FORMAT

Forecast and Roadmapping for Manufacturing Technologies

the handbook

Knowing the Future is Possible

FOR M A T

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For more details on the project: **http://www.format-project.eu**

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the

Knowing the Future is Possible

hand book

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http://www.polimi.it/

Whirlpool Italy, Italy
http://www.whirlpool.it/

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http://www.pwr.edu.pl/

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Outline

The handBOOK Team

Gaetano Cascini
Coordinator, FORMAT

He is Associate Professor at Politecnico di Milano, Faculty of Industrial Engineering. He coordinates a research team working on the following topics: Methods and tools for inventive design and Computer-Aided support to the innovation pipeline. His main fields of activity relate to methods and techniques for Systematic Innovation, Knowledge Based CAD/CAE tools, Knowledge Management and Patent Mining. He has been Coordinator and Scientific Responsible of the EU Project "Technology as Cultural Heritage", ref. n. CLT/2005/A1/CH/IT-55. He is author of more than 100 papers, mostly presented at International Conferences and published in authoritative Journals, and 10 patents.

Bala Ramadurai
Project Manager, handbook

He is an inventor, independent innovation consultant and researcher. He co-founded TRIZ Innovation India and is an entrepreneurship mentor at Mentor Edge, India. He has mentored students in an entrepreneurship course facilitated by Carnegie Mellon University, USA. He was a systematic innovation facilitator at MindTree Ltd, India. Prior to MindTree, Bala was a Research Scientist at General Electric Global Research, India. Bala has a PhD from Arizona State University, USA and a B.Tech from IIT Madras, India. He designed and crafted 5*50, a key innovation intrapreneurship program, at MindTree. He has been cited as an expert in innovation and creativity by Harvard Business Review. He has 3 patents to his credit and more than 10 publications in international research journals.

Mateusz Słupiński
Assistant Manager, handbook

He holds a MSc in Environmental Engineering and a PhD in Science and techniques of engineers, from ULP Strasbourg. Currently he is Assistant Professor at PWR Wroclaw, where he conducts researches on TRIZ and Technological forecasting applications in environmental engineering.

Mahmoud Rabie

Mahmoud Rabie holds a PhD in Advanced Chemistry with Cum Laude from the Complutense University of Madrid, Spain "March 2013". As part of a European PhD Program, he worked as a research fellow for 16 months at Max Planck Institute for Chemical Physics of Solids, Dresden, Germany. He holds a double Master in Materials Science and Enterprise from Rennes1 University, France, and from Ludwig Maximilian University of Munich, Germany "February 2009". In addition, he holds a Bachelor in Metallurgical Engineering (5 years) from the Faculty of Engineering at Cairo University, Egypt "May 2003". The Bachelor thesis was carried out at the Technical University of Berlin in a student-exchange theme. He has gained a substantial experience in new rare-earth, magnetic and smart materials. In addition, he received extensive training in quality management, Lean Six-Sigma, project management and research skills. He co-organized two scientific workshops in Stuttgart, Germany, and Timişoara, Romania.

Niccolò Becattini

He is a research fellow of the Department of Mechanical Engineering of Politecnico di Milano since 2009. He holds a PhD in Mechanical Engineering. He also works as a teaching assistant for classes of Technical Representation Methods and Methods for Systematic Innovation. He is currently working on national and international funded projects. His researches focus on different topics concerning the domain of Innovation: Computer-Aided Innovation, Engineering Design, Problem Solving Theories and Methods, Technology Forecasting and Creativity. He has co-authored several papers, which have been published in authoritative journals and presented in international conferences.

Igor Kaikov

Igor Kaikov has been recruited by Whirlpool Europe. He has been selected for this position through an open call. He is a researcher in the FORMAT project. He obtained a degree in Technology of Electrical Engineering, acoustic and ultrasonic tools in 1984 at the Leningrad Electro Technical Institute (St. Petersburg, Russia). He has an experience of over 25 years of practice and research in the Theory of Inventive Problem Solving (Russian acronym – TRIZ) as an engineer, researcher and consultant. In 2003, Igor Kaykov was invited to the European Institute for Energy Research (EIFER) in Karlsruhe, Germany – a daughter company of Électricité de France (EDF) and Karlsruhe Institute of Technology (KIT). From 2003 until August 2012, he consulted EIFER research groups about problem solving processes. His main field of activity relates to OTSM-TRIZ approaches for solving problems in various technical, technological, scientific, and sociological areas and projects. He is an author of 3 books, 6 patents and more than 50 scientific papers.

Dmitry Kucharavy

Dmitry Kucharavy has been recruited by PoliMI. He has been selected through an open call. He received his degree on Technology of Mechanical Engineering, metal machines and machine tools in 1988 from Belarusian State Polytechnic Institute (Minsk, USSR, now Belarus). He brings over 20 years of practical and research experience in Theory of Inventive Problem Solving (applied Russian acronym – TRIZ) as engineer, researcher, consultant, and teacher. In 2001, Dmitry Kucharavy was invited to officially join the Design Engineering Laboratory LGECO at INSA of Strasbourg. Since then and till December 2012, the regular participation in research projects has provided him with new and diverse opportunities for developing his research experience and for transferring his knowledge to young researchers. The main activities were related to research and development of a method and techniques for long-term technological forecasting. During his career, the research activities were suspended several times in favour of practical design and inventive problem solving activities. Currently he combines practical consulting with research in Technology Forecasting of systems evolution (Researching Future methodology) and Problem solving knowledge management.

Christopher Nikulin

He is a Mechanical Engineer and he received a Master in Science Mechanical Engineering from Federico Santa Maria Technical University (UTFSM, Chile) in 2009, Master of Technological Innovation and Entrepreneurship (UTFSM), and he is currently candidate for receiving a double graduation program for International MBA in the Polytechnic University of Catalonia (Spain). Since January 2012, he started a PhD program in Mechanical Engineering of Politecnico di Milano with a scholarship from the Chilean government. His areas of research concern Forecasting Technology, Systematic Innovation, Product Life Cycle and Uncertain Modelation Systems.

Sebastian Koziołek

Dr. Sebastian Koziolek is a young faculty in the School of Mechanical Engineering at the Wroclaw University of Technology in Poland. He is also a global scholar of Stanford University, George Mason University and Nottingham Trent University in the area of Inventive Engineering as applied to complex mechanical engineering problems.

Emanuele Festa

He graduated at Politecnico di Milano in 2014, with a master degree in Mechanical Engineering. With experiences in the field of Finite Element Method (FEM), Emanuele has built a curriculum in design engineering.

Focusing his studies on systematic innovation, he approached TRIZ theory, intellectual property fundamentals and the most recent technology forecasting methodologies. He joined the FORMAT team participating in a case study for Whirlpool Europe SRL. Downstream this work, he performed the assessment of the FORMAT methodology, which was the main subject of his master thesis. Since January 2015 he has been seconded to PNO Consultants.

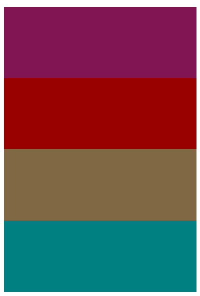
Acronyms

A	Act (to prepare the forecast)
DM	Decision maker
FORMAT	Forecast and Roadmapping of Manufacturing Technologies
FOR	Formulate
M	Modelling
T	Transfer
TF	Technology Forecasting
STF	System to be forecasted
WH	Whirlpool

How to use this handbook

This handbook is designed to be a practitioner's manual as well as a reference resource. The sections of the handbook serve to be dividers of the stages of the FORMAT methodology. The stages are colour coded according to the following scheme:

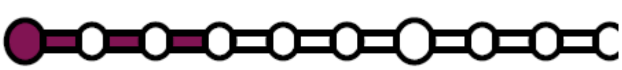
Stage	Colour
FOR	
M	
A	
T	



Some of the important sections of the stage are:
1. Method—An overview of the stage
2. Prerequisites—Preparations that need to be taken into account before executing the stage
3. Ingredients—Necessary to perform the stage
4. Instructions—What needs to be done in what order
5. Tips—Experiential advice from the FORMAT team

The highlighted portion indicates the current stage in the methodology

Some of the important section of the step are:
1. Method
2. Instructions
3. Tips
4. Example—An illustration of how the step works

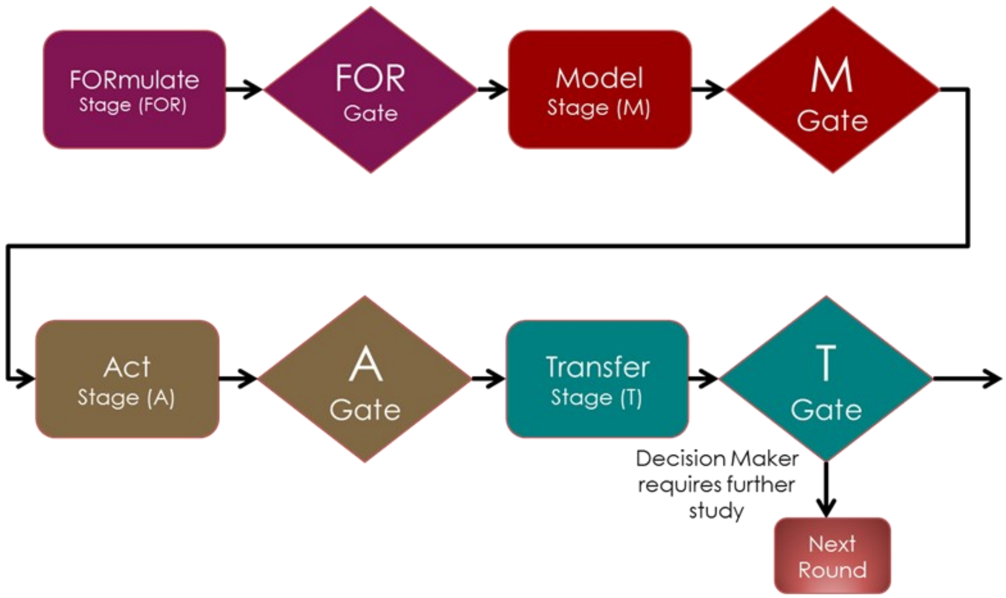


The progress bar indicates the step.

The step is indicated by the arrow on the top left area of the page. Case studies at the end give the results of the application of the methodology in organizational contexts.

INTRODUCTION

FORMAT Methodology



The FORMAT methodology has been conceived as a Stage-Gate process in order to retain control over project activities with the ultimate goal of maximizing process efficiency in terms of ratio between the forecasting project outcomes and the efforts dedicated to produce them.

The overall methodology counts four pairs of stages and gates; at the end of the final gate, the beneficiaries of the technology forecasting might ask for a second iteration of the process in order to increase the detail of the analysis or to enlarge the scope of the investigation.

prep time
12 working sessions

total time
22-28 working days

Each stage is described by means of two items, in order to give a similar internal structure to the stages. The first item is a description of the stage goal, by using a functional syntax: it allows the analysts to have a clear description of the goal to be accomplished.

The analysts have to address the functional description to move on to the next stage. The second item is a more detailed checklist of questions to be addressed, so as to fulfil the main function of the stage. Then, each stage is followed by a gate, depicting the detailed requirements (in terms of information needs) that prescribe what should be checked before deciding whether to continue with the following activities of the TF project.

The following Table describes the main functions, questions and requirements for each stage-gate pair. Four stages constitute the TF process: the stages are split according to the FORMAT acronym: FORmulate, Model, Act and Transfer.

Stage	Main Functions	Questions and Duties
FOR: Diagnose questions and plan project	<prepare & make> <decision> <about forecasting project> <define> <boundaries / resource> <of forecasting project>	WHY do we need to know the future? WHAT do we need to know about the future? HOW do we plan to learn about future?
M: Define the system for forecast and study contexts	<review> <existing knowledge> <about system>	WHAT The System To Forecast (STF) is for? (WHY we need the STF?) WHICH Systems allow to get the same results? HOW to measure the Performance and the Expenses of the STF and its alternatives? WHAT the STF and its main alternative(s) are, were and are expected to be?
A: Develop forecast for defined system and context	<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>	Extract limiting resources from problems of STF Define set of solutions addressing limiting resources Fit data-series about parameters measuring performance & expenses Build conclusions about future traits for STF
T: Prepare report and present results	<transfer> <results of study> <to decision makers>	Transfer the forecasting results to beneficiaries/ decision makers

Firstly, Stage FOR is related with the motivation of the forecasting analysis. This stage has to check whether the forecast is really needed or not. Moreover, at this stage the analysts needs to agree on: i) the description of the main objectives and the expected outputs of the forecasting project; ii) a clear statement about how the forecast will be applied within the decision making process; iii) the possibility to satisfy the formulated needs with or without TF. Additionally, the resources to address the forecasting project have to be defined and the activities suitably planned.

Stage M is about the definition of boundaries for the forecast and the analysis of the relevant existing knowledge about the technology or system under study. In order to address this review, the analysts have to produce: i) an AS-IS description of the technology and its context; ii) a list of performance and expenses (resources) relevant for the technology; iii) a description of alternative technologies (a set of) that deliver the same results. This stage should result in a complete overview of the technology and the contexts it operates in.

The activities of Stage A consider both qualitative and quantitative perspectives to forecast the future. The qualitative approach is further detailed into a problem- and a solution-focused generation of knowledge about future. The former defines critical problems and resources that limit the technological development (e.g. by using the TRIZ concepts of contradictions and resources). The latter aims at envisioning by analogical reasoning the potential evolutions addressing both the identified problems and the lack of system resources. The quantitative approach is based on data-series analysis (e.g. by applying regression analysis as logistic growth curve).

Eventually, the T stage aims at transferring the forecasting results to the project beneficiaries. The analysts have to develop a proper knowledge flow system in order to transfer their results to beneficiaries, such as a reports, presentations, lists, posters, etc. This last stage should not be overlooked: indeed, the process of formulating a technological forecast is similar to a learning process. The difference with respect to standard learning is that the team members gain knowledge about the future, rather than about the past. This implies that the beneficiaries of a TF project, i.e. the decision makers who are supposed to use those outcomes to define strategies and plans, face the interpretation of information they did not contribute to build. Here two opposite scenarios might emerge: either the forecast is fully plausible, but in this case the advantages deriving from the TF reveal to be quite limited, or the forecast sounds unexpected. The latter case, if the TF is lately confirmed, offers the greatest advantages, but clearly proper arguments should be provided to get trusted. In turn, the T stage has the role to provide significant contents and solid arguments in a concise form.

best practices for conducting working sessions

⇒ **Before working sessions**

- Send to the team members materials to learn, useful links and data charts.
- Upload presentations at least half a day prior to the sessions to allow team members to assimilate the information from the previous sessions
- Technology & market specialists should prepare an introductory presentation about technology and market details.
- Office software available for all participants of project (e.g. word processors, spreadsheets, for slides, pdf converters);
- Collaboration software to support VoIP meetings (necessarily including screen sharing features, preferably with recording option)

⇒ **During working sessions**

- Meeting room equipped with a table, chairs for 10 participants, whiteboard or flipcharts, video projector, the Internet connection;
- Photo camera (optional)
- any materials enabling a collaborative session
- Audio and/or screen recordings of the meetings is highly recommended for future reference

⇒ **After first working session(s).**

- Prepare a set of slides from the working sessions and submit it on the server for reviewing.
- In order to generate a draft version of a report for the project, write notes & comments in the notes section of the slides in the slide deck.
- Use the audio and/or screen recordings of the working sessions for preparation of these slides.

notes

FOR M A T

FOR Stage

notes

FOR Stage

The main function of FORmulate stage is to set up the technology forecasting project: identify main objectives of the project, decide whether the project is a forecasting activity or a problem solving exercise for attaining defined objectives. Once the decision has been taken to initiate a technology forecasting project, forecasting questions are developed and detail plan of the project is outlined.

