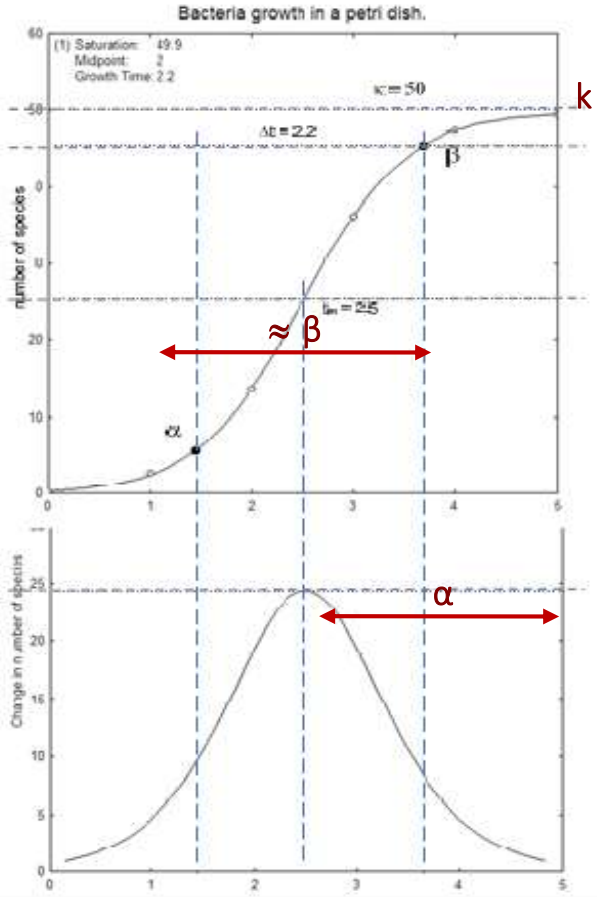
α – growth rate parameter, time required for "trajectory" to grow from 10% to 90% of limit κ

characteristic duration (Δt);

β – parameter specifies the time (t_m) when the curve reaches 0.5κ

midpoint of the growth trajectory;

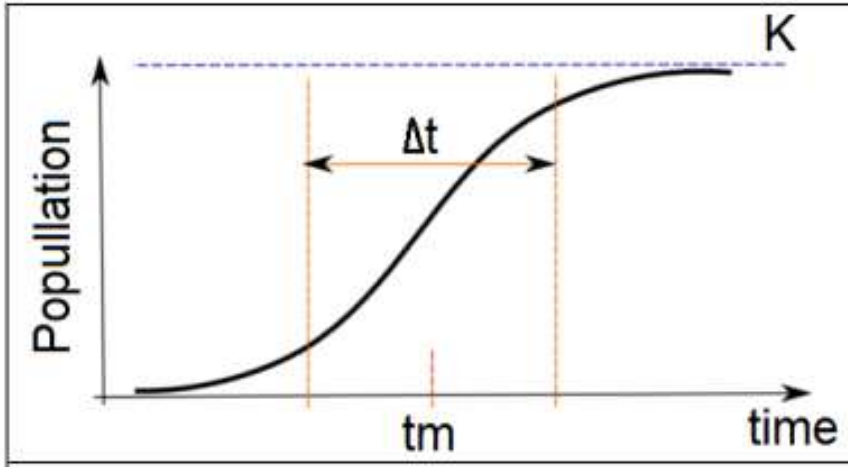
κ – is the asymptotic **limit of growth**.



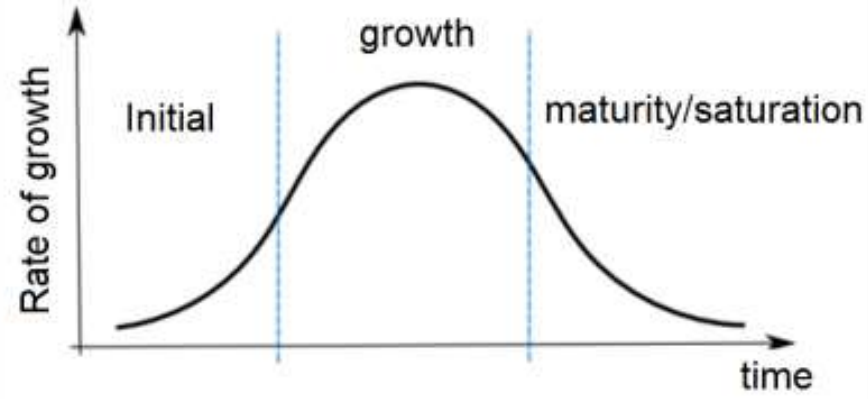
Technological forecasting

Trend Extrapolation: logistic curve

Figure 6: Graphical description of Meyer's logistic growth curve and its equations.



$$N(t) = \frac{K}{1+e^{-\frac{\ln(81)}{\Delta t}(t-t_m)}} \qquad (1)$$

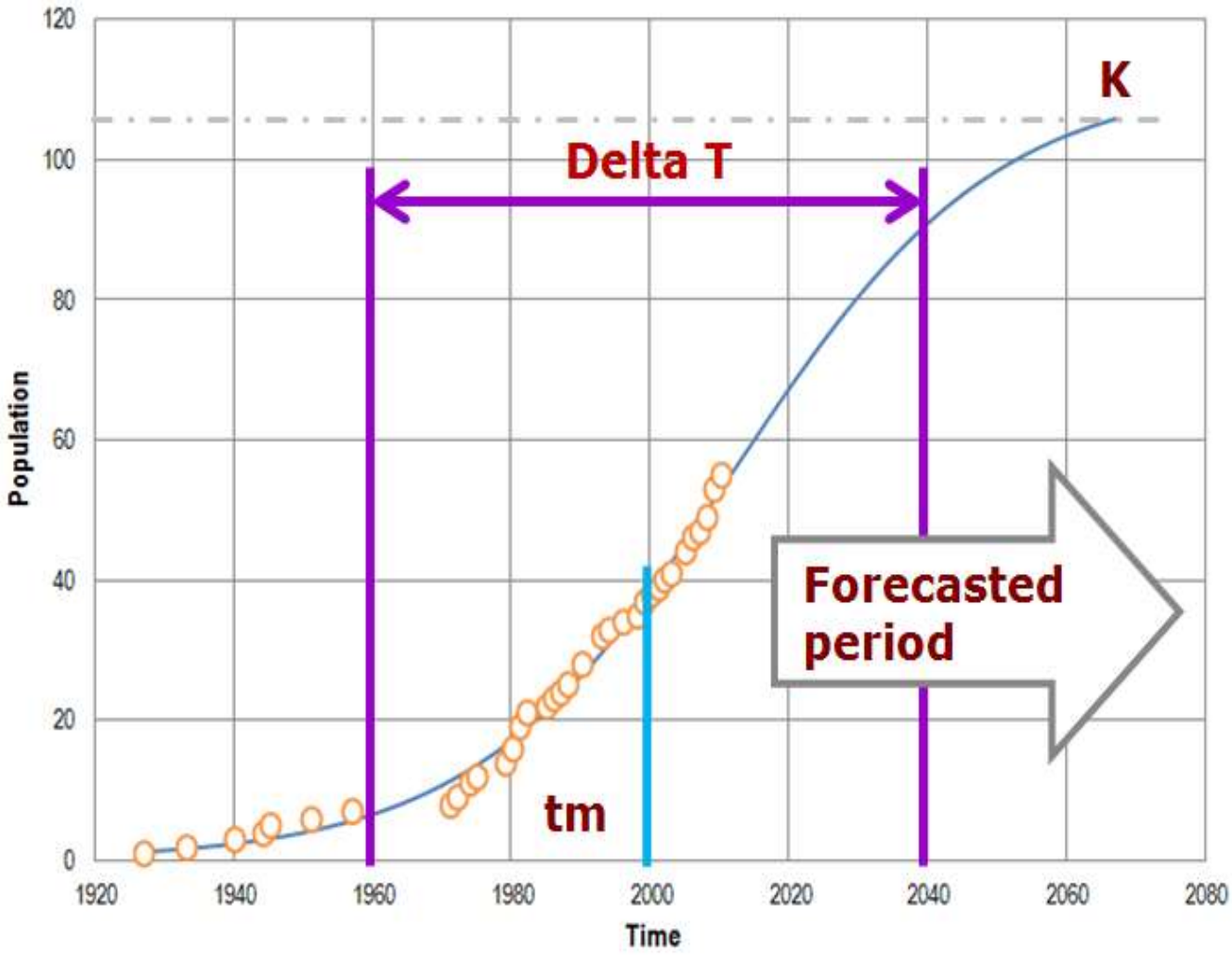


$$\frac{dN}{dt} = \frac{\ln(81)}{\Delta t} * N(t)\left(1 - \frac{N(t)}{K}\right) \qquad (2)$$

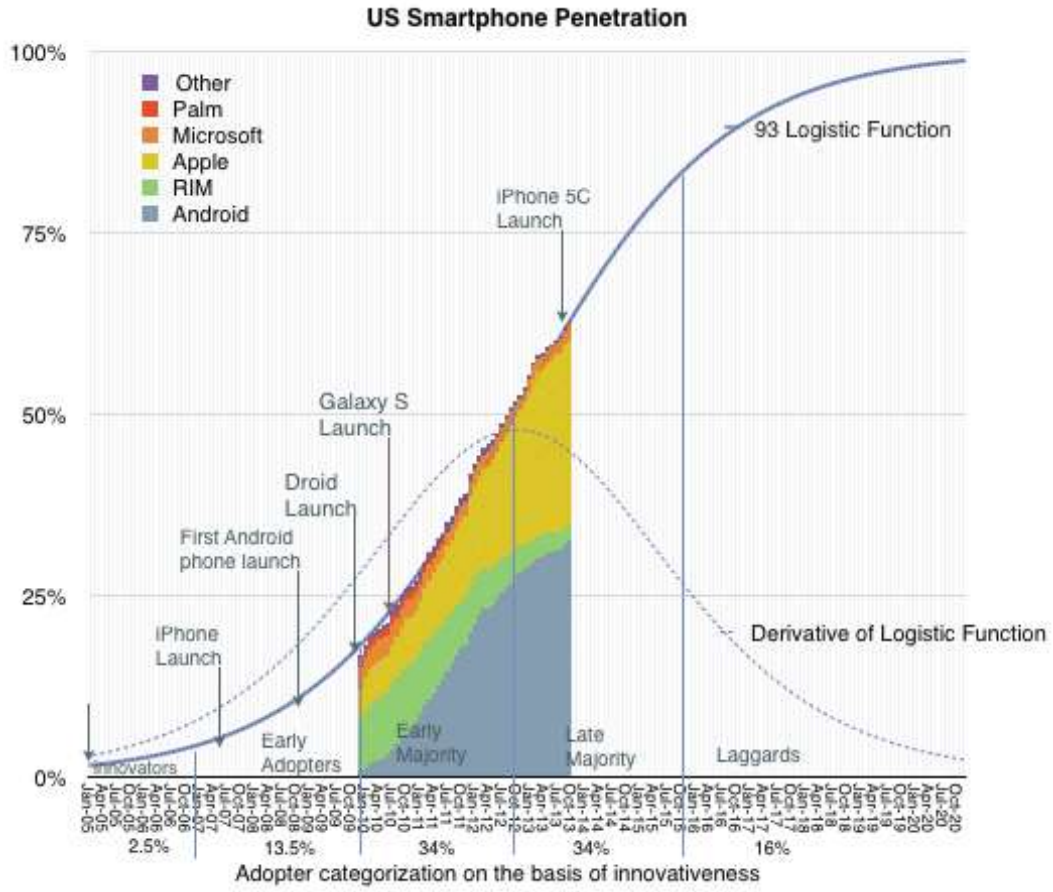
Trend Extrapolation: logistic curve

Growth under competition

- Natural growth of autonomous systems in competition might be described by LOGISTIC EQUATION and logistic S-curve
- Natural growth is defined as the ability of a 'species' to multiply in finite 'niche capacity'
- For socio-technical systems the 3-parameter S-shaped growth model is applied for describing "trajectories" of growth or decline in time



Trend Extrapolation: logistic curve



Growth under competition

⓾ Natural growth of autonomous systems in competition might be described by LOGISTIC EQUATION and logistic S-curve

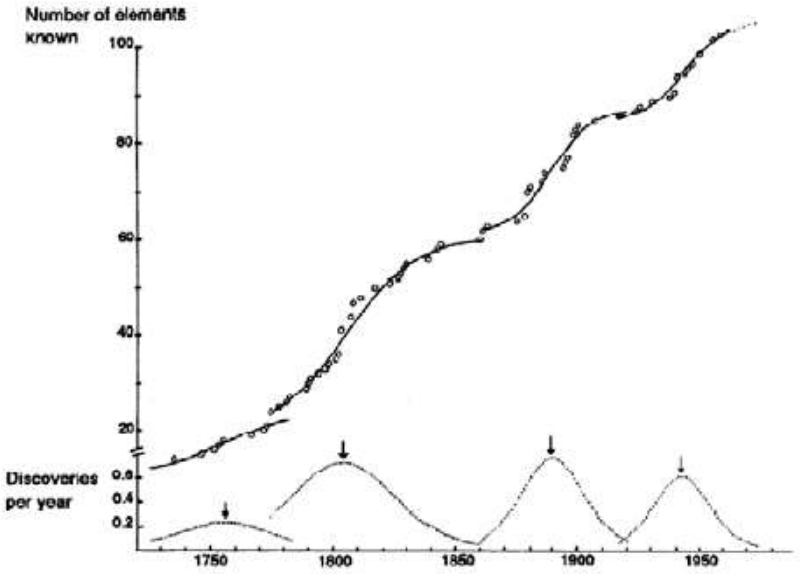
⓾ Natural growth is defined as the ability of a 'species' to multiply in finite 'niche capacity'

Trend Extrapolation: logistic curve

Component logistic model

...growth and diffusion processes consist of several sub-processes...

PROCESS OF DISCOVERY NEW CHEMICAL ELEMENTS (1735-1982)



The stable elements were discovered in clusters... (?)

* Source of graph: Modis, T. Predictions - 10 Years Later. (Growth Dynamics, Geneva, Switzerland, 2002), pp. 149. ISBN 2-9700216-1-7.

Technological forecasting

111

Dmitry Kucharavy | Vinci, Tuscany , Italy | June 2008

Trend Extrapolation: logistic curve

- **Emerging, growing, mature technologies and substitution of technology**

  - **Emerging technology:** is a technology before infant-mortality (α) threshold. It is necessary to foresee parameters of the process of transition from invention to innovation (adoption, diffusion, infrastructure, commercialization).

  - **Growing technology:** is a technology which growth exponentially (from α to β). It is necessary to foresee parameters (speed and limits) of exponential growth.

  - **Mature technology:** is a technology after saturation threshold (β). It is necessary to foresee parameters of the process of substitution of one technology by another (binary and multi- competition).

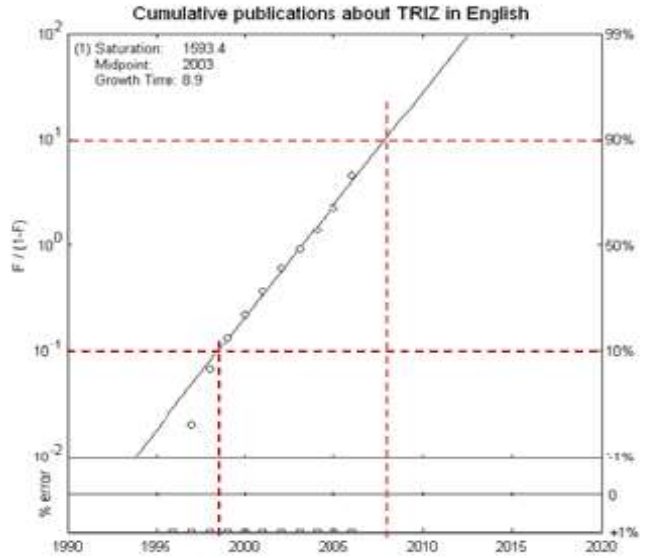
Source: Dmitry Kucharavy

Trend Extrapolation: logistic curve

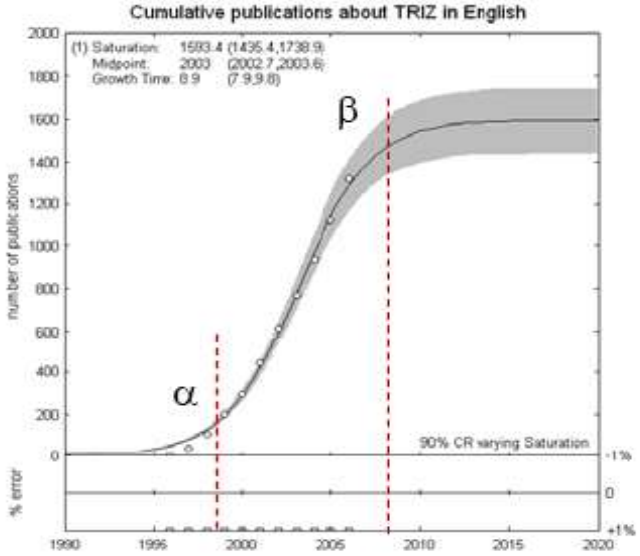
Fisher-Pry transform. Confidence intervals

Fisher-Pry transform

$$FP(t) = \left(\frac{F(t)}{1-F(t)}\right) \quad \text{where} \quad F(t) = \frac{N(t)}{\kappa}$$



Forecast with confidence intervals

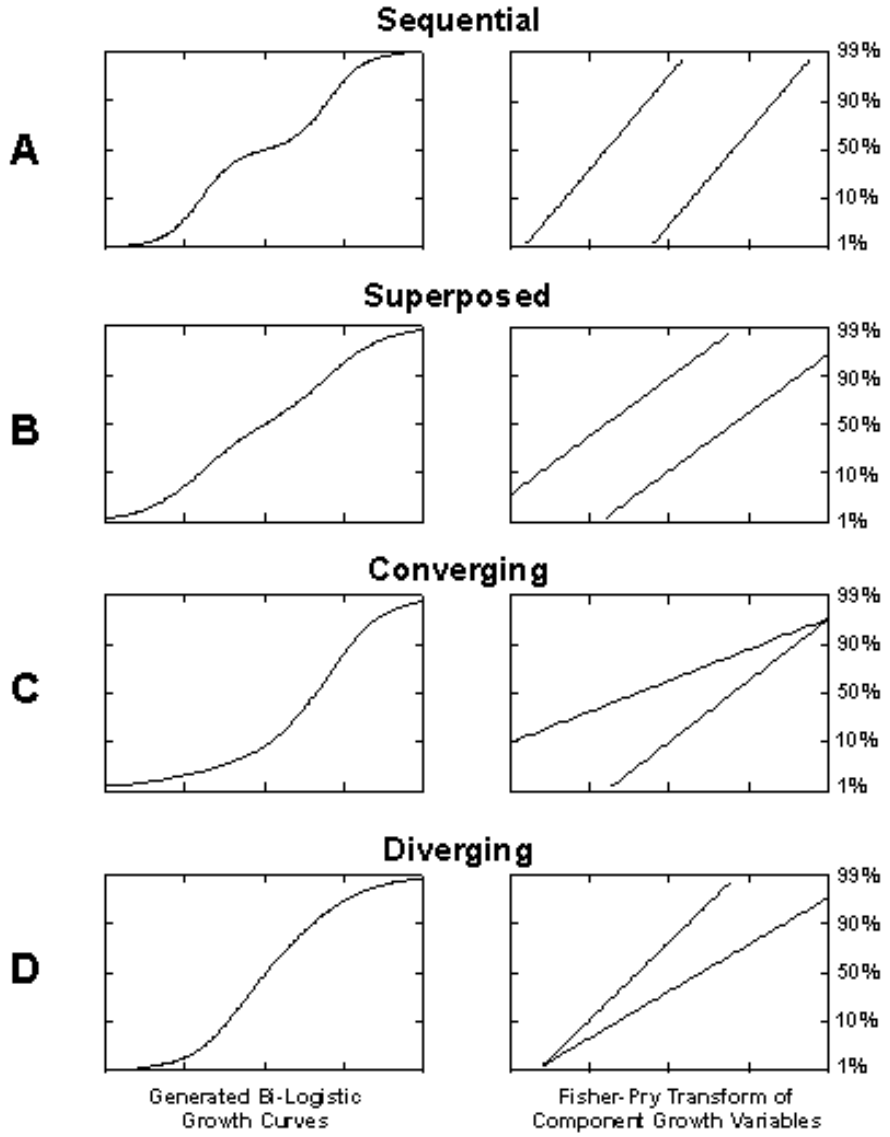


* S-curve fit on data by Loglet Lab Version 1.1.4

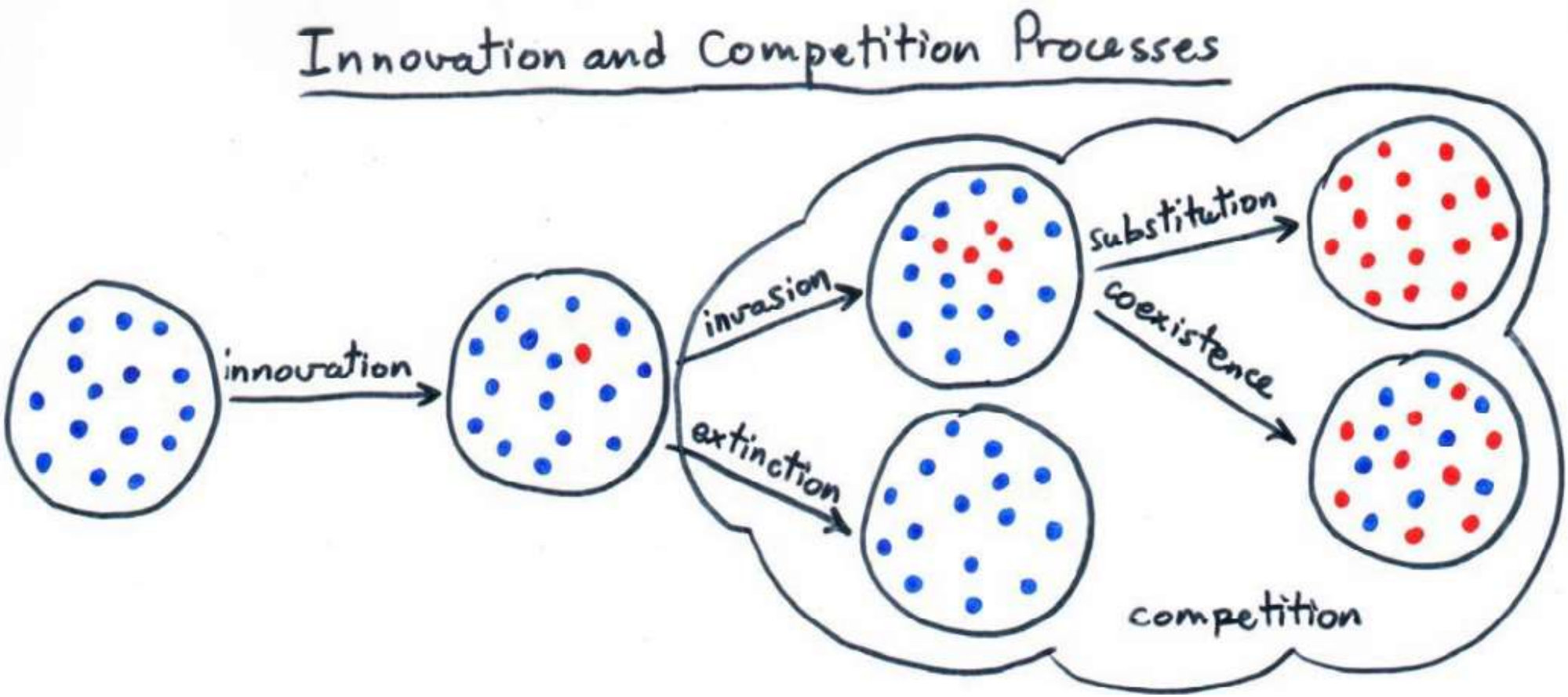
Technological forecasting

Trend Extrapolation: logistic curve

Bi-logistic growth



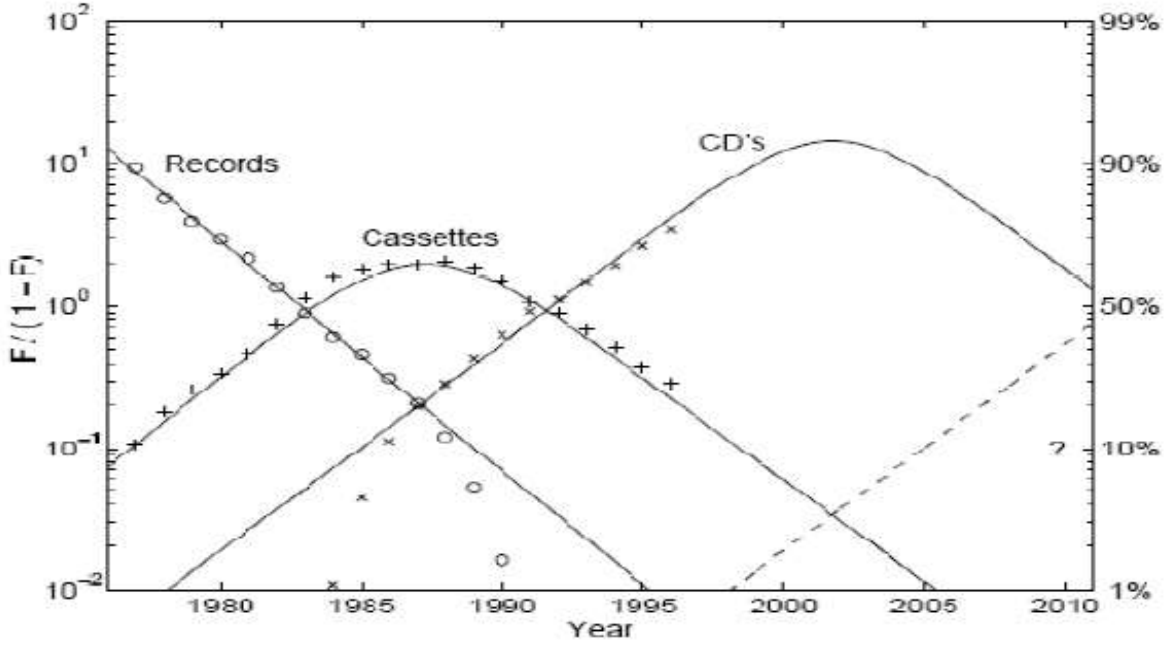
Innovation and Competition



Source: Carlo Piccardi

Trend Extrapolation: logistic substitution

LSM example: US music recording media (1997)



Technological forecasting

* Source: Meyer, P.S., Yung, J.W. and Ausubel, J.H. A Primer on Logistic Growth and Substitution: The Mathematics of the Loglet Lab Software. Technological Forecasting and Social Change, 1999, 61(3), 247-271.

Trend Extrapolation: logistic substitution

COMPETITION BETWEEN PRIMARY ENERGY SOURCES

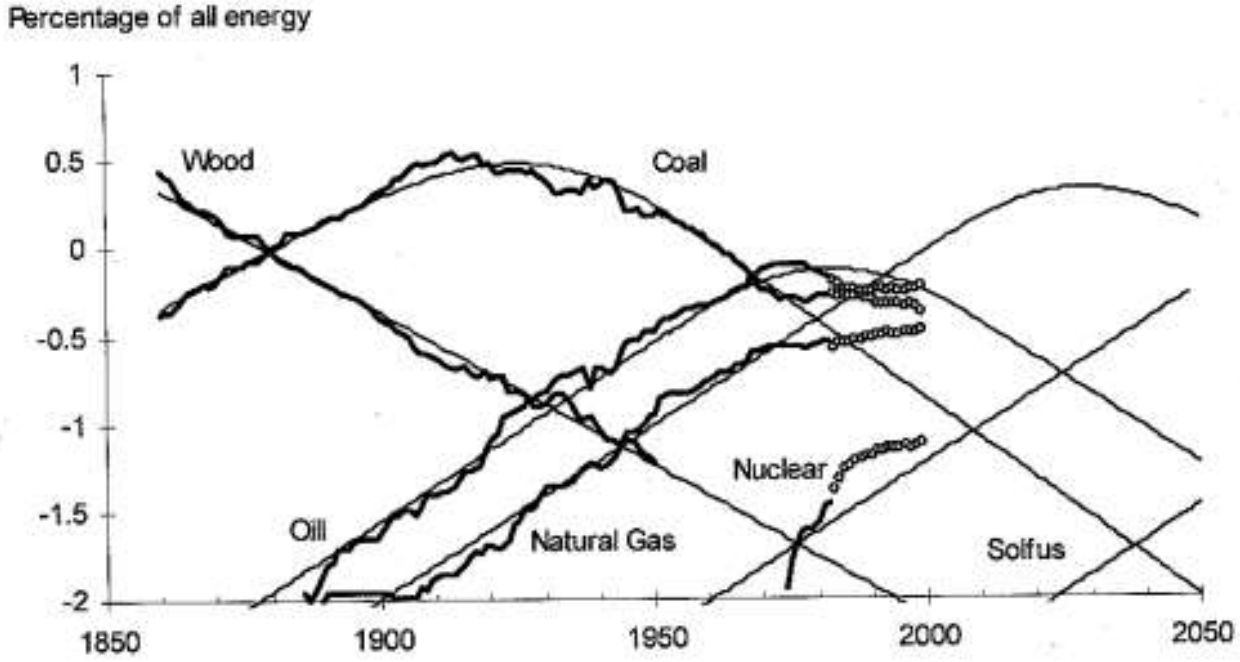
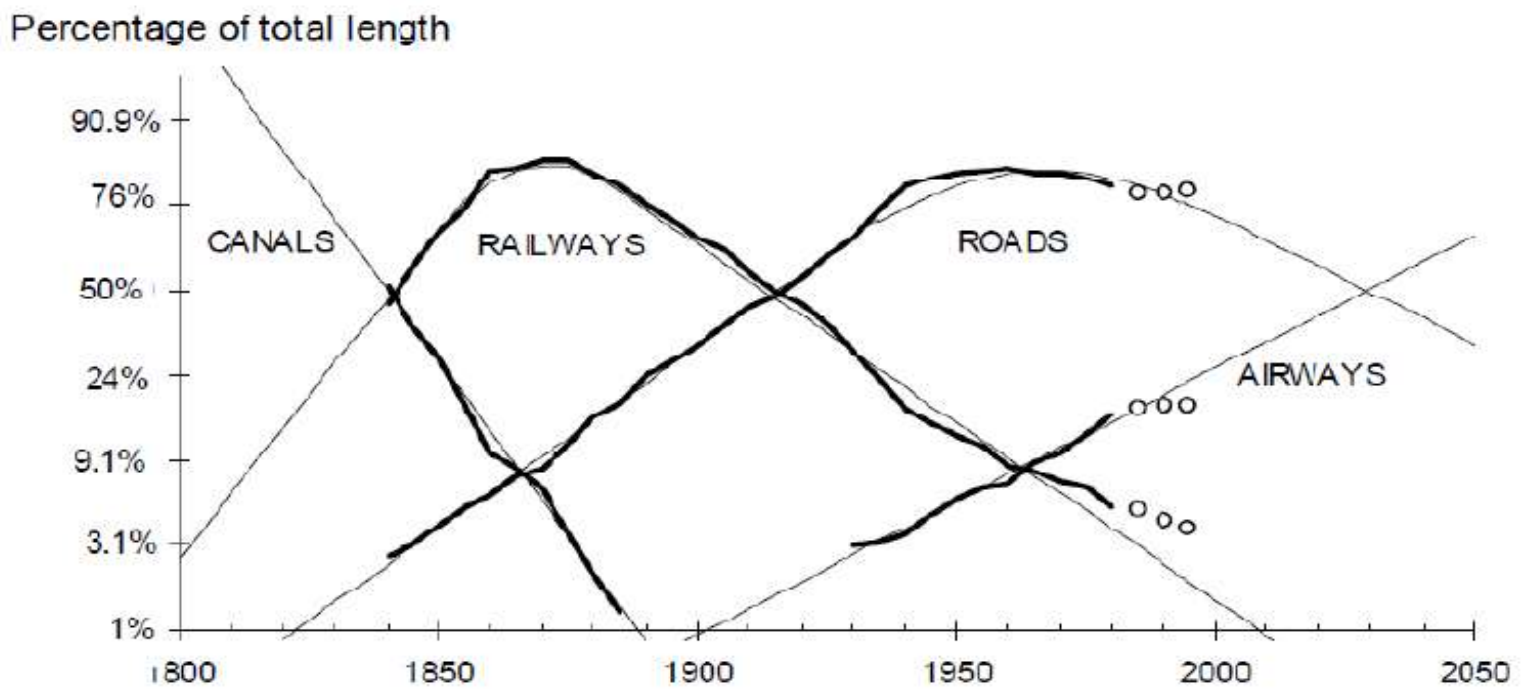


FIGURE 7.6 Data, fits, and projections for the shares of different primary energy sources consumed worldwide. For nuclear, the dotted straight line is not a fit but a trajectory suggested by analogy. The futuristic source labeled "Solfus" may involve solar energy and thermonuclear fusion. The small circles show how things evolved since 1982 when this graph was first put together, see text.*

Source: T. Modis

Trend Extrapolation: logistic substitution

LSM example: transport infrastructures in US



Technological forecasting

* Source: Adapted from a graph by Nebojsa Nakicenovic in "Dynamics and Replacement of U.S. Transport Infrastructures," in J.H. Ausubel and R. Herman, eds, Cities and Their Vital Systems, Infrastructure Past, Present, and Future, (Washington, DC: National Academy Press, 1988).