prep time

2-3 working sessions

total time

10 working days

people

4 to 7

ingredients

materials

Descriptions of existing industrial process; alternative or competitive

tools

Introductory presentation;
Structured interview;
Panel discussion;
Templates for presentation and report

knowledge

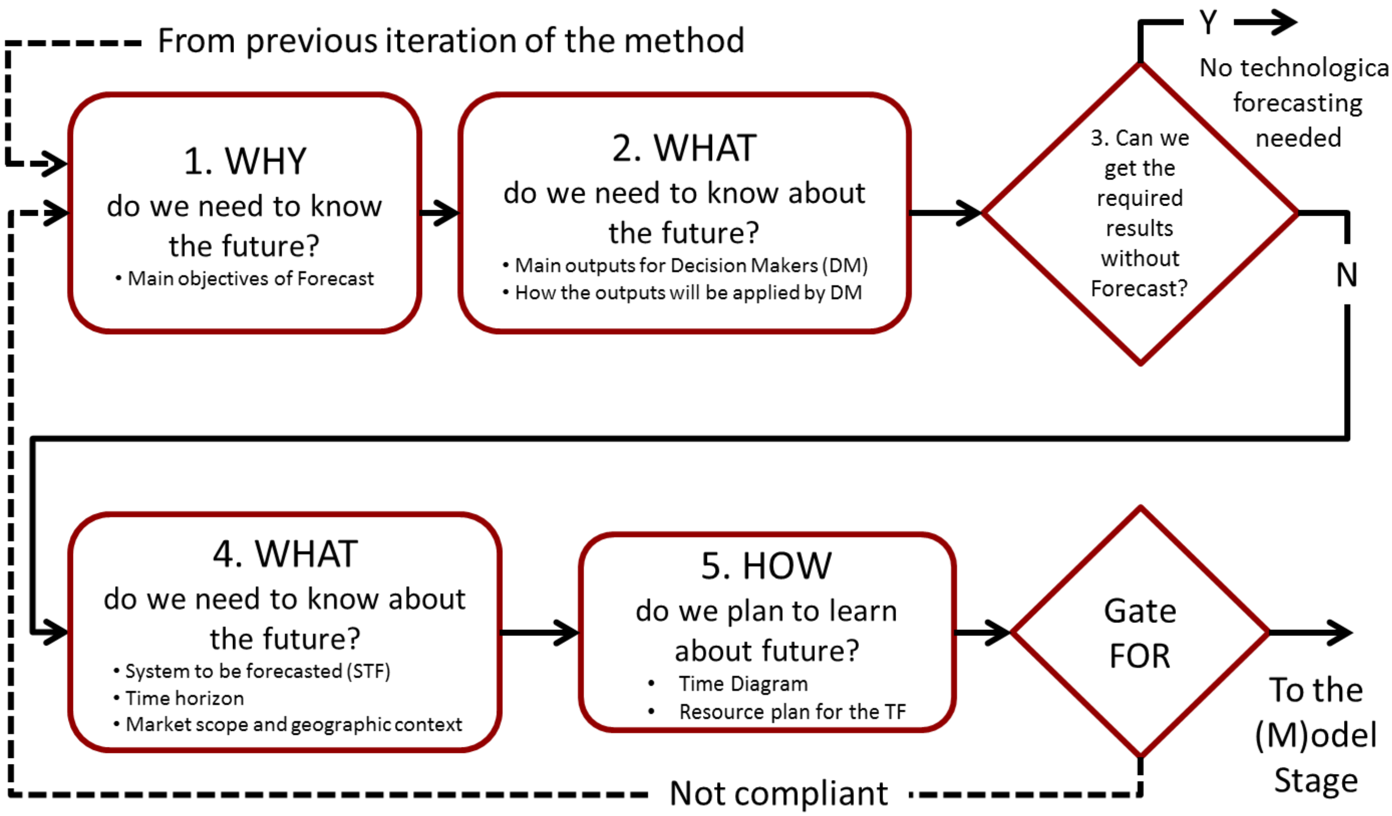
Members of the team should preferably have 3-5 years of applied design experience of new technologies.

software

Office software available for all participants of project (e.g. word processors, spreadsheets, for slides, pdf converters); collaboration software to support VoIP meetings (necessarily including screen sharing features, preferably with recording option)

people

Core team: 1-2 analysts + 2-3 Technology & Market specialists
(1 analyst is assigned as a leader to coordinate sessions and is responsible for the delivery of reports and presentations)
Extended team: 1-2 User & Beneficiaries



instructions

1 To discuss and elaborate main objectives of the study as target technology (engineering system) (See Step 1 of Stage FOR).

2 Identify expected results of the project and how the results will be applied (See Step 2 of Stage FOR).

3 Decide about the question:
Can we achieve the required results without Forecast? (Yes/No) (See Step 3 of Stage FOR).

4 If the answer to the question in instruction 3 is **Yes**, then classify and proceed with the project as a problem solving task.

5 If the answer to the question in instruction 3 is **No**, then proceed with the project as a technology forecasting project.

6 Prepare answers to the following questions: What is the system to be forecasted (STF)? What is the time horizon for the forecast? What is the market scope? What is the geographic context? (See Step 4 of Stage FOR).

7 Prepare a detailed project plan. The plan of the project consists of:

a. Human resources: List of beneficiaries of the results of TF, list of core team members, list of support specialists and a list of invited professionals.
b. Material resources: Travel funding, communication software, data sources, necessary sources of information (e.g. books, journal subscriptions).
c. Plan: detailed description of time and content of TF project (Gantt chart recommended) (See Step 5 of Stage FOR).

tips

⇒ For detailed tips on running sessions, refer to Setting up and Running Sessions

⇒ Limit the number of questions for specifying the formulated objectives to three.

a. Define a time horizon for the forecasts (e.g. "How will the main parameters change over the next 10-20 years?").
b. Specify a geographical area for the forecast (e.g. European and Middle-East market).

⇒ The number of members in the core team should be preferably between 3 and 5 and all core members should be available for all sessions.

suggested reading

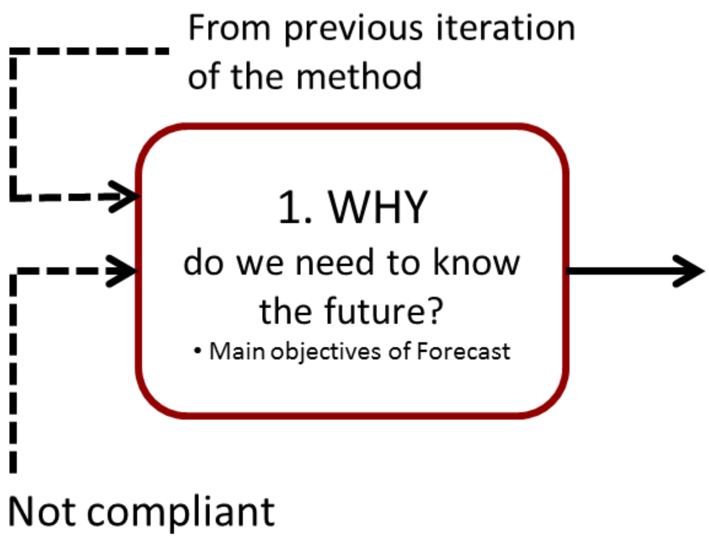
[1] Haugan, G. T. (2002). Project Planning and Scheduling, Management Concepts Press, ISBN: 9781567261363.

[2] Conchúir, D. Ó. (2011). Overview of the PMBOK® Guide: Short Cuts for PMP® Certification, Springer, ISBN: 9781935589679.

notes

Why do we need to know the future?

Step 1



highlight

Prepare objectives of the project/study from various viewpoints (e.g. beneficiaries, users, technology context, marketing context)

method

The key question to be answered in this step is Why do we need to know the Future about this project? The answer to the above question will constitute the main objective of the project. Main objective has to be approached from two perspectives at least. First, the context perspective: Why is this objective relevant? Second, is the results perspective: when the objective is met, how will it be applied to the decision making process?

instructions

1 Identify the main objective of the project and write down what beneficiaries and users would like to know about future changes in the analysed technology.

2 The stated objectives should be verified using the question:
Why do we need to know the future?
This question refers to the super-system (context of technology) (e.g. decision making, business strategy, economics, financial aspects).

3 During the first working session, get an answer to the following questions:
What are the expected results of the forecasting project for users and beneficiaries?

- What is the main function of the industrial process?
- What forecasting question(s) should be answered for taking intelligent and informed decision(s)?
- What would support the main questions and which among them are the most important?
- What is the necessary level of detail when answering forecasting question(s)?
- What is the form (e.g. roadmap, set of recommendation, list of answers, graphs, charts, report, video) in which results need to be presented?

4 During first session(s), get answers to:
how will the results of the forecast be applied?

- Are the results from the forecast required by some other decision making process? Which one?
- When will the results be applied (e.g. two years later, two quarters later)?
- Where will the results be applied (e.g. strategic planning, selecting suppliers)?
- Who will use these results? Who may gain from the acquired knowledge?

suggested reading

[1] R. L. Ackoff, "Thinking about the future." 2006.
[2] R. L. Ackoff, "A major mistake that managers make," 2006.

examples

Example 1. Super-Capacitor

Brief context - There are different types of super-capacitors for storage of electrical energy. For many of these types, scientific research may be required. However, to conduct research on several types of these super-capacitors, laboratories may require significant financial, technical and human resources. As an alternative, it may be possible to focus available funding on one of these types of super-capacitors. In the latter case, there is a risk that in 10-15 years, the market may be dominated by another type of super-capacitors that were not researched as result of the decision to focus on one type.

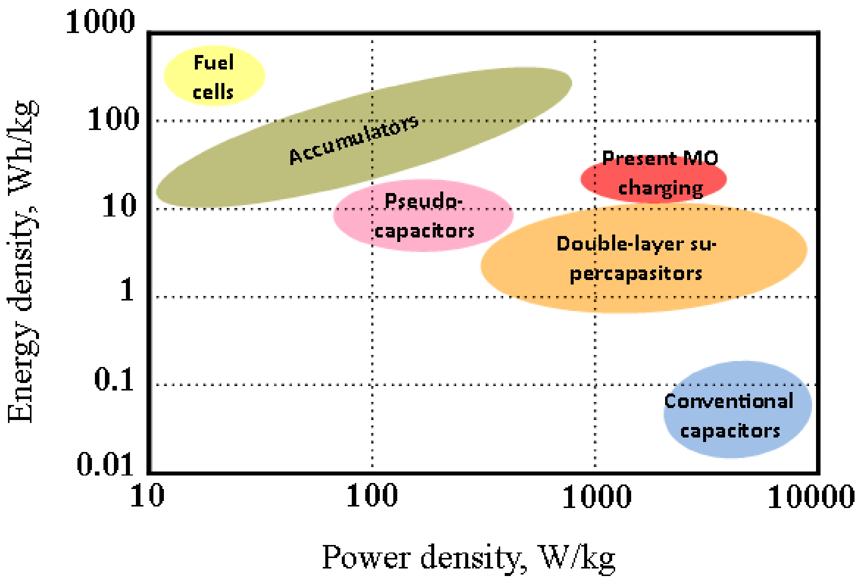


Figure FOR-Step1-1. Ragone plot.

Step 1: Why do we need to know the future?

We need to know the future of super-capacitors for long-term planning of a research laboratory.

Example 2. Gas leak checks in refrigerator

Brief Context - A refrigerator consists of parts made of different materials. These parts work under cyclic loading, vibration, various temperatures and pressure differences. These parts must be combined into a sealed system. The individual parts of the system must be leak-proof and when sealed together, the assembly should also be leak-proof.

Gas leak detection is the process of identifying potentially hazardous gas leaks using various sensors. These sensors are equipped with a sound alarm to alert people when dangerous gas has been detected.

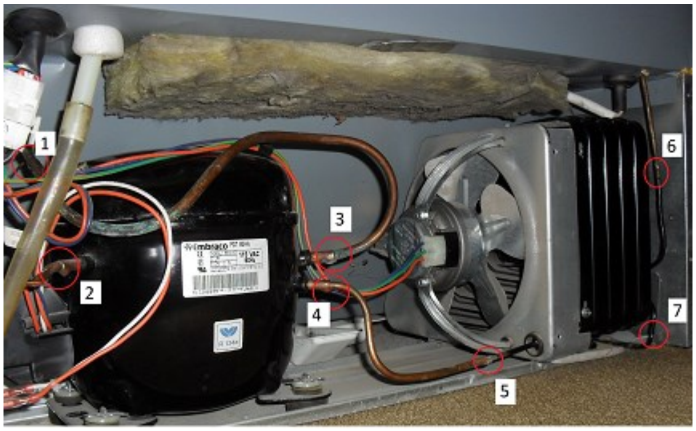


Figure FORStep1-2. Refrigerator system assembly. There are some connections between different parts of the system marked by numbers (1) – (7).

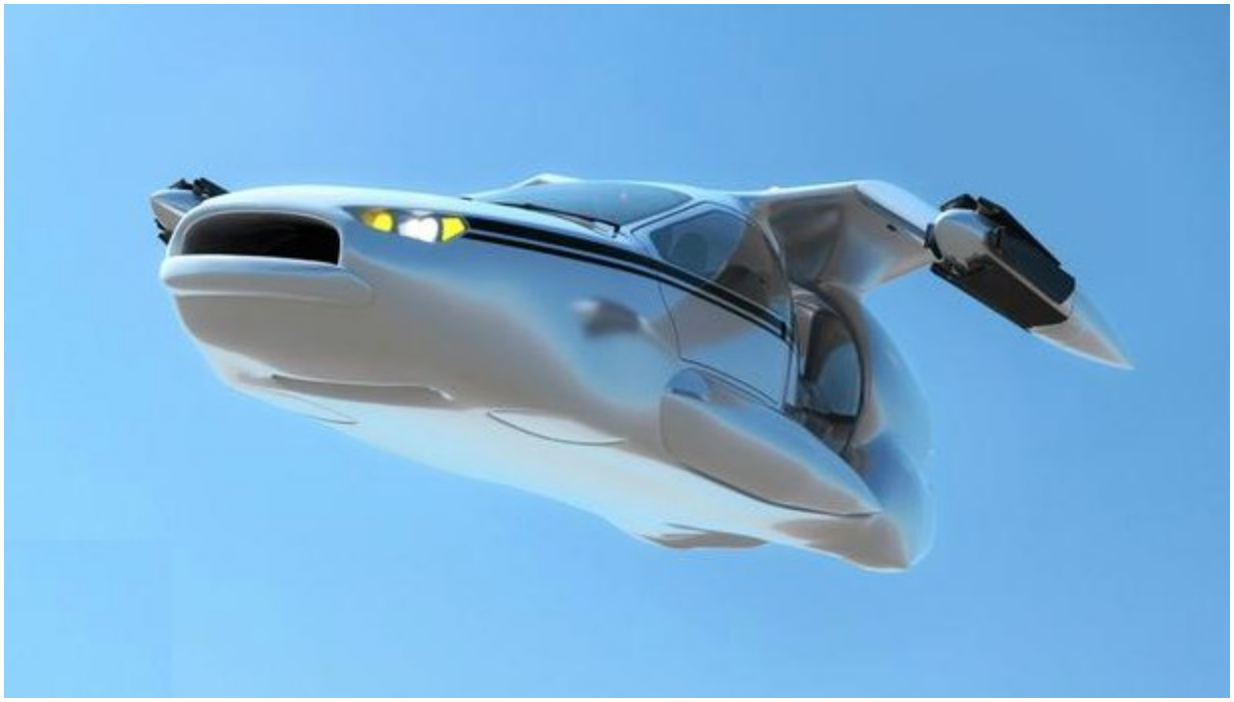
Figure FORStep1-3 Gas leak checks in a refrigerator

Step 1: Why do we need to know the future?

We need to know the future of gas leak checks in a refrigerator in order to understand when and how refrigerators will be produced without the need for gas leak checks.

Example 3. Flying car

Brief Context – A reputed car manufacturer established a subsidiary "Flying car" for the development and production of a future personal "Flying car". Financial investor decides on long-term (20 years) placing part of their capital into shares of the company "Flying car".



http://www.bbc.com/future/story/20131031-a-flying-car-for-everyone

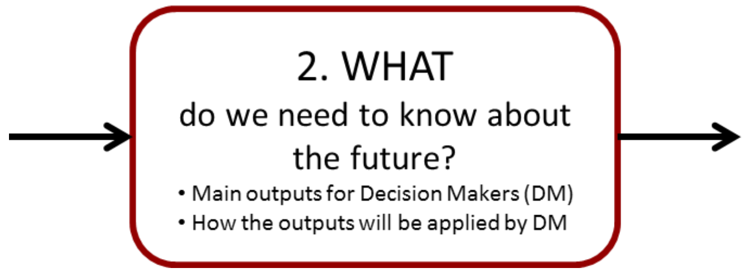
Step 1: Why do we need to know the Future?

We need to know the future of the "Flying car" for helping decision making for the financial investor.

notes

What do we need to know about the future (I)?

Step 2



highlight

Identify the system to be forecasted and identify what results will be required by the decision makers. Also, identify how the decision makers will use the results from the forecast.

method

After the question "Why do we need learn about the future", now it is time to clarify the "What" do we need to know about the future? It is required to specify the main objectives of the project from the perspective of what is desired to learn about the future, and what we would like to know about the future in order to enhance strategic planning and decision making.

instructions

1 Answer the following question (to be answered by the whole working team):
What do we need to know about the future?
This question has to have the system to be forecasted (STF) as the central component.

2 During the first working session, clarify and formulate the decision criteria for the STF.

3 These questions need to be answered in the above mentioned working session:
What is expected by users and beneficiaries as a result of the forecast?
What questions should be answered for decision makers?
What is the necessary level of detail?
How do the results need to be presented? (e.g. graphs, charts, report)
How will these results be used by users and beneficiaries?
Will the results of the forecast be used for other purposes? Which ones?
What is the approximate time span when a result may be used?
Where are the results going to be useful?
Who is going to use the results of the forecast?

tips

⇒ Keep in mind that the next step will require you to take a decision on the following question: Can we get the required results without forecast? (Yes/No)

suggested reading

[1] For rules to define function of a system see: D. Kucharavy, "Course materials: Technological forecasting (prediction technology change)," INSA Strasbourg, Strasbourg, 2008.

examples

Example 1. Super-Capacitor (Context defined in FORStep1)

Step 2: What do we need to know about the future?

Main outputs for Decision Makers (DM)

What are the parameters that may be used for forecasting the market of super-capacitors?

Energy density, (Wh/kg)

Power density, (W/kg)

Time horizon and geographical context - next 5 to 10 years in Europe

Example 2. Gas leak checks in refrigerator (Context defined in FORStep1)

Step 2: What do we need to know about the future?

Main outputs for Decision Makers (DM) (What?)

Will it be possible to produce refrigerators without the need for gas leak checks in the next 10 to 15 years in Europe?

How the outputs will be applied by DM (Why?)

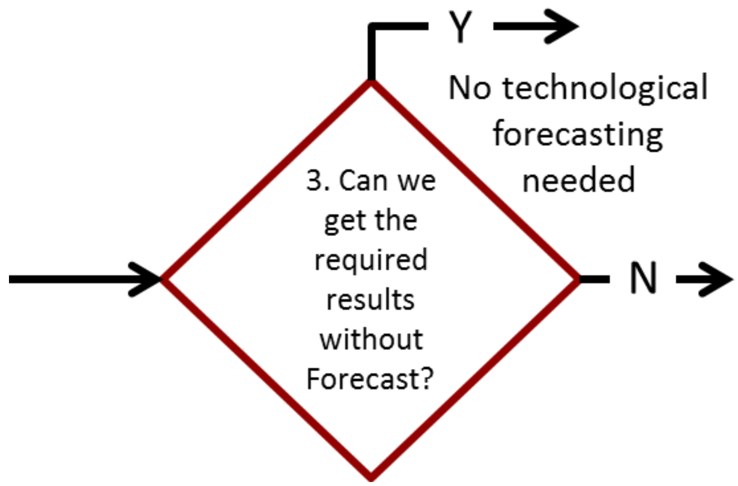
Support economic and strategic decisions

Define factory plan.

notes

Can we get the required result without forecast?

Step 3



highlight

This is a decision step that differentiates forecasting and problem solving activities for the formulated objectives.

method

In this step the key question has to be answered:
Can we get the required results without Forecast?

Restating the above question: Can we satisfy the formulated needs (*Step 1: Why?* + *Step 2: What?*) without Technological Forecast? (**Yes/No**)

A **decision** has to be made at this step whether to proceed with the project as a technology forecasting project OR to switch to a problem solving task.

instructions

1 Review results of Step 1 of Stage FOR and Step 2 of Stage FOR for logical consistency.

2 Discuss this question:

How can the main objectives be satisfied if there was no forecast? For example, by strategic planning, by problem solving or by quality assessment.

4 The following question needs to be answered with a clear yes or a no: *Can the formulated needs (Step 1: Why? + Step 2: What?) be satisfied without technological forecast?*

tips

⇒ The decision should be made with the participation of beneficiaries and users.

⇒ Be aware of the following situation: the main objective may seem to be a candidate for technology forecasting, but after preliminary investigation of Step 1 and Step 2 of the FOR stage, it may turn out to be "just" a request to solve a specific problem that does not require a forecast about the future.

suggested reading

[1] I. Kaikov. "METHOD OF SELECTION OF TEST CASES FOR FORMAT". 2013. [Online] Available: http://www.format-project.eu/deliverables/white-papers/december-2013-method-of-selection-of-test-cases-for-format/at_download/file

examples

Example 1. Super-Capacitor (Context defined in FORStep1)

Step 3: Can we get the required results without Forecast?
Do we really need to forecast the future to answer that question or is it sufficient to address the problem with a problem solving approach?
Decision: we cannot get the required results without a forecast, hence proceed to Step 4.

Example 2. Gas leak checks in refrigerator (Context defined in FORStep1)

Step 3: Can we get the required results without Forecast?
Do we really need to forecast the future to answer that question or is it sufficient to address the problem with a problem solving approach?
Yes, we can. We need not forecast the future if we can solve the problem "How to connect all parts in a sealed system assembly?"
Decision: Project for problem solving.

notes

What do we need to know the future (II)?

Step 4

highlight

This step is an elaboration of the activities performed in Step 1 of Stage FOR – defining main objectives, time horizon of the forecast and market and geographical context of the system to be forecasted.

method

The purpose of this step is to elaborate further the objectives of the technology forecasting by answering the questions that were posed in Step 1 of Stage FOR. For this purpose, the system to be forecasted (STF) has to be depicted in generic terms (The “What” Of the forecast); the time horizon should be specified (The “When” of the forecast) and the market scope with geographic context (The “Where” of the forecast) should be identified.

instructions

1 Review results of Step 1 and Step 2 of Stage FOR and define a main function of the system to be forecasted (STF).

2 Identify time horizon of forecast in months or years consistent with the objectives of study (and how the results of the forecast will be applied).

3 Specify the target geographical area or market explicitly.

4 Integrate the developed "What", "When" and "Where" of the forecast into the form of questions to be answered at the end of the technology forecasting study (Questions for Forecast).

tips

⇒ The objectives and viewpoints of the forecast should be clear (see previous steps).

⇒ Avoid industry jargon as far as possible especially when defining the function of the industrial process

⇒ Define the function of STF using a three-step procedure:

a) Describe the function using common words and expressions (e.g. pencil – to write, to draw)

b) Reformulate the defined function according to the pattern:

<verb> + <noun > (e.g. <draw> <letters>)

c) Reformulate again the defined function by replacing the <verb> with the pattern:

<change> + <features (and values) (of the <noun/object)> (e.g. <change> <colour>; <change> <…>)

tips

⇒ Function of STF is defined based on the outcome of step b) from the above procedure after checking consistency with step c (see the three step procedure above).

⇒ While identifying the time horizon for a forecast, keep in mind the lifetime of the STF. Typically, the time horizon specified in the technology forecasting project has to be greater than the lifetime of the STF.

⇒ STF can evolve differently in different geographies or for diverse markets. Therefore, a particular country(s) and/or market(s) should be specified unambiguously in accordance within the scope of forecast defined in the previous steps.

⇒ Clearly formulate one main question for forecast and try to achieve a consensus on it. The question for forecast is usually formulated integrating several questions. The question for forecast is typically composed of 2-4 sub-questions.

⇒ The following questionnaire can help you to answer the question "what to know" about the future (to drive a meaningful definition of the boundaries of the STF and support data gathering):

1. Will you take your future decisions on the basis of the features of a product or its related manufacturing process? Which product? Or which manufacturing process? [STF]
2. What characteristics of the future STF are more essential to let you make a decision?
    a) Costs? If yes, what to pay for?
        i. Space (space for + examples); [m, m^2, m^3]
        ii. Time (time to + examples); [s, m/s; m/s^2,…]
        iii. Information/Knowledge (examples); [days to knowledge, Kb]
        iv. Material (Material to + function) [kg & specific properties]
        v. Energy (Energy to + function) [kJ, kW, BTU, efficiency,…]

b. Improved functionality? If yes, what kind of functionality? Do you want to know if the system will be more performing (go to i.) or less problematic (go to ii.)? Or is it a matter of aesthetics (go to iii.)?
    i. More Performing
        1. Do you want to know if the main performance indicators of the STF will undergo a radical shift in the future? Which indicators?
        2. Do you want to know if the STF will be more versatile, more robust/ repeatable, more controllable? If yes, what characteristics would you like to have more versatile (examples), robust (examples) or controllable (examples) and in which context (examples)?
    ii. Less Problematic
        1. More resistant STF [specify to what substance]
        2. Less polluting STF [specify an appropriate indicator, e.g. eqCO2, % NOx, ...]
        3. With reduced undesired side effect [specify which ones]
    iii. Improved aesthetics
        1. Is it a matter of variety of styles? [finishing,…]
        2. Is it a matter of colors? [number of colors, nuances,…]
        3. Is it a matter of diversity from standards [standards]

3. Filter the amount of characteristics you want to forecast by those that are compulsory to support decision-making (3-4) and the complementary ones.
4. Start organizing the compulsory characteristics in a System Operator
5. Check in other screens if and how other characteristics to be measured can help in building inferences about the STF

suggested reading

[1] D. Kucharavy, “Course materials: Technological forecasting (prediction technology change)", Strasbourg, 2008.

examples

Within a case study about Decoration of home appliances surfaces, the main function of STF (What?) was formulated as: <to modify> <colour of> <a surface[1]>.

Main objectives of Forecast were preliminarily identified as:

- To envision: What to do to improve the Decoration process? (1st priority)
- To be aware: What will happen around in the field of Decoration technologies (2nd priority)
- To get explicit description of future changes of Decoration process for home appliances (3rd priority)

Time horizon for forecast (When?) was identified as: 5-10 years (i.e. 2019-2024), since the last change in decoration machines was introduced about 3-5 years ago.

Market scope and geographic context (Where?) was identified as:

home appliances (refrigerators; ovens, microwave ovens; dishwashers; washing machines, dryers; cooktops) in Europe, Middle East and Africa (EMEA).

Starting from the review of such information collected during the previous steps, the output of the step 4 in Stage (FOR) resulted as follows:

Questions for Forecast

(Questions to be answered at the end of study)

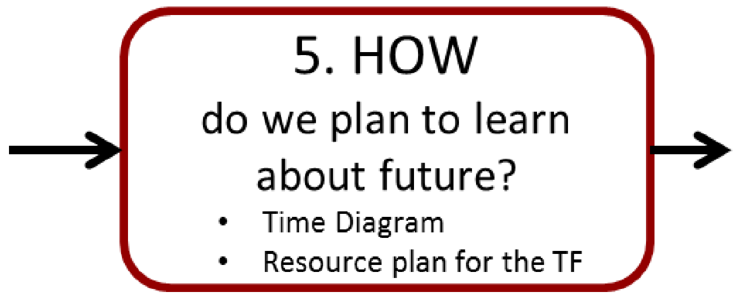
a. Which is the most promising decoration technology for achieving present and future product need (quality, flexibility, cost effectiveness) in the future 5 to 10 years (2019-2024) for home appliances in Europe, Middle East, Africa (EMEA) markets?

[1] surfaces: plastic, metal, glass, porcelain; flat, 2D curved, 3D curved, perforated, texture

b. Will decoration technologies be needed?
c. Which will be the expected (estimated) evolution of Main Parameters of ink-jet and laser marking?
d. When will inkjet technology be ready to substitute silk screening and pad printing for domestic appliances?
e. When will laser marking be able to produce coloured marks on plastic?

How do we plan to learn about the future?

Step 5



highlight

While meeting beneficiaries, get decisions about resources allocation – human, data, restricted access permissions – formalize these decisions.

method

Gather standard project management data about time and resources in order to prepare a schedule of working sessions and engage resources.

instructions

1 List resources

- Human resources of analysts [2],
- Human resources of invited experts [3],
- Beneficiaries [4] and users [5],
- Access rights (e.g.: to data, area of a factory),
- Means for: communication, session organization, file sharing utility

2 Schedule the first session with the participation of beneficiaries and experts.

3 Check availability of human resources in advance for the period of the entire technology forecasting project

4 Outline a standard time planning for a first cycle of methodology application.

- Build a Gantt chart with time split into four stages of FORMAT methodology i.e. FOR, M, A and T.
- Identify unavailability periods among analysts and adjust overall time.

5 Schedule sessions with a minimum of two open days between sessions.

- Provide dates and beginning hours for sessions.
- Agree on predefined session end time – 3-4h time is advised.
- Set a location for sessions (and alternative communication means e.g. telephone, VoIP, teleconferencing service)

[2] Analyst - see glossary
[3] Invited experts - see glossary
[4] beneficiaries - see glossary
[5] Users - see glossary

- Plan for factory (system in real environment) visits – indicate who should be contacted, by whom and how much advanced notice is needed in order to organize a visit.

6 Plan the forecasting project using the suggested timeframe and number of sessions in Table FORStep5-1. Detailed planning for each stage and sessions can be represented on a Gantt chart. Gantt chart presenting main stages in a sequence without schedule of particular sessions is shown on Figure FORStep5-1.

Table FORStep5-1: Number of sessions and duration of stages in FORMAT methodology

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

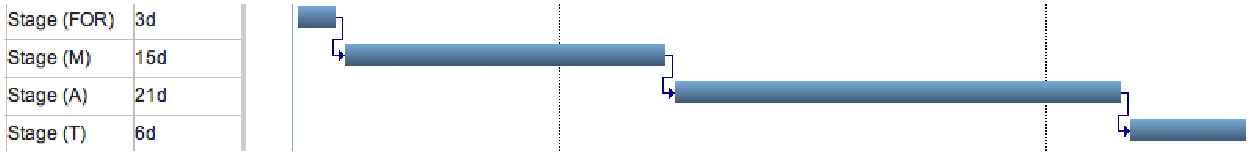


Figure FORStep5-1: Gantt chart for 4 stages in FORMAT methodology and specified duration in days for each stage

tips

- ⇒ Ask about project management tools and approach used in the user's organization.
- ⇒ Ask users about preferable time for advance notice in sending out meeting requests.
- ⇒ Ask about human resources of external experts who may be useful for the forecasting study.
- ⇒ Although it is possible to conduct working sessions by means of video-conferencing service (e.g. VoIP), face-to-face working sessions are preferable. As a thumb rule, the number of face-to-face sessions should be at least one fifth of all the working sessions. Gate closing sessions should be online meetings and not offline sessions.
- ⇒ A minimum two day space is required between sessions to allow time for learning process of analysts working on the forecasting project.
- ⇒ Schedule a time – usually minimum two weeks of advance – to invite beneficiar-

suggested reading

PMI. (2013). A Guide to the Project Management Body of Knowledge: PMBOK(R) Guide (5th ed., p. 589). Project Management Institute.

Project cycle management guidelines. (2004). European Commission, Aid Delivery Methods. Retrieved from http://ec.europa.eu/europeaid/multimedia/publications/publications/manuals-tools/t101_en.htm

examples

Brief Context - Project "packaging" has an objective to forecast a future material for packaging of home appliances products. Human and other basic resources for scheduling this project are listed in Table FORStep5-2.

Table FORStep5-2: Review of resources for project 'packaging'

Analysts	3 analysts
Beneficiaries	2 beneficiaries i.e. department director, department leader
Users	Packaging expert, process manager
Invited experts	Packaging expert, process manager
Access rights	Visit to the production plant of refrigerators
Means of communication	Face-to-face meetings, email, web-accessed file repository

Second working session – the first meeting after the meeting with beneficiaries and users – was scheduled in three days i.e. with a two-day open space. Analysts had been informed about planning for all subsequent working sessions. All known lapses in time availability had been taken into account e.g. public holidays, individual vacation leaves and individual appointments. Members of analysts' team declared full availability for working sessions.

Working sessions lasted 4 hours each, had been scheduled with three workdays between sessions. An example of scheduling without particular dates is shown in Figure FORStep5-2. Days of a forecasting project are numbered in a sequence and associated with particular stages i.e. FOR, M, A and T. Days with working sessions are marked by rectangles with red background.

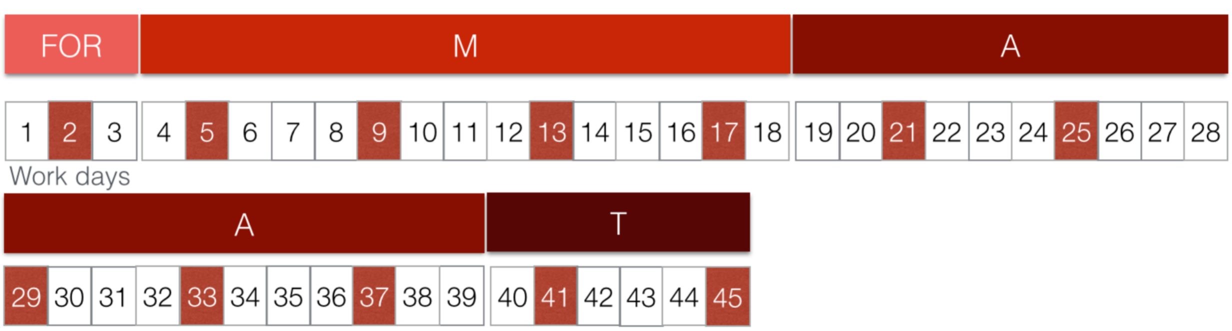


Figure FORStep5-2: Scheduling of forecasting project with indicated days that contain working sessions.

All working sessions were planned to take place in a meeting room adjoining the main open-space office. A meeting room was equipped with a table, chairs for 10 people, whiteboard, overhead projector, internet and phone connections. A meeting room had been booked for all pre-planned working sessions. Last working session took place in a larger room. Visits to packaging factory had been planned at the beginning and at the end of stage M.