109

Dmitry Kucharavy | Vinci, Tuscany , Italy | June 2008

Logistic Curves: Warnings

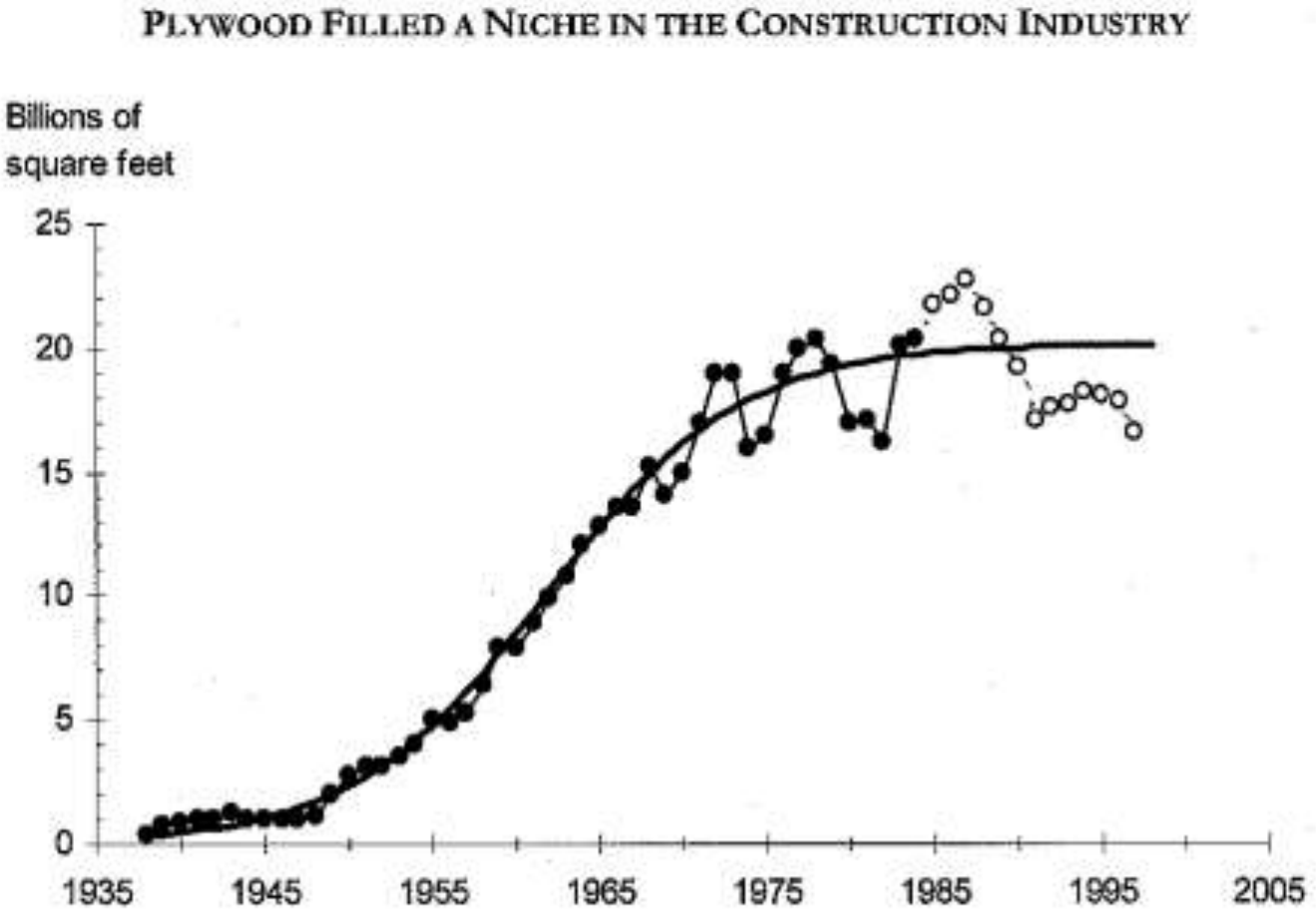


FIGURE 10.2 Annual plywood sales in the United States. Significant deviations from the S-curve appear when the ceiling is approached. The small circles show what happened in the last twenty years.*

Source: T. Modis

Logistic Curves: Warnings

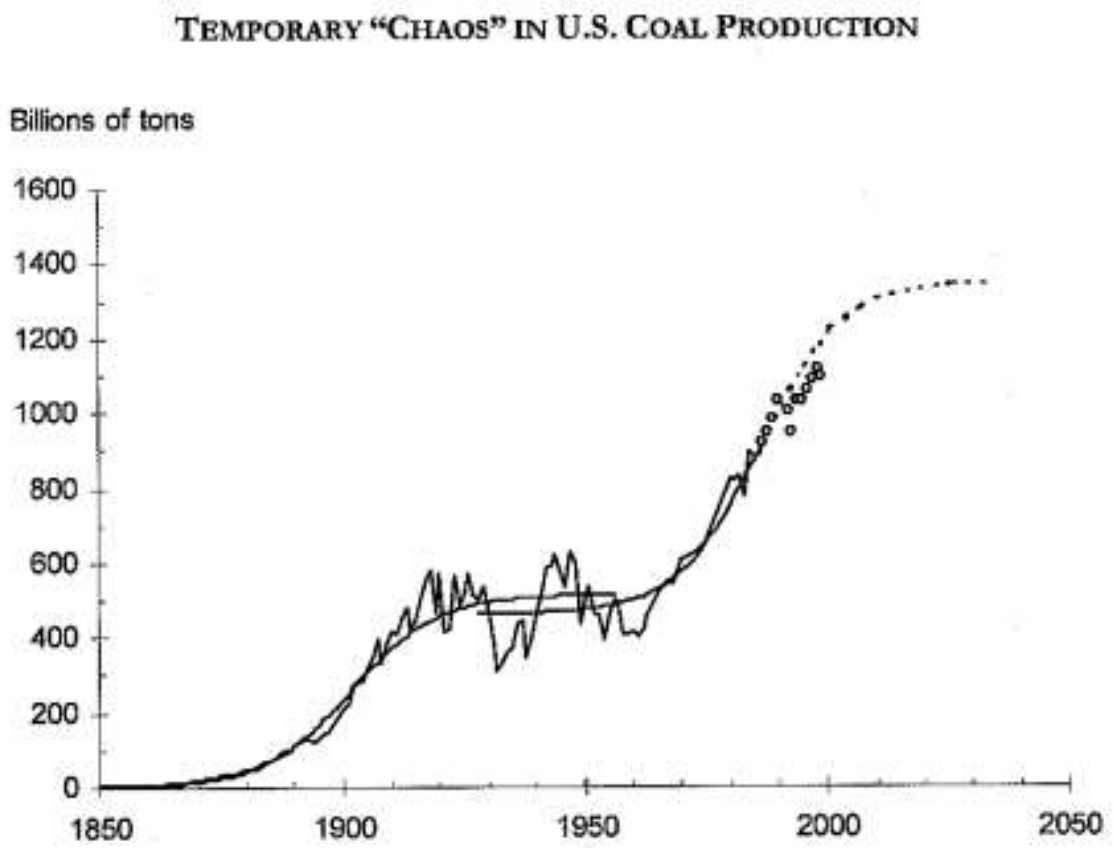


FIGURE 10.3 Annual production of bituminous coal in the United States. The two S-curves are fits to the data of the respective historical periods. The interim period shows large fluctuations of chaotic nature. The small circles show what happened during the twelve years following the original prediction.*

We can see a fairly good example of exponential growth with a change in that pattern from 1917 to 1961. This deviation from exponential growth teaches us an important lesson about projections. Any mathematical model that involves human decision such as whether to use coal or oil, or models that include the chaotic, human driven economy will deviate from mathematical perfection. Any model that we devise will only be a decent fit at best.
(Gregson Vaux)

Source: T. Modis

Logistic Curves: Warnings

- **Logistic S-curve describes evolution of system under limitation of resources through time**
  - **Strength:**
    - Properly established logistic growth reflects the action of a natural law
    - Relatively easy to apply. Clear concept and working mechanism.
    - Can be applied for systems where the growth mechanisms are understood and where the mechanisms are hidden.
  - **…and Weakness:**
    - What is growing variable (species) and what is underlying competing mechanism in particular case? Lack of formal procedure to define
    - Bias towards low or high ceiling: 'no two people, working independently, will ever get EXACTLY the same answer for an S-curve fit'.
    - Should we fit S-curve to the raw data or to cumulative number?
    - Fitting technique errors and uncertainties.

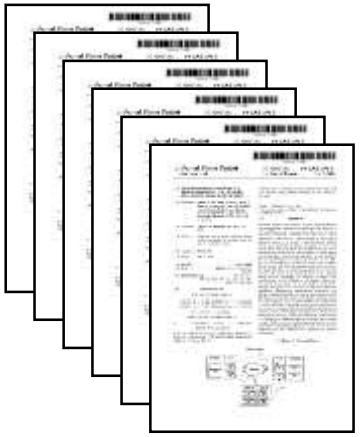
Source: Dmitry Kucharavy

Introduction to Technology Forecasting:

Analogical reasoning and envisioning through evolutionary patterns

Theory of Inventive Problem Solving

Genrich Altshuller (1926-1998)



Analysis of hundreds of thousands inventive solutions

- **99% of inventions use already known solution principle**
- **Less than 1% are really pioneering inventions**
- **Breakthrough solutions emerge from resolving contradictions**
- **Inventors and strong thinkers use patterns**
- **Creative problem solving patterns are universal**
- **Creative ideas can be produced in a systematic way**

Theory of Inventive Problem Solving

- The architecture of TRIZ is based on:
  - Three Postulates:
    - Postulate of Objective Laws of Systems Evolution
    - Postulate of Contradiction
    - Postulate of Specific Situation
  - Main models:
    - Models of the problem solving process
      - Hill model (abstraction-embodiment)
      - Tongs model (from current situation to ideality, barriers identification)
      - Funnel model
    - Description of systems, problems, solutions
      - ENV model
      - Model of function
      - Substance-Field Model
      - Model of contradiction
    - "System operator" (multi-screen approach)
      - Round about problems
      - Resources search
  - Instruments:
    - ARIZ (Algorithm of Inventive Problem Solving), main instrument of Classical TRIZ for Non-Typical Problems, which integrate all others TRIZ instruments
    - System of Inventive Standard Solutions
    - Pointers to Physical, Chemical, Geometrical Effects

Theory of Inventive Problem Solving

Postulate 1

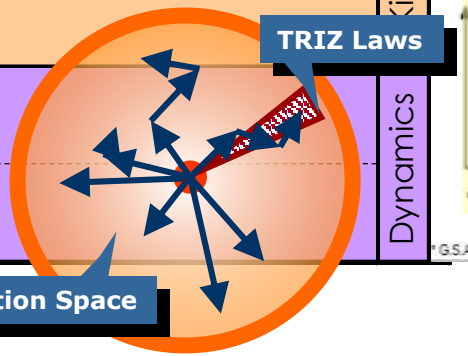
Laws of Engineering Systems Evolution

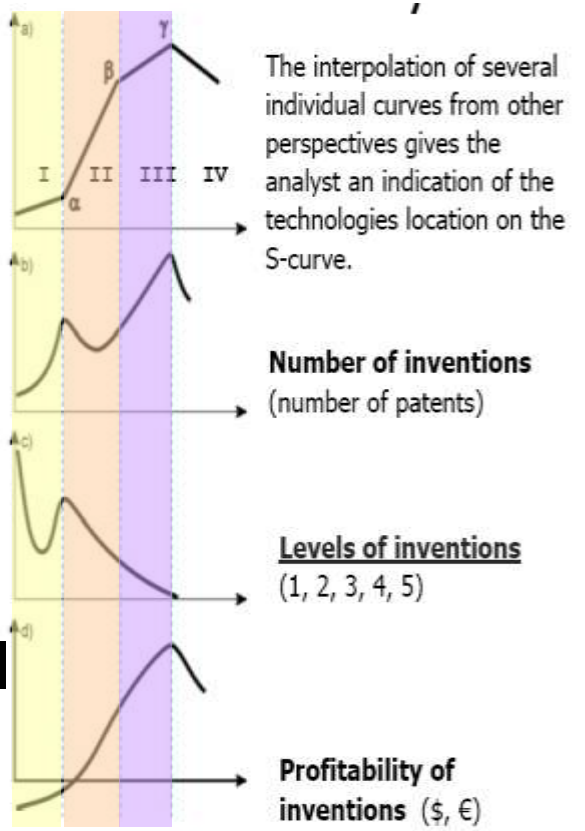
Theory of Inventive Problem Solving

Laws of Engineering Systems Evolution

Postulate 1

Laws of Technical System Evolution		
1	Law of System Completeness Corollary: Controllability Trend of elimination of human involvement from systems Trend of increasing dynamicity	Static
2	Law of "energy conductivity" of a system	
3	Law of harmonizing the rhythms of parts of the system	
4	Law of increasing ideality	Kinematics
5	Law of uneven development of the parts of a system	
6	Law of transition to a super-system Trend Mono-Bi-Poly	
7	Law of Transition from macro to micro level	Dynamics
8	Law of increasing Su-Field inyteractions	



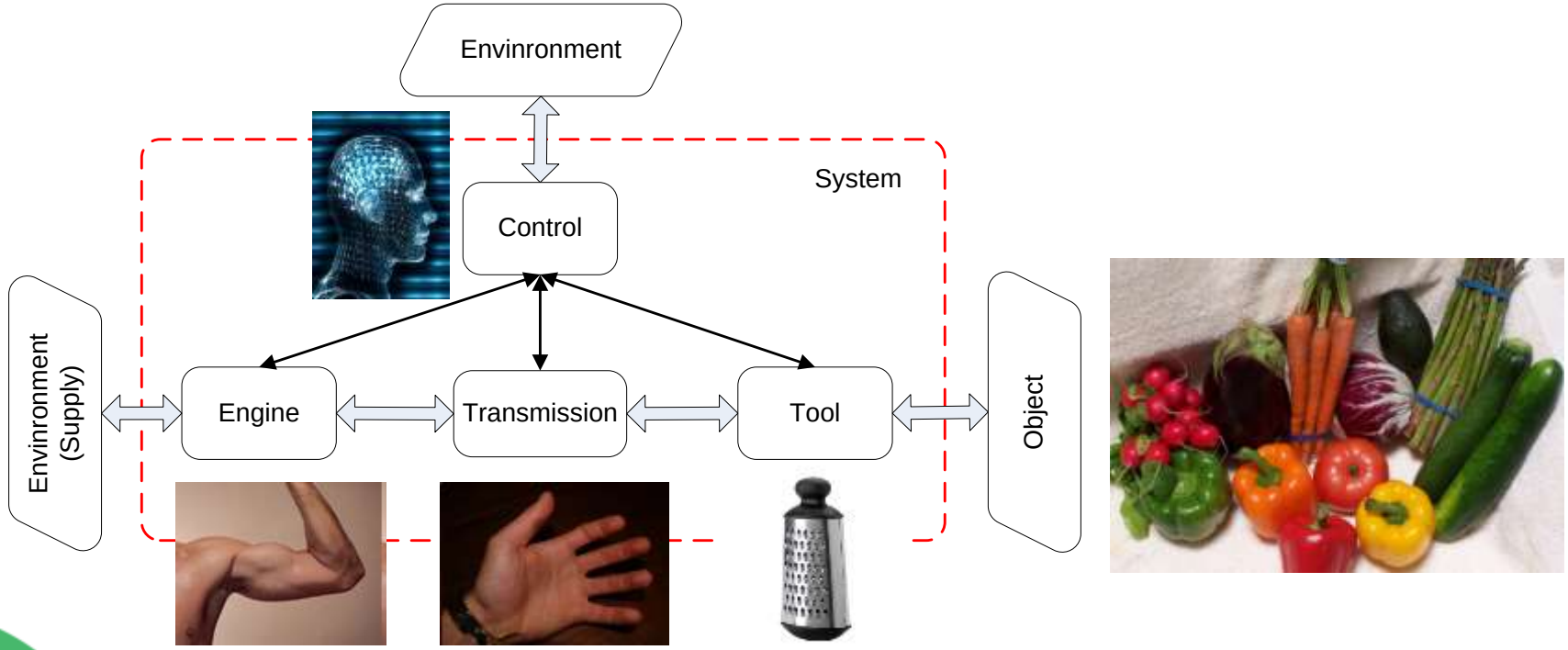


- **Conclusions for practice:**
  - **Good solutions are developed in accordance with the objective laws of system evolution**

Postulate 1

1. Law of System Completeness

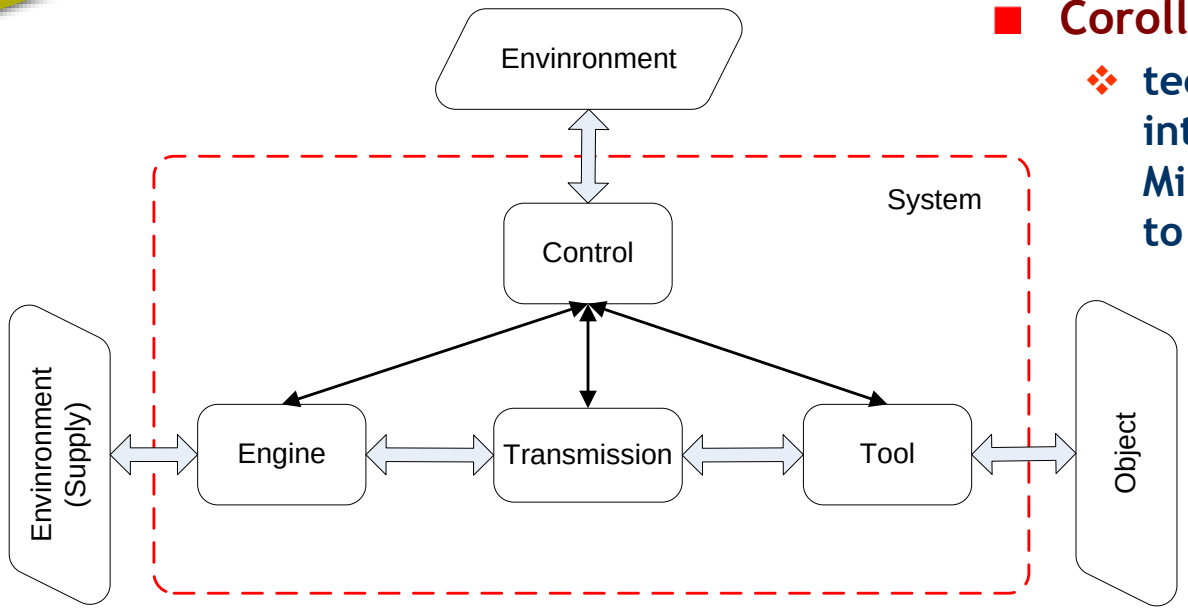
In order to deliver its function, a Technical System must include, internally or externally (e.g., through the contribution of a human operator), four elements:
- a Tool, which is the working element delivering the function of the TS, i.e., exerting a certain effect on its object;
- an Engine, i.e., the element providing the energy necessary to produce the expected effect of the function;
- a Transmission, i.e., the element transmitting energy from the Engine to the Tool;
- a Control, i.e., an element governing at least one of the previous elements.



Theory of Inventive Problem Solving

Postulate 1

1. Law of System Completeness (corollary)



- **Corollary:**
  - **technical systems evolve by integrating all the elements of the Minimal Technical System in order to reduce human involvement**

Theory of Inventive Problem Solving

Postulate 1

- **Patterns of Engineering Systems Evolution (8 Laws, 76 Standards)**




TOOL

TRANSMISSION

TOOL

ENGINE

TRANSMISSION

TOOL

CONTROL

ENGINE

TRANSMISSION

TOOL



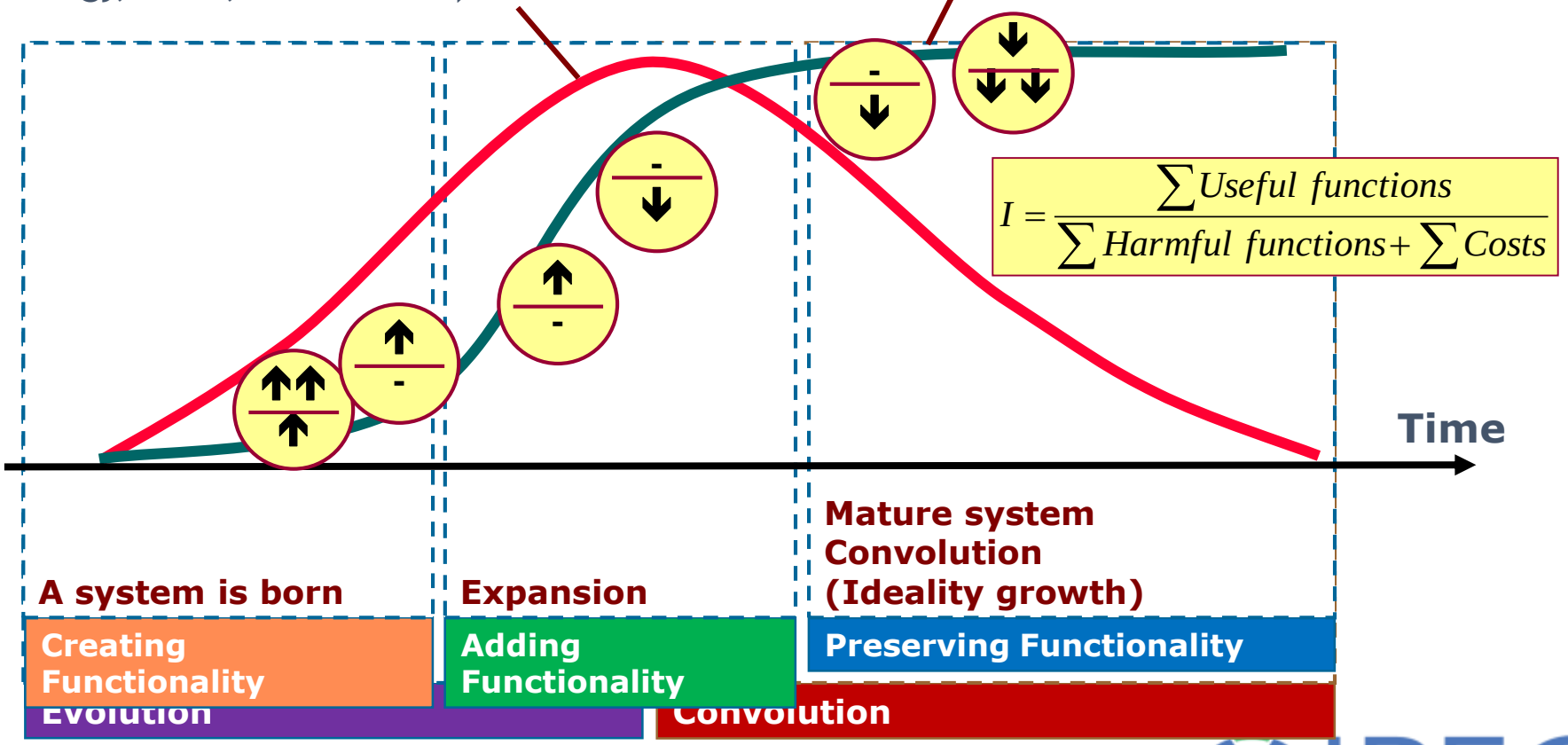

Theory of Inventive Problem Solving

Postulate 1

4. Law of increasing the degree of ideality

Wave of Evolution: Expenses to create value and deliver functionality (material, energy, labor, information)

S-Curve of Evolution: Degree of the system's performance (main function)



Theory of Inventive Problem Solving

Postulate 1

4. Law of increasing the degree of ideality

$$I = \frac{\sum Useful\ functions}{\sum Harmful\ functions + \sum Costs}$$

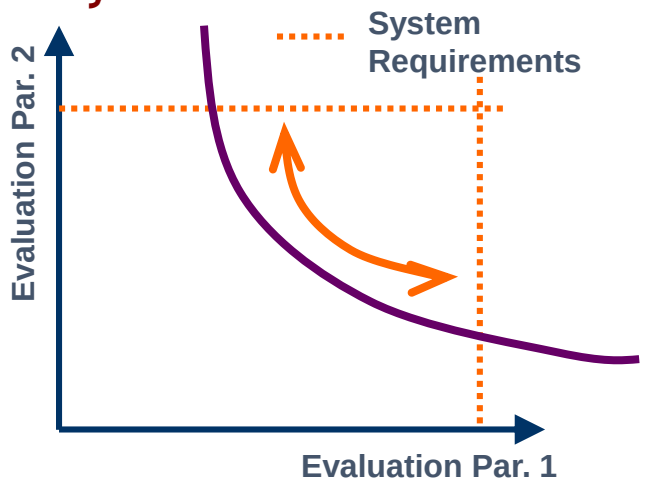
What is the ideal ...?

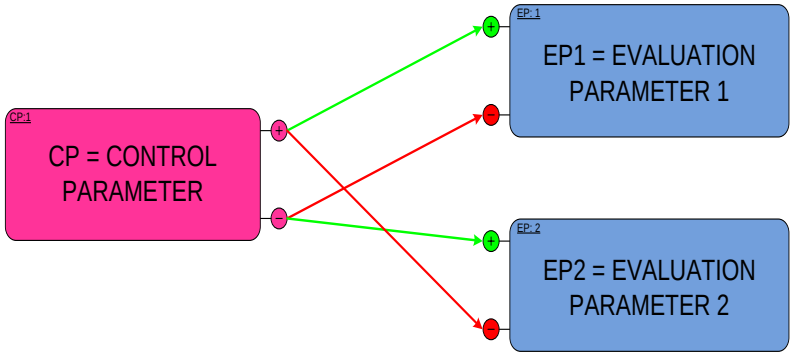
Theory of Inventive Problem Solving

Postulate 2

Contradictions

- **System evolution implies the resolution of contradictions, i.e. conflicts between a system and its environment or between the components of the system itself**





- **Conclusions for practice:**
  - To solve a problem we should first discover underlying contradictions
  - To achieve maximum benefits, contradictions should be resolved, not compromised
  - Overcoming contradictions is a driving force behind technology evolution. Resolving contradictions instead of compromising or optimizing, results in breakthrough solutions

Theory of Inventive Problem Solving

Postulate 2

Contradictions

"Technical" Contd:

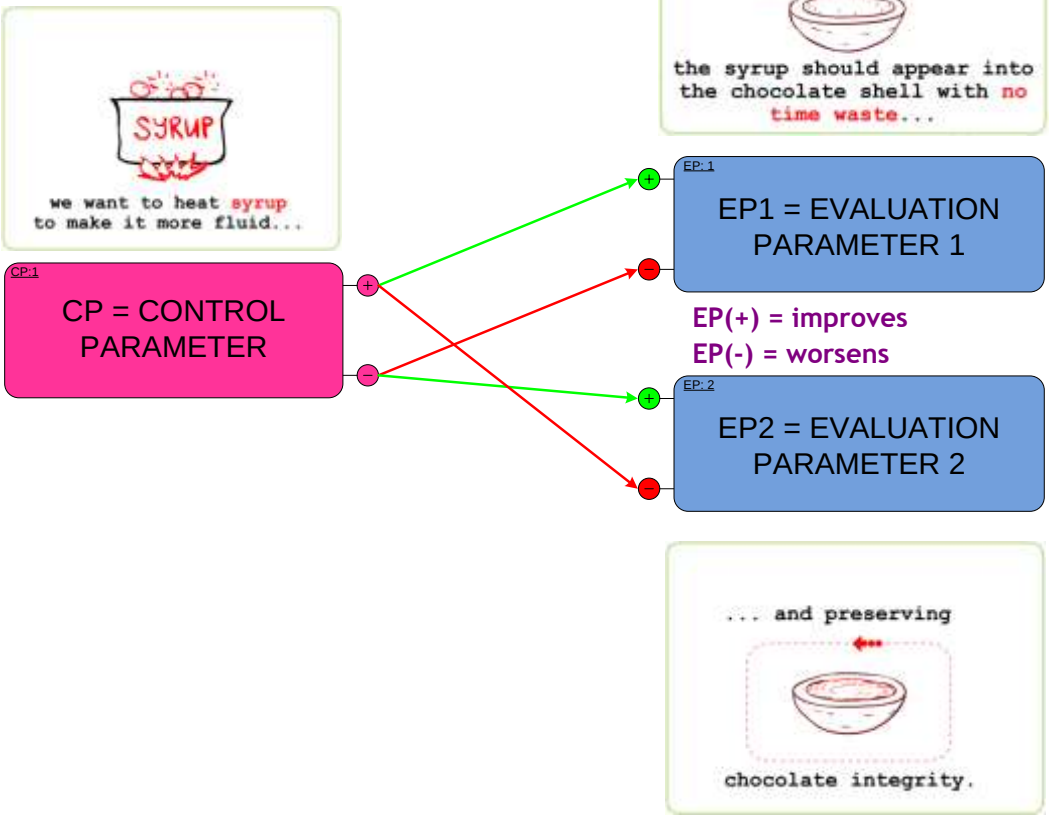
TC1: EP1(+) - EP2(-)

TC2: EP2(+) - EP1(-)

"Physical" Contd:

CP = V ➔ EP1(+) - EP2(-)

CP = anti-V ➔ EP1(+) - EP2(-)



Theory of Inventive Problem Solving

Postulate 2

Contradictions

"Technical" Contd:

TC1: EP1(+) - EP2(-)

TC2: EP2(+) - EP1(-)

"Physical" Contd:

CP = V ➔ EP1(+) - EP2(-)

CP = anti-V ➔ EP1(+) - EP2(-)

Problems from different domains, sharing the same contradiction, can be solved by means of the same solving principles

Specific Situation - Resources

Postulate 3

- Each stage of evolution of a system takes place in a specific environment (context, situation) which influences the evolution (transformation) of the system and provide specific resources

Spatial Resources:
- Empty space, encapsulating
- Other dimensions
- Shape
- Size (1D, 2D, 3D)

Energy Resources:
- Energy in the system
- Energy from the supersystem
- Potential energy
- Dissipated energy

Information Resources:
- Inherent properties
- Mobile information
- Temporary information
- Redundant information

Time Resources:
- Parallel working
- Preliminary action/counteraction
- Reworking
- Frequency of action

Material Resources:
- Waste flow
- Cheap materials
- Substance characteristics
- Void

- Conclusions for practice:
  - Good solutions must (first of all) take into account the resources available in the specific situation

Specific Situation - Resources

Postulate 3

Example: Transforming undesired/harmful elements into fruitful resources

tetris "Creativity is not a born gift. Every engineer can learn to be inventive."

http://www.tetris-project.org/

Education and Culture DG
Lifelong Learning Programme

- **5 Animations**
  - TRIZ History
  - Nina @ school/university/work
  - Theory of Inventive Problem Solving
- **Handbook**
  1. Introduction(s)
  2. Laws of Engineering Systems Evolution
  3. Algorithm of Inventive Problem Solving
  4. Su-Field Analysis and System of Inventive Standards
  5. Tools and Principles for solving contradictions
  - Appendix (Step-by-step solved problems)

Freely accessible animations in English, French, German, Italian, Latvian, Chinese, Spanish, Russian, Japanese, Romanian, Korean, Farsi (Iranian)

Freely accessible educational materials in English, French, German, Italian, Latvian

Structure

- Definition: short definition of the selected topic (T);
- Theory: theoretical aspects related to T;
- Model: conceptual model and graphical representation of T;
- Method/Tool: operative instructions about how to use/implement T;
- Example: exemplary application of T;
- Self-Assessment: exercises to assess the reader's level of understanding about T;
- References: further readings about T.

FORMAT
Forecast and Roadmapping for Manufacturing Technologies

MARIE CURIE ACTIONS

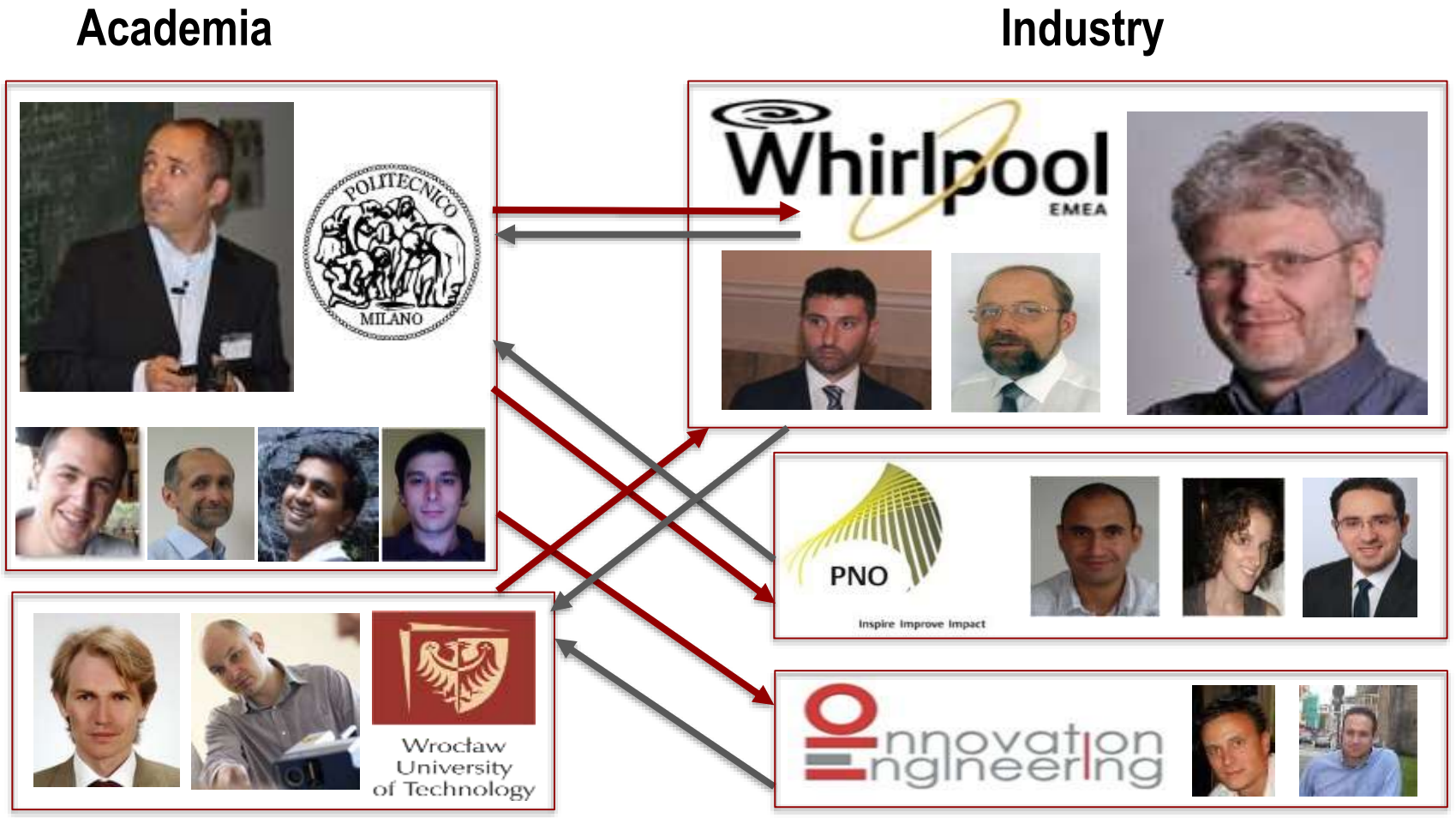
FORMAT Project:

Essential Information

FORMAT Project

- ✓ Grant Agreement number: **286305**
- ✓ Project acronym: **FORMAT**
- ✓ Project title:
  Forecast and Roadmapping for Manufacturing Technologies
- ✓ Starting date: **01/01/2012**
- ✓ Project Duration: **48 months**
- ✓ Total estimated eligible cost: **1,690,454.00€**
- ✓ Total requested EU contribution: **1,690,454.00€**

FORMAT Project



Whirlpool EMEA at a glance

#1 player in 5 of the top 7 markets

#1 in refrigeration & laundry

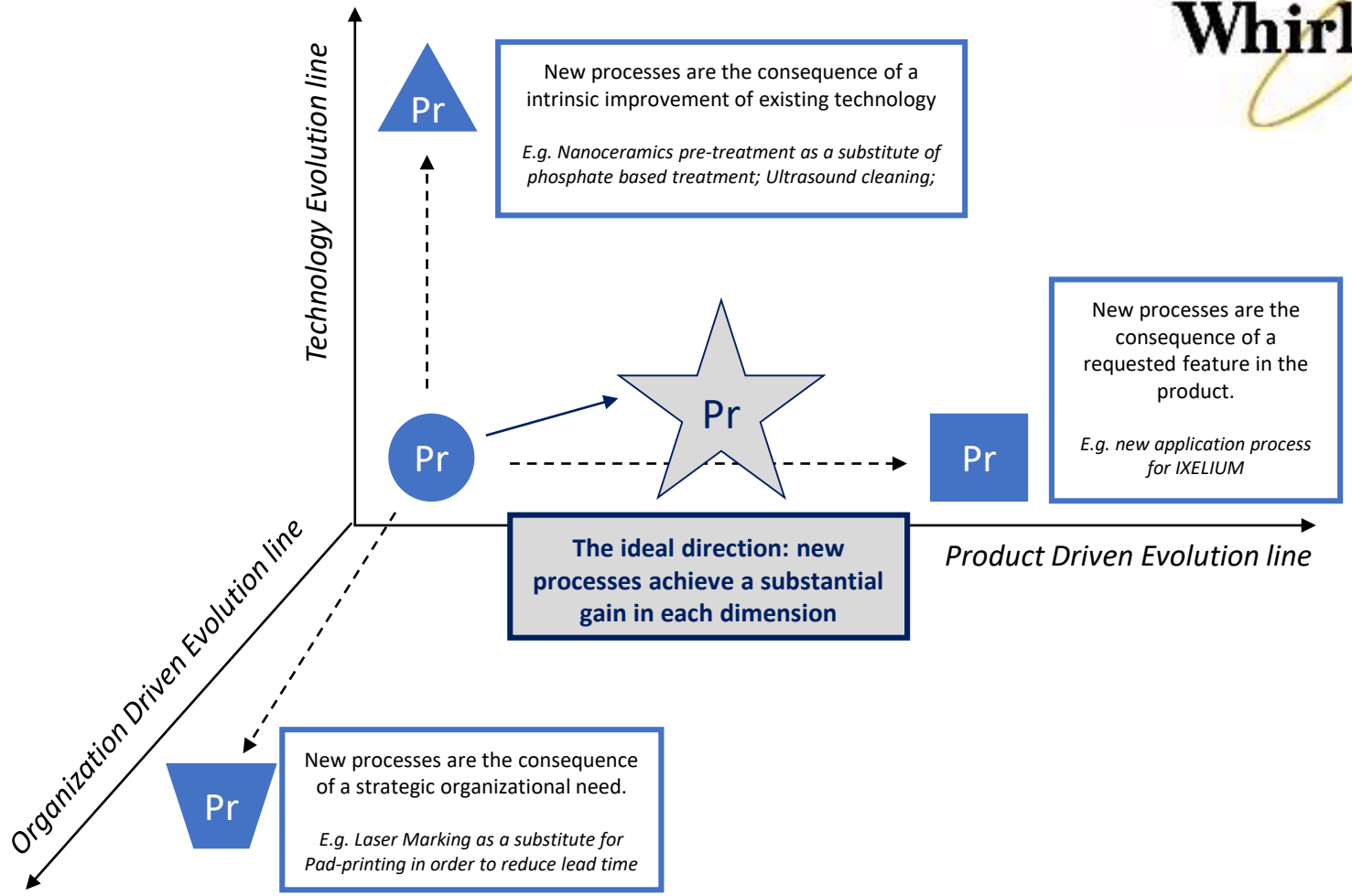
Strong industrial footprint

26,000 employees
best team in the industry

4.4%
operating profit

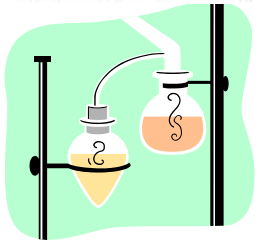
$6.8 B
revenues

A Tridimensional Space of Research



TF Objectives: to support decision

Give consistency in technology / product roadmap



Drive research activities (i.e. where to allocate money and resources)

Design new products

Identify competences needed to improve competitivity

Invest on technology

FORMAT
Forecast and Roadmapping for Manufacturing Technologies

MARIE CURIE ACTIONS

FORMAT Methodology:

Reference Models and Procedure

Theory of Inventive Problem Solving

SuperSystem Future:

?

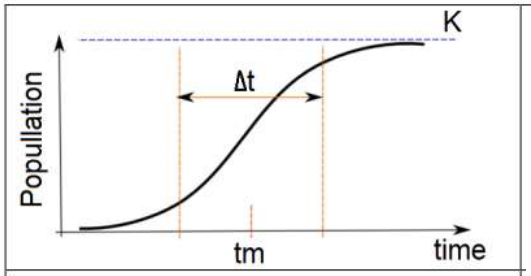
System Future

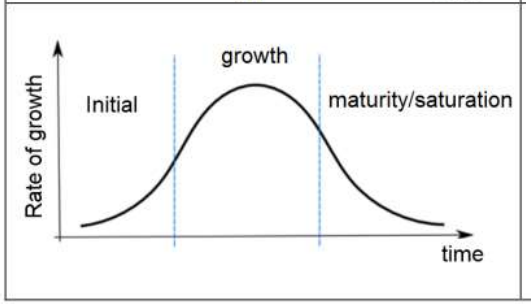
?

SubSystem Future

?

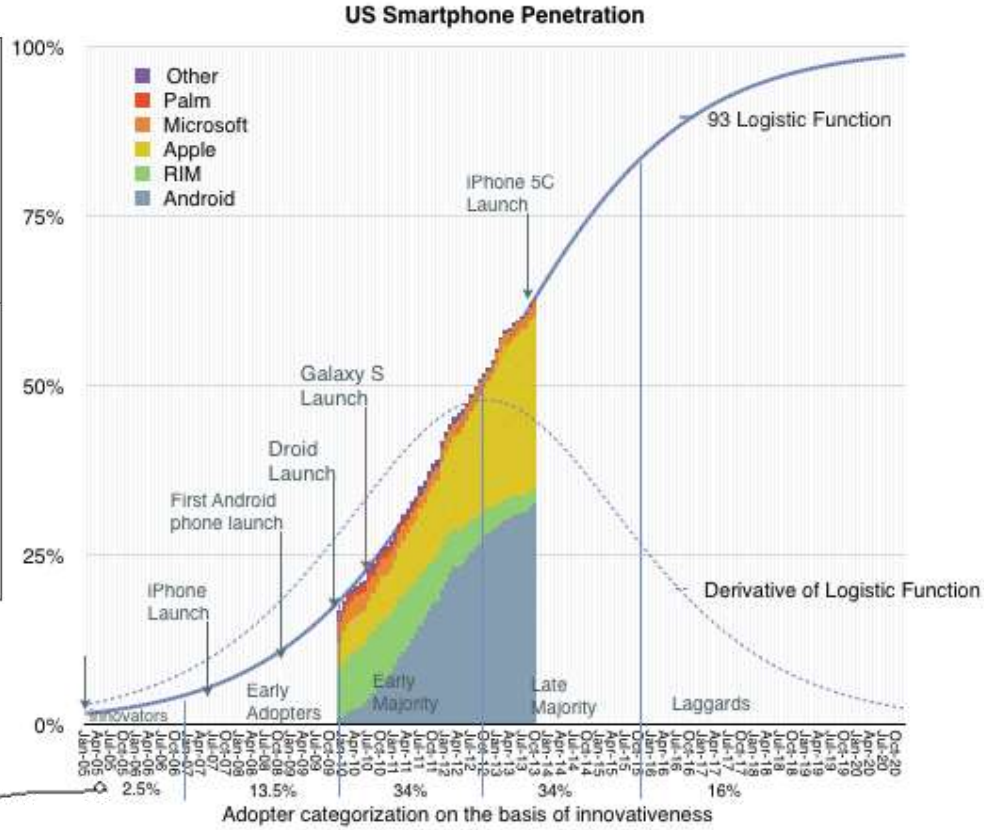
Technology Forecasting based on trend extrapolation

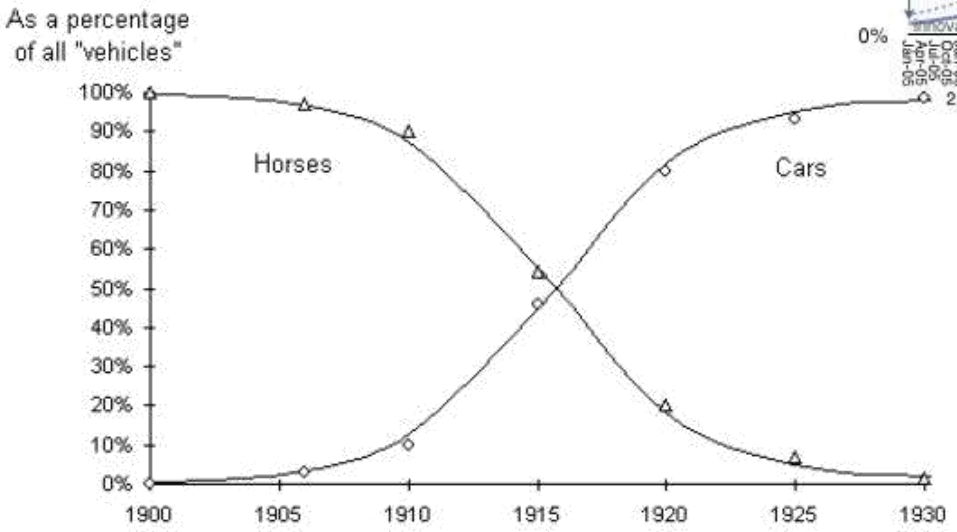




Growth under competition

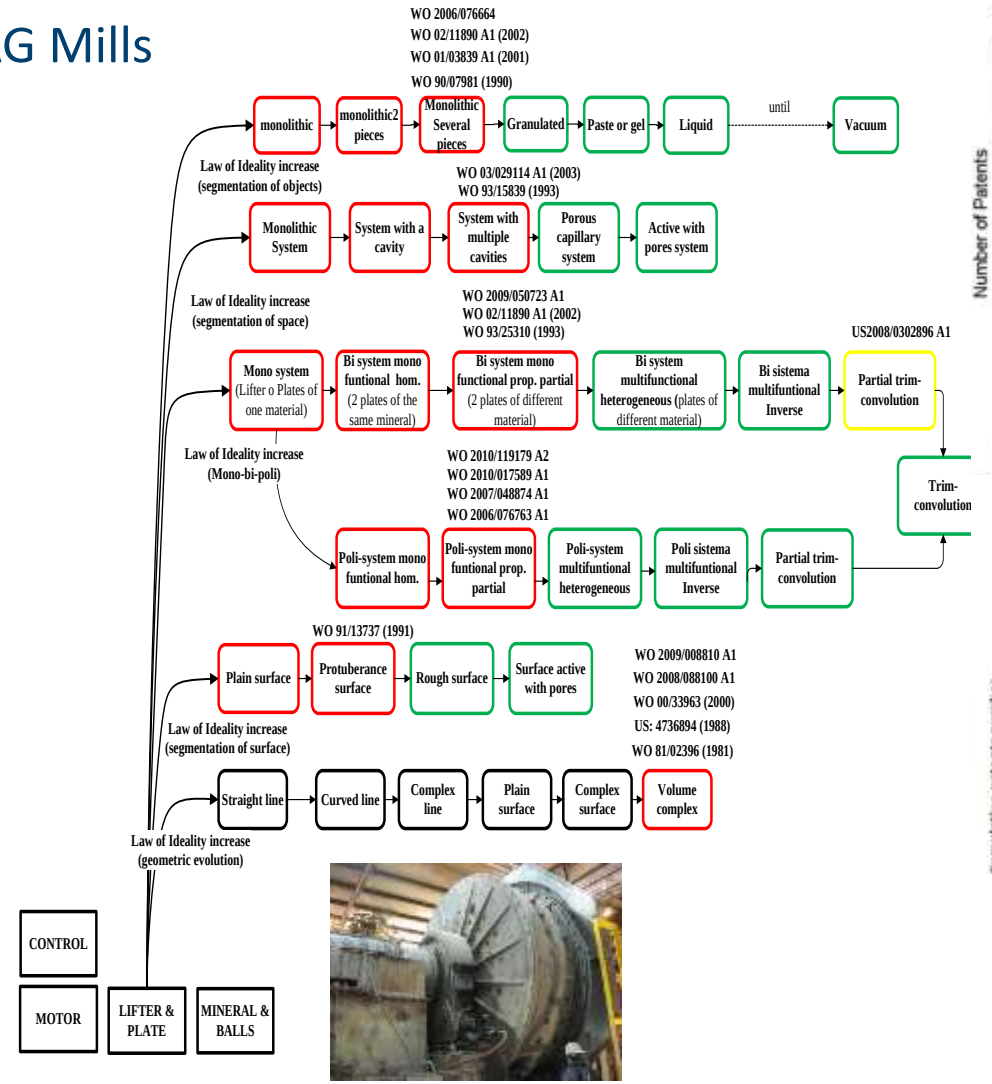
- Natural growth of autonomous systems in competition might be described by LOGISTIC EQUATION and logistic S-curve
- Natural growth is defined as the ability of a 'species' to multiply in finite 'niche capacity'

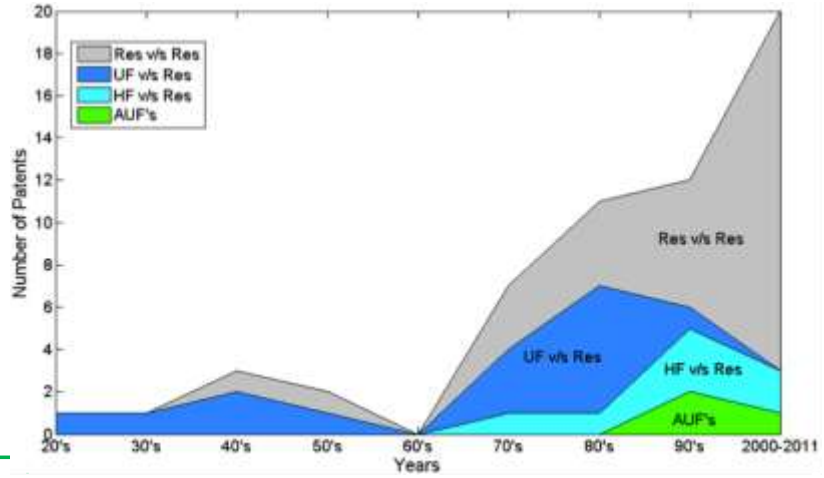


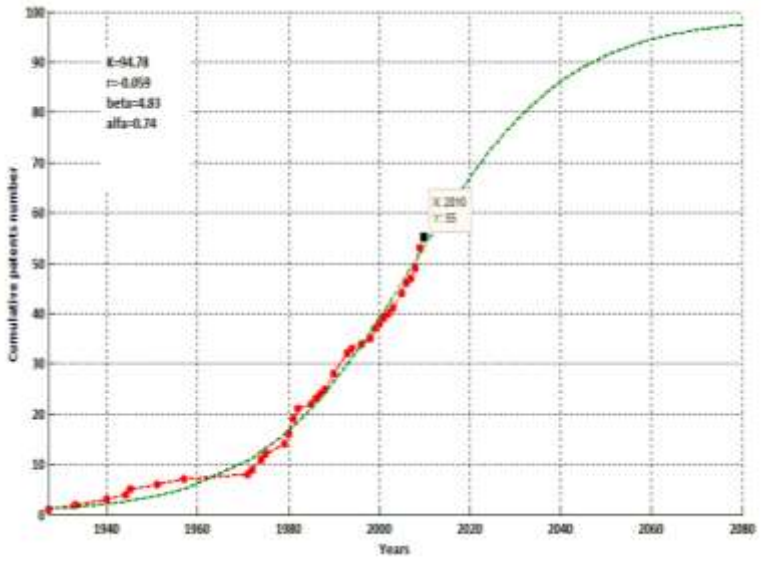


Combination of qualitative and quantitative models

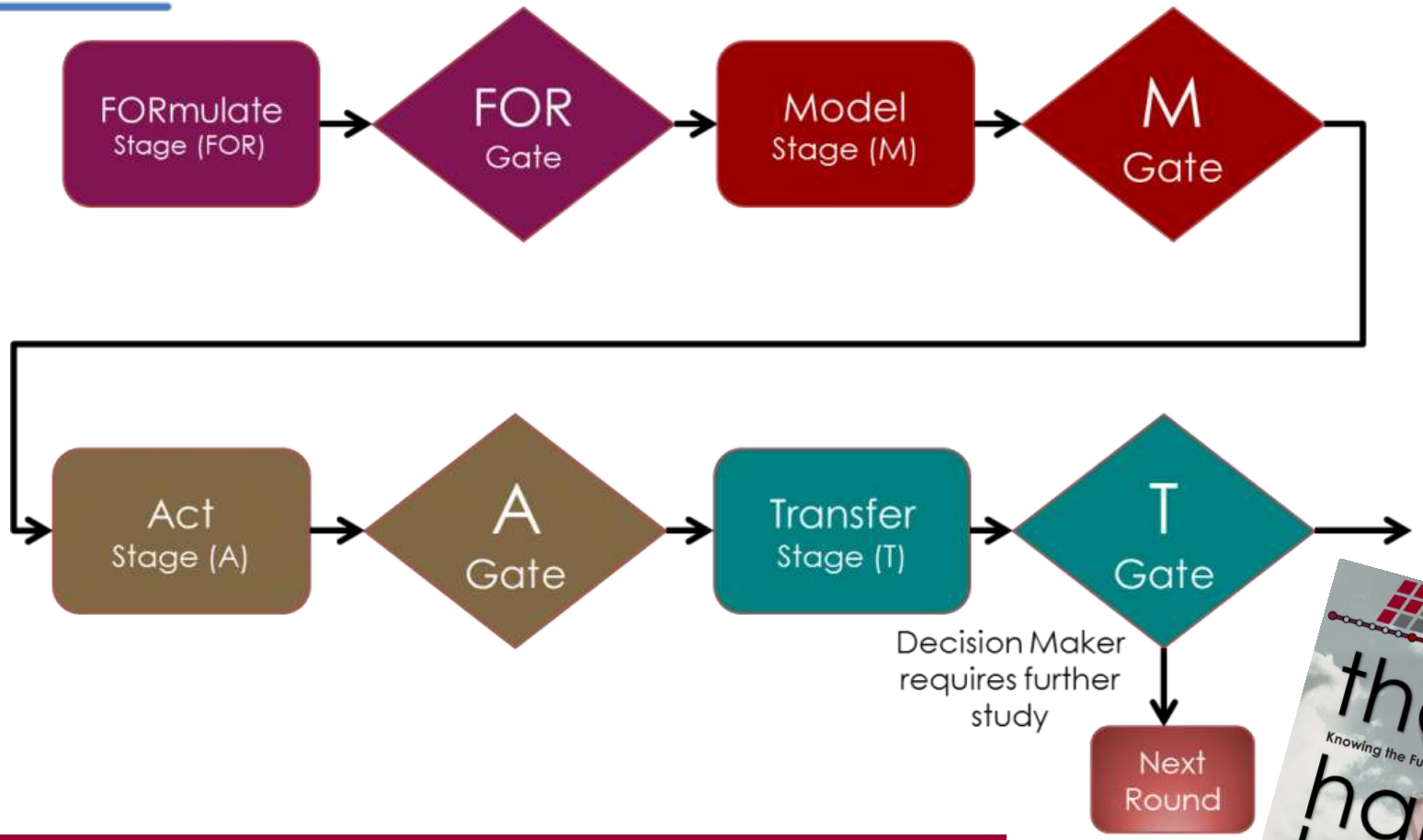
- SAG Mills





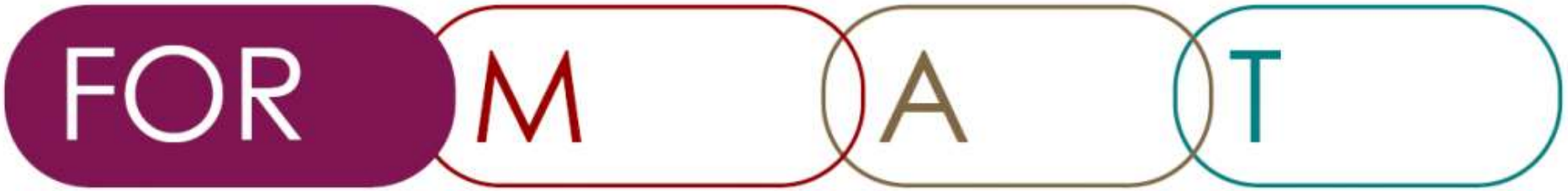


FORMAT Methodology: Stages and Gates



http://handbook.format-project.eu

FORMAT Methodology: Stages and Gates



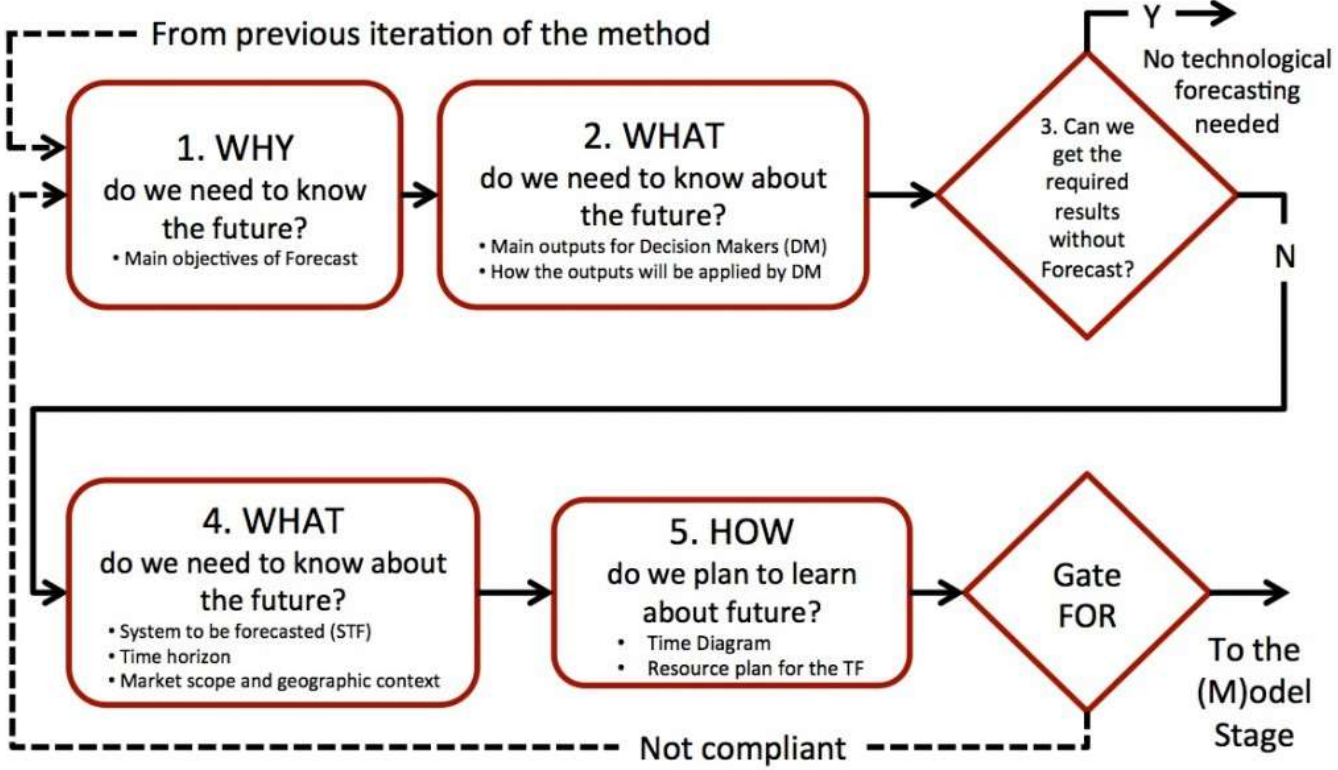
Diagnose questions and plan project (FOR)

<prepare & make> <decision> <about forecasting project>
<define> <boundaries / resource> <of forecasting project>

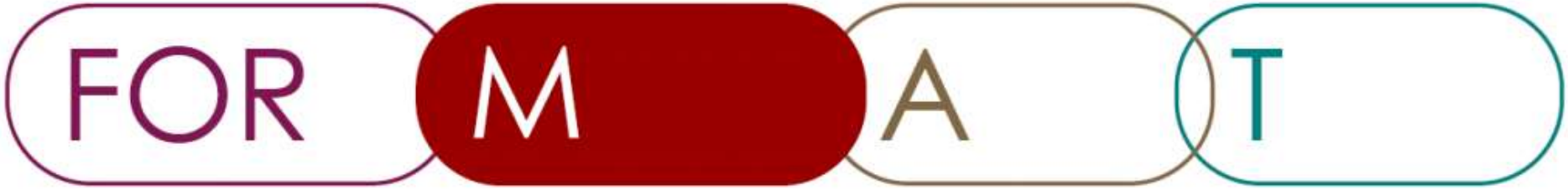
- ✓ Formulate the **questions** about the Future to be addressed
- ✓ Identify human/time/information resources
- ✓ **Plan** activities

FOR M A T

Diagnose questions and plan project (FOR)



FORMAT Methodology: Stages and Gates

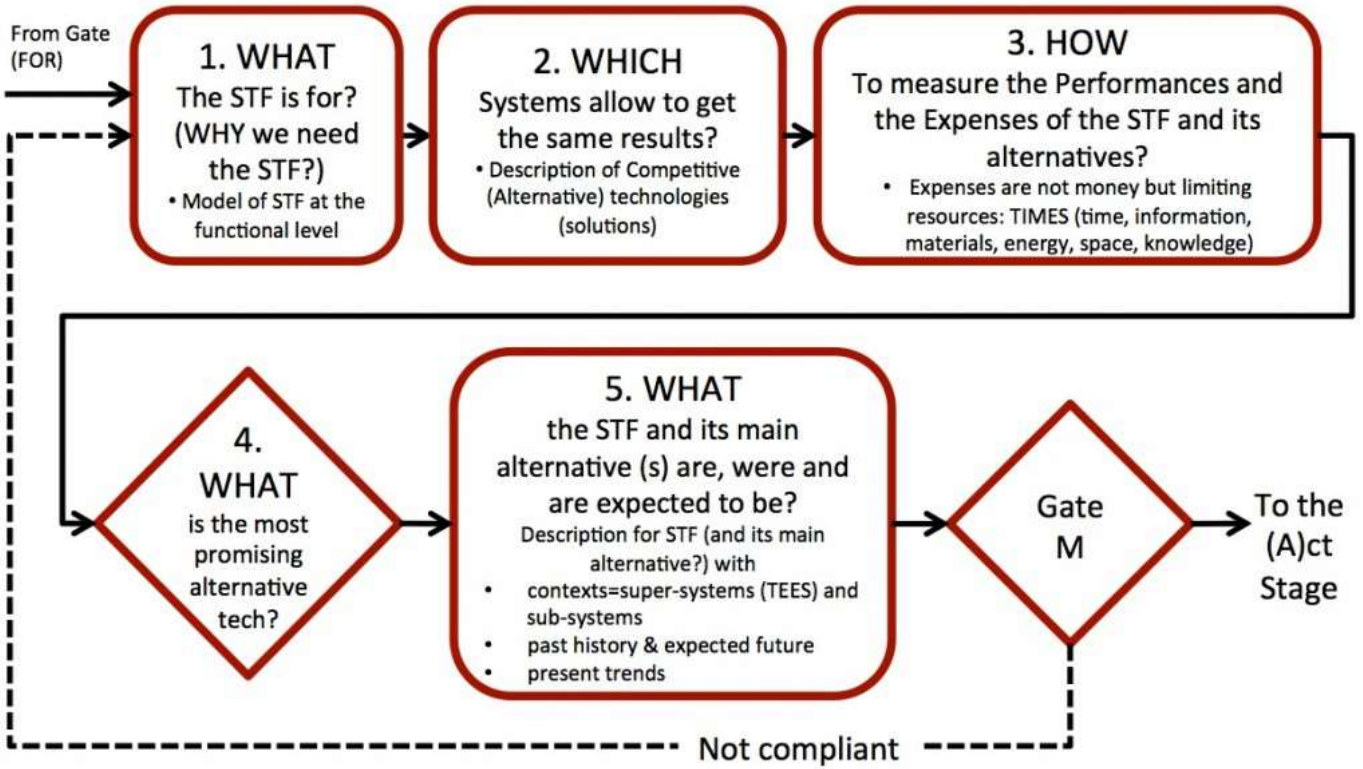


Define the system for forecast and study contexts (M)

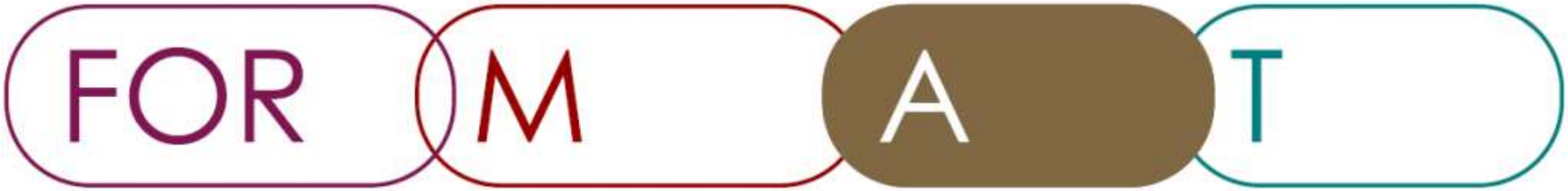
<review> <existing knowledge> <about system>

- ✓ Define the **boundary** of the system under study
- ✓ Elicit **knowledge** about the present and about the past
- ✓ Identify the **Drivers** that have led the evolution so far
- ✓ Identify the **Barriers** that have limited the evolution so far

Define the system for forecast and study contexts (M)