An extended view of the planning of the working sessions is shown in the spreadsheet version of the schedule with specific tasks for each session (Table FORStep5-3). This schedule was prepared as soon as each working session was connected to a particular stage.

Table FORStep5-3: Example of part of the schedule for working sessions – with task description and work progress monitoring.

Session	When	hours	Activities planned				
1	2	3	4	5	6	7	8
#4	11/08 at 9 a.m.	4 h	<*to model*> <*existing knowledge*> - Develop the answer for question: WHAT the **STF** (System to be forecasted) and its main **alternative** (s) are, were and are expected to be?				
#5	18/08 at 9 a.m.	4 h	<*to model*> <*existing knowledge*> - to review developed materials - **Visit #2** to production process				
#6	22/08 at 2 p.m.	4 h	<*to identify*> <*future traits*> *for STF* **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 - Visit #2 to production process				

Additional columns in Table FORStep5-3 may contain:
Column 5 - activities performed
Column 6 - techniques & methods e.g. presentation of slides, reporting, question & answers, logistic S-curves, laws of evolution etc.
Column 7 - outputs planned
Column 8 - outputs delivered
This form of scheduling merges instructions of methodology's steps with calendar scheduling of working sessions.

When scheduling your forecasting project, be aware of:

- Availability of invited experts in time for executing a particular step in the methodology.
- Availability of people who will guide you to the real, implemented system that you are forecasting may not always match with desired time moments of stages in methodology application.
- Storming[2] phase within the analyst group – time to set rules of work, agree on methods being applied to describe a system to be forecasted (STF).
- Plan your activities keeping in mind the subsequent steps in the stages M, A and T. Gather data for methods to be used later on, in order to do it once for several purposes.
- From the project management point of view, time in stage T at the end of the project is considered to be a time reserve for delays that may appear in the preceding stages.

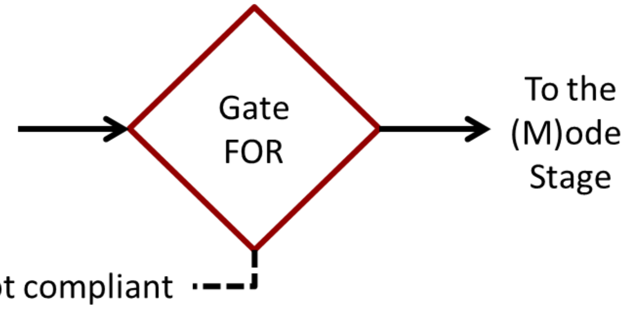
[2]Tuckman's stages of group development see http://en.wikipedia.org/wiki/Tuckman's_stages_of_group_development

notes

FOR Gate

function

<to check> <completeness and



Complete the following:

- Main objectives of forecast (Project) (Why?)
- Definition of knowledge elements for the application of the forecasting results
    - Main outputs for *Decision Makers* (DM) (What?)
    - How the outputs will be applied by DM (link between Why-What?)
- INTERIM CHECK: Can we get the required results without forecast?
    - Go/NoGo -> to forecasting project
- Definition of preliminary constraints for the project
    - System (Process) to be forecasted (STF) from technological, economics, environmental and social (TEES) perspectives (What?)
    - Time horizon (When?)
    - Market scope and geographical context (Where?)
- List of Questions for Forecast (Questions to be answered at the end of study)
- Plan of Project (How?)
    - Time diagram (Gantt or similar)
    - Resources for the activity (People, knowledge, IT instruments)

tips

- ⇒ It is highly recommended that you print this list out for your FOR gate session
- ⇒ It is recommended to meet with the decision maker at this gate to check the conformity of the objectives with the needs of the decision maker.
- ⇒ This gate will serve as reference to later stages
- ⇒ Tick the task only after the item is 100% complete
- ⇒ Proceed to the next stage only after completing all items on this list

FOR M A T

M Stage

notes

M Stage

The main function of the Model stage is to contextualize the system to be forecasted, as well as to capture and review existing and available knowledge relevant for the project. As a result, this stage allows the team of analysts to harmonize their knowledge through the integration of their different perspectives and to collect relevant information from external sources.

prep time

4 working sessions

total time

10 working days

people

2-4 analysts plus requested experts

ingredients

materials

Already available process models or diagrams. Already available datasets or technical info sheets. Access to patent databases and scientific literature

tools

Chosen by user

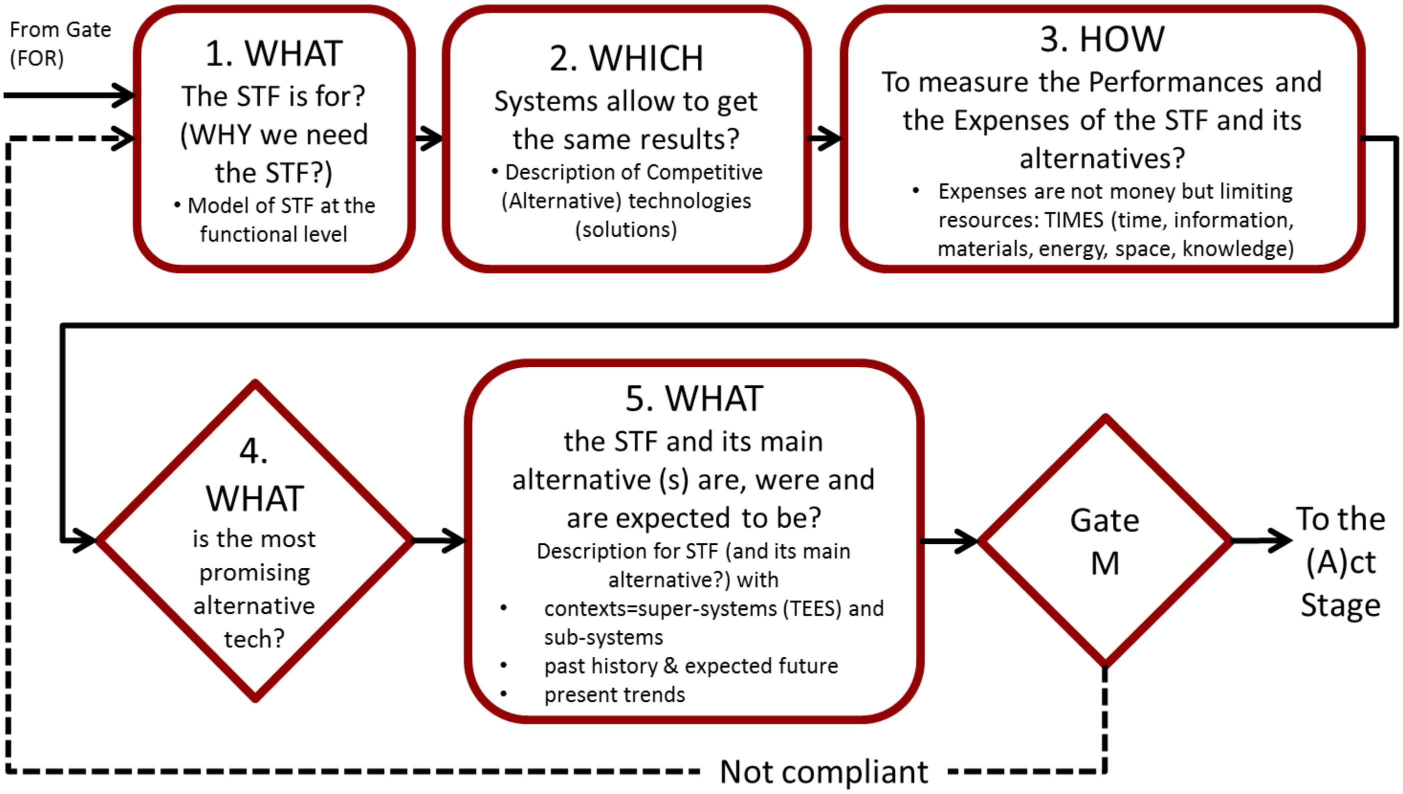
knowledge

Expertise or practice in functional modelling techniques. Technical knowledge in the field

software

Applications for product/process functional modelling (optional)

M Stage



instructions

1 Describe the system to be forecasted (STF) by its function, by answering the questions: "What is the STF for?" and "Why do we need the STF?". The definition of an IDEF0 (or analogous) model would be beneficial.

2 Describe the specific technologies or, in general, solutions that compete with or offer an alternative to the STF. Answer following question: "Which systems get the same results?".

3 Define the main criteria for comparing alternative technologies (including the STF) in terms of both performance and expenses (to be intended as consumption of resources of time, information, material, energy and space). In order to define such criteria, answer the following question: "How would I measure that the STF is better (or worse) than Alternative X?"

4 Select the most promising alternative technology/solution that represents the best candidate for substituting the STF in the context object of study (even if not completely suitable for its substitution). This step aims to shorten the time required for the forecasting study with minimum loss of relevant information. Besides, in the final stage, this choice should be clearly reported in the limitations of the study.

5 Prepare a structured description of the STF and its main alternatives (also in terms of the measurable criteria identified at Instruction #3). Approach the analysis from two perspectives:

a. System hierarchy.
   i. The STF as a whole technology (system);
   ii. The parts and/or the phases composing the STF (sub-systems);
   iii. The contexts, the STF and its main alternative operate in or where they are required (super-systems);

b. Dynamics of evolution - Consider what the situation of the past was and what the expected situation (no forecast yet) for the future will be.

c. Considering the dynamics of the evolution at the three different hierarchical levels, extract a set of features characterizing the expected evolution in terms of factors pushing the development of novel solutions (drivers) and traits preventing it (barriers).

tips

⇒ In order to properly address the whole activity of Stage M, select the relevant content by focusing on the forecasting questions defined in Stage FOR.

⇒ Beyond the instructions described above, use FORMAT Deliverable 2.2 for a review of modelling techniques with descriptions, examples and hyperlinks to the sources.

⇒ Use the STF functional model produced in step M-1 as a trigger for the identification of alternative technologies/solutions at step M-2. The alternatives must be capable of producing the same results of the STF or, at least, satisfying the same overall objectives or needs.

⇒ Use the Element-Name-Value (ENV) model to generate the criteria to measure the performances and the expenses of the STF and its alternatives/competitors (FORMAT Deliverable 2.2), to help distinguish between the name of what is measured and its value. The collection of such values with a time perspective can be significantly beneficial to both Step M-5 and the A Stage of the methodology, e.g. for the identification of Y-axis units of S-curves statistical regressions.

⇒ The criteria defined at step M-3 should be capable of capturing the main parameters characterizing the technologies under investigation without introducing excessive details. Suggestions for the identification of these criteria can be found in checklists for requirements identification and characterization. Please refer to the suggested readings.

⇒ For the identification of the most suitable solution for the substitution of the STF at step M-4, please consider what you consider as the most relevant and the most critical parameters for the competition of such a technology in the field (e.g., a parameter that prevents implementation).

⇒ In order to be sure of identifying a sufficiently broad amount of contexts in which the STF and its main alternative are used, think about their impact in 4 domains: technological, environmental, economic and social (TEES). If you cannot cover these domains, retrieve the relevant content from sources of explicit knowledge (books, papers, info sheets, etc.) or tacit knowledge (experts in the fields of the study).

⇒ The timespan in systems evolution at step M-5 should range forward and backward at least the same time span as forecasting time defined in Stage FOR. Actually, the backward analysis should be preferably pushed twice more than the expected forward perspective to gain a better understanding of the system evolution (e.g. a team interested to study the expected evolution 10 years ahead, should preferably study the past 20 years or more, definitely not less than the last 10 years).

⇒ In case this is not your first application of the FORMAT methodology (or you are familiar with the System Operator logic), it is suggested to start organizing the retrieved data and info about the STF consistently with the logic and the structure of the System Operator from the very beginning, so as to speed up what is required at step M-5. This should allow a more efficient management of the knowledge flow along the whole Stage. For instance, when you define the STF and its function at step M-1, fill the System-Present screen. When you get in touch with relevant information and data about the parts/components of the STF (as a product) or STF phases (as a process), organize them in the Sub-system level, choosing the screen concerning the timespan the data refer to, etc.

suggested reading

Beyond the specific description of the Steps characterizing the Stage M of the FOR-MAT methodology, the following reference may come in handy.

Modelling Techniques

Becattini N, (2013) PRODUCT AND PROCESS MODELLING – STATE OF THE ART UPDATE - FORMAT Deliverable 2.2 - http://www.format-project.eu/deliverables/public-reports-and-white-papers/deliverable-2.2/view

Identification of relevant criteria for comparing alternative technologies/solutions

Becattini N, Cascini G, Petrali P, Pucciarini A, (2011) Production processes modeling for identifying technology substitution opportunities, Proceedings of the ETRIA TRIZ Future Conference p. 17–34.

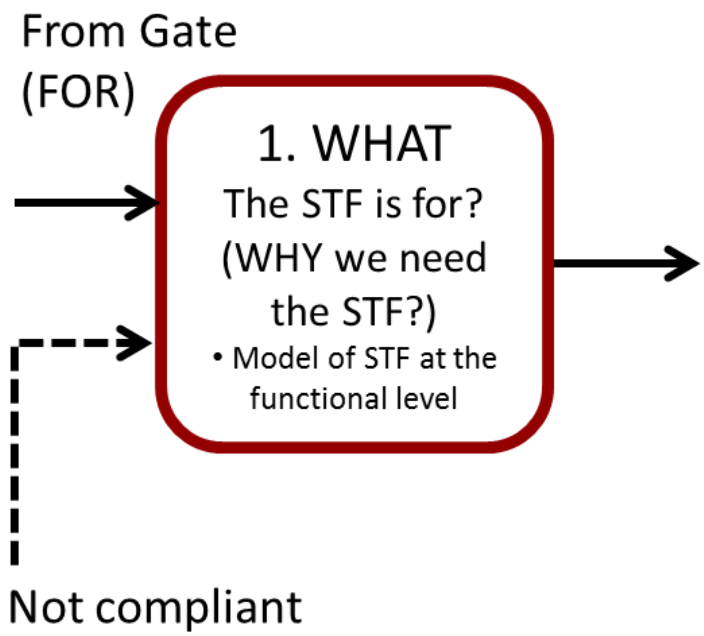
Pahl G, (2007). Engineering Design: A Systematic Approach - Section 3.3.2 (Vol. 157). K. Wallace, & L. T. Blessing (Eds.). Springer.

Structured and Systematic description of the STF

Altshuller, G. S. (1984). Creativity as an exact science: The theory of the solution of inventive problems (Vol. 320). New York: Gordon and Breach Science Publishers

notes

What is the system for?



Step 1

highlight

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.

method

Define the function of the system to be forecasted (STF), highlighting the capability of the STF to transform a given input into a desired output. Produce a clear model of this transformation.

instructions

1 Recall the questions to be answered and the STF as defined in Stage FOR. (e.g. the STF is: (a) “domestic oven”; (b) “mixer”, and its function is defined in Step 4 of stage FOR).

A reminder for defining a function (Stage FOR Step 4):

a. The function should be expressed according to the following template: <the STF> <makes/produces> <outcome>. (e.g. “<the domestic oven> <makes> <grilled and baked food>; <the mixer> <makes> <creamy smoothies>”)
b. The desired outcomes should be considered as the “OUTPUT” of the function the STF is able to deliver. The output represents what the STF aims at transforming (The OUTPUT in the example is “grilled and baked food” and “creamy smoothie” respectively).
c. In the above examples “grilled and baked” or “creamy” is the performance to be achieved through the STF function, for the entities processed by the STF or on which it carries out its function, i.e. “food” and “smoothie” respectively.

2 Define the outcomes of the STF qualitatively.

- Keep in mind the entities the STF interacts with to achieve the results the STF has been designed for.
- Answer the question: “What is the system for?”

Note the following:

a. The STF strictly requires all the entities associated with producing the desired output. The initial state of those entities should be referred to as the “desired INPUT”. (Desired INPUT: “raw or partially cooked food” and “fruit, milk and ice” respectively).
b. The STF requires some other material or immaterial (e.g. energy or information) entities to carry out its function on the desired INPUT. Such entities represent the “required INPUT” for the STF (Required INPUT: “electric energy” (a); electric energy (b)).

3 Build a model (EMS or IDEF0 like) of the industrial process the STF belongs to in terms of its function.

- It will be used in the next steps of the project.
- Check 'example section' below for an overview on how to build the model.

4 If you want to add more detailed level.

In case you are dealing with a process-oriented perspective, you might consider worth the analysis to be examined at a more detailed level for the functional description of the STF. Processes are usually considered as sequence of phases (e.g. using specific machinery). Each of them represents an overall function (potentially delivered through other specific, say, sub-functions) whose sequence already represents a functional representation of the process. This requires the overall function (after instructions #1, #2 and #3) to be decomposed in more elementary functions.

The following instructions clarify how to proceed with the functional decomposition:

a. The overall modelling approach follows the logic proposed in instructions #1 and #2 also for the sub-functions;

b. In order to identify and model sub-functions, consider what the intermediate transformations the OUTPUT undergoes from its "desired INPUT" state; all these transformations highlight the presence of a sub-function carried out on them. The overall logic of functional decomposition is to follow the sequence of intermediate functions the desired INPUT/OUTPUT flow is undergoing.

tips

⇒ Double check the consistency of the STF function by applying the following definition of a function: "a function is an action that a subject (the STF) carries out on an object (the desired INPUT/OUTPUT) in order to change or stabilize one of its features, characteristics or parameters."

⇒ For a further clarification about the concept of Function and its modelling techniques (e.g. EMS and IDEF0) please refer to the FORMAT White Paper published on May 2013 and to Deliverable 2.2

⇒ In case of difficulties encountered in performing the above instructions, identify the overall STF function by answering the following questions: “What is the STF for?” and “What would happen if STF was not existing, or suddenly disappeared while delivering its function”;

⇒ The INPUT and the OUTPUT of a function can be considered as material or intangible entities (refer to the further examples at the end of this step).

⇒ Involve people with knowledge about the STF to elicit information about the various contexts where the STF is used. A sensible combination of these contexts may produce a better definition of the STF function.

⇒ This functional description is beneficial in the next steps of the FORMAT methodology. In such a step, the analysts are asked to identify competitive or alternative solutions to be considered for a potential substitution of the STF. Therefore, this functional description represents an abstract description of the purpose of the technical system beyond its embodiment and working principle.

⇒ When you need to carry out the functional decomposition of the STF from a process viewpoint (instruction #4), consider what the most relevant sub-functions are, with reference to the question of forecast defined along the FOR Stage. A manageable amount of sub-functions for each level of description should be comprised between 2 and 7.

⇒ To ease the logic of functional decomposition, example 4 here below shows the functional decomposition of the process of “cooking pasta” that, by itself, represents a function (see A-0 Context diagram). That example is presented with the IDEF0 logic. The A-0 Context diagram also clarifies how the arrows should be interpreted with reference to previous examples. The 1st level functional decomposition is presented in the A0 model as the sequence of three sub-functions: Preparation (further detailed in A1); Cooking (A2); Plating up (A3). The background colour of each Ax model reflects the links among the models.

⇒ If you are already familiar with the System Operator logic (Deliverable 2.3) or have already carried out a study with the FORMAT methodology, it could be beneficial to start organizing information and data according to that framework. This will allow you to record the information in a unique model and speed up the activity along the whole stage (especially step M5). The example #5 shows how to start inserting the information of this step inside the System Operator model. The content is the same as proposed along example #4.

suggested reading

Becattini N, (2013) On the definition of functions for the identification of system Requirements. FORMAT Project White Paper May 2013, available at http://www.format-project.eu/deliverables/white-papers

Becattini N, (2013) PRODUCT AND PROCESS MODELLING – STATE OF THE ART UPDATE - FORMAT Deliverable 2.2 - pp. 18-34 - http://www.format-project.eu/deliverables/public-reports-and-white-papers/deliverable-2.2/view (it includes full references about IDEF0 and EMS)

Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. H. (2007). Engineering Design: A Systematic Approach (Vol. 157). pp.31-38 - Springer.

examples

Example #1a-b: STFs processing materials

a. The STF is the (a) "domestic oven"; (b) "mixer";
b. The OUTPUT is "grilled and baked food" (a); "creamy smoothie" (b);
c. The INPUT for the function is:
    i. Desired INPUT: "raw or partially cooked food" (a); "fruit, milk and ice" (b);
    ii. Required INPUT: "electric energy" (a); electric energy (b);
d. The diagram of the functions for (a) and (b) is presented in Figure MStep1-1.

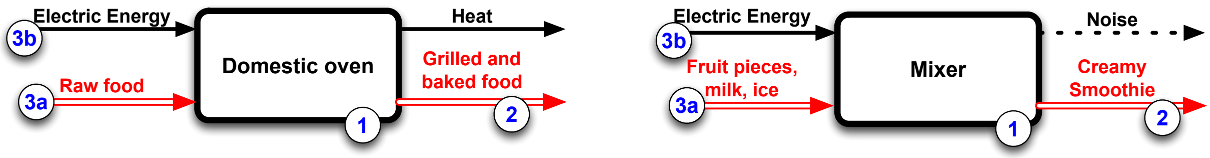


Figure MStep1-1: EMS functional diagram of a domestic oven (left) and a mixer (right). The examples present also real OUTPUTS, even if not necessarily desired.

Example #2: STFs processing energy

a. The STF is the "photovoltaic panel";
b. The OUTPUT is "electric energy flow";
c. The INPUT for the function is:
   i. Desired INPUT: "solar radiation";
   ii. Required INPUT: none;
d. The diagram of the function is presented in Figure MStep1-2.

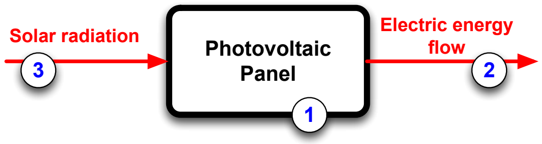


Figure MStep1-2: EMS diagram of a photovoltaic panel (STF processing energy)

Example #3: STFs processing signal (intangible entity)

a. The STF is the "digital audio compression algorithm";
b. The OUTPUT is "portable file of adequate audio quality";
c. The INPUT for the function is:
   i. Desired INPUT: "big size Hi-Fi audio recording";
   ii. Required INPUT: "electric energy …";
d. The diagram of the function is presented in Figure MStep1-3.

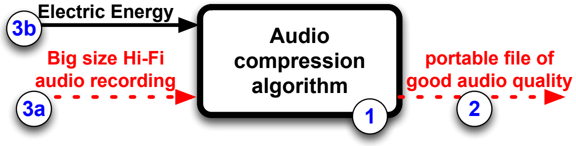


Figure MStep1-3: EMS diagram of an audio compression algorithm (STF processing signal)

Example #4: Process modelling - Cooking Pasta

a. The STF is the "process for cooking pasta";
b. The OUTPUT is "Plated spaghetti";
c. The INPUT for the function is:
   i. Desired INPUT: "Raw spaghetti, Water, Salt";
   ii. Required INPUT: "Heat, Pot, User, Colander, Scale";

d. The diagram of the function is presented in Figure MStep1-3. It also includes the real outputs include "Hot salty water" and as controlling elements for the process, doses and timing have been made explicit.

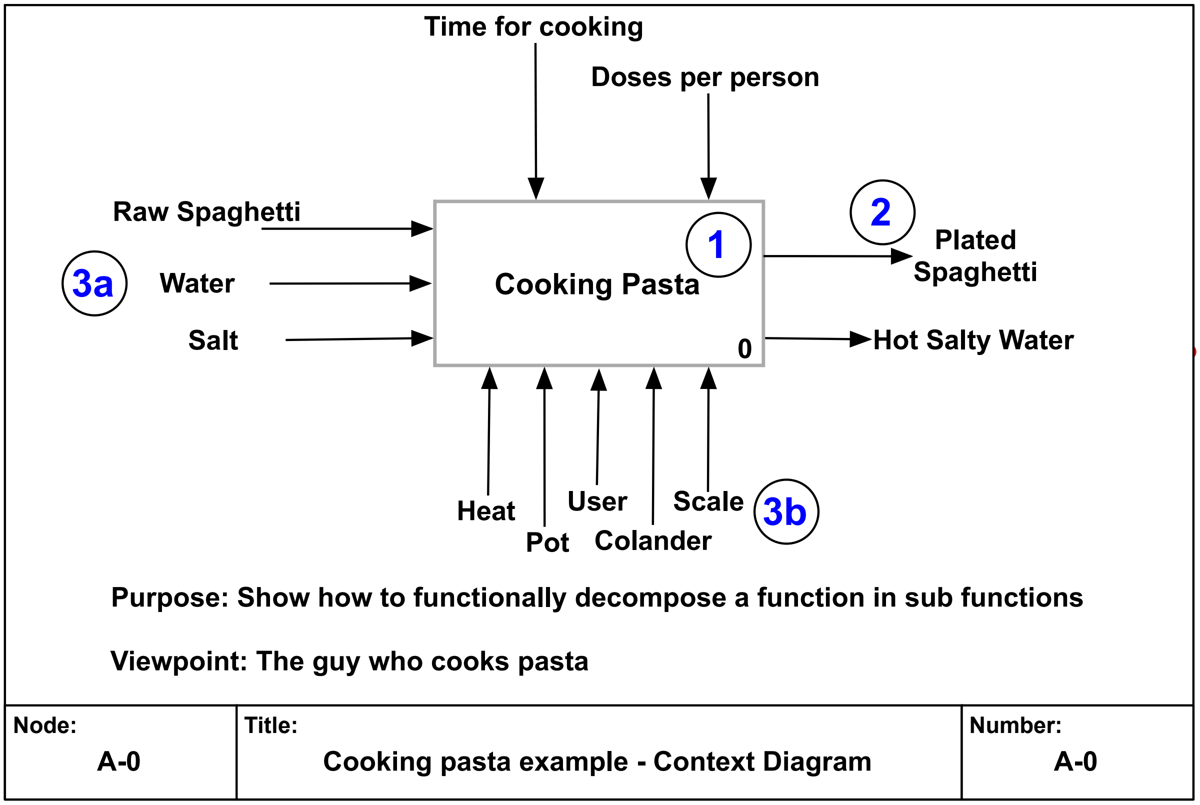


Figure MStep1-4: The IDEF0 A-0 Context Diagram for the process of cooking pasta. The model includes circled numbers to show the link with the modelling technique proposed in the instructions. The orange background colour highlights the connection with the A0 model, which represent a first level functional decomposition of the process.

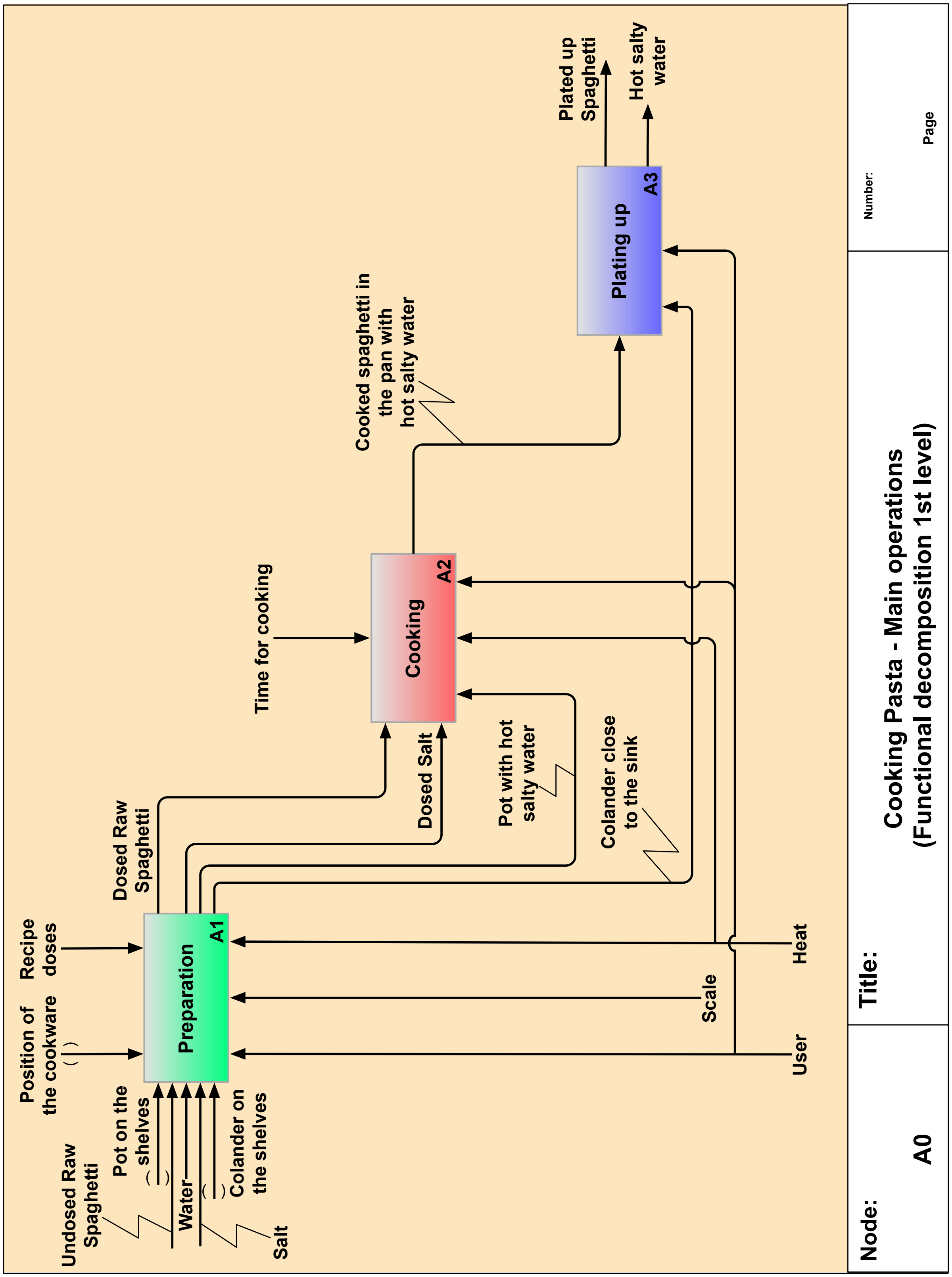


Figure MStep1-5: The first level functional decomposition of cooking pasta. A1, A2, A3 are coloured consistently with the colour background of the next models.

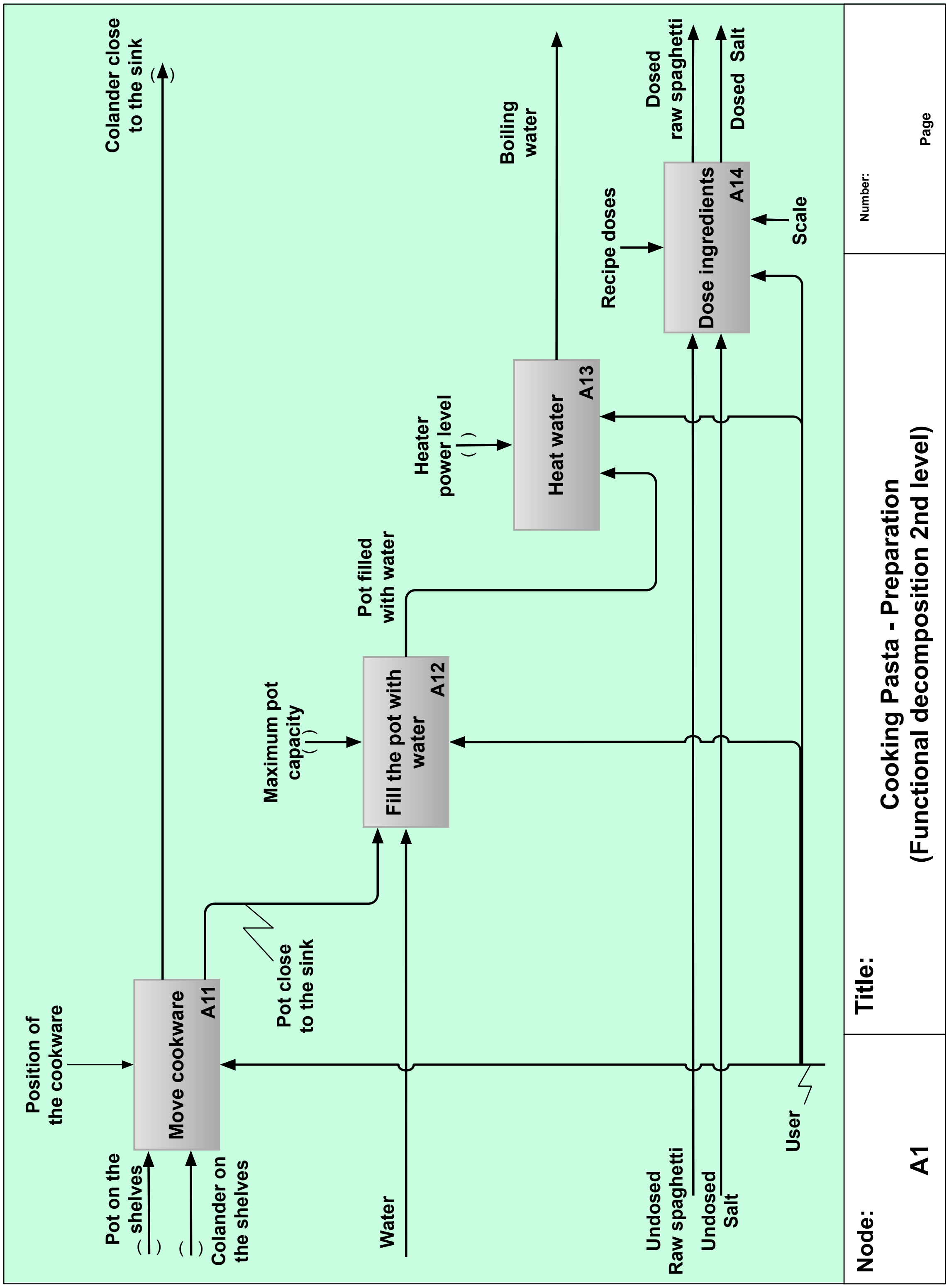


Figure **MStep1-6**: A more detailed perspective about the function characterizing the overall stage of Preparation