FORMAT Methodology: Stages and Gates

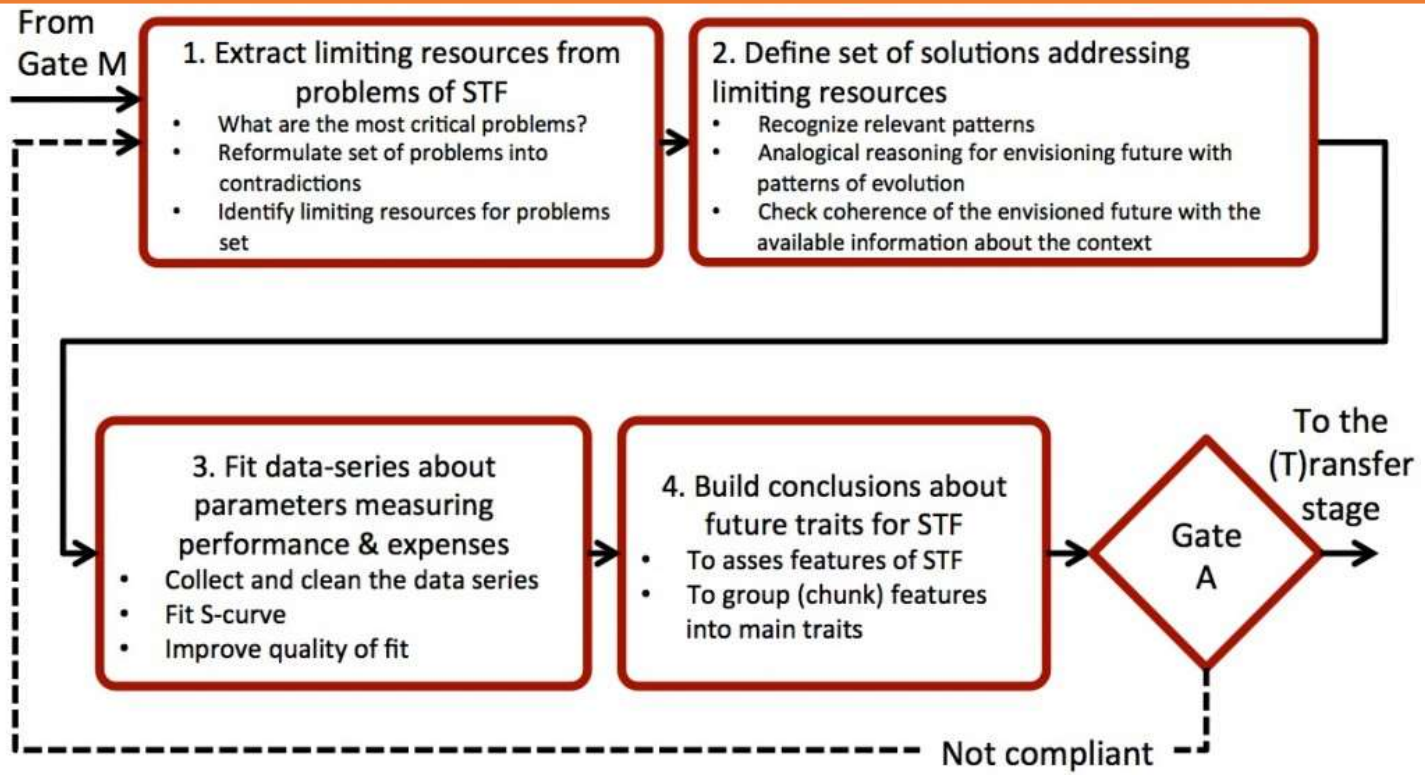


Develop forecast for defined system and contexts (A)

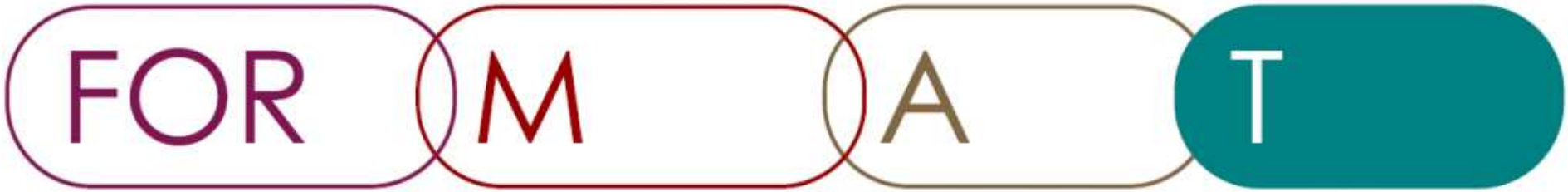
<identify> <a system of problems> <that drives evolution of system>
<recognize> <evolutionary trends> <for identified system>
<identify> <changes of performance characteristic in time>
<aggregate and validate> <results of qualitative and quantitative studies> <into forecast>

- ✓ Identify the limiting resources behind the **contradictions** between Drivers and Barriers
- ✓ Envision scenarios by analogy with **trends of evolution** and identify limiting resoures for their achievement
- ✓ Quantitatively assess the evolution of the **limiting resources**
- ✓ Aggregate **results**

Develop forecast for defined system and contexts (A)



FORMAT Methodology: Stages and Gates



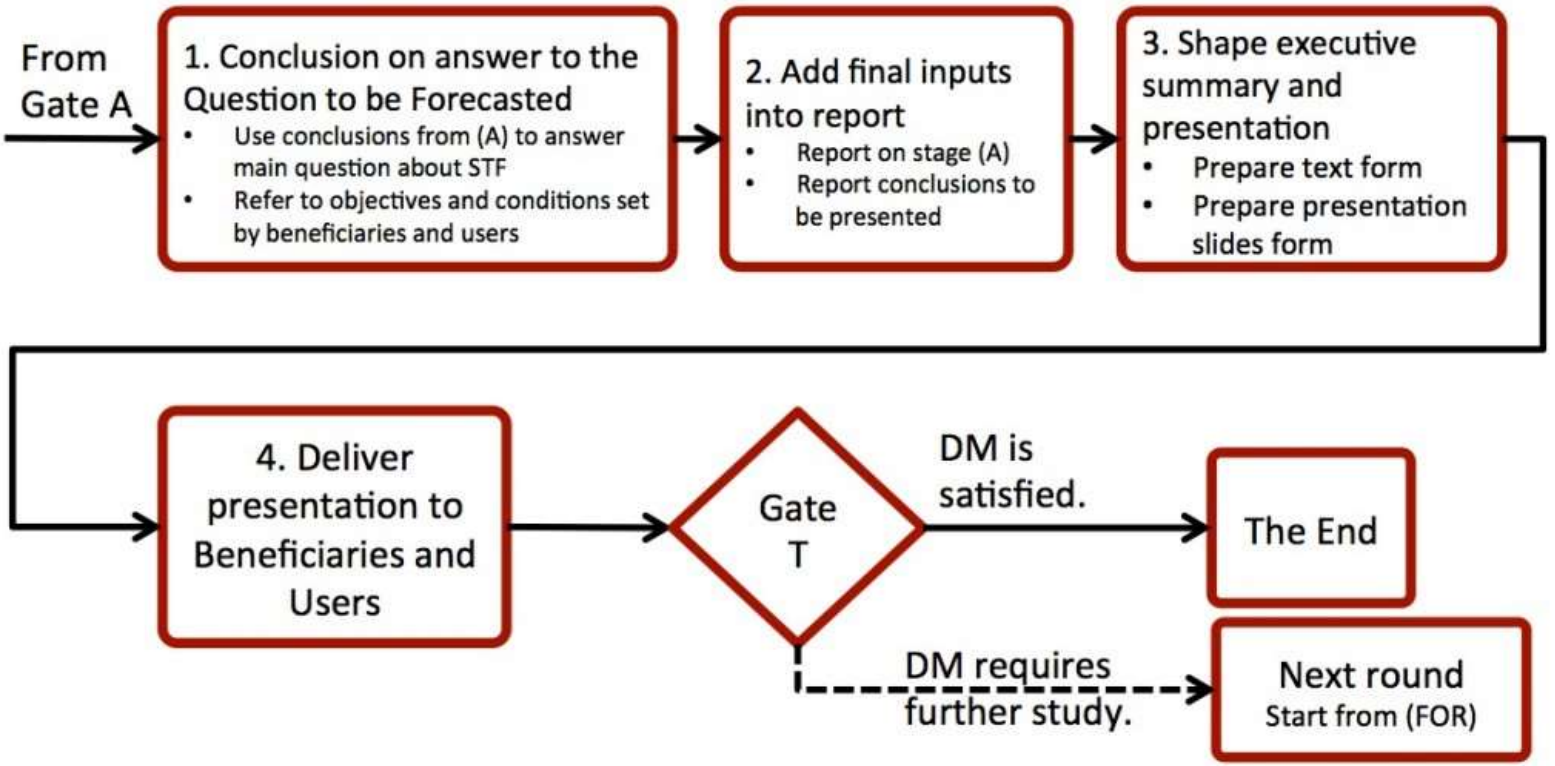
Prepare report and present results (T)

<transfer> <results of study> <to decision makers>

- ✓ Formulate **answers** to the questions of the forecast
- ✓ Produce final **report** and **presentation** for the beneficiaries

FOR M A T

Prepare report and present results (T)



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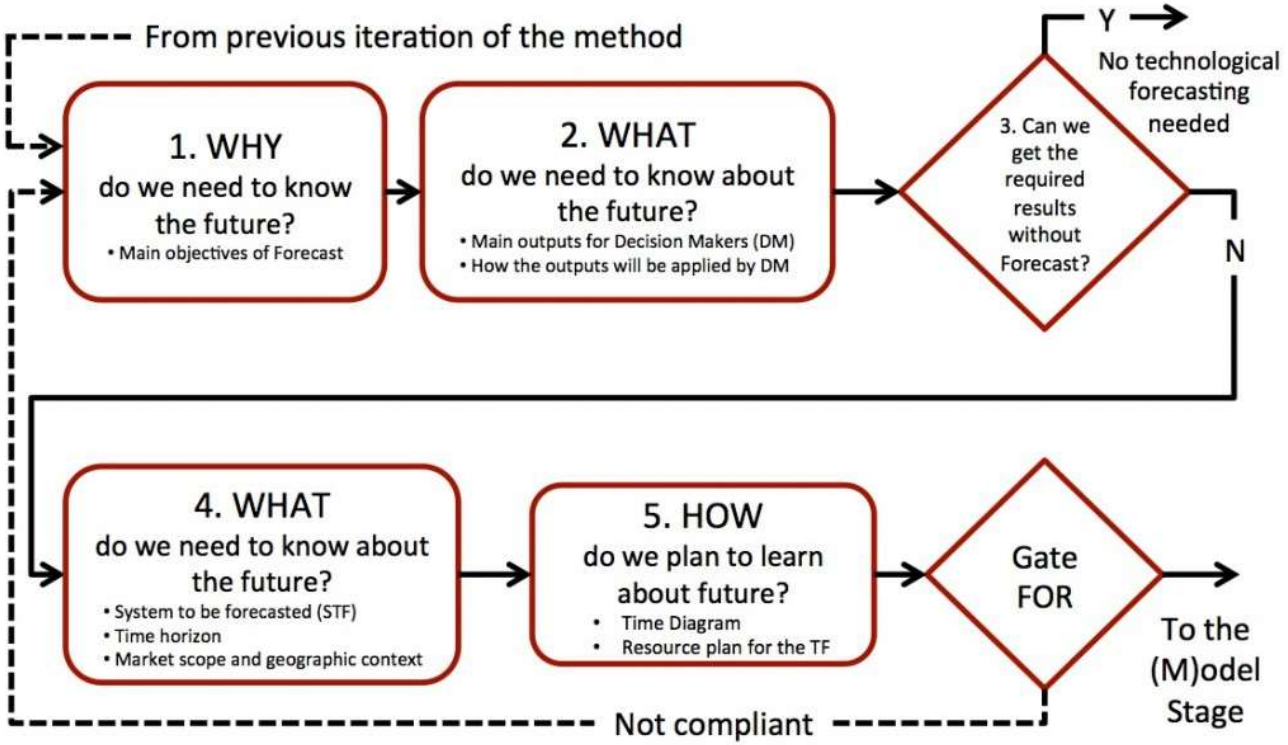
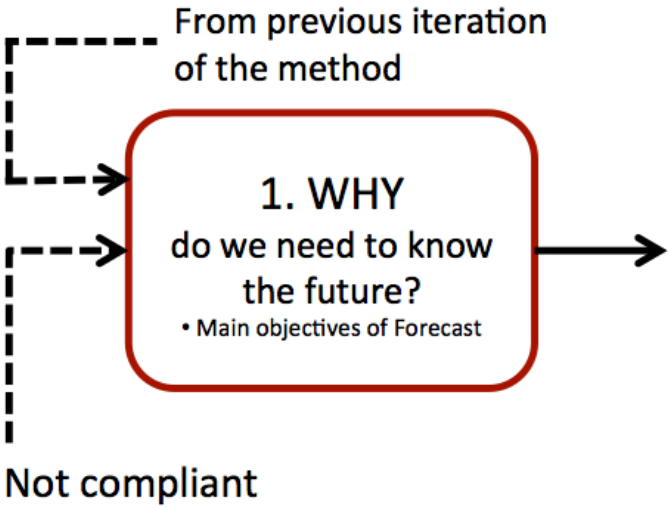
Diagnose questions and plan project (FOR)



FORMAT



- ✓ **Share the <u>motivation</u> of the TF project**
- ✓ **Define the <u>objectives</u> of the TF project from complementary viewpoints (e.g. beneficiaries, users, technology context, market context, social context…)**

FOR M A T

From previous iteration of the method

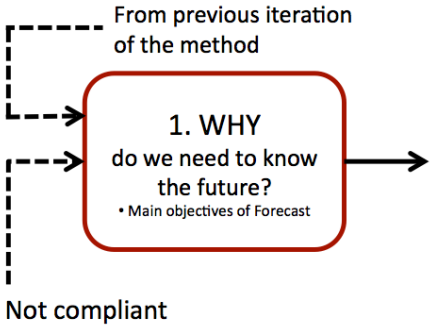
1. WHY do we need to know the future?
• Main objectives of Forecast

Not compliant

✓ **What packaging technologies for protecting refrigerators, ovens, dishwashers, washing machines, cooktops?**

EPS (Expanded polystyrene) substitution?

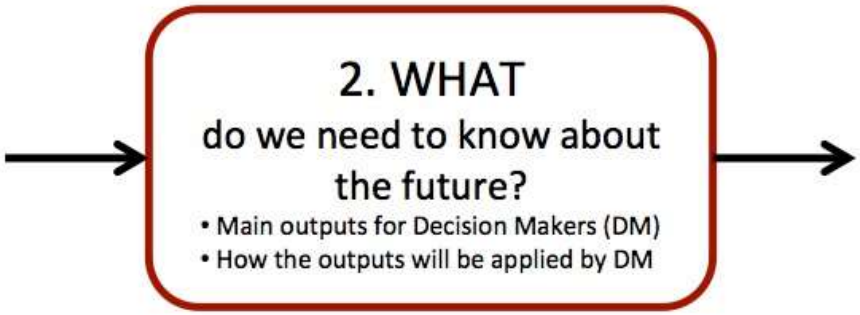
FORMAT



- ✓ **Which is the most promising decoration technology for achieving present and future product need (quality, flexibility, cost effectiveness) in the next 10 years for household appliances?**

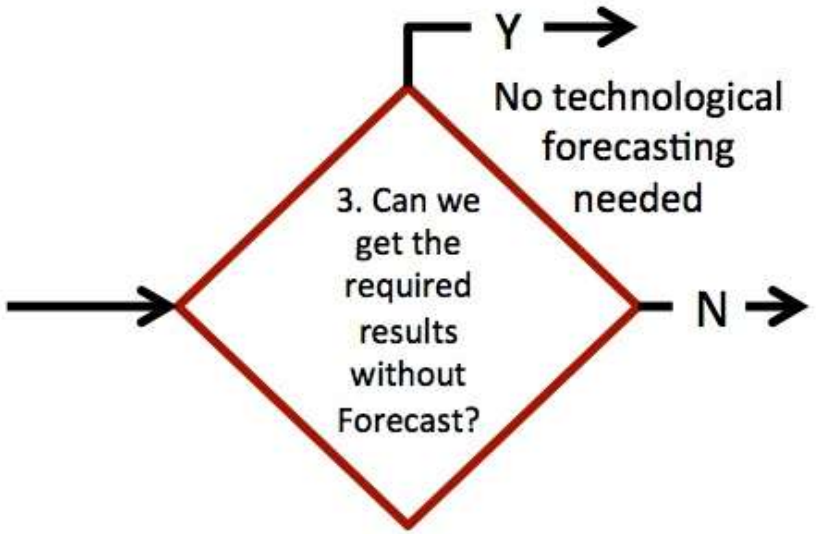
Ink jet printing? Pad printing? Laser marking? Chemical etching? Others?

FORMAT

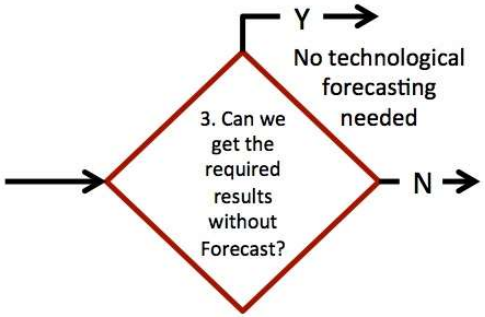


- ✓ **Identify a System To Be Forecasted (STF) and identify what results will be required by the decision makers.**
- ✓ **Identify how the decision makers will use the results from the forecast**

FOR M A T

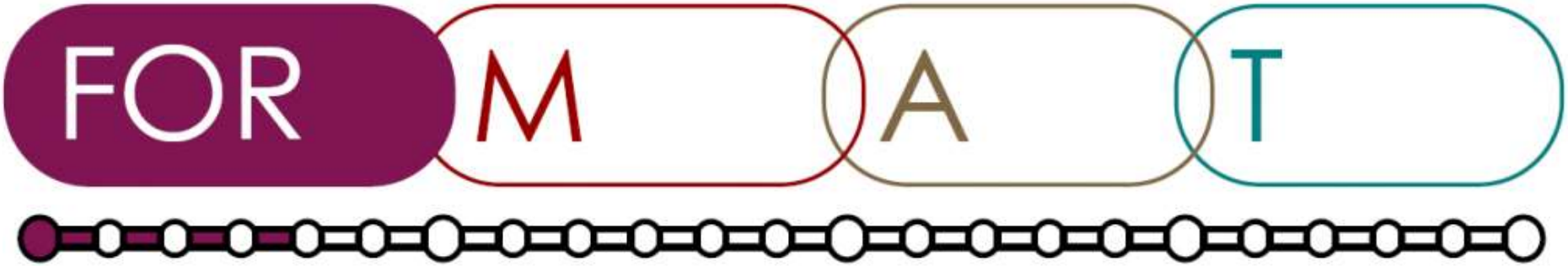


! **This is a <u>decision step</u> that differentiates forecasting and problem solving activities for formulated objectives**



Example: Gas leak checks

Currently known technologies to detect micro leakages from a sealed system are not completely satisfactory because of their limitation.
However, the present limitation is potentially solvable through a problem solving process.



(This step is an elaboration of the activities performed in Step 1 of Stage FOR)

- ✓ **Define main objectives, time horizon of the forecast and market and geographical context of the system to be forecasted**

FOR M A T

4. WHAT
do we need to know about the future?
- System to be forecasted (STF)
- Time horizon
- Market scope and geographic context

✓ **What packaging technologies <u>for the next 5-10 years (2018-2023)</u> to protect refrigerators, ovens, dishwashers, washing machines, cooktops, during their delivery from the factory to a customer's house <u>in Western countries</u>?**

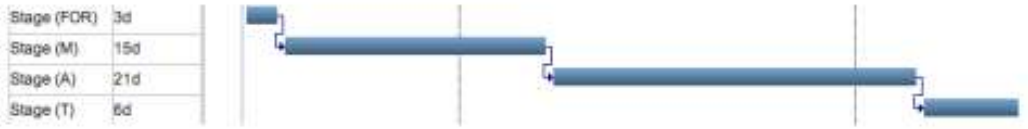
5. HOW

do we plan to learn about future?

- Time Diagram
- Resource plan for the TF

✓ **get decisions about <u>resources allocation</u> – human, data, restricted access permissions etc.**

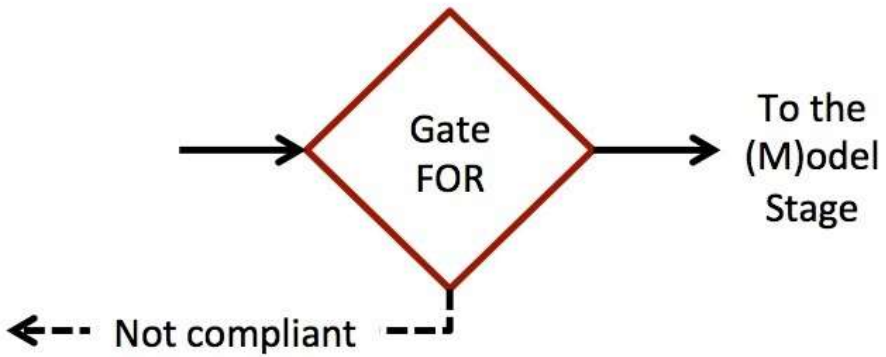
Name of a stage	Duration [days]	Number of working sessions [sessions]	Resources
FOR	3	1	Beneficiaries, users, 2-3 analysts
M	15	4	2-3 analysts
A	21	5	2-3 analysts
T	6	2	Beneficiaries, users, 2-3 analysts



FOR M A T

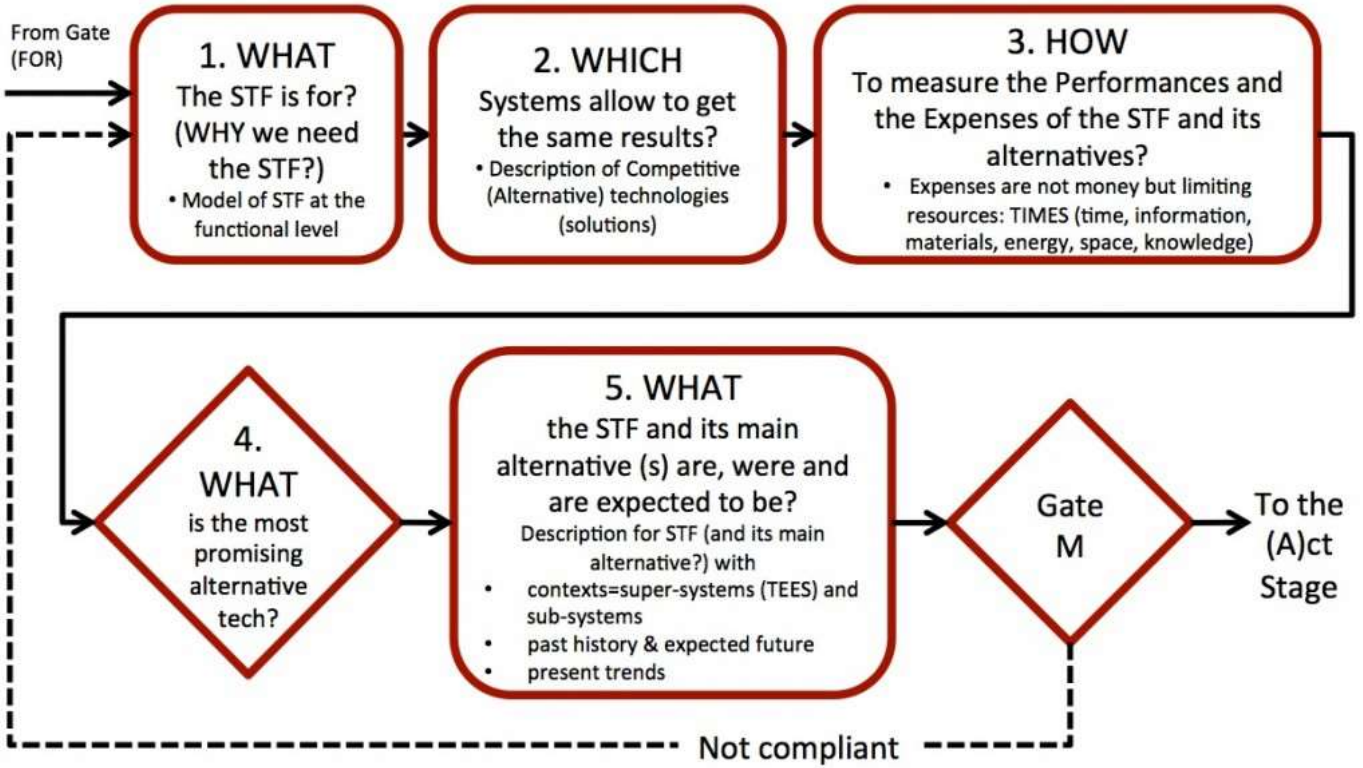
5. HOW
do we plan to learn about future?

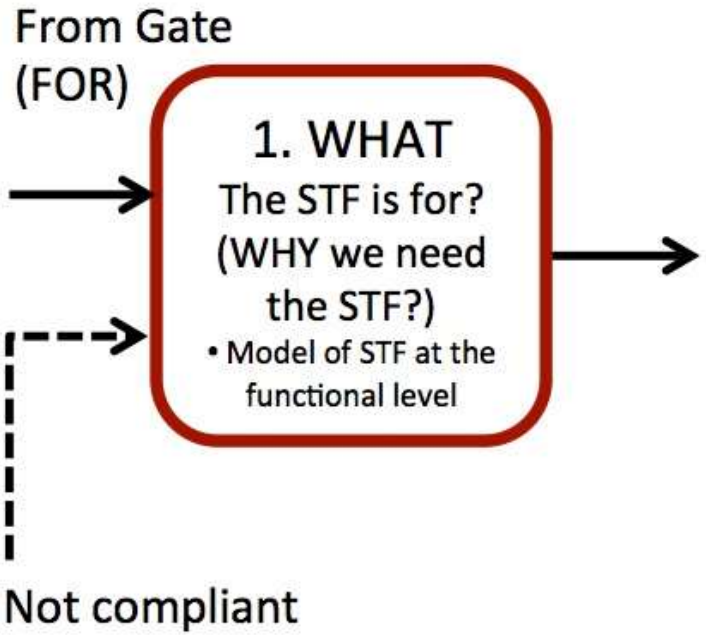
- Time Diagram
- Resource plan for the TF



- ✓ **Check completeness and consistency of the required information**

Define the system for forecast and study contexts (M)





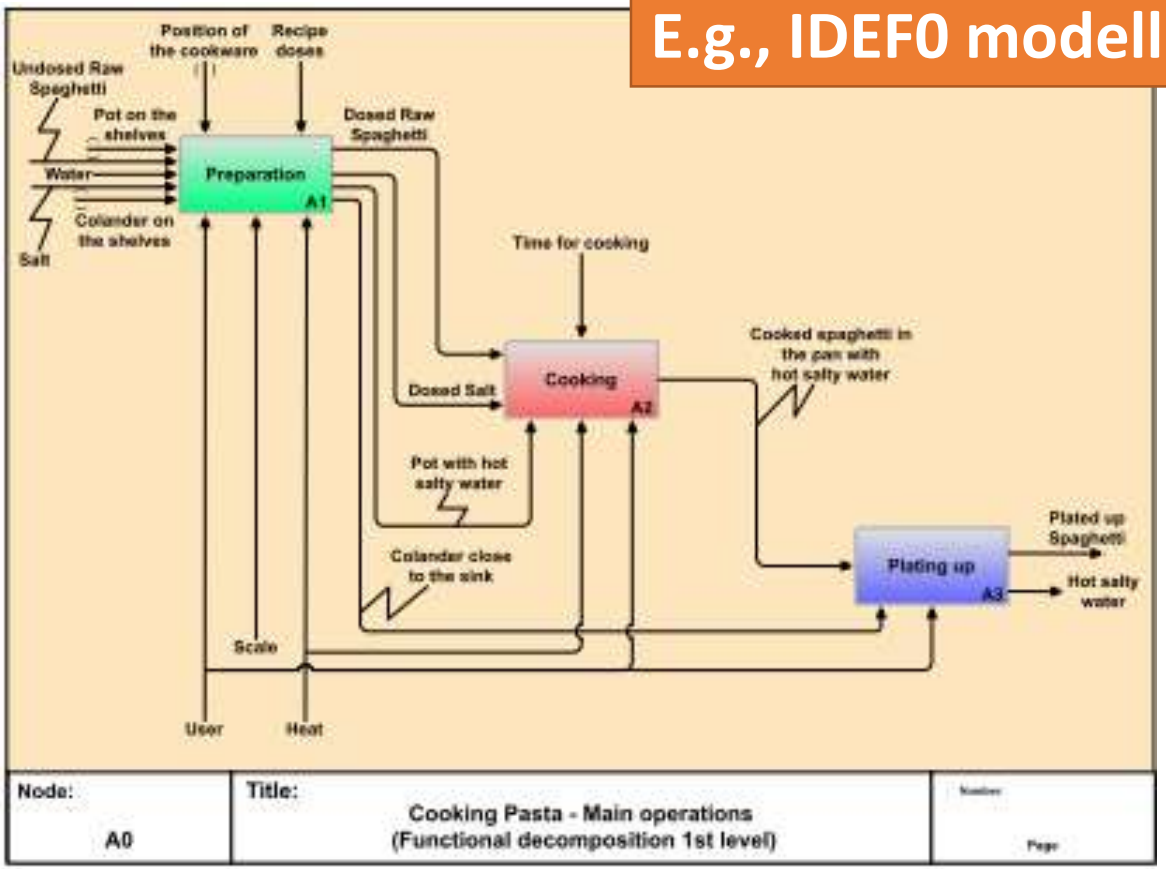
- ✓ **Involve people having different viewpoints about the system to be forecasted**
- ✓ **Define a uniform and robust vision about the function(s) the system is carrying out**

From Gate (FOR)

1. WHAT
The STF is for? (WHY we need the STF?)
• Model of STF at the functional level

Not compliant

E.g., IDEF0 modelling

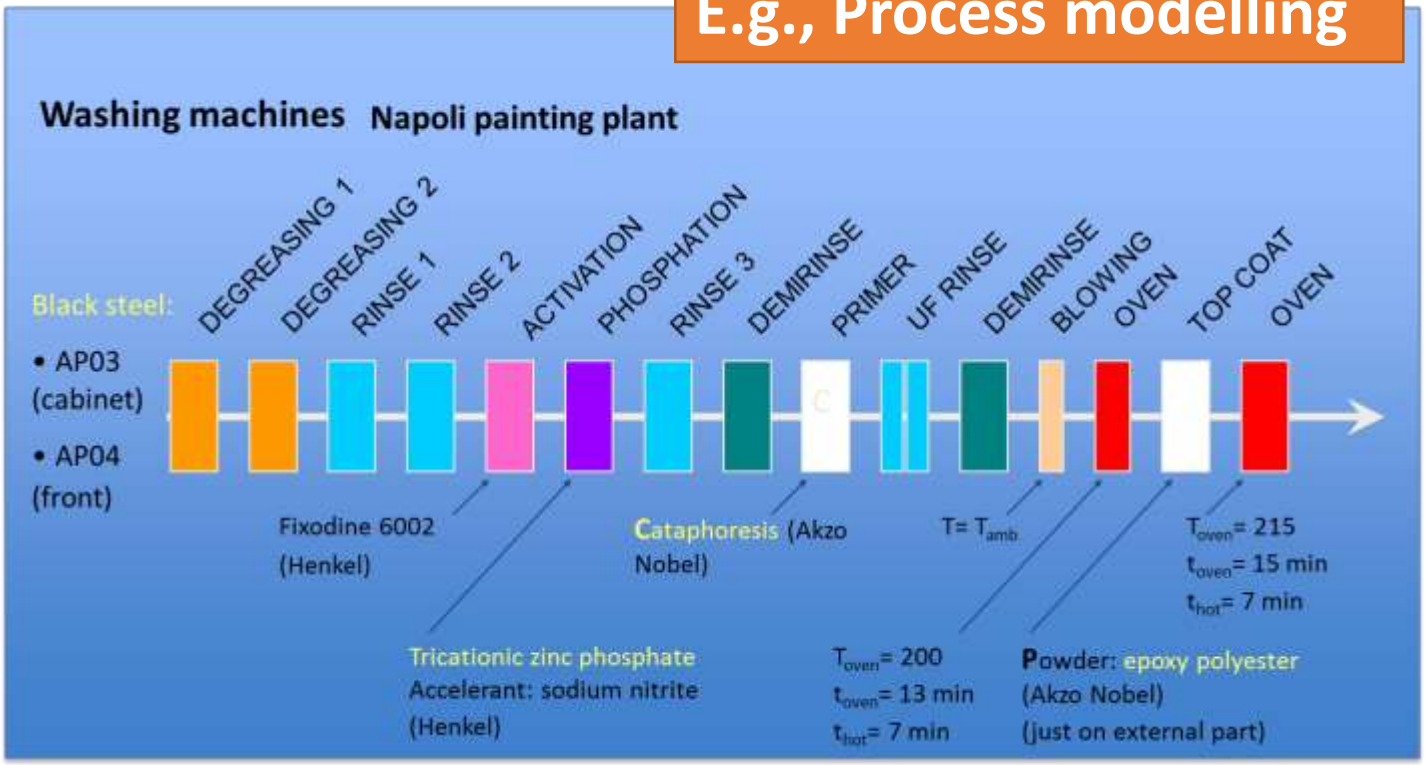


From Gate (FOR)

1. WHAT
The STF is for? (WHY we need the STF?)
• Model of STF at the functional level

Not compliant

E.g., Process modelling



From Gate (FOR)

1. WHAT
The STF is for? (WHY we need the STF?)
• Model of STF at the functional level

Not compliant

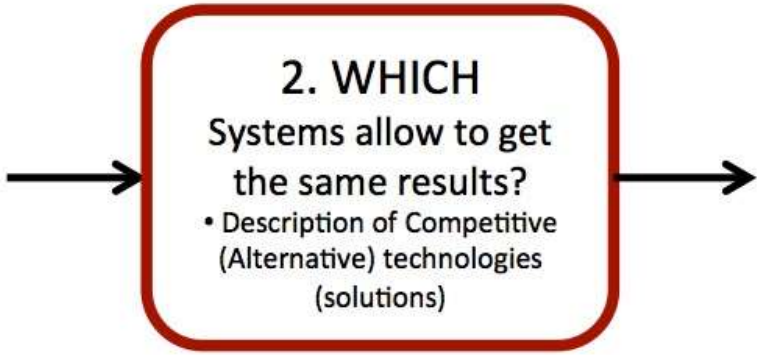
Main function of car interiors: <accommodate> <passengers>

E.g., Product modelling

<remove from sight>
<functional or anti-aesthetical elements>

<transmit>
<positive feelings to passengers>

<hold>
<small devices>



- ✓ **Define what can potentially compete (technical and non-technical alternative solutions) with the STF in the satisfaction of the same overall demand**

2. WHICH
Systems allow to get the same results?
• Description of Competitive (Alternative) technologies (solutions)

Leave metallic parts visible

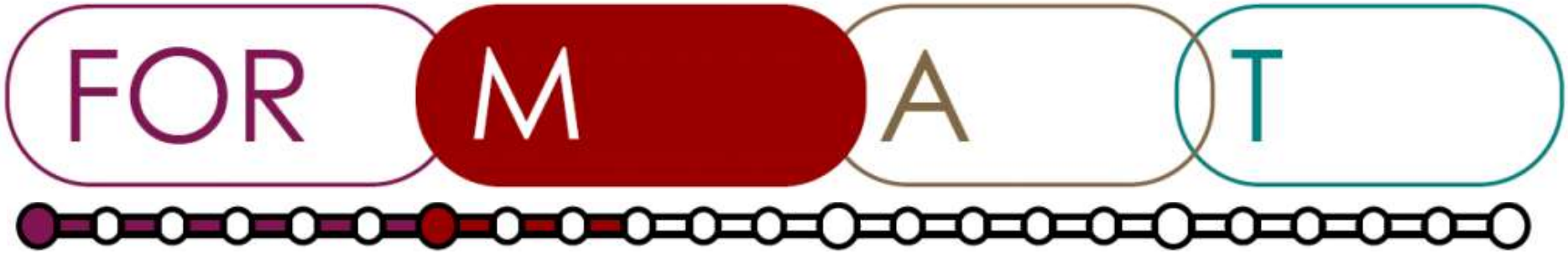
Briar-root

Plastics

Leather and textile

Aluminum alloys

Compositie materials



3. HOW

To measure the Performances and the Expenses of the STF and its alternatives?