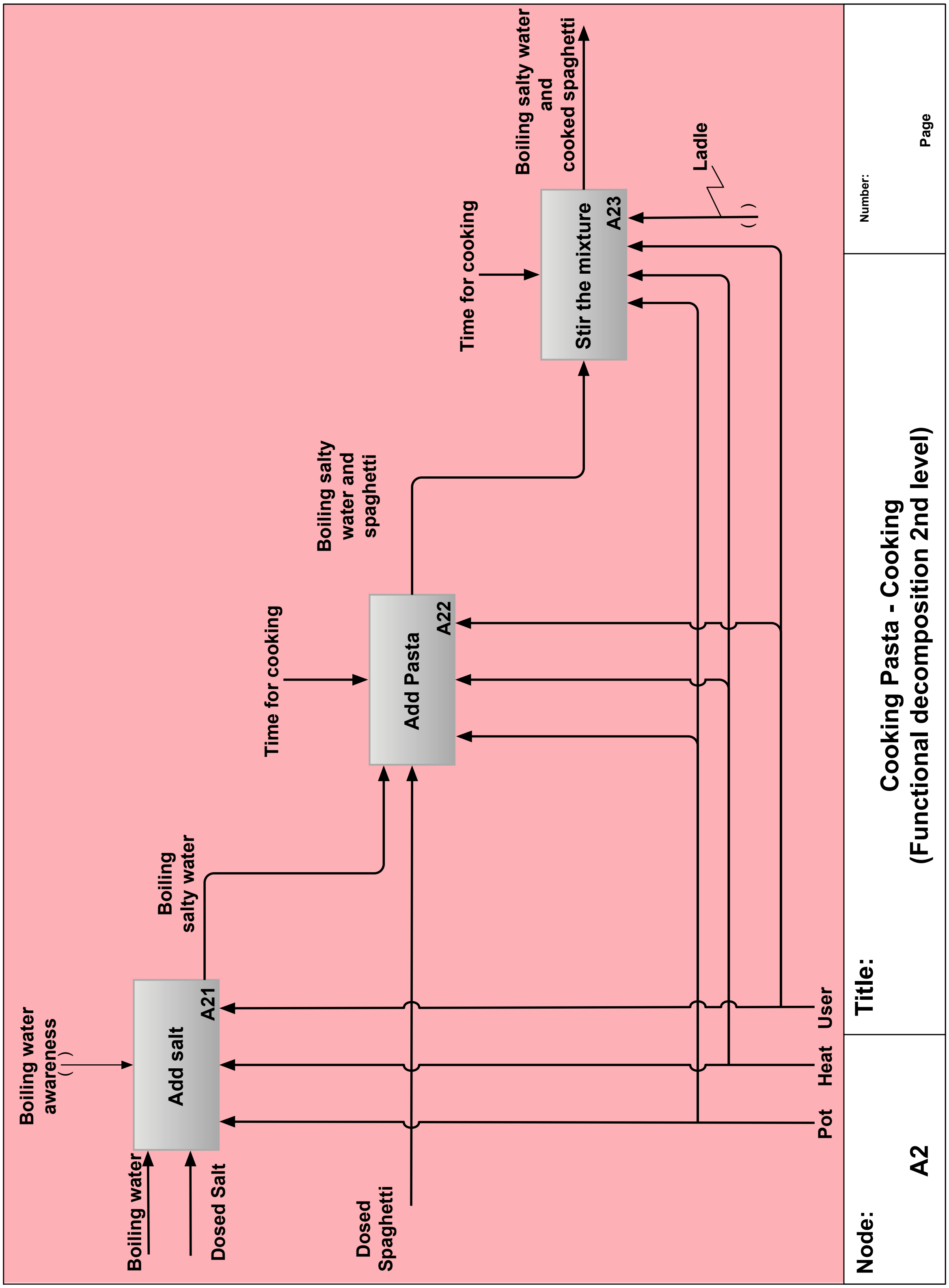


Figure **MStep1**-7: A more detailed perspective about the function characterizing the overall stage of Cooking

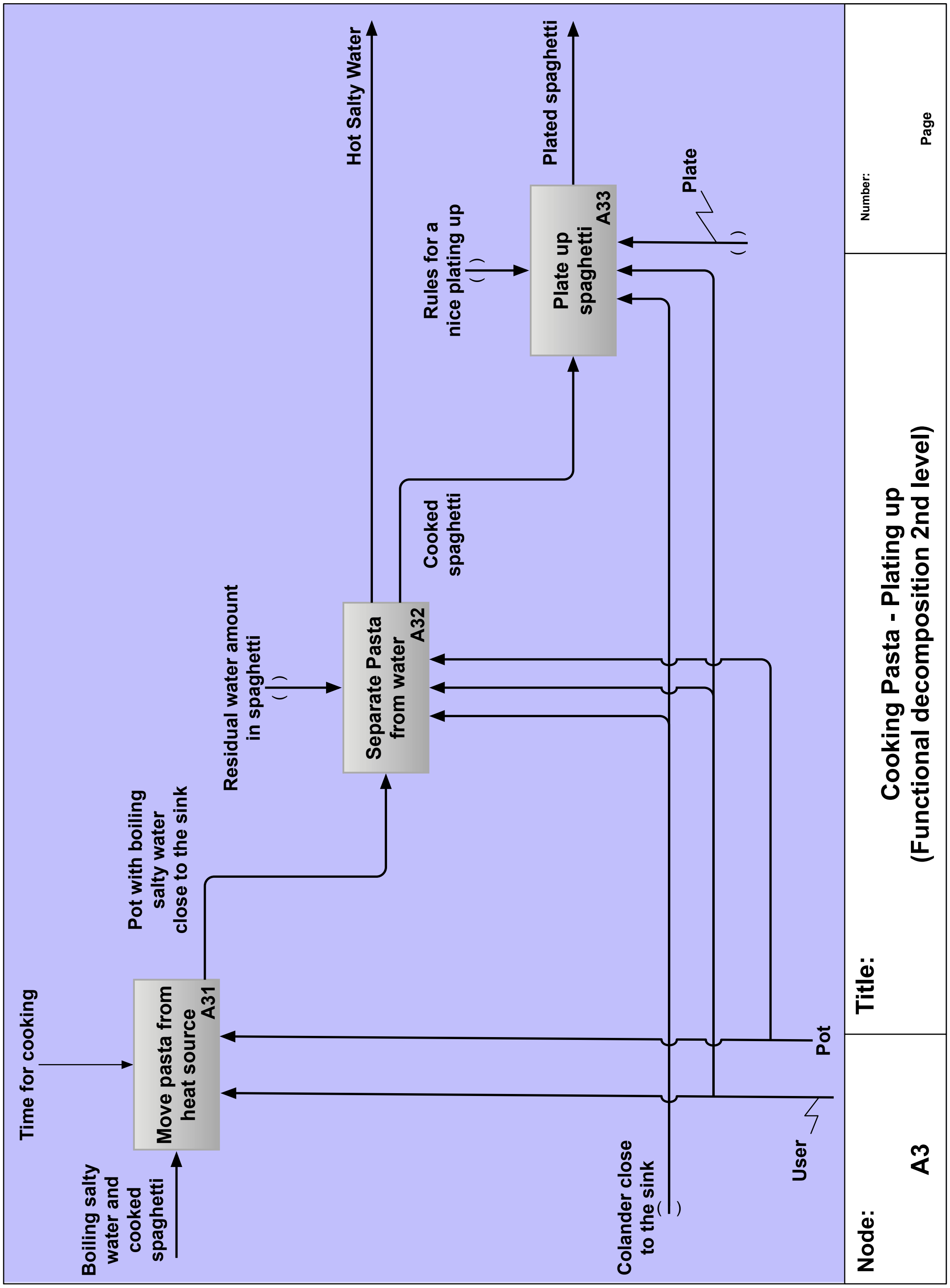


Figure **MStep1-**8: A more detailed perspective about the function characterizing the overall stage of Plating up.

Example #5: Integration of a Functional model within the System Operator framework.

This example shows how to organize the information or formalized knowledge according to the System Operator logic. Figure 9 shows a 3x3 matrix, where each cell corresponds to specific content in space (vertical axis) and in time (horizontal axis). The content defined along this step (M1) pertains to the function of the whole STF, which has to be intended as the system corresponding to the current state of the art.

The function of the STF, therefore, is a content that pertains to the system level. Being a description of the current STF, it should be placed in the cell corresponding to the present time frame. Accordingly, an excerpt of Figure 4 is placed inside the "System level - Present" cell.

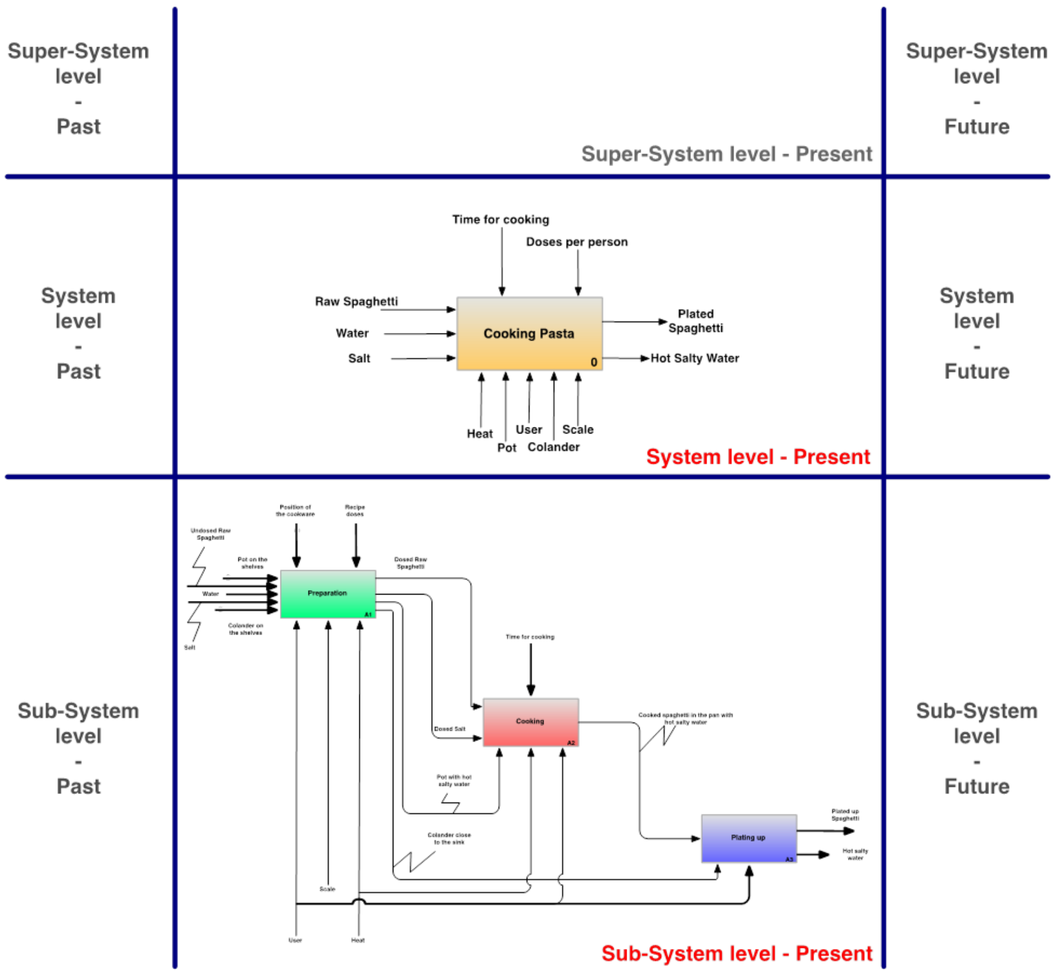


Figure MStep1-9: Example to show how the content developed along this step can be organized consistently with the System Operator logic.

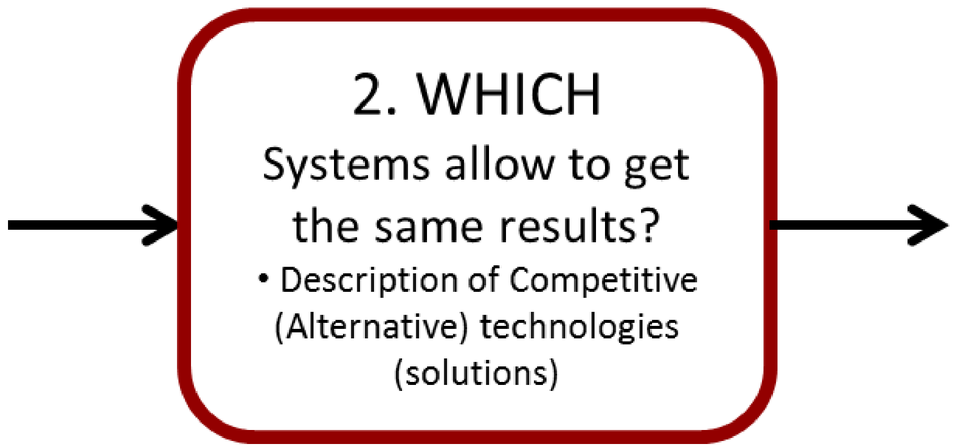
In case you decide to further detail the investigation of the main function to a model where sub-functions become explicit, your analysis is focusing on the sub-system level. The functional decomposition of the STF, therefore, pertains to the "Sub-system level - Present". An excerpt of Figure 5 has been accordingly placed in the related cell.

Please note, that you may also opt to characterize the STF in terms of its components or parts. This decomposition, being structural instead of functional, still pertains to the Sub-System level.

notes

Which systems allow to get the same results?

Step 2



highlight

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

method

Identify the alternative solutions or the competitive technologies that allow users to get the same results or, in principle, satisfy the same overall need that the STF currently fulfils. At the end of this step present a list of alternatives.

instructions

1 Recall

- questions of forecast defined in Stage FOR,
- the functional model of the STF prepared at the end of the previous step.

2 Focusing on the output of the function, enumerate the alternatives.

Consider:

a. competing systems capable of obtaining similar outcomes,
b. systems satisfying the same overall need.

3 Construct a list of 3÷5 alternatives considered by analysts and experts as the most relevant.

Please note:

a. The alternatives to the STF may be technical or non-technical systems. (e.g. among the competitors for giving advanced warning to people about tsunamis, door-to-door notifications could be considered as a non-technical alternative to SMS- and radio-based alarms).
b. The alternatives do not need to share the same working principles of the STF. Generally, the difference between the alternatives may be the structure or the functioning of the system.

tips

⇒ The main idea behind studying alternative systems is to collect problems-limitations about STF and its context. Therefore the selected alternative technologies should be representative rather than numerous.

⇒ Cluster similar alternatives and refer to them by a cluster name. In case the number of identified alternatives are not easily manageable (time-consuming), conclude this step with no less than 3 and no higher than 7 alternatives.

⇒ To each STF's alternative, add a short description of its working principle; this may help in understanding the differences between the competing alternatives, as well as to cluster them.

- ⇒ Search for alternative solutions may be difficult. A good source of inspiration for the technical domain may come from patent databases. They are usually available for free at the websites of national or international patent offices. Search for available alternatives through "classification searches" by:
  - ⇒ Using keywords that represent the STF in order to highlight the most related patent class,
  - ⇒ Exploring higher and lower (i.e. both increasing and decreasing the number of digits specifying a class content) in the hierarchy of classification in order to check the existence of specific subclasses collecting patents about competing technologies.

  It should be kept in mind though that patent classes refer to established technologies and do not include emerging ones.
- ⇒ As soon as you observe any strengths and weaknesses among alternative technologies, list them for use in Stage A.
- ⇒ A good practice is to express strengths and weaknesses in measurable values.
- ⇒ If during the previous step of the M stage you started organizing knowledge and information in the System Operator scheme, you can continue enriching it also along this step. The example #3 here below shows how.

suggested reading

Cooperative Patent Classification (CPC) - Available at worldwide.espacenet.com
Moreover, given the domain-free perspective of the FORMAT methodology, it is quite hard to suggest specific readings that may come in handy for the identification of alternative technologies. A generic suggestion for said readings can follow

publishers' websites (*=requires a subscription):

- Elsevier's Scopus - http://www.scopus.com (*)
- Thomson Reuters's Web of Science/Web of Knowledge - http://webofknowledge.com (*)
- Elsevier's ScienceDirect - http://www.sciencedirect.com (Journal titles and paper abstracts are visible also without any subscription).

examples

Example 1: alternative solutions to "domestic ovens":

STF: Domestic Oven

Alternative technologies:

- Microwave oven
- Bread Machine
- Electric Cooktops
- Gas cooktops
- Cooking food processors

Example 2: alternative solutions to "cars":

STF: Car

Alternative technologies:

- Train
- Airplane
- Boat
- Horse coach
- Bus
- Metro
- Bicycle

It is worth noticing that in the specific context of a car used as a technical system to allow people to meet and talk, an alternative technology may be a web meeting system.