- Expenses are not money but limiting resources: TIMES (time, information, materials, energy, space, knowledge)

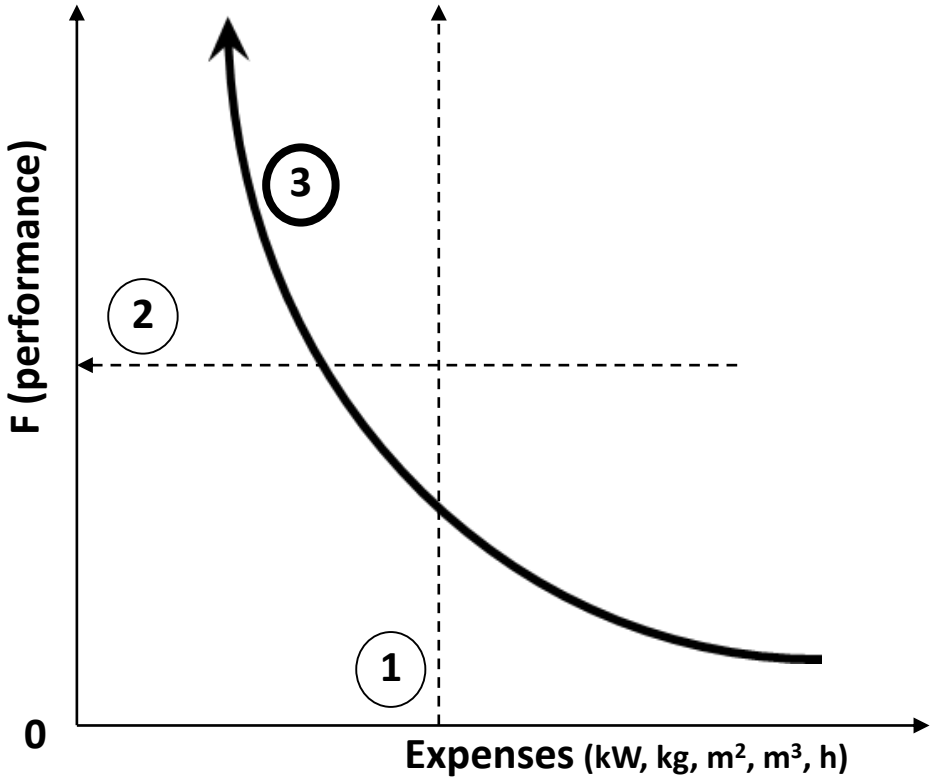
✓ **Retrieve and organize knowledge of the <u>key aspects of the alternative technologies</u> and prepare a comparison with the current technology**

3. HOW

To measure the Performances and the Expenses of the STF and its alternatives?

- Expenses are not money but limiting resources: TIMES (time, information, materials, energy, space, knowledge)

$$I = \frac{\sum Useful\ functions}{\sum Harmful\ functions + \sum Costs}$$

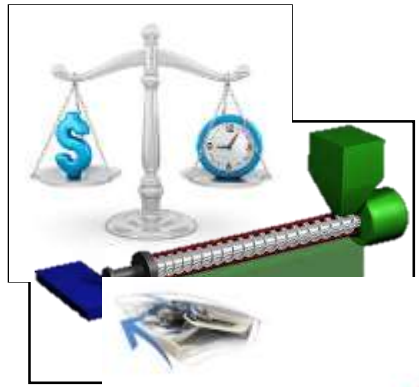


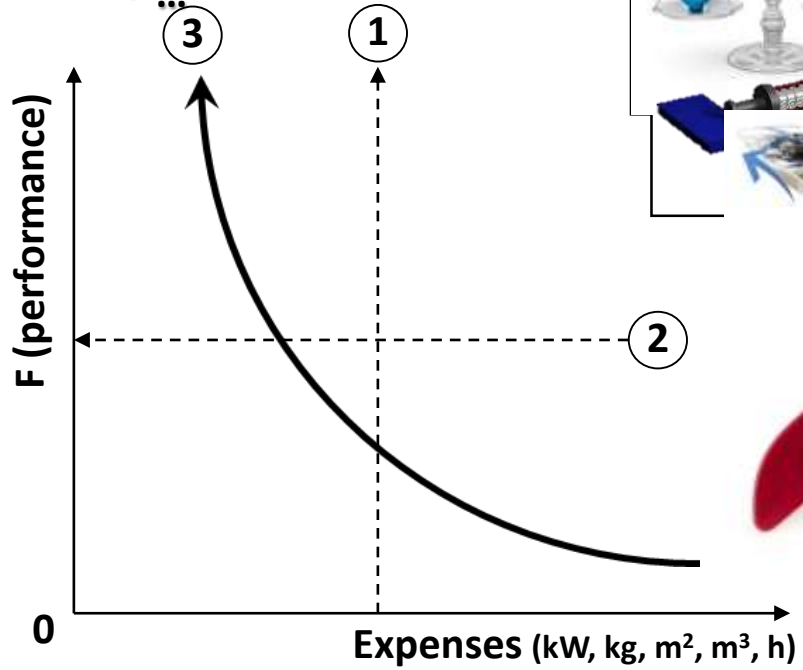
3. HOW

To measure the Performances and the Expenses of the STF and its alternatives?

- Expenses are not money but limiting resources: TIMES (time, information, materials, energy, space, knowledge)

- Colour, brightness
- Finishing
- Scratch resistance
- …



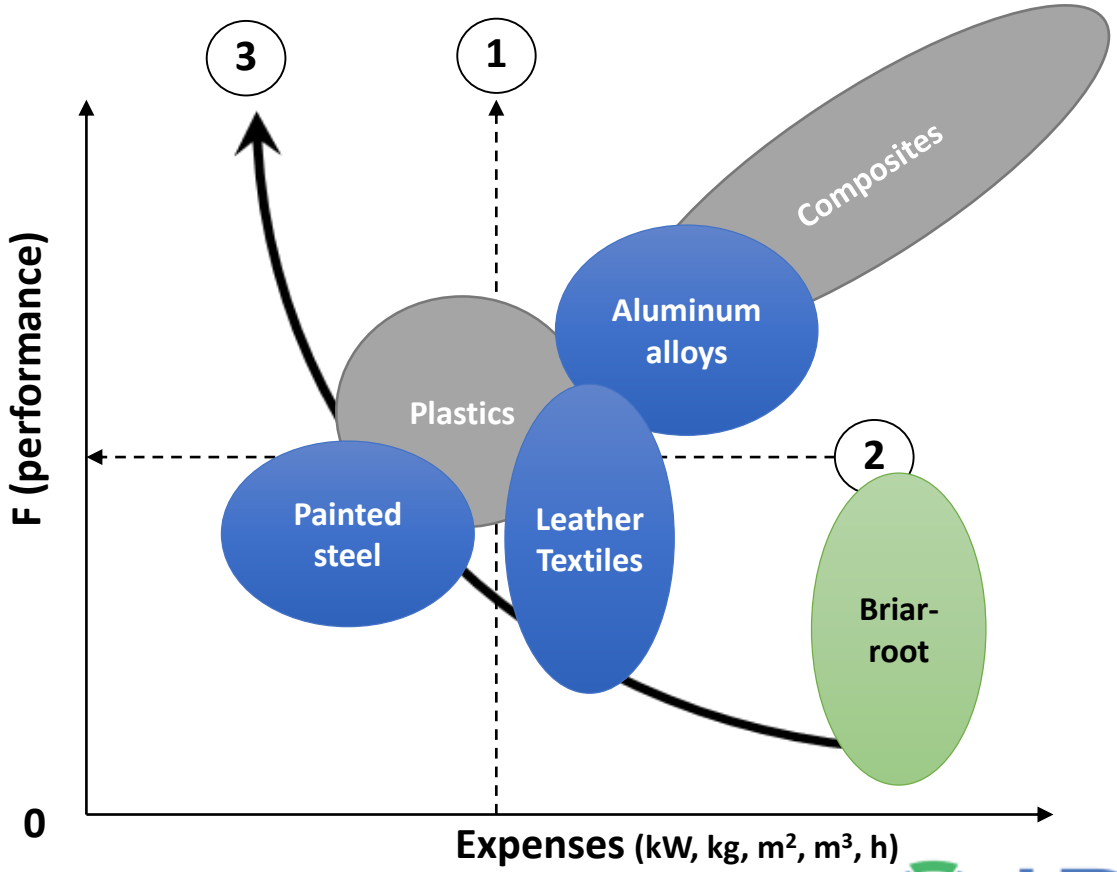


materials

- Working time
- Tools wear
- …

- ✓ **Prepare a clear description of previously performed steps for facilitating the assessment of alternatives**
- ✓ **Choose the alternative technologies to investigate deeper**

4.
WHAT
is the most promising alternative tech?



- ✓ **Identify SuperSystems and SubSystems of the STF**
- ✓ **Share a vision about Past and Present of the System**
- ✓ **Project visions about the Future**
- ✓ **Identify Drivers**
- ✓ **Identify Barriers**

5. WHAT
the STF and its main alternative (s) are, were and are expected to be?
Description for STF (and its main alternative) with
- contexts=super-systems (TEES) and sub-systems
- past history & expected future
- present trends

SuperSystem Past	SuperSystem Present Cabin, navigation system…	SuperSystem Future:
System Past (1990-2010)	System Present System: E.g. car interiors	System Future (2015-20
SubSystem Past	SubSystem Present E.g., dashboard, rear-view mirrors, steering wheel, seats…	SubSystem Future

Naive projection

FOR M A T

5. WHAT
the STF and its main alternative (s) are, were and are expected to be?
Description for STF (and its main alternative) with
- contexts=super-systems (TEES) and sub-systems
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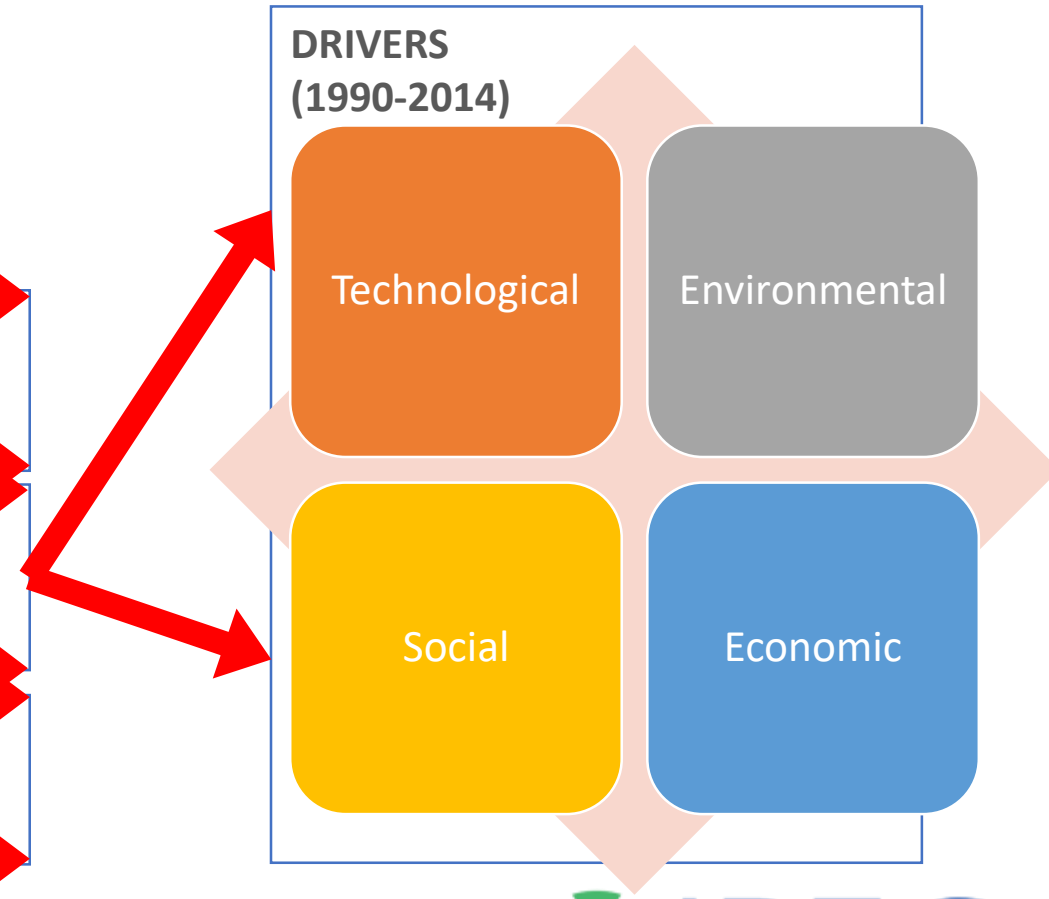
- present trends

SuperSystem Past	SuperSystem Present Cabin, navigation system…	SuperSystem Future:
System Past (1990-2010)	System Present System: E.g. car interiors	System Future (2015-2025)
SubSystem Past	SubSystem Present E.g., dashboard, rear-view mirrors, steering wheel, seats…	SubSystem Future



FOR M A T

5. WHAT
the STF and its main alternative (s) are, were and are expected to be?
Description for STF (and its main alternative) with
- contexts=super-systems (TEES) and sub-systems
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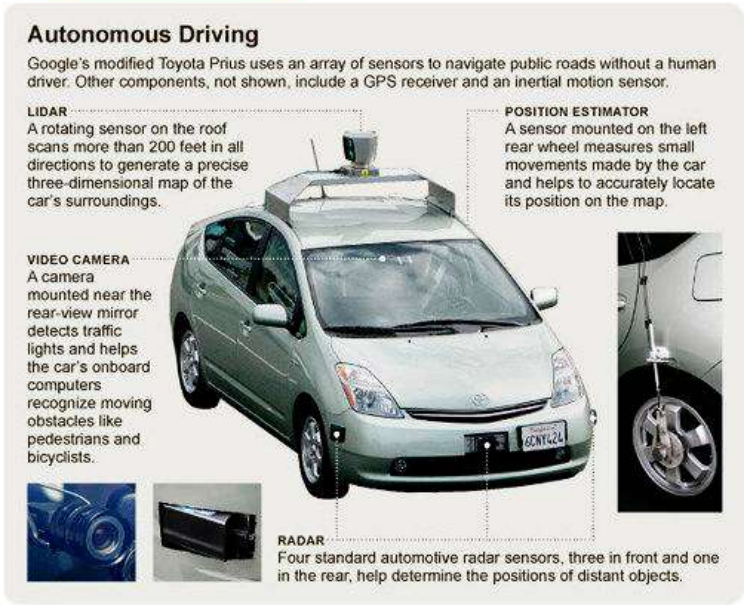
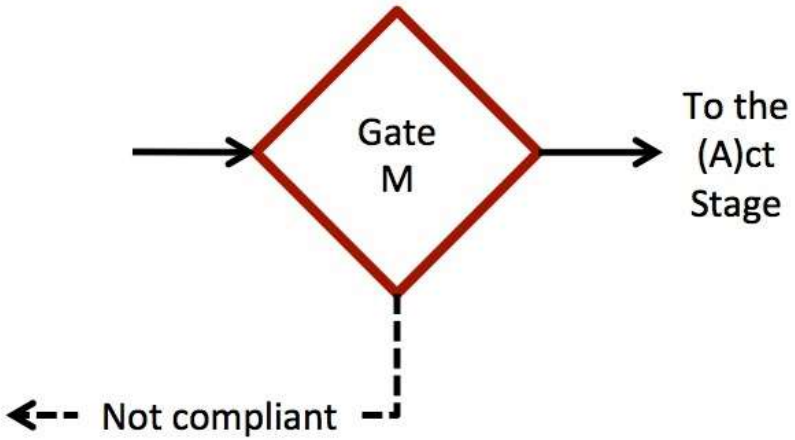


Technological:
E.g., GPS accuracy (barrier)

Environmental
E.g. Lower emissions (driver)

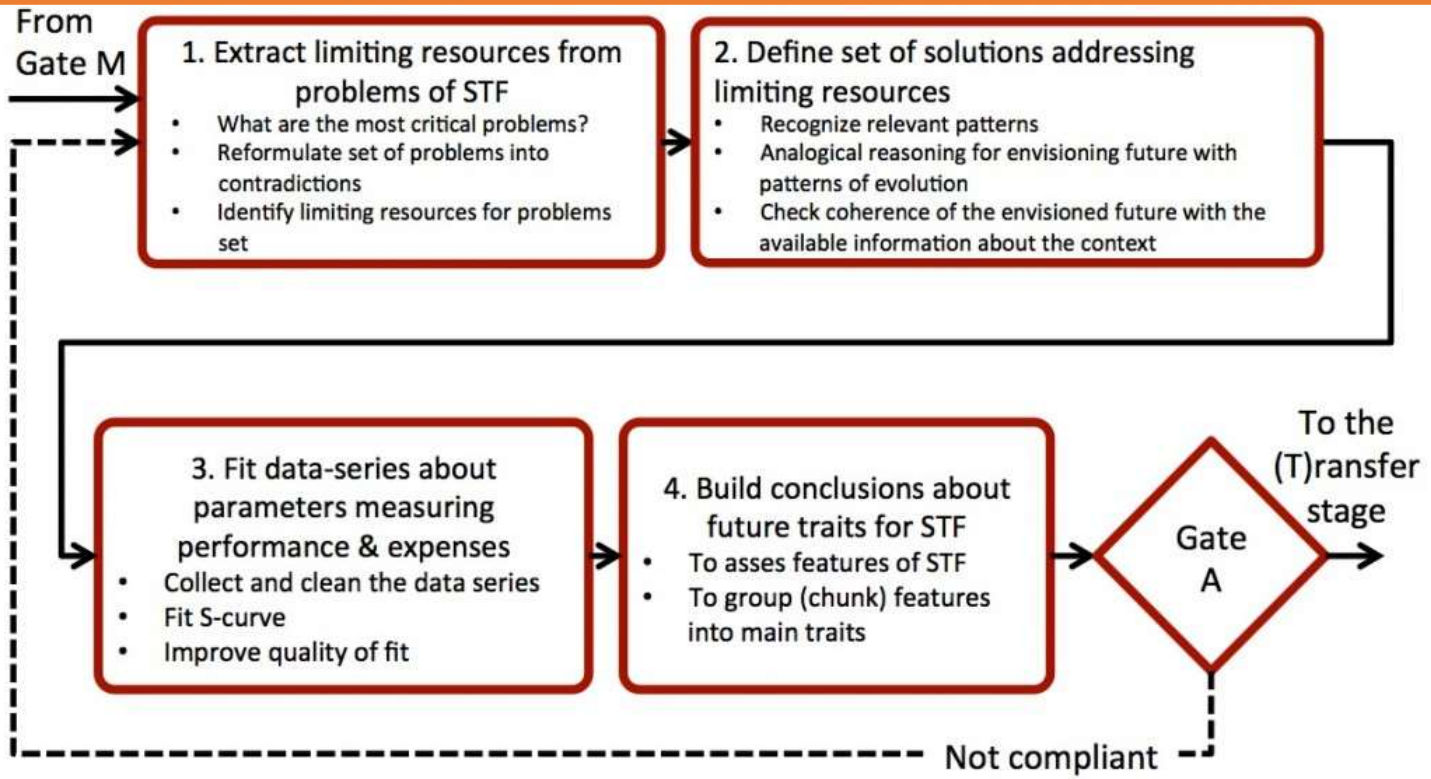
Social
E.g., Insurance regulations (barrier)

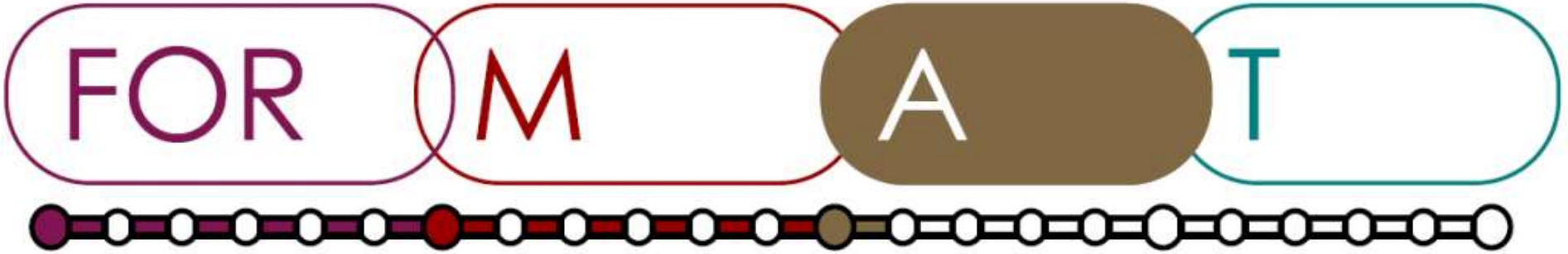
Economic
E.g., Lower fuel consumption

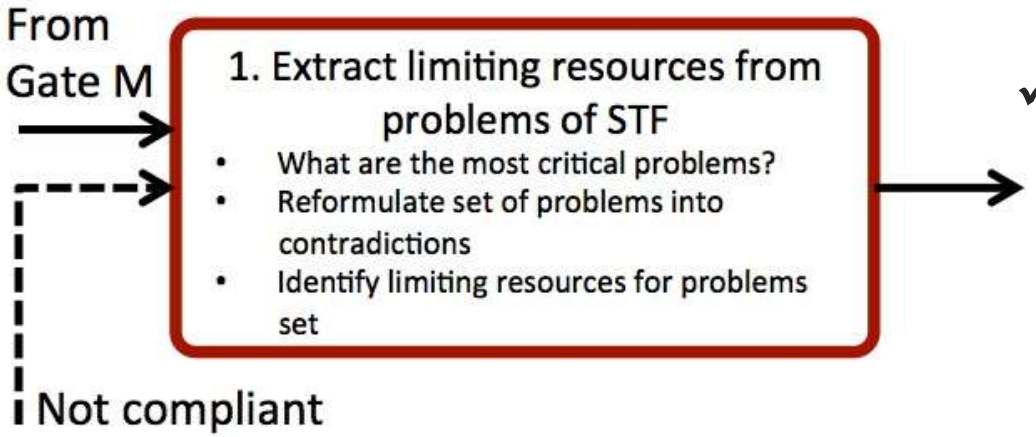


- ✓ **Check completeness and consistency of the required information**

Develop forecast for defined system and contexts (A)







✓ **List the <u>problems</u> of system to be forecasted (STF) and identify <u>limiting resources</u> that are linked with them**

FOR M A T

From Gate M

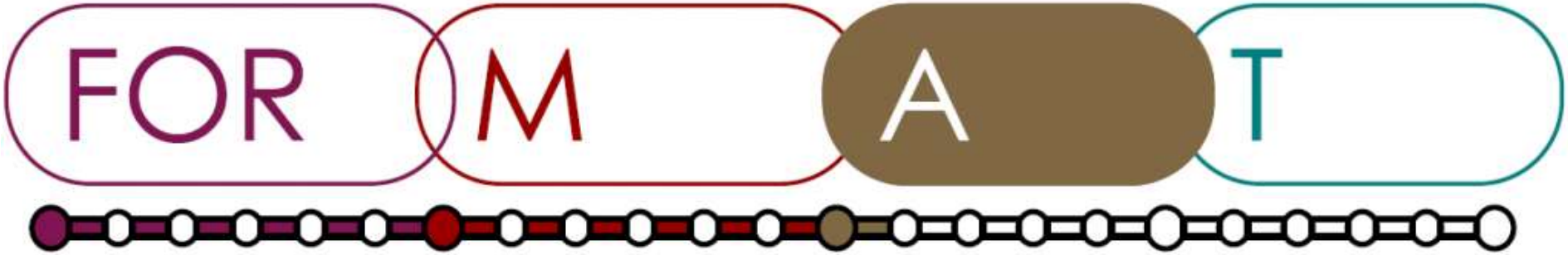
1. Extract limiting resources from problems of STF
   - What are the most critical problems?
   - Reformulate set of problems into contradictions
   - Identify limiting resources for problems set

Not compliant

DRIVERS

BARRIERS

LIMITING RESOURCES



From Gate M

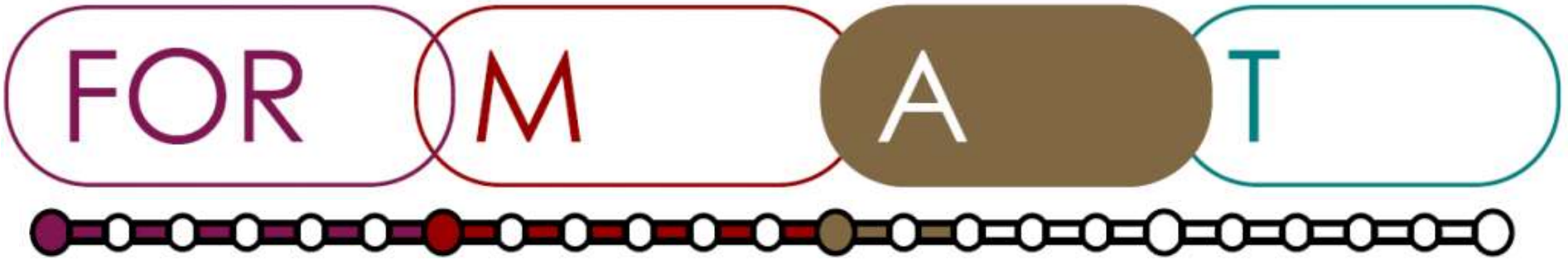
1. Extract limiting resources from problems of STF
   - What are the most critical problems?
   - Reformulate set of problems into contradictions
   - Identify limiting resources for problems set

Not compliant

DRIVERS
E.g., Autonomous driving

BARRIERS
E.g., GPS accuracy
…

LIMITING RESOURCES
Number of GPS satellites
…

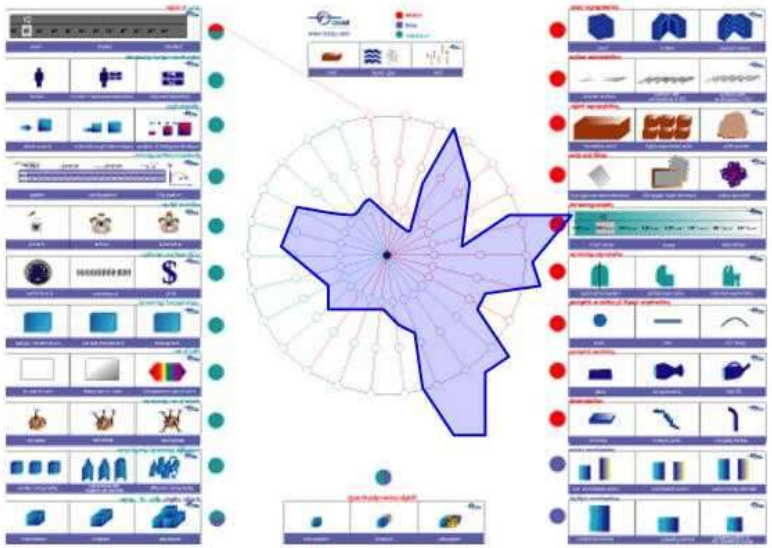


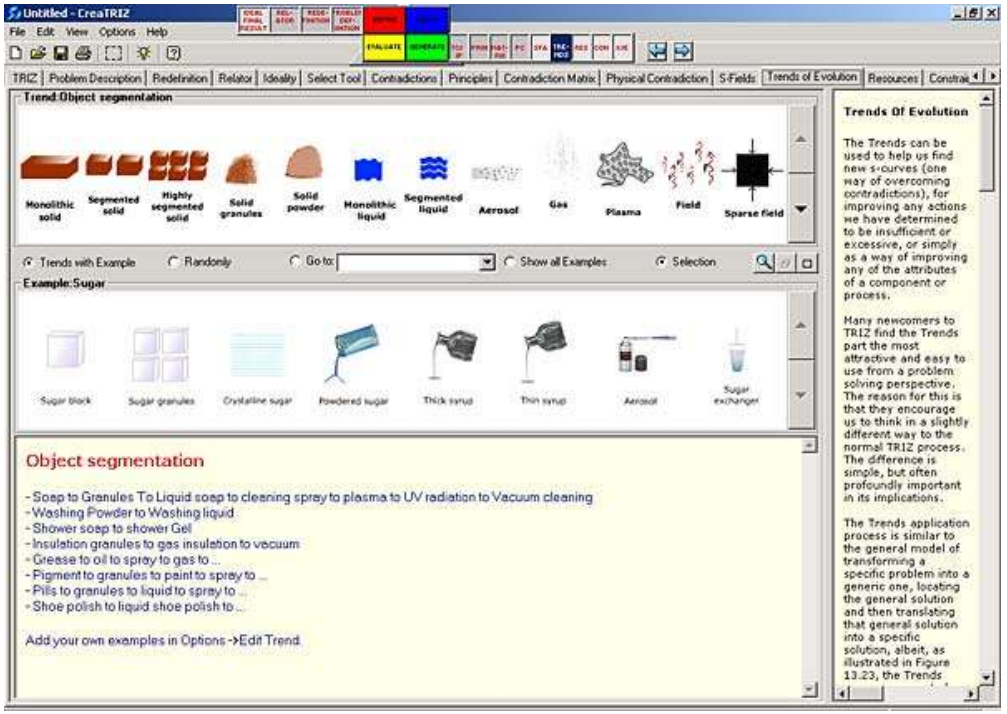
2. Define set of solutions addressing limiting resources
- Recognize relevant patterns
- Analogical reasoning for envisioning future with patterns of evolution
- Check coherence of the envisioned future with the available information about the context

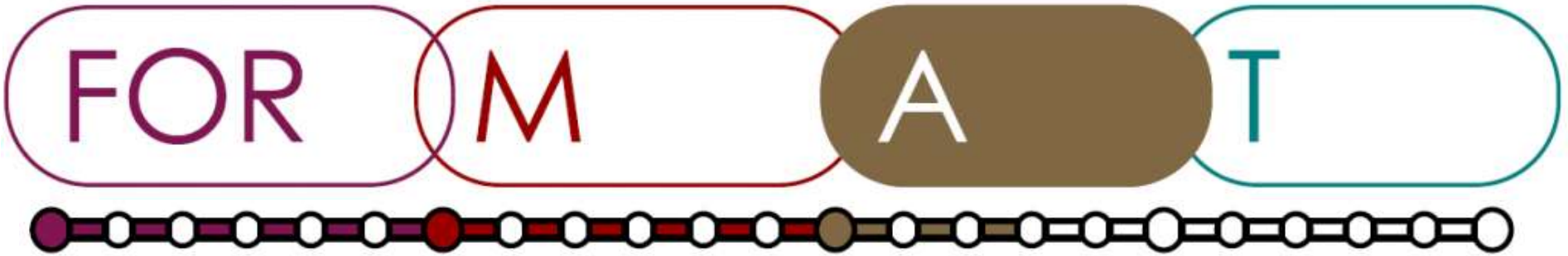
- ✓ **Identify the directions of technological development based on historical evolution of the STF**
- ✓ **Envision the characteristics of future solutions for the STF by analogy with trends of evolution**

FOR M A T

2. Define set of solutions addressing limiting resources
- Recognize relevant patterns
- Analogical reasoning for envisioning future with patterns of evolution
- Check coherence of the envisioned future with the available information about the context



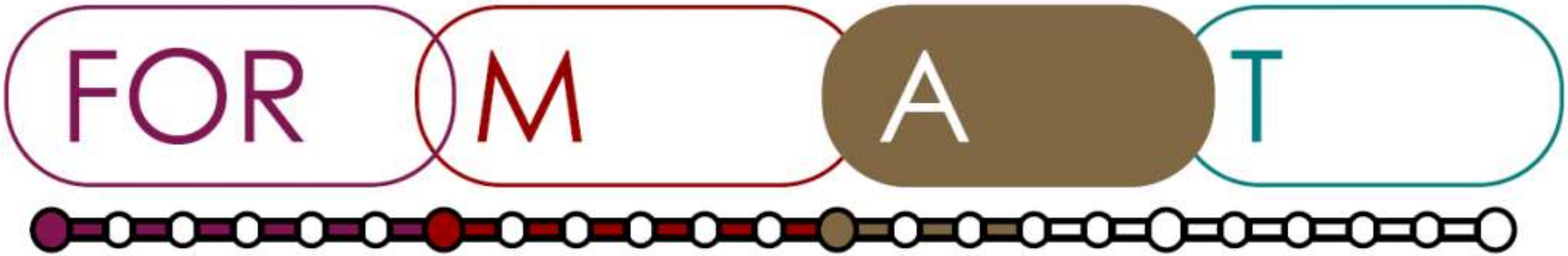




3. Fit data-series about parameters measuring performance & expenses

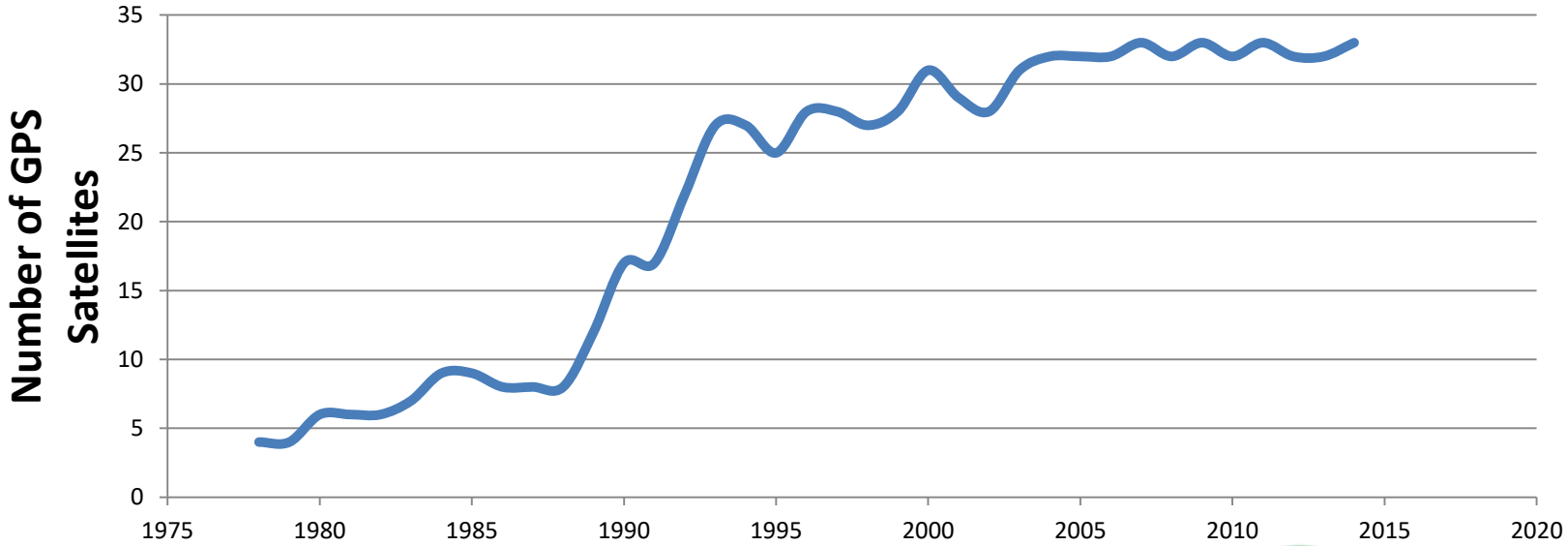
- Collect and clean the data series
- Fit S-curve
- Improve quality of fit

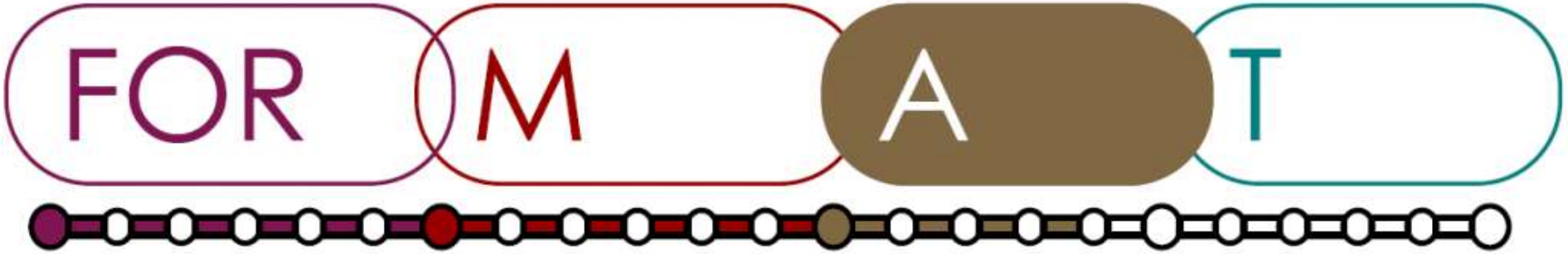
- ✓ **Identify by quantitative means how <u>technology-related parameters</u> have evolved in the last years**
- ✓ **Collect <u>time series</u>**
- ✓ **Forecast by <u>regression analysis</u> how the technology is going to continue its evolution in the next years**



3. Fit data-series about parameters measuring performance & expenses
- Collect and clean the data series
- Fit S-curve
- Improve quality of fit

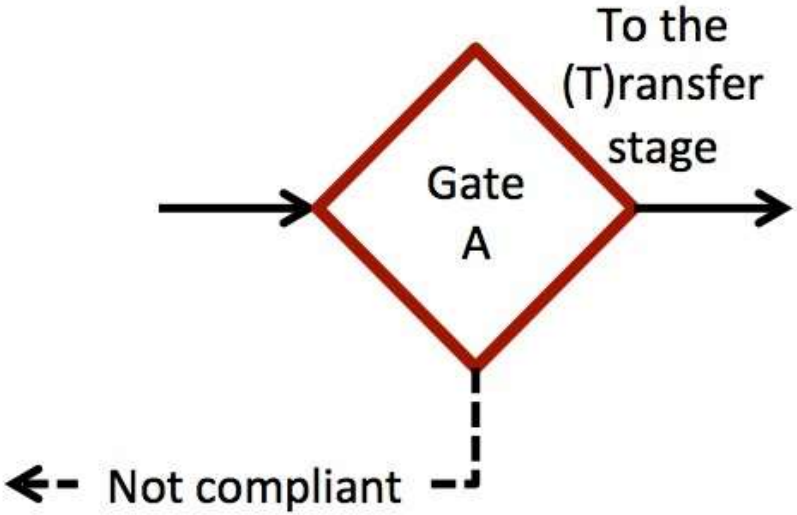
LIMITING RESOURCES
Number of GPS satellites





4. Build conclusions about future traits for STF
- To assess features of STF
- To group (chunk) features into main traits

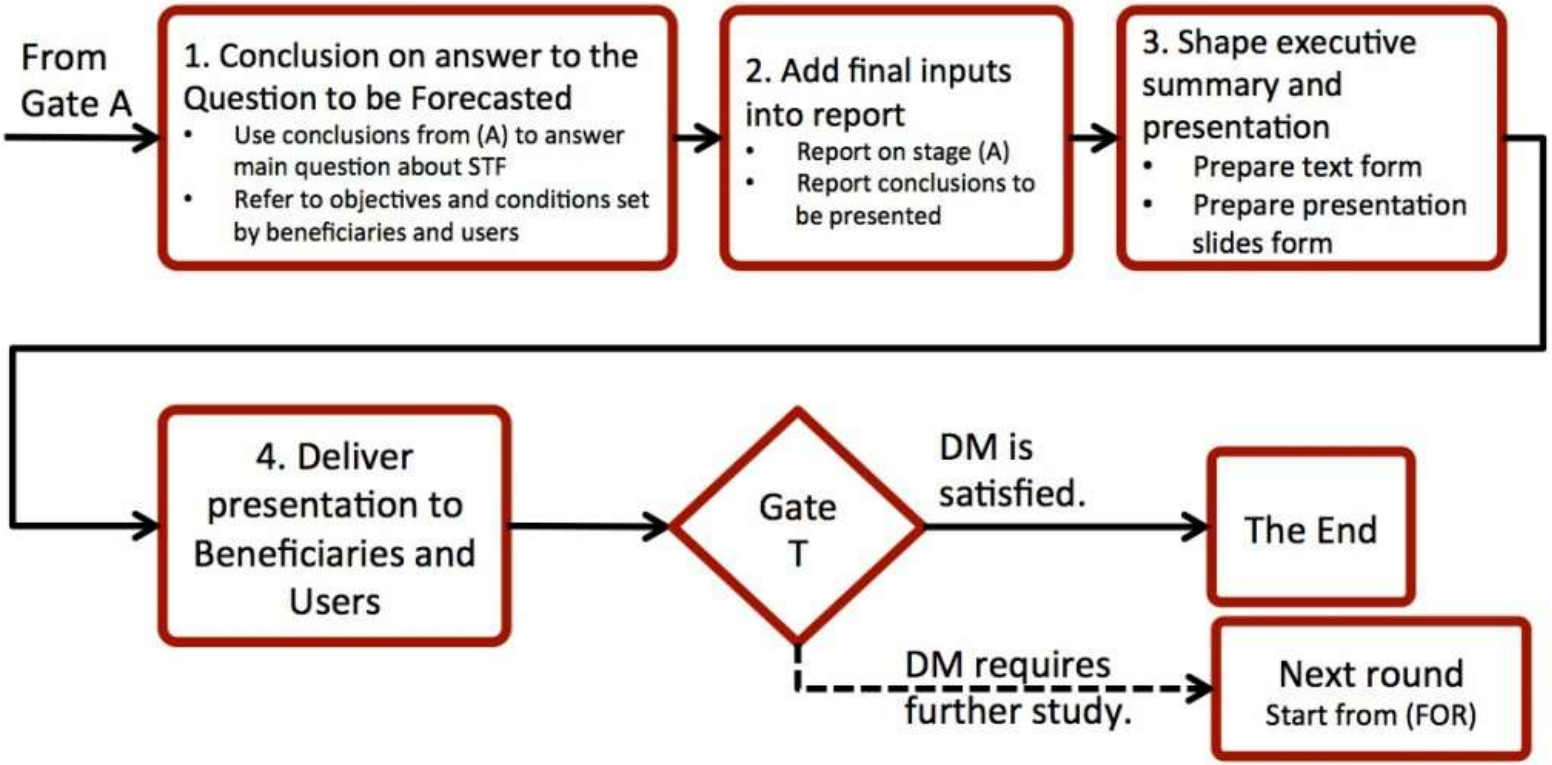
- ✓ **Combine the results of the previous steps**
- ✓ **Check consistency of the overlapping information**
- ✓ **Build a shared vision on the evolution of the STF**



- ✓ **Check completeness and consistency of the required information**

FOR M A T

Prepare report and present results (T)



FOR M A T

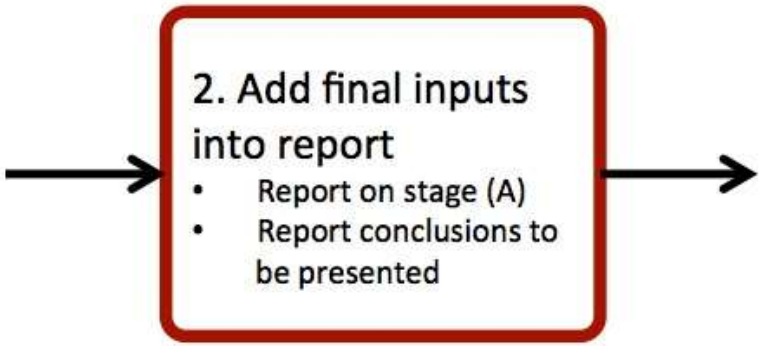
From Gate A

1. Conclusion on answer to the Question to be Forecasted

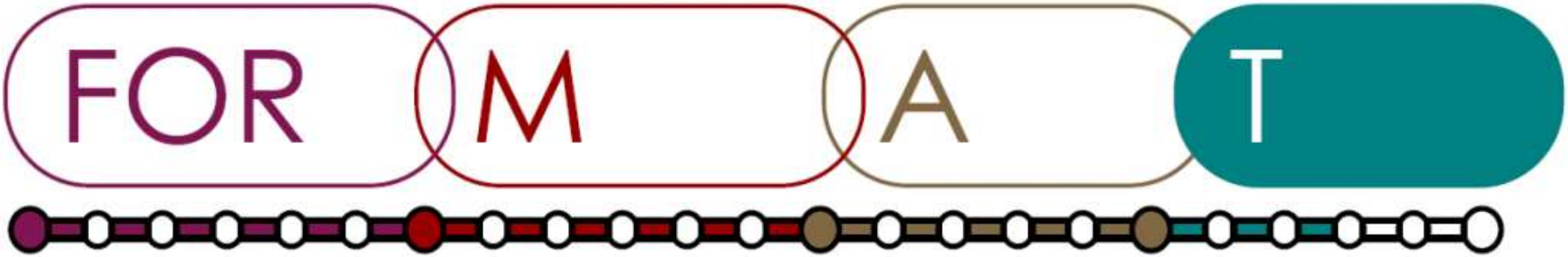
- Use conclusions from (A) to answer main question about STF
- Refer to objectives and conditions set by beneficiaries and users

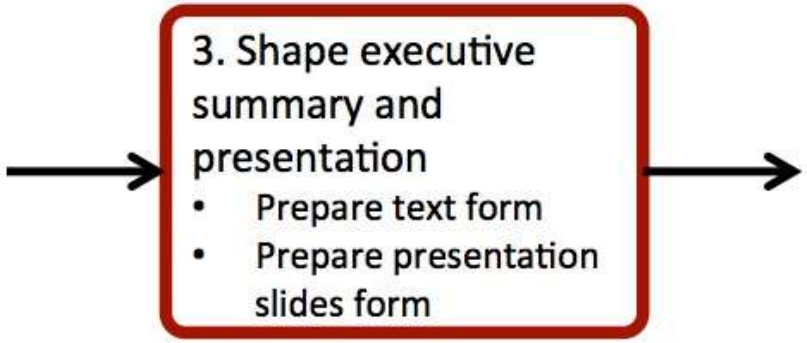
- ✓ **Use results from Stage A for <u>answering questions</u> defined at Stage FOR**
- ✓ **Check consistency of answers with <u>objectives</u> and conditions set by beneficiaries and users in Stage FOR**

FORMAT

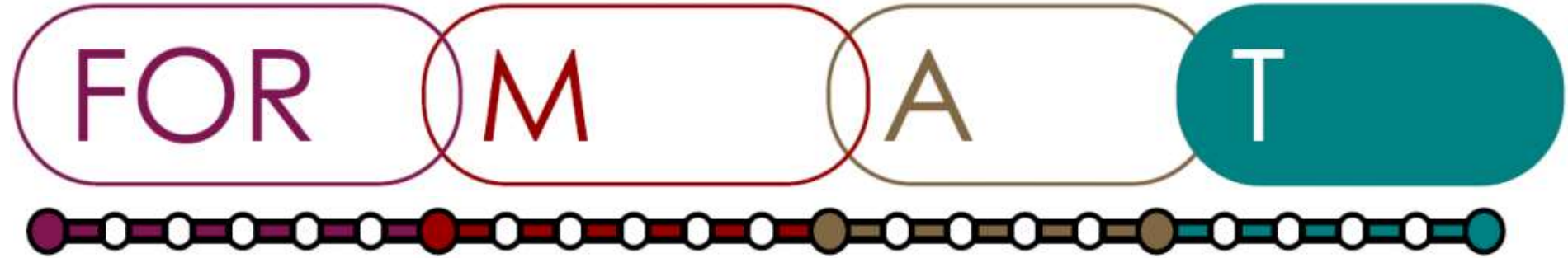


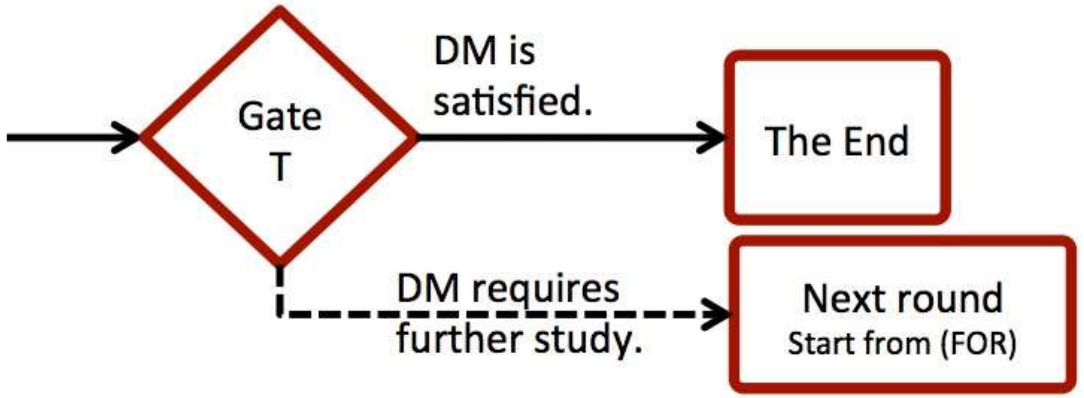
- ✓ **Combine the documents and materials collected in the previous stages and select the relevant pieces of information**
- ✓ **Complete the report of the TF project combining brevity with credibility**





- ✓ **Prepare the answers to the question for forecast and support the answers with <u>qualitative and quantitative arguments</u>**





- ✓ **Make decision about follow up of the TF project**

Case Studies


Il Laboratorio della Camera di Commercio di Treviso
Soggetti Partecipanti
Nominativi
ANODICA INDUSTRIES
aesthetic components
Giorgio Zanchetta
FMB
Renato Buziol
LUCCHESE INDUSTRIA
Mario Lucchese
METEOR
Tanja Colautti, Luca Nadal, Ivan Samogin
SAG Serigrafia
Silvia Stocco
POLITECNICO DI MILANO
mecc
Niccolò Becattini, Gaetano Cascini
12ª GIORNATA DELL'ECONOMIA
FORMAT
Il Laboratorio della Camera di Commercio di Treviso
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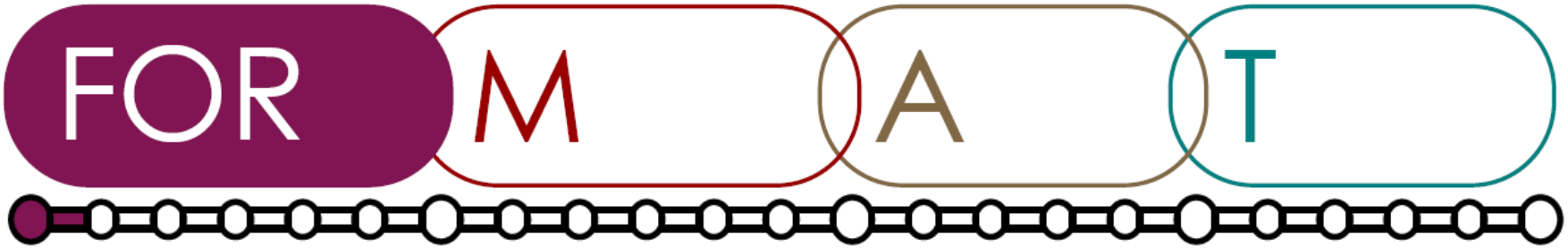
ANODICA INDUSTRIES
aesthetic components
Davide Staiano
FUTURA
Marco Dedin
LUCCHESE INDUSTRIA
Gabriele Gerometta
Mario Lucchese
SAG Serigrafia
Sandro Feltrin
POLITECNICO DI MILANO
Paolo Santi
mecc
Niccolò Becattini
Gaetano Cascini
FORMAT
12ª GIORNATA DELL'ECONOMIA
POLITECNICO DI MILANO

Case study:
Evolution of domestic ovens (some features)

Chamber of Commerce of Treviso

SMEs	Participants
ANODICA INDUSTRIES aesthetic components	Giorgio Zanchetta
FMB s.r.l.	Renato Buziol
LUCCHESE INDUSTRIA	Mario Lucchese
METEOR	Tanja Colautti, Luca Nadal, Ivan Samogin
SAC Serigrafia	Silvia Stocco
POLITECNICO DI MILANO mecc	Niccolò Becattini, Gaetano Cascini



WHY
do we need to know the future?

- Suggest R&D directions about competences and manufacturing technologies suitable for keep competitivity in the field of domestic ovens production

  Subsystems:
  - Aesthetical elements;
  - Automation devices (e.g. door lock, cleaning, actuators).

FORMAT

WHAT
do we need to know about the future?

- What is the expected evolution of high range domestic ovens with respect to:
  - Controllability/Programs
  - Cooking modes
  - Automation

  in Europe until 2025?
- What is the expected evolution of materials and finishing of hjigh range domestic ovens with a specific focus on
  - Visual aspect
  - Touch feeling
  - Interaction

  of surfcaces according to design trends in Europe until 2025?

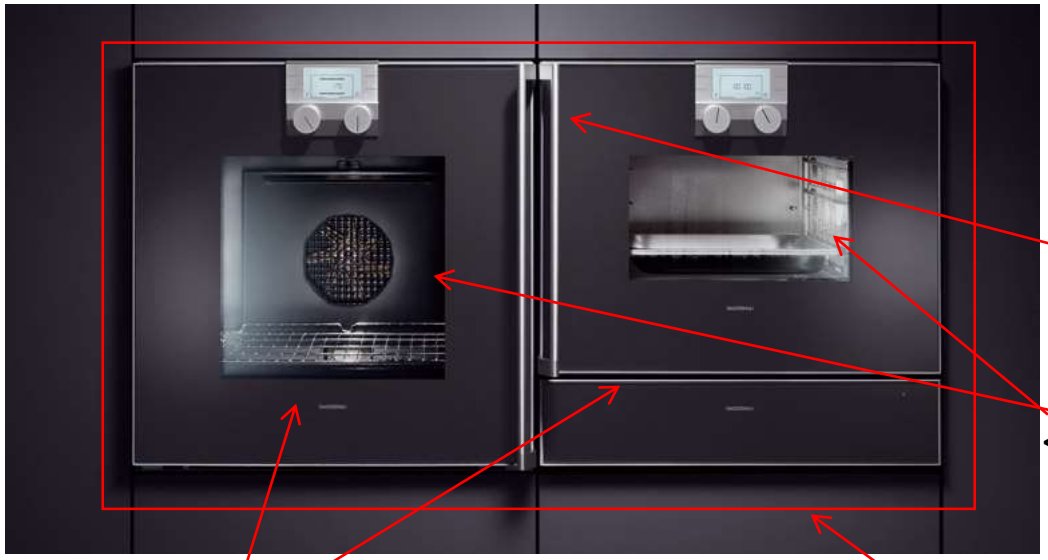
FOR M A T

HOW
do we plan to learn about future?

- (detailed schedule of meetings)
- (web meeting tool)
- Sources:
  - **Journal** and **Web**
    - Cose di casa
    - AE
    - Appliance
    - Ristorando
    - Master Chef
  - Clients and suppliers
    - SMEG
    - Electrolux Professional
    - Whirlpool
  - Associations and Organizations
    - ANIE
    - ENEA
    - Tourism School Castelfranco V.
    - Gheggin
    - ISTAT
  - Internal resources
    - Catalogues and notes from fairs
    - Market data collection

1st - WHAT
The STF is for? (WHY we need the STF?)
• Model of STF at the functional level

PRIMARY FUNCTION: <trasform> <food> <by heat>



STF = System to be Forecasted

AUXILIARY FUNCTION:
<aid><user> <handling>

<detach> <organic residuals>

<trasform> <food> <by heat>
<controllable on temperature, humidity, heat exchange mechanism, time and direction>

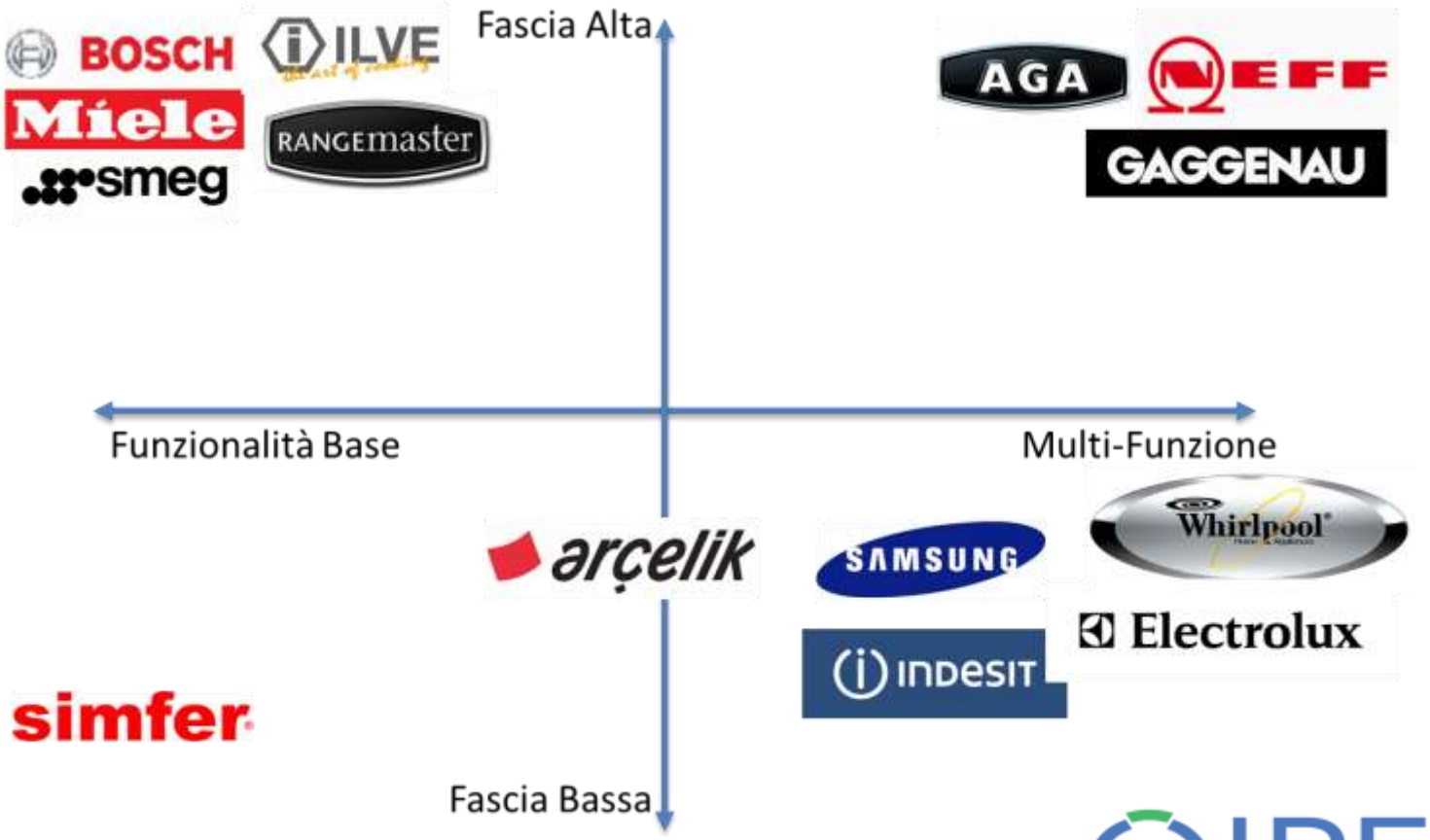
SECONDARY FUNCTION:
<trasmit> <to people in the environment> <feeling about wealth and cooking skills of the owner>

FOR M A T

1st - WHAT

The STF is for? (WHY we need the STF?)

- Model of STF at the functional level



2nd - WHICH

Systems allow to get the same results?

- Description of Competitive (Alternative) technologies (solutions)

Alternative technologies…

2nd - WHICH

Systems allow to get the same results?

- Description of Competitive (Alternative) technologies (solutions)

…don't seem to be about to take over the usage of the oven in the selected time span (2014-2025):

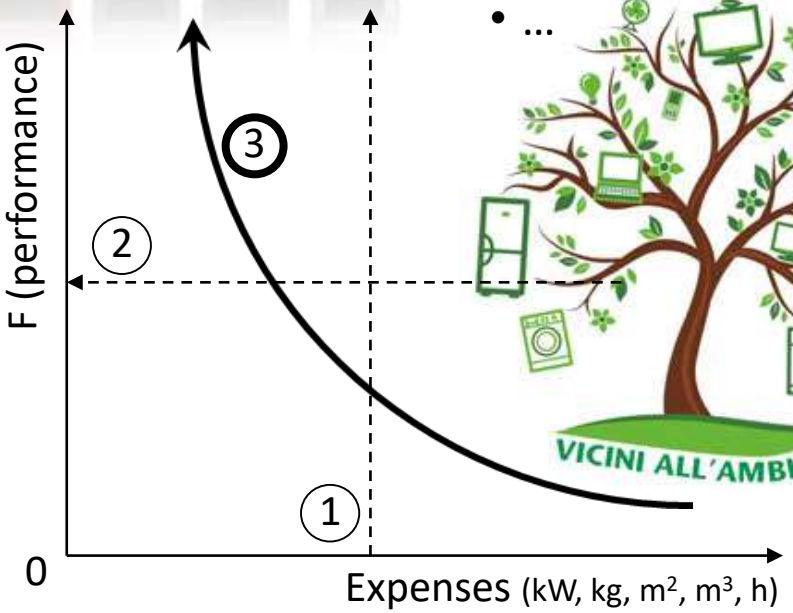
ANALISI COTTURE A FORNO		
RICETTARIO CUCCHIAIO D'ARGENTO		
	1986	**2009**
ANTIPASTI/PIZZA	145	195
COTTURA A FORNO	37	93
% COTTURA A FORNO	**25,5**	**47,7**
PRIMI PIATTI	220	287
COTTURA A FORNO	17	29
% COTTURA A FORNO	**7,7**	**10,1**
SECONDI PIATTI PESCE	257	224
COTTURA A FORNO	49	58
% COTTURA A FORNO	**19,1**	**25,9**
SECONDI PIATTI CARNE	483	406
COTTURA A FORNO	50	90
% COTTURA A FORNO	**10,4**	**22,2**
SECONDI PIATTI	740	630
COTTURA A FORNO	99	148
% COTTURA A FORNO	**13,4**	**23,5**
	14%	**24%**
% forno su TOTALE		

3rd - HOW

To measure the Performances and the Expenses of the STF and its alternatives?

- Expenses are not money but limiting resources: TIMES (time, information, materials, energy, space, knowledge)

- Temperature and humidity control
- Finishing variants (colours, texture, brilliance…)
- Functional surfaces (no fingerprint, self-cleaning, anti-bacteria…)
- …



- Energy consumption
- Recyclability of materials
- Time and efforts for cleaning…

5th – WHAT the STF and its main alternative(s) are, were and are expected to be?

Description for STF (and its main alternative?) with

- contexts=super-systems (TEES) and sub-systems
- past history & expected future
- present trends

SubSystem Future (2015-2025)

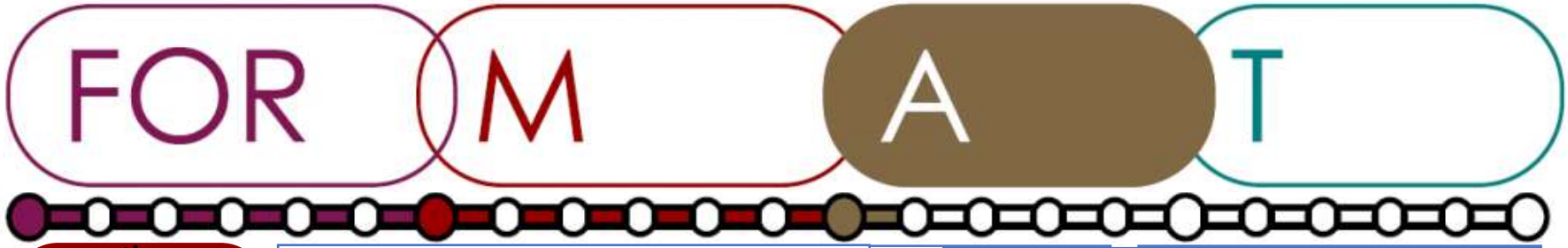
Flexibility of design, customizability

Functional glasses (display, digital interface)

Functional surfaces (selfcleaning, light emission …)

Automation

Energy recovery



5th – WHAT the STF and its main alternative(s) are, were and are expected to be?