Example 3: alternative solutions within the logic of System Operator

The alternatives to the STF share, by definition, the same function. Thus, the STF and its alternatives share the same hierarchical level (System level). As for Figure M Step2-1, in fact, the alternative transportation systems have been organized and collected within the same cell of the System Operator (System level - Present).

Moreover, even if this action has to be carried out in step M5, you can also start considering the contexts in which the STF and its alternatives are used. These contexts, by themselves, can be considered as articulated systems that include the STF (or its alternatives) as Sub-Systems. In these terms, the context represents a higher hierarchical level than the System Level. Thus, the information about the different relevant contexts have to be included in the "Super-System level - Present" cell of the System Operator (see Figure M Step2-1).

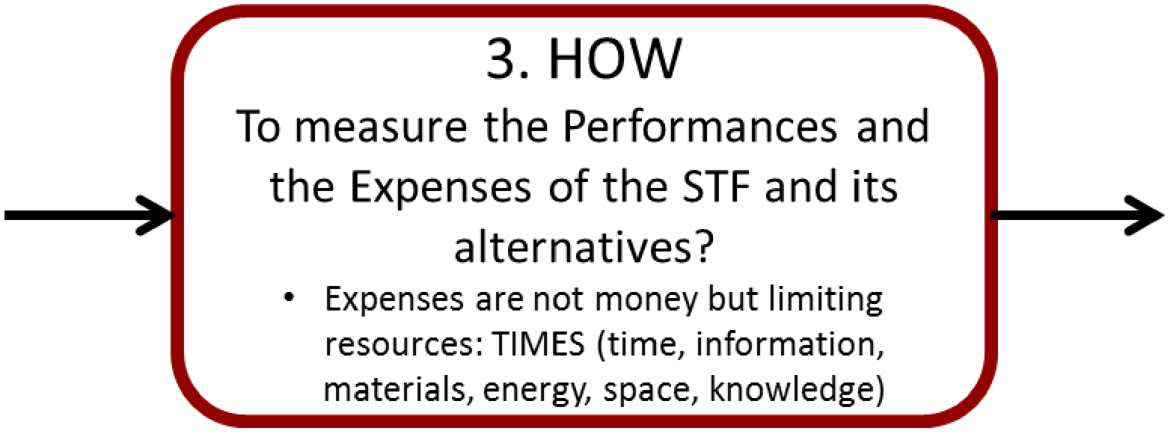
Super-System level - Past	Relevant Contexts: • Roads • Parking lots • Refueling sites • Docks • Railways • Stations • Ticketing system • Maintenance sites • Spare parts selling networks • End-of-life processing sites • ... **Super-System level - Present**	**Super-System level - Future**
System level - Past	STF: Car Alternatives 1. Train 2. Airplane 3. Boat 4. Horse coach 5. Bus 6. Metro 7. Bicycle 8. ... **System level - Present**	**System level - Future**
Sub-System level - Past	**Sub-System level - Present**	**Sub-System level - Future**

Figure M Step2-1: Example to show how the content developed along this step can be organized consistently with the System Operator logic.

notes

How to measure performances and expenses of STF and alternatives?

Step 3



highlight

Retrieve and organize knowledge of the key aspects of the alternative technologies and prepare a comparison with the current technology.

method

Define criteria for measuring the performance of the STF and its alternatives. Along with the performance, define a structured list of resources needed (expenses) for the systems to work.

instructions

1 Recall:

- questions of forecast (Stage FOR)
- the functional model (step 1 in Stage M)
- the list of alternative technologies (step 2 in Stage M)

2 Browse the alternatives and define the main factors for selecting one solution against the others.

a. Define criteria for measuring the performance of the systems:

i. Think about the OUTPUT of the function of the STF, as defined in Step 1 of Stage M.

ii. Explore, if needed, the relevance of the functional performance to the questions of forecast.

iii. Consider the alternative technologies in terms of:

- Achievement of threshold values,
- Versatility/Flexibility ,with respect to qualitative and quantitative variations of process inputs,
- Robustness (of results),
- Controllability of process outputs,
- Capability to work in different conditions.

b. Define criteria for measuring the expenses of the competing systems.

Expenses here are not strictly costs, but are the reasons for the expenses to make a system work.

Consider the following, general set of resources that can be consumed by the STF or by the alternative technologies:

i. Time resources,

ii. Information and knowledge resources,

iii. Material resources,

iv. Energy resources,

v. Space resources.

3. Organize (or re-organize, if necessary) the criteria in a list, so that they are categorized as performance and expenses.

tips

⇒ In order to facilitate the definition of the criteria, consider the pros and the cons (advantages and drawbacks, strength and weaknesses) of each solution against the others. These pros and cons, once transversally linked by meaning-associations among the alternatives, shall allow the emergence of the main criteria relevant to the technological competition.

⇒ In order to understand the real impact of the resources that the systems consume, don't forget to consider the resources that the system may need before its use (e.g.: during transportation, installation) or after (e.g.: during disassembly, disposal).

⇒ If possible, gather external experts' opinions on the different competing technologies and on their input/output flows and contexts.

⇒ If a specific measure of performance or expenses appear for just one of the alternatives, it may be an outlier capable of addressing a niche or, on the contrary, a potential emergence of a new factor for competition.

⇒ In case the time boundaries for the forecasting activity would not allow a thorough and comprehensive analysis of these factors, limit the investigation to the ones that the panel of analysts and experts consider the most relevant.

⇒ The criteria to measure the performance and the expenses of the STF and its alternatives/competitors can be conveniently organized by means of the (Element-Name-Value) ENV model (FORMAT Deliverable 2.2), differentiate the name of what is measured and its corresponding value. Please refer to the Example at the end of the Step to clarify this aspect.

⇒ When defining a measurement criterion, do not limit yourself to available data.

⇒ Keep in mind the possibility to account variables that are not measured yet in the current practice.

⇒ Ask the experts about the availability of data for the chosen measures of performance and expenses.

⇒ As for the previous steps, it is also possible to organize knowledge, information and data about performances and expenses of the STF and its alternatives in the System Operator structure. The last example of this section shows how to deal with performances and expenses, as they are expressed in the first example. Especially for this step of the methodology, the organization of data, information and knowledge within this framework allows speeding up the execution of the subsequent steps.

suggested reading

Becattini, N., Cascini, G., Petrali, P., & Pucciarini, A. (2011). Production processes modelling for identifying technology substitution opportunities. In Proceedings of the 11th TRIZ Future Conference (pp. 17-33).

Becattini, N., (2013). Requirements identification and characterization in innovation processes. PhD Dissertation available at https://www.politesi.polimi.it/handle/10589/74123

Becattini N, (2013) Product and Process Modelling – State of the Art Update - FORMAT Project Deliverable 2.2 - http://www.format-project.eu/deliverables/public-reports-and-white-papers/deliverable-2.2/view

examples

Excerpt of criteria for transport systems (STF: Car; Alternatives: Train, Airplane, Bicycle, …).

Table MStep3-1 is based on both qualitative and quantitative criteria. Criteria are in the first column, in bold. In the same column, in brackets, it is clarified if the measure pertains the performance (P) or the expenses (E) of the technical system. Please note that the values in the tables have merely the function of clarifying the identification of criteria for comparisons.

With reference to the organization of such information in terms of the ENV model, the following table reorganizes the first column of Table 1 with that perspective. Please note that the last column of Table MStep3-2 does not include actual values, but units of measurements (specific values depend on the vehicle to be considered and they can differ significantly.)

The evolutionary analysis required at the Stage A, step 3, can benefit from the organization of such values with a time-related perspective.

Table MStep3-1: measurement criteria for comparing transport systems.

	ALTERNATIVES			
CRITERIA	Car	Train	Airplane	Bicycle
Maximum distance without stops (P)	500-1000 km	500-1000 km	1000-15700 km	40-80 km
Maximum speed (P)	150 km/h	≈300 km/h	≈1000 km/h	20-40 km/h
Amount of transportable people (P)	5	≈700	30-300	1
Room occupied by the system (footprint) (E)	≈1,5 x 3 m	≈3x320 m	73x80 m (A380)	0,30x1,20 m
Distance to get in from home (E)	50 m	2-10 km	60 km	10 m
Passenger's Safety (E)	High	High	Maximum	Not so high
Required fuel (E)	Gasoline	Electric energy or Diesel	Avgas or Kerosene	Human propulsion

Table MStep3-2: generalized measurement criteria for comparing transport systems with explicit distinction between the name of the comparison parameters and the units to measure their values.

CRITERIA	Element it belongs to	Name of the parameter	Value of the parameter
Maximum distance without stops (P)	Vehicle	Range of movement (no stops)	[m] or [km] or [mi]
Maximum speed (P)	Vehicle	Top Speed	[km/h] or [mi/h]
Amount of transportable people (P)	Vehicle	Amount of seats	[# (number)]
Room occupied by the system (footprint) (E)	Vehicle	Surface occupation	[m^2] or [ft^2]
Distance to home (E)	User	Distance to reach the vehicle	[m] or [km] or [mi]
Passenger's Safety (E)	User	Safety	[QUALITATIVE]
Required fuel (E)	Vehicle	Allowed propellant	[QUALITATIVE]

For what concerns the last two rows of Table MStep3-2, the units of measurement haven't been made explicit because of the qualitative nature of the parameter to be measured.

Please consider that the same analysis could have been tackled from a more quantitative perspective.

The following reformulations capture different nuances (qualitative/quantitative) concerning the same overall criteria to be considered for technology comparison.

Table MStep3-3: reformulation of the qualitative parameters of Table 2 so as to allow a quantitative comparison.

Criteria	Element	Name of the parameter	Value of the parameter	Qualitative vs Quantitative
Passenger safety (E)	User	Safety	[-]	Qualitative
	Vehicle	Amount of safety devices per passenger	[#]	Quantitative
Required fuel (E)	Vehicle	Allowed propellant	[-]	Qualitative
	Vehicle	Amount of propellant suitable for the engine	[#]	Quantitative

Example: criteria for measuring performance and expenses within the logic of System Operator

As mentioned in the tips, also the criteria to measure performances and expenses might be organized within the overall structure of the System Operator. Especially along this step, such a structured data management becomes beneficial for the whole forecasting study. Subsequently, the data retrieved in the rest of the investigation should be examined with a historical perspective, so as to extract qualitative trends to be further confirmed by quantitative evidences. Figure 1 shows how the parameters highlighted along Table 2 (from the criteria reported in Table 1) can be placed among the different levels of the System Operator. Please note that parameters referring to:

- The whole vehicle have been placed in the cell concerning the "System level - Present";
- the contexts in which the transport system is used have been placed in the cell concerning the "Super-System level - Present";
- the parts or components of the vehicle have been placed in the cell about "Sub-System level - Present".

Super-System level - Past	• Distance to reach the vehicle • Distance to next refilling station • Amount of alternative pathways • .... **Super-System level - Present**	Super-System level - Future
System level - Past	• Range of movement (no stops) • Top speed • Amount of seats • Surface occupation • Amount of safety devices per passenger • ... **System level - Present**	System level - Future
Sub-System level - Past	• Tank Capacity • Number of doors • Number of windows • .... **Sub-System level - Present**	Sub-System level - Future

Figure M Step3-1:The parameters identified along the first example to characterize performances and ex-

Moreover, it might happen that while searching for information relevant for the forecasting analysis, you get in touch with data about those parameters. In case you consider those data useful to answer the forecasting questions formulated along the FOR Stage, it is suggested to distinguish data about the current situation from those pertaining to the past. The former should be placed in the central column of the System Operator, while the latter should be used to feed the column on the left. It is also possible, even if less common, that you get in touch with some data about the future values of measurable parameters (e.g.: in case a law sets future standards about emissions, when reliable predictions about some contextual data are available, etc.). Future-related data should be organized consistently with the hierarchical level on the column on the right hand side. Thus, figure 2 aims at clarifying that data should not be placed only in the central column of the System Operator, but they should be properly organized on a time perspective before understanding qualitative trends about the STF and what relates to it.

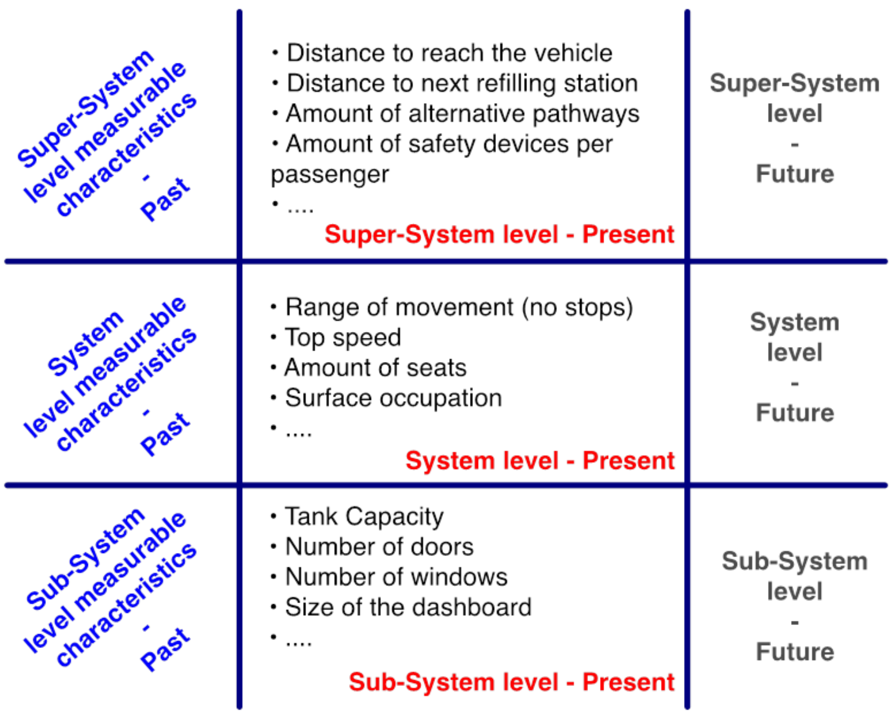


Figure M Step3-2:The System Operator also supports the organization of data to be retrieved with an historical perspective. The column on the left (Past, in blue) is highlighted because it is common to retrieve data describing also past conditions for the STF, its parts or the context it works in. The column about the future has been left in dark grey, but it is also possible to find some data about future plans, standards or regulations.

What is the most promising alternative tech?

Step 4

highlight

Prepare a clear description of previously performed steps for facilitating the assessment of alternatives.

To check consistency of the developed results. All members of the working team should agree on the consolidated results.

method

Summarize the results of the preceding Step 2 and Step 3. Reduce the number of alternative technologies for further analysis to keep the set of alternatives operational and to preserve the efficiency of the forecasting project.

instructions

1. Compare the collected alternative technologies with respect to the selected performance characteristics.
2. In accordance with the main function of STF, identify the most essential performance characteristics for the expected upcoming changes in the super-system.
3. Discuss and extract a small number (e.g., 2-3) of the most promising alternative technologies.
4. Identify the problems and limitations characterizing the alternative technologies of the STF, by focusing on the most promising selected ones.

tips

⇒ As mentioned in Step 2 of Stage M, studying alternative systems essentially aims at collecting problems-limitations about STF and its contexts. Therefore the selected alternative technologies should be representative rather than numerous.

⇒ Number of alternative technologies can be reduced by cutting inappropriate ones or by clustering several technologies into one.

⇒ Performance characteristics, identified in M Step 3 are used as a guideline to reduce number of alternatives.

⇒ Based on the most important performance characteristic, the most promising technology compared to the current technology may even be costlier than the current technology.

⇒ Most promising technology may be more harmonized to future changes in super -systems.

- ⇒ On the one hand, it is necessary to limit the number of alternative technologies in order to ensure the feasibility of the forecasting project; on the other hand, it is necessary to keep the most relevant problems and limitations within the scope of the study. Therefore, cutting out some less promising alternative technologies involves the risk of neglecting some potentially meaningful aspects. This should be taken into account at the end of the study when the TF is validated and the overall limitations of the study are made explicit.
- ⇒ If you have already organized data about the characteristic performances and expenses of the STF with the logic of the System Operator, use them to get fact-based support in the selection of the most promising alternative. Indeed, with data organized on a time perspective, it might emerge that an alternative technology that today is properly working has a relative small growth margin in the future. This could be because of a long history of improvements or, vice versa, something that is not yet working, as needed, might grow rapidly for novel developments of some of its parts or favourable context conditions.

suggested reading

Multiple-criteria decision analysis. (2014, July 19). In Wikipedia, The Free Encyclopedia. Retrieved 15:35, July 31, 2014, from http://en.wikipedia.org/w/index.php?title=Multiple-criteria_decision_analysis&oldid=617610175

examples

While analysing technologies for the decoration of plastic parts for household appliances, six alternative systems were identified as relevant: silk printing, pad printing, hot stamping, laser marking, chemical etching and inkjet printing.