Description for STF (and its main alternative?) with

- contexts=super-systems (TEES) and sub-systems
- past history & expected future
- present trends

Driver (1995-2015)

- **Customization** (aesthetics and functionalities)
- **Interaction** (with the user and other appliances)
- **Energy Efficiency**
- **Sustainability** of materials and production means
- **Usefulnes of innovation** (no gadget)
- **Professional use** of appliances and high level cooking performance
- **Higher value of the kitchen** with respect to other rooms of the house ✓
- Growing attention for **hygiene** and **health** issues ✓

tem

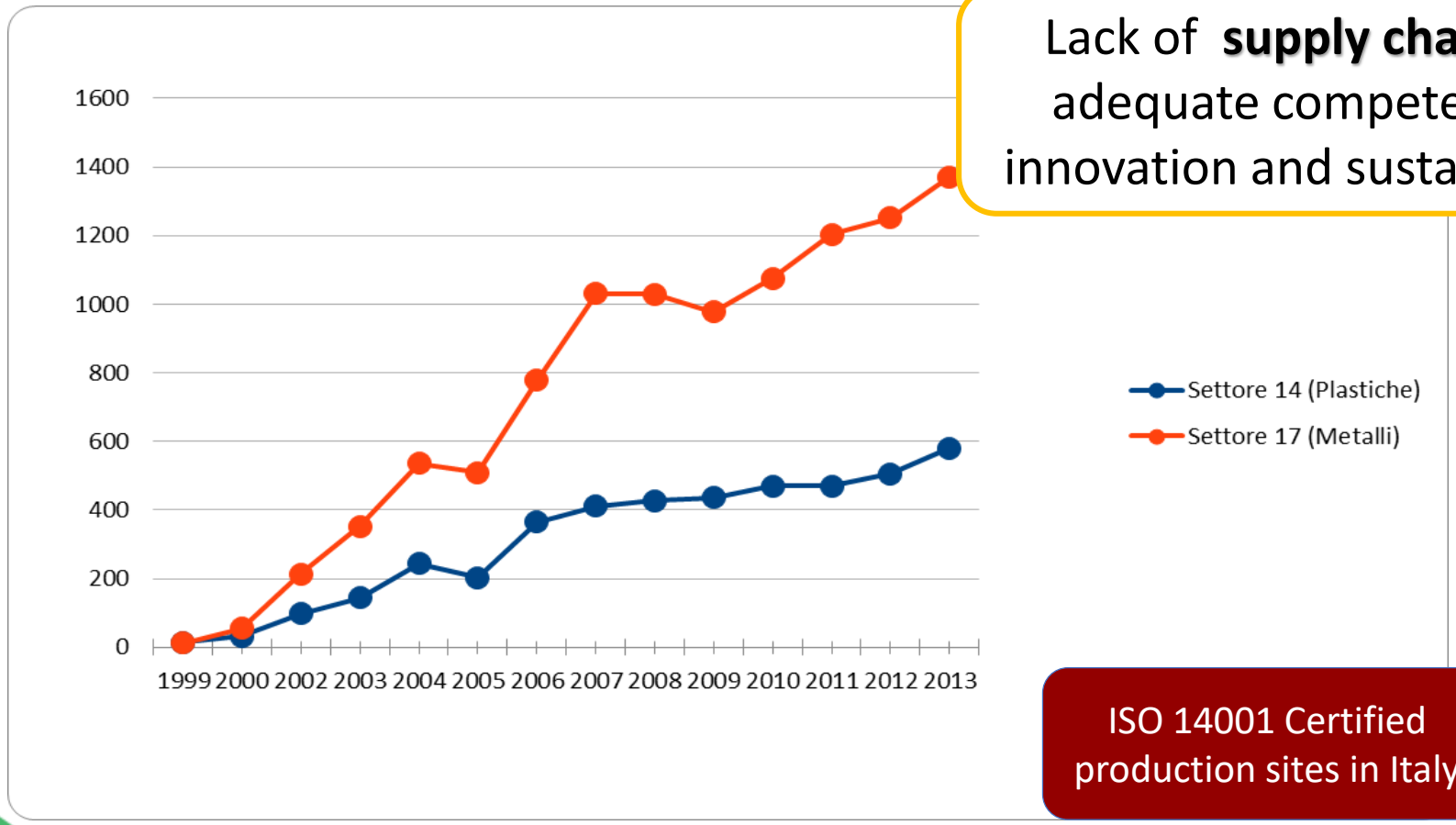
rese

m Pr

Barriers (1995-2015)

- Limited industrial availability of **eco-friendly materials** with adequate functionalities/performance
- Limited availability of low-cost **manufacturing technologies** for extensive mass-customization
- **Failure and Safety** issues
- **Lack of dominant standards** for communication protocols and for materials characterization
- Lack of **supply chains** with adequate competences on innovation and sustainability

FOR M A T



Lack of **supply chains** with adequate competences on innovation and sustainability

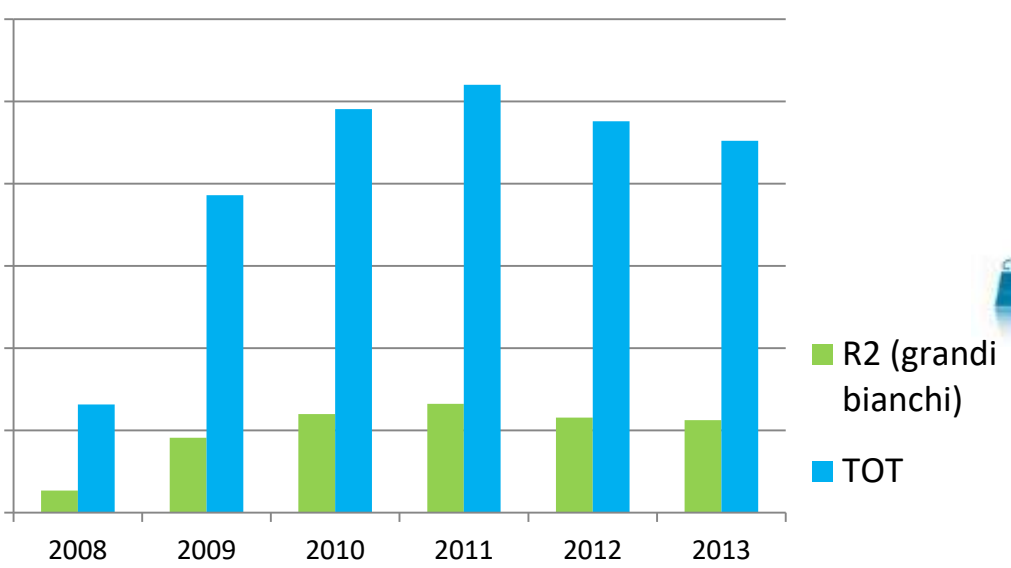
ISO 14001 Certified production sites in Italy

FOR M A T

Tabella 5
RIPARTIZIONE DEI RAEE PER RAGGRUPPAMENTO 2013/2011 (KG)

RAGGRUPPAMENTO	TOTALE 2013	TOTALE 2012	TOTALE 2011	VARIAZIONE 2013/12	VARIAZIONE 2013/11
R2 Grandi bianchi					
lavatrici, lavastoviglie, cappe, forni, ecc.	56.156.357	57.709.717	66.132.447	- 2,69%	-15,09%

Lack of **supply chains** with adequate competences on innovation and sustainability



FOR M A T

Limited industrial availability of **eco-friendly materials** with adequate functionalities/ performance

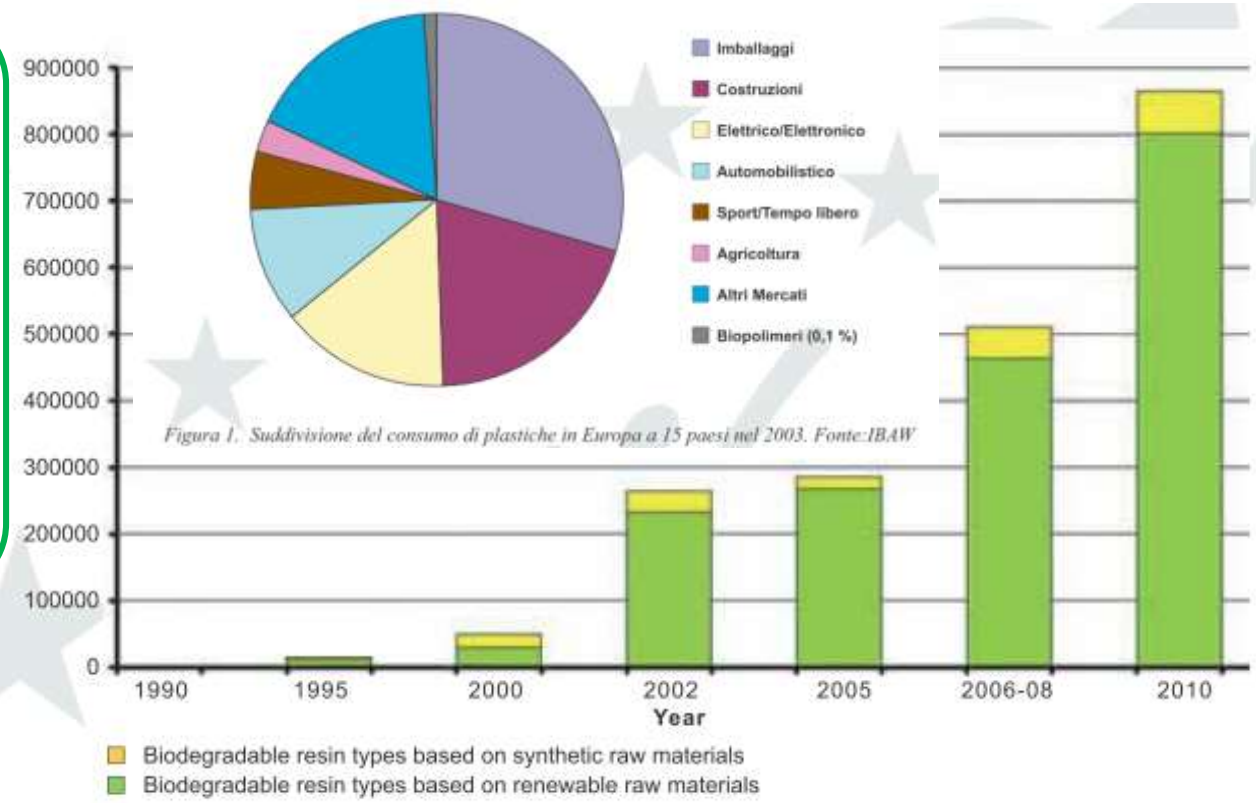
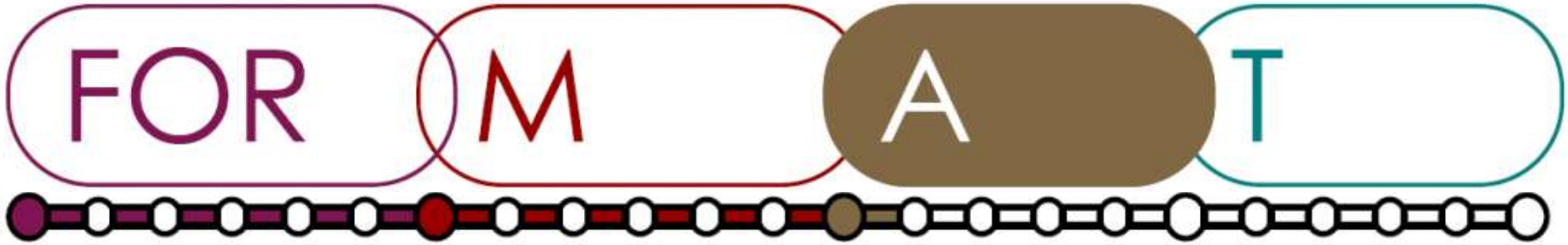


Figura 2. Evoluzione della capacità produttiva delle bioplastiche Fonte:IBAW



Customization (aesthetics and functionalities)

Electrolux - Rex

Anno	2008	2010	2011	2012	2013
	5	5	2	5	5
	4	4	1	4	4
	4	4	1	4	3

SMEG

Anno	2008	2010	2011	2013	2014
	6	7	9	8	8
	3	6	5	6	6
	1	3	3	6	6
	1	2	3	4	3

Colour variants in the catalogue

Bosch

2009	2010	2011	2012	2013	2014
inox	inox	inox	inox	inox	inox

Siemens

2008	2010	2011	2012	2013	2014
inox	inox	inox	inox	inox	inox

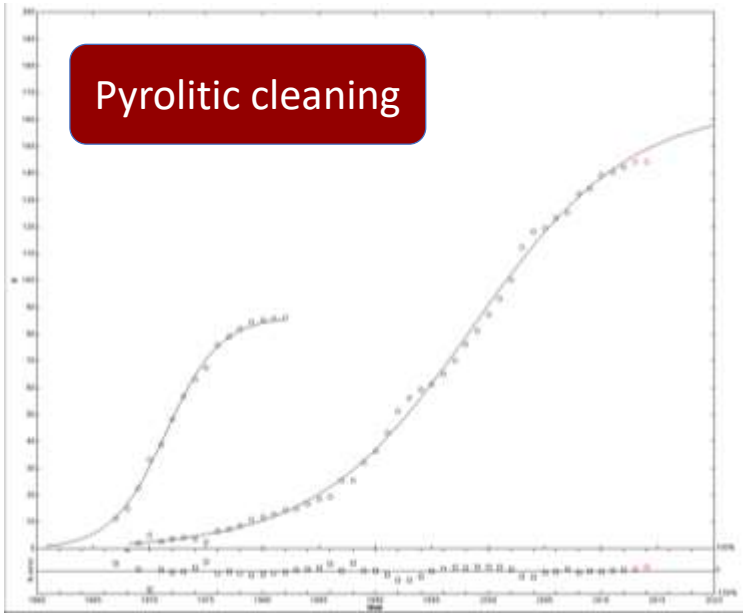
FUNZIONI	2008	2009	2010	2011	2012	2013	2014
	10	13	18	18	19	21	23

Define set of solutions addressing limiting resources

- Recognize relevant patterns
- Analogical reasoning for envisioning future with patterns of evolution
- Check coherence of the envisioned future with the available information about the context

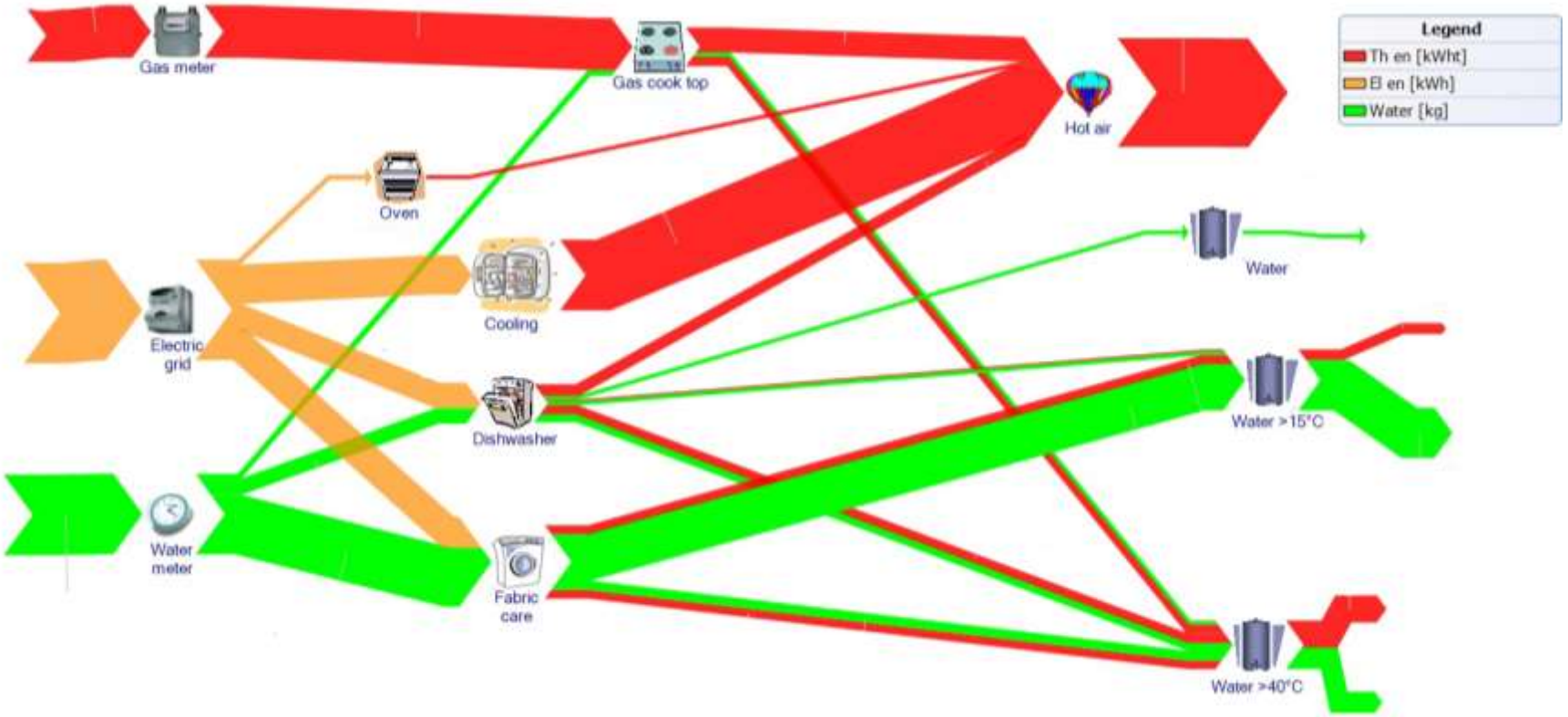
FUNZIONI	2008	2009	2010	2011	2012	2013	2014
Parete posteriore con Ecolyse	x						
Pulizia Ecolyse per tutte le pareti		x	x				
Pulizia Ecoclean per tutte le pareti			x	xx	xx	xx	
Pulizia Ecoclean per tutte le pareti e fondo del forno							x
Autopulizia pirolitica	x	xx	xx	xx	xx	xx	xx
Vapour Clean						x	x
Estetica antimpronta						x	x

Legenda: Bosch Siemens Smeg



FOR M A T

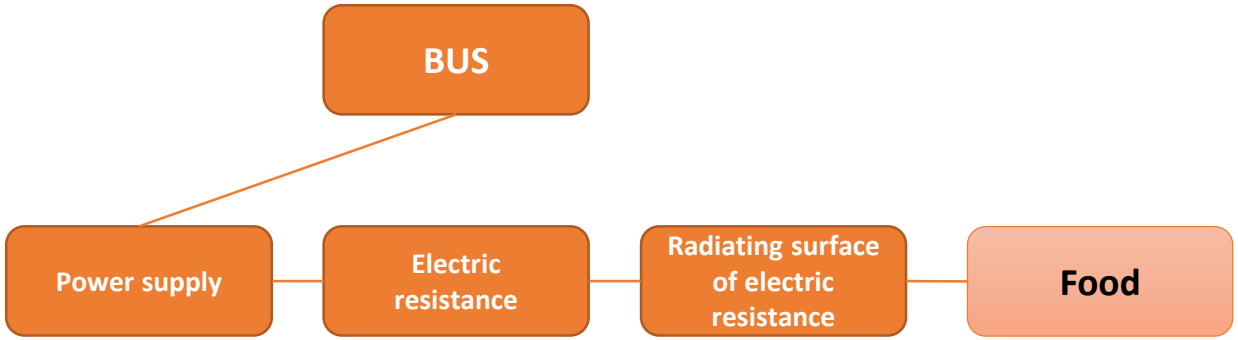
Energy efficiency



Define set of solutions addressing limiting resources

- Recognize relevant patterns
- Analogical reasoning for envisioning future with patterns of evolution
- Check coherence of the envisioned future with the available information about the context

- <trasform> <food> <by heat> <controllable on temperature, humidity, heat exchange mechanism, time and direction>

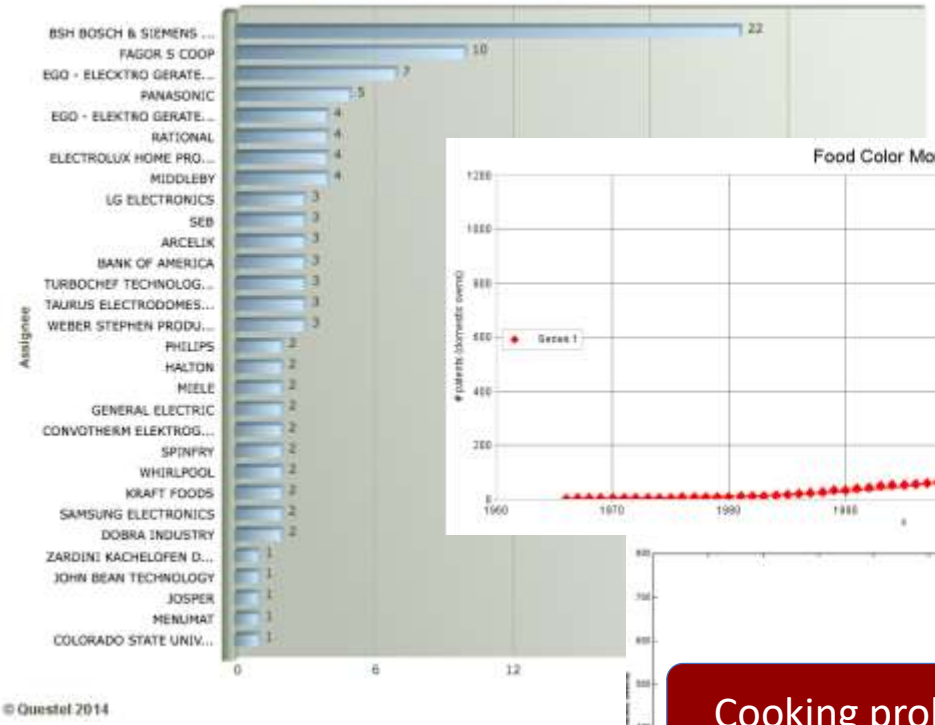


➢ Check (e.g. on patents) trends of food preparation control

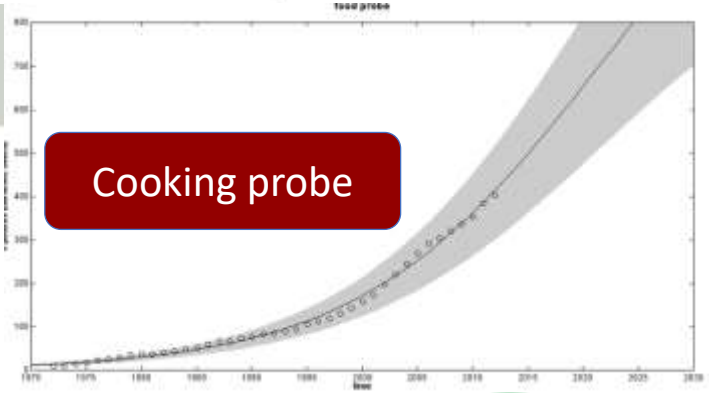
FOR M A T

Define set of solutions addressing limiting resources

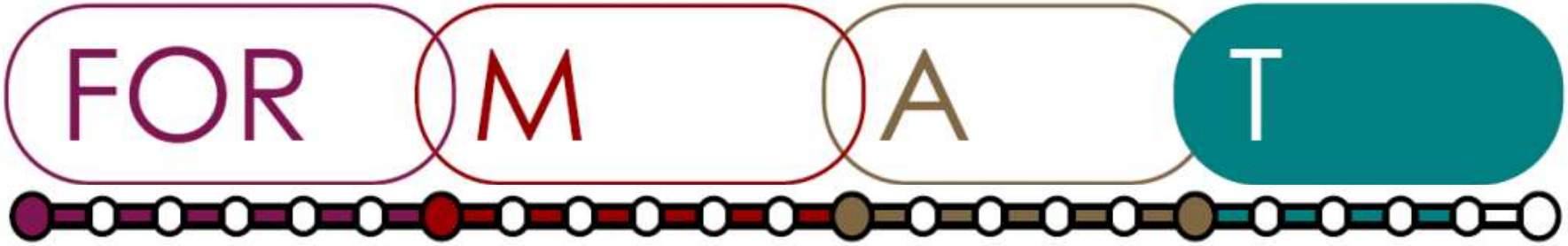
- Recognize relevant patterns
- Analogical reasoning for envisioning future with patterns of evolution
- Check coherence of the envisioned future with the available information about the context



Food colour monitoring



Cooking probe

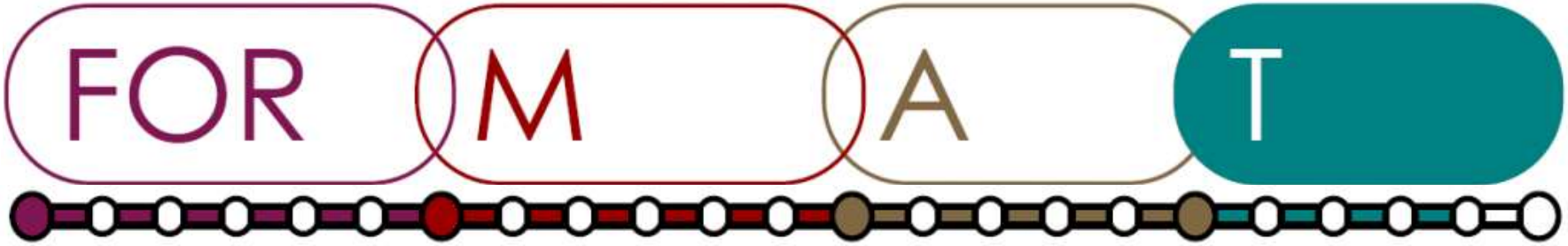


Build conclusions about future traits for STF

- To asses features of STF
- To group (chunk) features into main traits

Aggregated conclusions on the evolution of domestic ovens (2014-2025)

1. About the usage of domestic ovens
2. «Green» supply chains
3. Bio-plastics
4. Colour customization
5. Energy consumption
6. Cost of components for automation
7. Auxiliary functions
8. Cleaning systems
9. Professional cooking
10. Other aspects to keep monitored

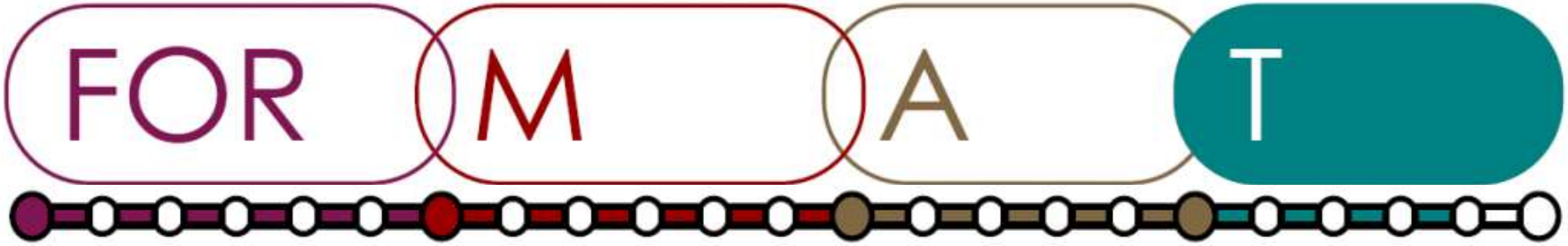


Build conclusions about future traits for STF

- To asses features of STF
- To group (chunk) features into main traits

Aggregated conclusions on the evolution of domestic ovens (2014-2025) (2/10)

- The development of supply chains with adequate competences on eco-innovation is growing linearly (more on metals than on plastics) ➔ the barrier for the joint development of green solutions will remain

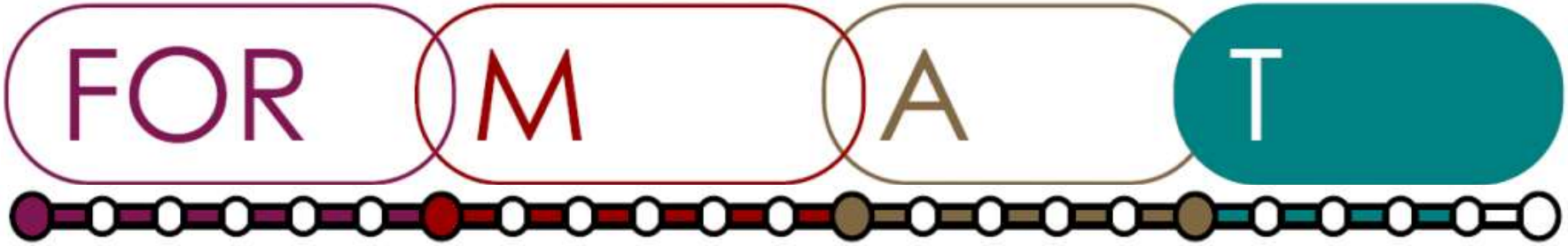


Build conclusions about future traits for STF

- To asses features of STF
- To group (chunk) features into main traits

Aggregated conclusions on the evolution of domestic ovens (2014-2025) (3/10)

- The use of bio-polymers is growing, but its extensive adoption in the field of domestic ovens is not expected in the time span of study

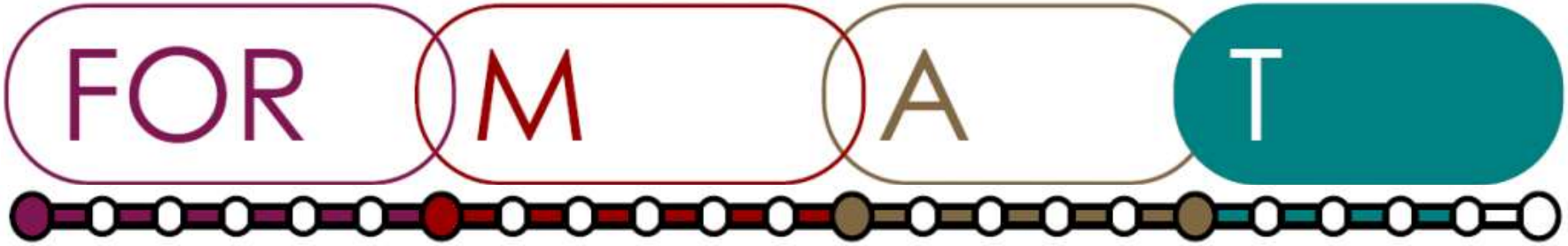


Build conclusions about future traits for STF

- To asses features of STF
- To group (chunk) features into main traits

Aggregated conclusions on the evolution of domestic ovens (2014-2025) (8/10)

- Pyrolitic ovens have reached a technical maturity, no further significant improvements are expected
- Vapour cleaning is about to start an exponential growth of performance



Build conclusions about future traits for STF

- To asses features of STF
- To group (chunk) features into main traits

Aggregated conclusions on the evolution of domestic ovens (2014-2025) (9/10)

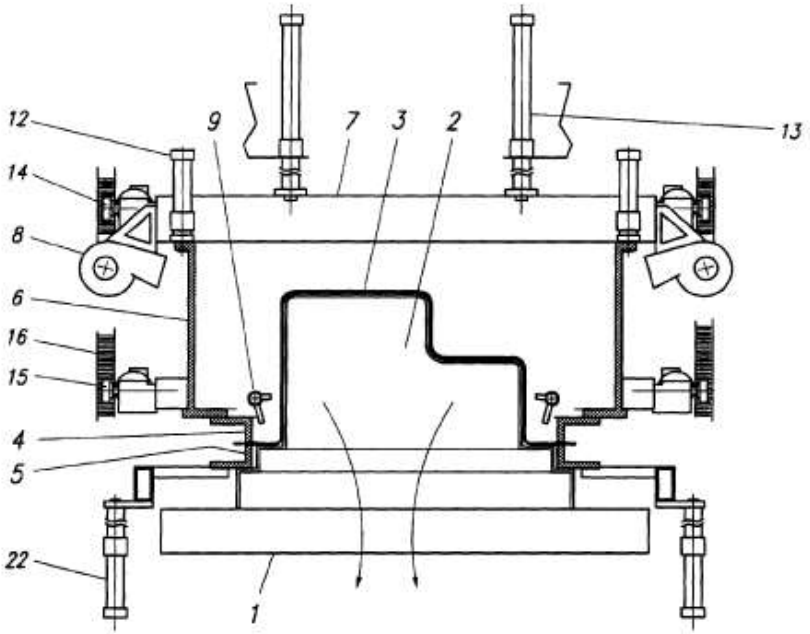
- The introduction of “professional” features in domestic ovens will go ahead:
  - Cooking probes and colour monitoring
  - New ways of cooking: with vapour, sous-vide (under vacuum)

Il Laboratorio della Camera di Commercio di Treviso

Lessons learned (by SMEs)

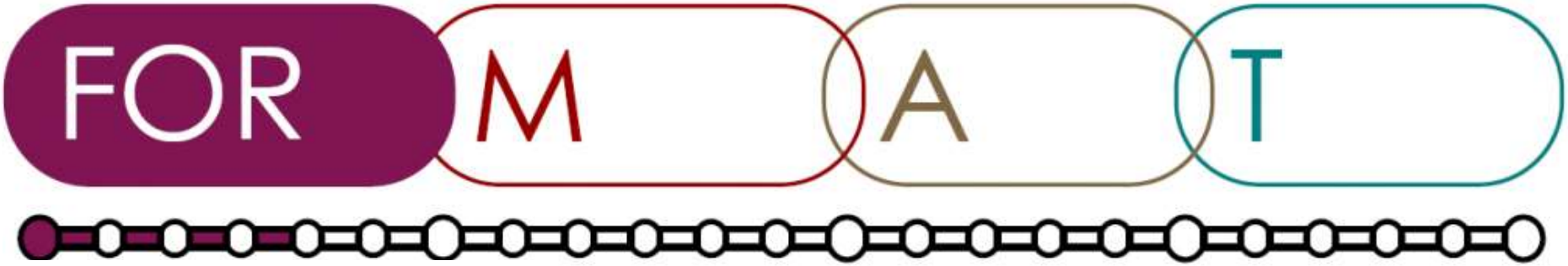
- Initial skepticism, growing enthusiasm within the process, great satisfaction in the end
- Opportunity to combine in an effective way the complementary competences of different partners
- A method to add “numbers” to entrepreneurs' intuition; a method to filter emotions and allows to manage the conflicting visions of the participants
- Initial time investment is necessary
- The same study should be repeated every 1-2 years to keep monitoring the evolution in the field

Case study:
Vacuum forming in domestic refrigeration industry



Vacuum Forming

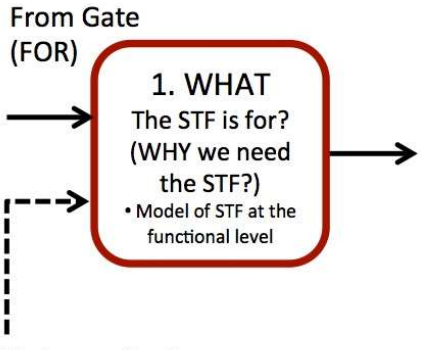
From Patent EP 0 947 307



4. WHAT
do we need to know about the future?
- System to be forecasted (STF)
- Time horizon
- Market scope and geographic context

What will be the evolution of Main Parameters of polymers forming technologies in 10-20 years, (2013-2033) for Whirlpool Refrigerators* in Whirlpool factories in EMEA?

a) Will vacuum forming technologies be needed in 10 years, (2013- 2023) for Whirlpool Refrigerators* in Whirlpool factories in EMEA? (Yes/No)
b) What will be the most suitable polymer forming technologies in 10 years, (2013-2023) for Whirlpool Refrigerators* in Whirlpool factories in EMEA?
*excluding chest freezers; EMEA - Europe, Middle East, Africa

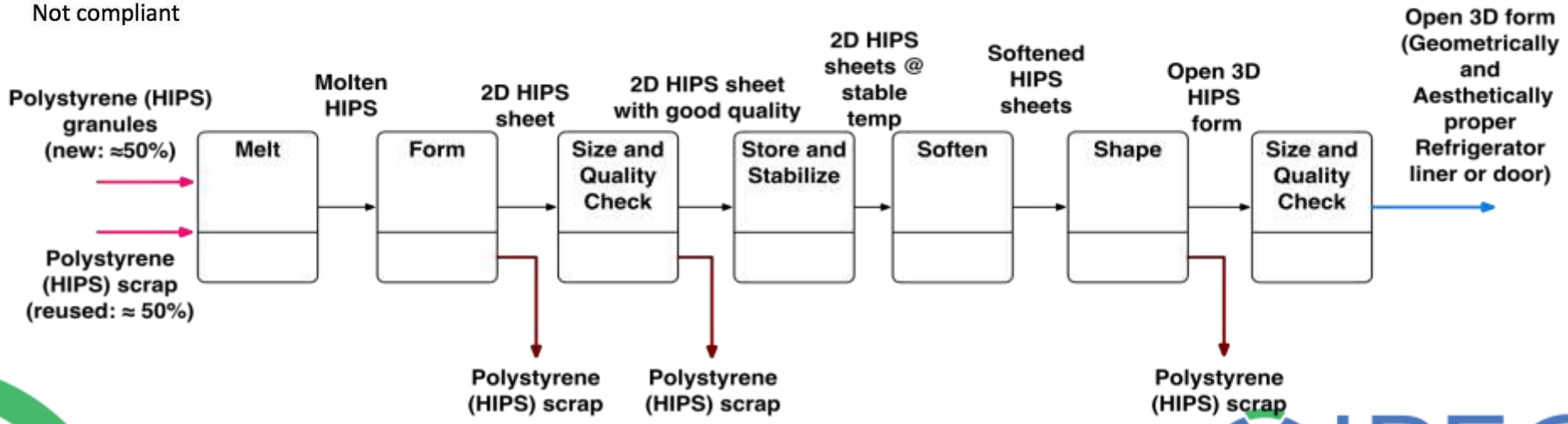


Main function of process:

<to make>

<open polymer 3D-form (box-form)>

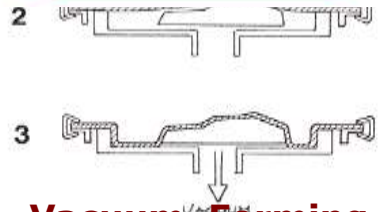
<from granules



FOR M A T

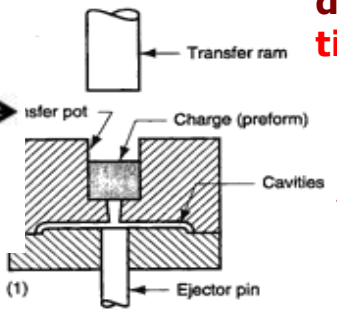
2. WHICH
Systems allow to get the same results?
• Description of Competitive (Alternative) technologies (solutions)

Description of Competitive (Alternative) technologies



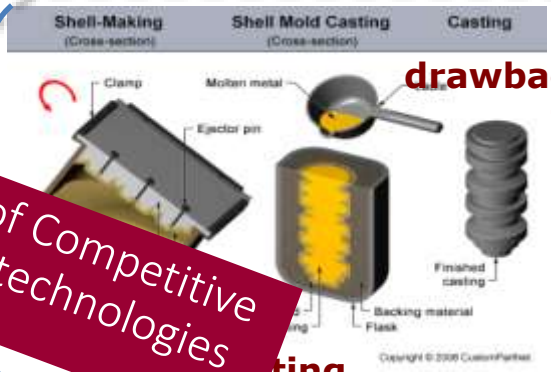
Vacuum Forming

drawbacks : time



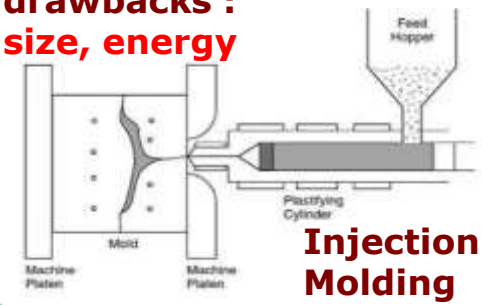
Transfer Molding

drawbacks : time



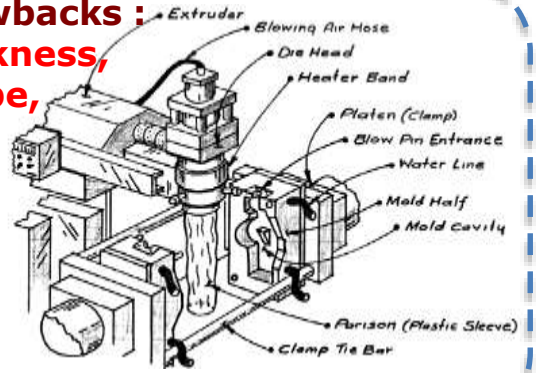
ting

drawbacks : size, energy



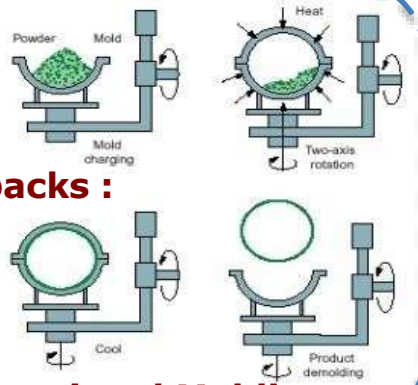
Injection Molding

drawbacks : thickness, shape, size



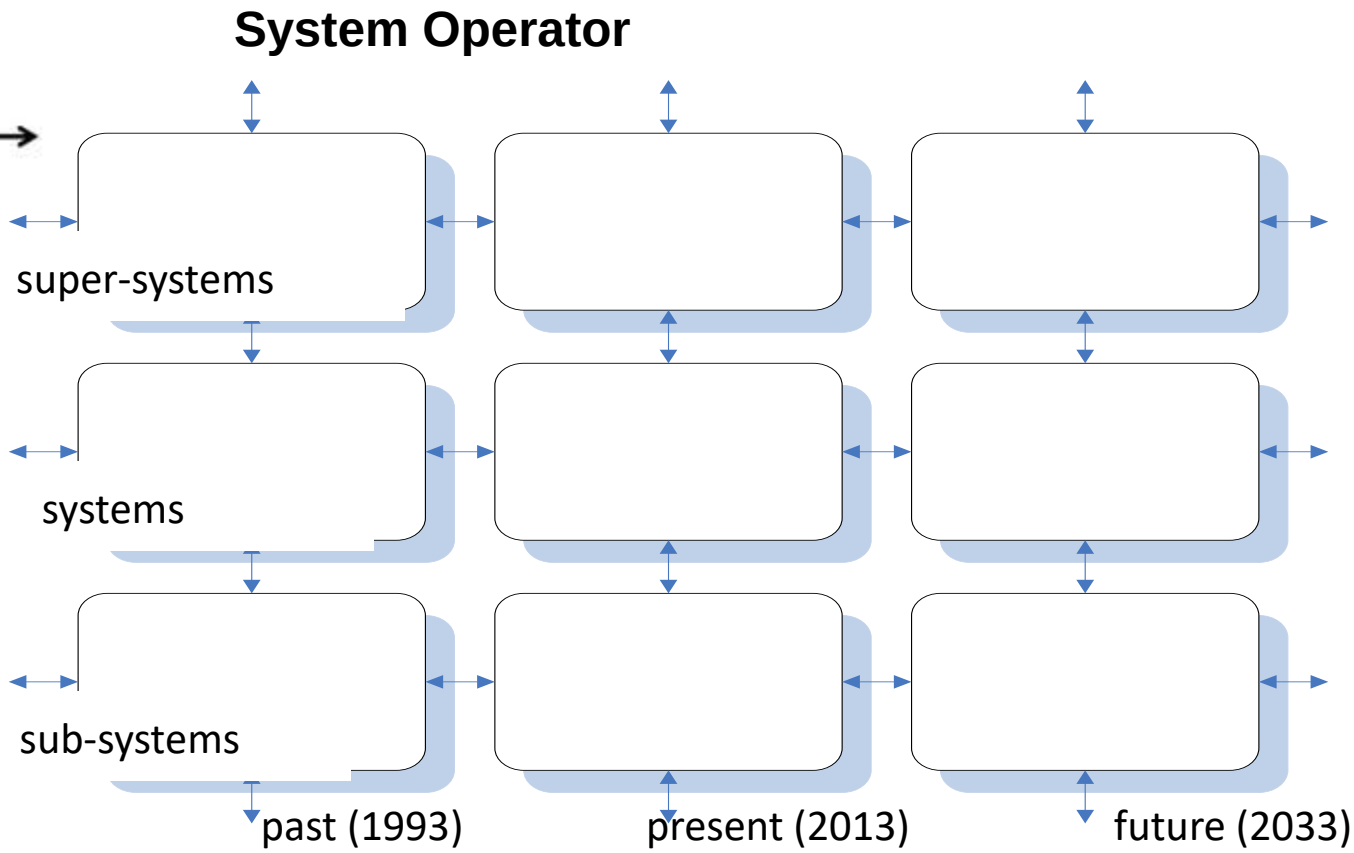
Blow Molding

drawbacks : Size, time



Rotational Molding

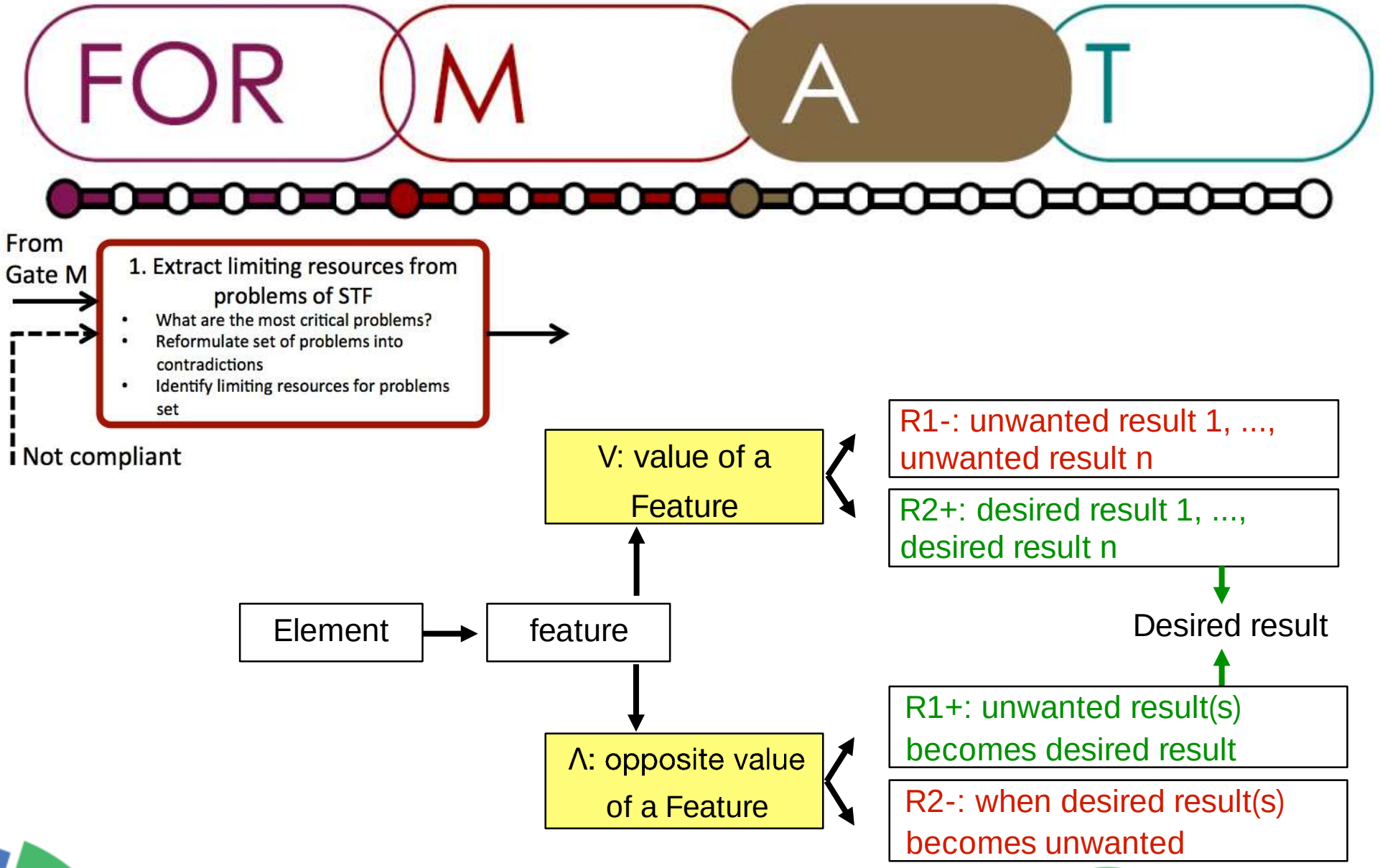
5. WHAT
the STF and its main alternative (s) are, were and are expected to be?
Description for STF (and its main alternative) with
- contexts=super-systems (TEES) and sub-systems
- past history & expected future
- present trends



FOR M A T

Technology		Environment	
Drivers	Barriers	Drivers	Barriers
Cycle time of forming	Non-reactive with food	Separation of foam from inner liner	Polystyrene is based on petrochemical
Development of CAD/CAM tools …	Anti-bacterial properties …	Easy separation of parts after disposal …	Foaming agent safe for ozone layer …

Social		Economy	
Drivers	Barriers	Drivers	Barriers
Access for cleaning	Height size (a standard person height)	Low energy consumption of MP	Initial investment in equipment
Longer food preservation (e.g.: under energy blackouts)	Depth size (standard kitchen furniture design)	Environmental taxes	Initial investment in tools
…	…	…	…

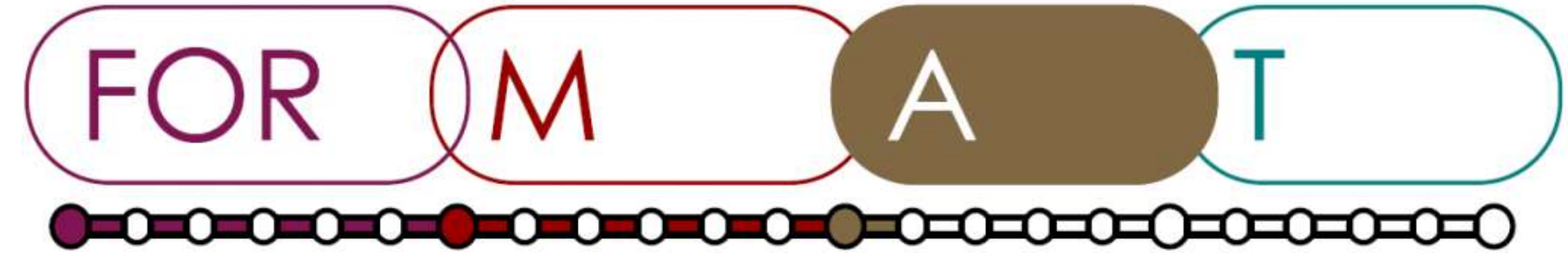

FOR M A T
From Gate M
1. Extract limiting resources from problems of STF
• What are the most critical problems?
• Reformulate set of problems into contradictions
• Identify limiting resources for problems set
Not compliant
V: value of a Feature
R1-: unwanted result 1, ..., unwanted result n
R2+: desired result 1, ..., desired result n
Element
feature
Desired result
Λ: opposite value of a Feature
R1+: unwanted result(s) becomes desired result
R2-: when desired result(s) becomes unwanted

FOR M A T

From Gate M

1. Extract limiting resources from problems of STF
   - What are the most critical problems?
   - Reformulate set of problems into contradictions
   - Identify limiting resources for problems set

Not compliant



From Gate M

1. Extract limiting resources from problems of STF
   - What are the most critical problems?
   - Reformulate set of problems into contradictions
   - Identify limiting resources for problems set

Not compliant

#4: Long time and large space to stabilize temperature in sheet

2D sheet in the pallet → Temperature profile

Temperature profile → V: equal to ambient

- R1-:
  - long stock time (3 days),
  - big space for 2D sheet stock,
  - high immobilized capital (WIP)
- R2+:
  - no scrap (3D open shape),
  - No human intervention (for heater power receipt adjustment in thermoforming process)

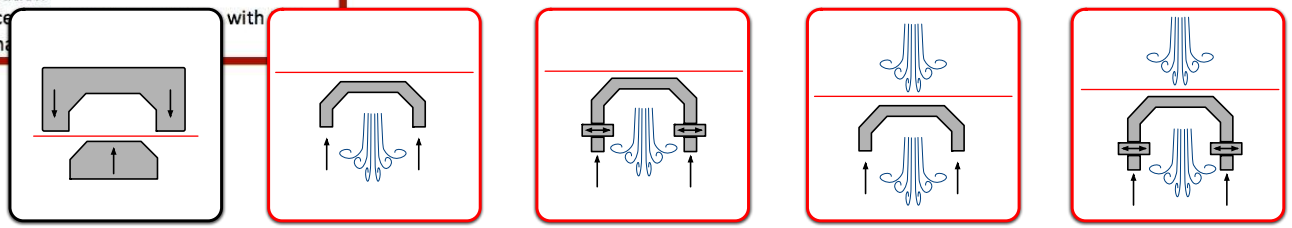
Desired result

Temperature profile → Λ: not equal to ambient

- R1+:
  - short stock time,
  - no big space for 2D sheet stock,
  - lower immobilized capital (WIP)
- R2-:
  - scrap (3D open shape),
  - Human intervention (for temp. receipt adjustment in thermoforming process)

2. Define set of solutions addressing limiting resources
- Recognize relevant patterns
- Analogical reasoning for envisioning future with patterns of evolution
- Check coherence with available informa

Recognize relevant patterns in technology evolution



1953 | 2003 | 200x | 200x | 2012

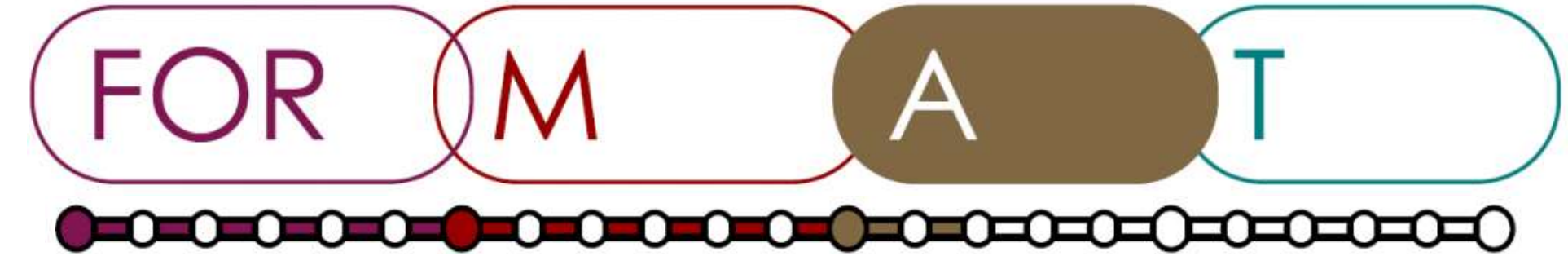
Year (Forming in Vacuum Forming)

Introduction of
- more degrees of freedom for the mold (Dynamization)
- blown air so as to increase the Δp (Su-Field interaction)

Substitution of one mold with air (Su-Field interaction + Macro to Micro)

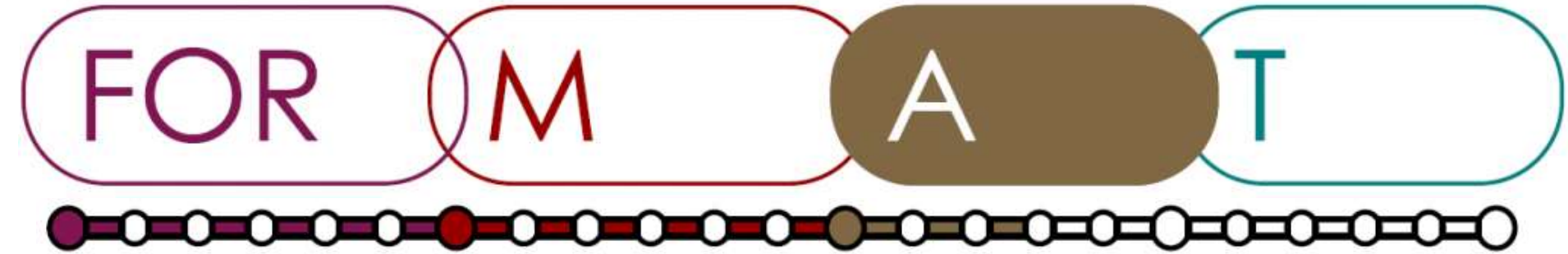
Introduction of more degrees of freedom for the mold (Dynamization)

Introduction of blown air so as to increase the Δp (Su-Field interaction)



2. Define set of solutions addressing limiting resources
- Recognize relevant patterns
- Analogical reasoning for envisioning future with patterns of evolution
- Check coherence of the envisioned future with the available information about the context

Recognize relevant patterns in technology evolution



3. Fit data-series about parameters measuring performance & expenses

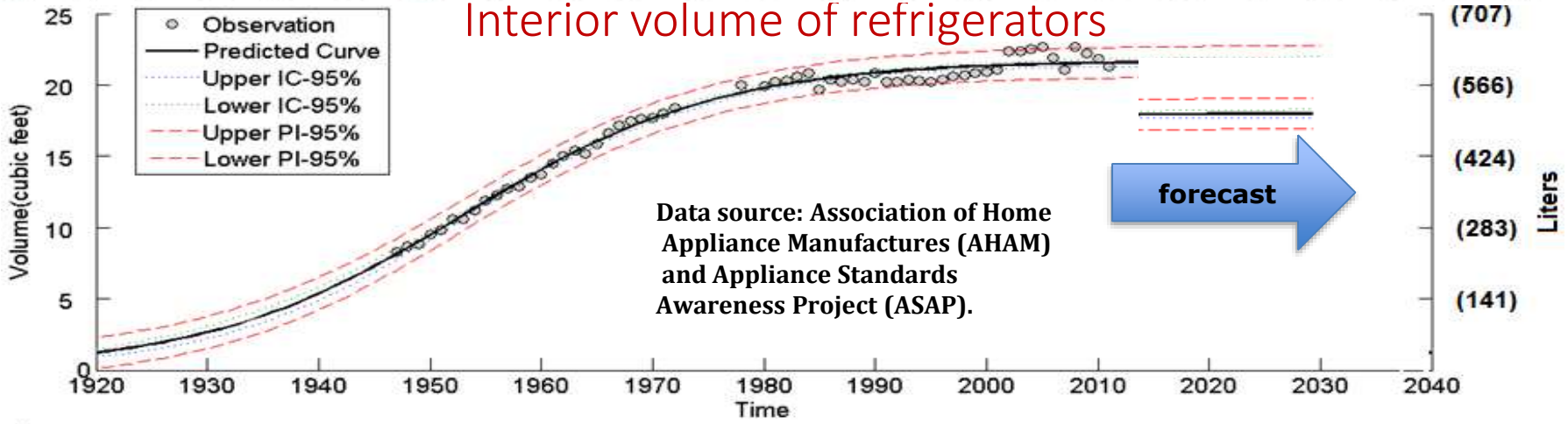
- Collect and clean the data series
- Fit S-curve
- Improve quality of fit

Example data:

- ✓ Market volumes
- ✓ Cumulative use of resources (e.g. energy sources, rare materials etc.)

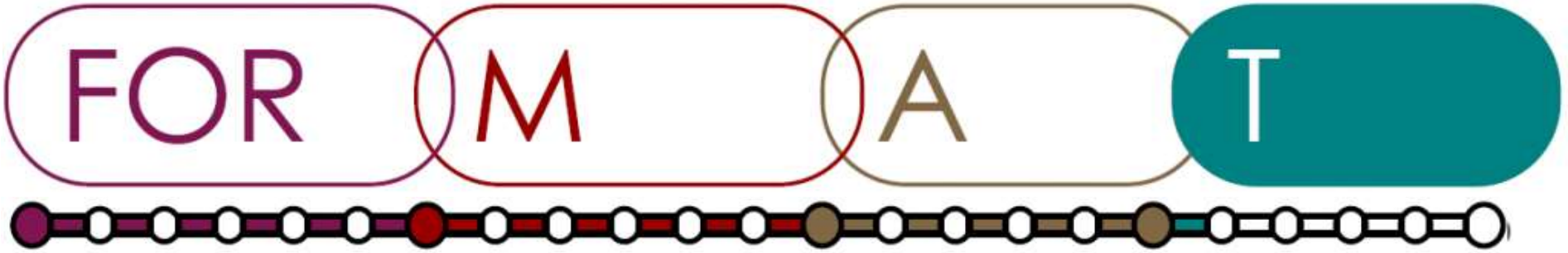
FOR M A T

Interior volume of refrigerators



Data source: Association of Home Appliance Manufactures (AHAM) and Appliance Standards Awareness Project (ASAP).

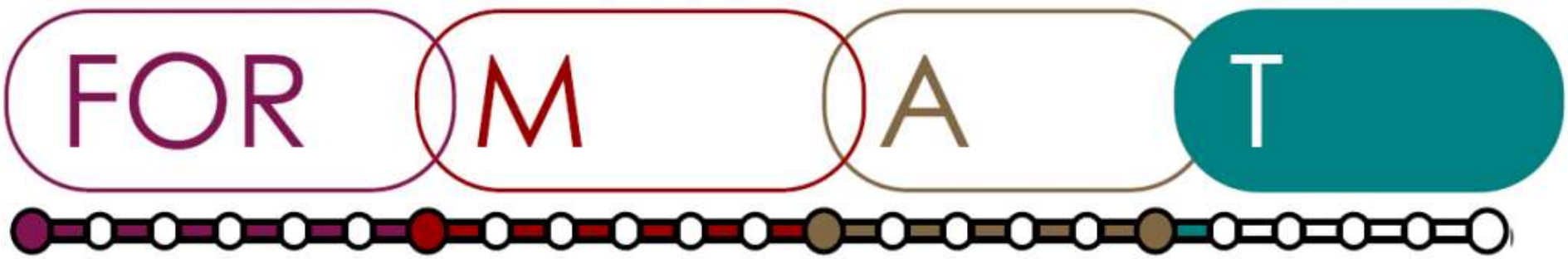
Parameter	Value	P-value
Parameter of the regression		
Maximum average size expected for interior volume of household refrigerator [cubic feet] and [liters]	21,70 cu ft (614,47l)	p<0,01
Period of time for 80% of the cycle [years]	52 years	p<0,01
Middle time when interior volume growth achieve his 50% [years]	1953 years	p<0,01
Results of the fit		
R-Squared [%]	98,5%	-



From Gate A

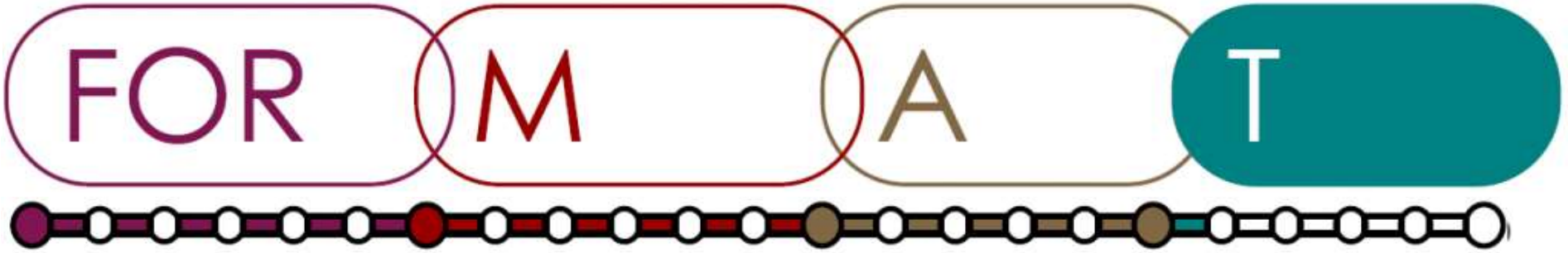
1. Conclusion on answer to the Question to be Forecasted

- Use conclusions from (A) to answer main question about STF
- Refer to objectives and conditions set by beneficiaries and users



What will be the evolution of main parameters of polymers forming technologies in 10-20 years, (2013-2033) for WHRIT Refrigerators* in WHRIT factories in Western countries?

FEATURES OF POLYMER FORMING TECHNOLOGY in 10-20 years for Western Countries (Europe, Middle East, Africa) (from granules to 3D shape for domestic refrigerators)
1. Complexity of mold will increase due to multi-part molds.
2. Attention to Energy consumption of manufacturing process (MP) will rise.
3. Footprint of MP should decrease.
4. The degree of Automation of MP will increase.
5. The degree of Integration of MP with other phases of production will increase.
6. Maximal Productivity might increase (cooling time) when minimal Productivity of MP will not change significantly.
7. Initial Investments into equipment will not increase significantly.
8. Amount of Materials to produce 3D shapes will decrease when cost might increase slightly.



a) Will vacuum forming technologies be needed in 10 years, (2013-2023) for WHRIT Refrigerators* in WHRIT factories in Western countries? (Yes/No)**

Yes (no strong alternative has been identified)

b) What will be the most suitable polymer forming technologies in 10 years, (2013-2023) for WHRIT Refrigerators* in WHRIT factories in Western countries? (list of technologies)**

- Vacuum forming: very fast equipment option (frequent molds changeover and setup consume time that need to be gained by very fast equipment).
- Vacuum forming – with following upgrades: integration of extrusion and forming, variable thickness within one sheet, improved cooling, complicated molds, increased automation, decreased footprint, decreased energy consumption.

Some learning (by Whirlpool)

- Importance of keep the history
  - Look back in order to look forward
- Prepare to grow data miners
  - Ability to quickly understand nature and relevance of data
- Data are not (always) for free
  - Budget for buy quantitative data from external
- Keep beneficiaries constantly aligned
  - avoid the risk to answer the unwanted question

Web Resources

Web Sites:

http://format-project.org (FORMAT Project web site)
http://www.seecore.org/ (Dmitry Kucharavy - Technology Change and Forecasting)
http://www.iiasa.ac.at/ (International Institute for Applied Systems Analysis)
http://www.millennium-project.org/ (The Millennium Project - Global Futures Studies & Research)
http://forecasters.org/index.html (International Institute of Forecasters)
http://www.cesaremarchetti.org/ (Cesare Marchetti Web Archive)
http://www.growth-dynamics.co.gr/ (Modis Growth-Dynamics)
http://phe.rockefeller.edu/LogletLab/ (LogletLab)

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