In order to compare alternative technologies, main performance factors for each technology were evaluated as adequate, neutral, and inadequate. For facilitating inadequate = -1 (see results of evaluation analysis in Table MStep4-1)

All recognised performance factors were grouped into six performance characteristics. For every alternative technology the score was calculated for each performance characteristics. The total score was calculated for every alternative technology. See short version of evaluation matrix in Table MStep4-2.

Table MStep4-1: Expanded table of multi criteria decision analysis of the various printing processes

Performance characteristics	performance factors	silk printing	pad printing	hot stamp-ing	laser mark-ing	chemical etching	inkjet printing
	1.Color complexity management	0	0	0	-1	-1	1
	2.Chrome/ Metallic appearance	-1	-1	1	-1	-1	-1
	3.Resolution	1	1	1	1	0	1
	4.Chemical resistance	1	1	1	0	1	-1
	5.Abrasion resistance	1	1	1	0	1	-1
	6.Durability	1	1	1	1	1	0
Controllability of printing process: more control on image		0.5	0.5	0.8	0.0	0.2	-0.2
	1.Multiple substrate application	1	1	0	0	-1	1
	2.Curved / Non flat surface applica-tion	0	1	0	0	0	0
	3.Range of application small to large	1	0	0	1	1	1
	4.Quick Change Over (when com-pared between the alternatives)	0	-1	1	1	1	1
Flexibility		0.5	0.25	0.25	0.5	0.25	0.75
	1.Cycle time	1	1	1	0	-1	0
	2.Lower Scrap Rate	1	1	-1	1	1	1
Productivity of process (pcs/h)		1	1	0	0.5	0	0.5
	1. Ease of maintenance	1	1	-1	-1	1	0
Maintainability (non-working, h)		1	1	-1	-1	1	0
	1.Possible for continuous flow to assembly	1	1	1	1	-1	0
	2.Change over under one cycle (40-60 sec)	-1	-1	-1	1	-1	1
Integration level with production line		0	0	0	1	-1	0.5
	1.Low investments (when compared between the alternatives)	1	1	1	-1	1	1
	2.Operation cost effectiveness	1	1	-1	-1	1	-1
	3.Environment friendly Green	-1	-1	1	1	-1	0
Price of machine (EUR)		0.3	0.3	0.3	-0.3	0.3	0.0
SCORE:		**0.56**	**0.51**	**0.07**	**0.11**	**0.13**	**0.26**

Table MStep4-2: Concise table of the results of multi criteria decision analysis of the various printing processes

Performance characteristics	silk printing	pad printing	hot stamping	laser marking	chemical etching	inkjet printing
Controllability of printing process: more control on image	0.5	0.5	0.8	0.0	0.2	-0.2
Flexibility	0.5	0.25	0.25	0.5	0.25	0.75
Productivity of process (pcs/h)	1	1	0	0.5	0	0.5
Maintainability (non-working, h)	1	1	-1	-1	1	0
Integration level with production line	0	0	0	1	-1	0.5
Price of machine (EUR)	0.3	0.3	0.3	-0.3	0.3	0.0
SCORE:	**0.56**	**0.51**	**0.07**	**0.11**	**0.13**	**0.26**

After performing the functional analysis and recognizing the resources involved, the domain experts identified the following performance characteristics as the most representative for decision making: controllability of printing process (more control on image), flexibility, productivity of process (pcs/h), maintainability (non-working, h), integration level with production line, price of machine (EUR).

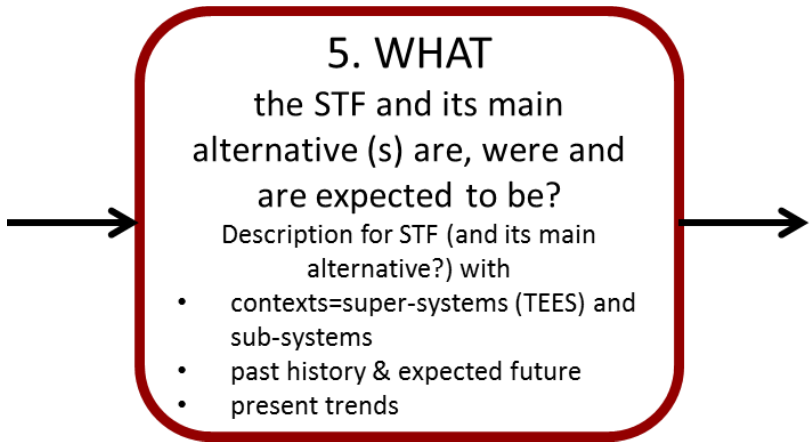
The alternative technologies were then compared with respect to the performance characteristics.

Controllability of printing process, Flexibility and Integration level with production line were identified as the most vital performance characteristics for coming changes in super-systems.

From the above list, one of the most promising alternative technology is **Inkjet printing,** since it shows the best score for *Flexibility* and *Integration level with production line* and an adequate score for *Productivity of process*. **Chemical etching** and **Laser marking** are second and third promising alternative technologies consequently.

What is the STF and its main alternatives?

Step 5



highlight

This step allows the team of analysts to harmonize their knowledge through the integration of their different perspectives. It also produces a structured and systemic overview of the STF suitable for enabling the subsequent forecasting stage (A).

method

Produce a harmonized and holistic description of the STF and its alternatives. Form an overview of the identified technology alternatives as the evolution from the past, through the present to a first description of their expected future.

instructions

1 Prepare a structured description of the STF in terms of a system hierarchy.

- The STF as a whole technology (system);
- The parts and/or the phases composing the STF (sub-systems);
- The contexts the STF and its main alternative operate in or where they are required (super-systems);

2 Prepare a structured (multi-screen, nine windows) description of the STF within the context of super-systems by taking into account the four complementary domains: technology, environment, economics and society (TEES). Describe the STF and its problems from the TEES points of view.

3 Prepare a structured description of the STF also in terms of its dynamics of evolution, by considering what was the situation in the past and what is the current situation.

4 Identify the drivers that characterized the evolution of the STF so far (from the past to the present) and intuitively propose their expected impact for the future.

5 Identify the barriers that limited the evolution of the STF with respect to the directions depicted by the drivers recognized at step #4.

6 Develop a cross-check analysis among the drivers and barriers at System, Super-System and Sub-System level, in order to create a consistent vision of the future.

tips

⇒ The multi-screen description of the STF can be built according to the logic of System Operator, a model of TRIZ representing the way of thinking of talented problem solvers (Altshuller, 1984).

⇒ It is convenient to start describing the present system, super-systems and sub-systems from the present perspective. Then, go back to the past for a period of (preferably double). Once the past and present descriptions have been produced, look at the changes occurred in the system, super-systems and sub-systems and formulate your intuitive vision about what could happen in the time span of the analysis to be performed.

⇒ The multi-screen description should equally balance technical, economic, environmental and social information. Try not to focus only on the domain(s) of experience of the core team members.

⇒ If several significant transformations occurred in the time span taken into consideration, you can add more "Past" columns instead of only one, so as to visualize the different staged of evolution occurred.

⇒ The intuitive projection about the future is not really meant to be the outcome of the forecasting project (in fact, it will be built within stage A); the real objective it to recognize relevant tendencies as a means to identify drivers and barriers that characterize the STF. These will be further processed within the following steps of the analysis, after passing Gate M.

⇒ The experts' vision of the future is likely to be biased by their professional experience, but it is also essential to exploit their know-how and intuitive capabilities. In order to minimize those biases, it is recommended to elicit the experts' opinion on the future problems to address (in the form of conflicts between drivers and barriers), rather than to ask them their prediction about the future of the STF itself.

⇒ In the previous step of the M stage, if you have already started organizing the data within the System Operator structure, it is suggested to also double check the correctness of what was done before, with reference to the above instruction to carry out a complete System Operator analysis.

suggested reading

Altshuller, G., 'Creativity as an Exact Science', Gordon & Breach, 1984. (Structure of talented thought, pp.117-123).

Cascini G., TRIZ-based anticipatory design of future products and processes, Journal of Integrated Design & Process Science, 16(3), 2012, pp. 29-63.

Kucharavy Dmitry, The hierarchy axis of the system operator. (22 Feb 2010)

http://www.youtube.com/watch?v=-RYn47y3EfY

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

examples

Example 1 . An application example for the System operator

The goal of applying the System Operator (MStep5-1) is the following. It is necessary to describe the System to be forecasted (STF) on the "screens" of the System Operator. Namely: the description of the system itself (1), its super-systems (2), its sub-systems (3). The past of the System (4), its super-systems (5), its sub-systems (6). Based on the analysis of the information obtained and the study of the System's evolution trends, the description of the future of the System (7), its super-systems (8) and its sub-systems (9) is built.

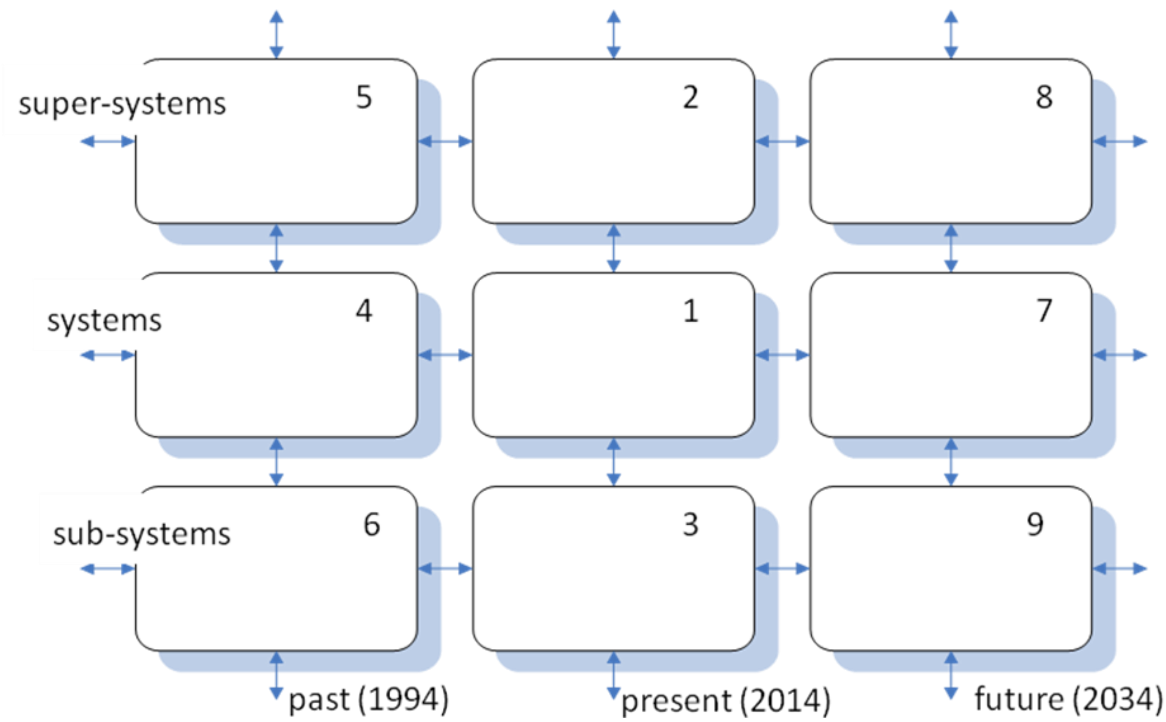


Figure MStep5-1. System Operator (the dates in the diagram are purely indicative)

However, filling the "screens" is not a goal by itself. The descriptions of the changes in the System (STF) (observed while moving from a screen to another) and the structured elicitation of the team knowledge about the System are the essential in-

However, filling the “screens” is not a goal by itself. The descriptions of the changes in the System (STF) (observed while moving from a screen to another) and the structured elicitation of the team knowledge about the System are the essential interest of this task.

The following labels refer to the screen depicted in Figure MStep5-1:

1. The system itself – STF – System to be Forecasted.
2. STF’s nearest super-systems.
3. STF’s nearest sub-systems.
4. The system’s past.
5. STF’s nearest super-systems’ past.
6. STF’s nearest sub-systems’ past.
7. The system’s future.
8. STF’s nearest super-systems’ future.
9. STF’s nearest sub-systems’ future.

It is advised to begin the description with the system itself (1). As an example, let’s take the modern ballpoint pen for writing.

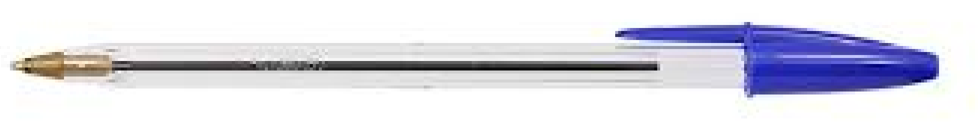


Figure MStep5-2. Ballpoint pen.

First, let’s formulate the main function of our system: “To change the colour of the paper (of the information carrier)”, “to leave traces on the information carrier”.

A remark. The System Operator is a powerful analysis tool. During the analysis of the System, in order to be able to forecast using the screens of the System Operator, one is often required to change his/hers established vision on the object of the analysis. Sometimes one has to return to already filled "screens", to detail, add or revise something.

Second, let's list the features and resources, which interest us in the future of this system, from various points of view: technological, social, economic, ecological. For example:

a. The system's production. (technological)
   - Cost
   - Resources used for the production of the system

b. The system's utilization. (socio-technological)
   - Trace line length (duration of continuous writing)
   - Diversity of pen types
   - Diversity of information carriers' types (that, on which the pen leaves traces)

c. Process for Recycling. (environmental, technological)
   - Impact on the environment
   - System utilization time

Third, let's successively describe the "screens" of the System Operator with a brief characteristic of the processes that interest us.

1. System for writing: Ballpoint pen, paper.

A remark: the system for writing constitutes the pair "pen + information carrier." Various materials can serve as a carrier: paper, wood, leather, plastic, metal, glass and others. Why do we need a pair? To catch this concept, let's hypothetically remove the carrier. Does the pen fulfil its function? No, it doesn't. An analogous situation arises when viewing the means of transportation "the car". Can a car move without a road (a surface)? No, it can't. In this case, we also have a pair: "car + surface (road)". The surface (road) should be considered in a broad sense: it can be an asphalt pavement, a primer coating, a water surface or others.

In fact, the whole System for writing consists of: Ballpoint pen, paper, atmospheric pressure and man (writer).

By which parameters is the System for writing being characterized at the current time?

- Resources used for the production of the system: plastic; ink and artificial colorants; metal (steel) for the ball; metal (brass) for the burner assembly; cellulose and water for the paper; electric energy; manpower.
- Cost: simple ballpoint pens are fairly cheap (you can buy it for ~30-50 cents). Many of them are of disposable use.
- Diversity of types of produced pens: a broad variety in structure, design, colours of the writing element, the number of writing elements of different colours in one body tube, in the cost…
- Line length (continuity of writing): a typical ballpoint pen with a 139-142mm long body tube leaves during its lifetime a trace of around 2'000 meters.
- Types of information carriers: the most common carrier are the various types of writing-paper. There exist special ink types, which are able to leave a trace on such carriers as glass, ceramics, metals and others.
- Impact on the environment: the processing of ballpoint pens doesn't require special measures (for example, like for chemical current sources – batteries and accumulators). The typical technologies of processing household waste are used. However, large volumes of production and utilization of this System cause significant harm to the environment.
- System utilization time: the full cycle of utilization, starting with collecting household waste and finishing with processing or burning, lasts several days depending on the technologies being used.

2. Super-systems of the "System for writing":

Products of petroleum refining to produce plastic, ink and colourants; metals; vegetative raw material (trees) for cellulose production, water…

By which parameters are these super-systems being characterized at the current time?

- Resources used for the production of the super-systems,
- Cost,
- Diversity of types of produced pens,
- Line length,
- Types of information carriers,
- Impact on the environment,
- Super-system utilization time.

3. Sub-systems of the "System for writing":

body tube (plastic, wooden, paper, metal, ceramic and from other materials); colouring substance, colouring substance distribution unit (micro-ball), tube for storing the colouring substance, protection caps, fibers (micro-structure) of the carrier (paper).

By which parameters are these sub-systems being characterized at the current time?

- Resources used for the production of the sub-systems:
- Cost:
- Diversity of types of produced pens:
- Line length:
- Types of information carriers:
- Impact on the environment:
- Sub-system utilization time:

A remark. It is necessary to give descriptions of the System operator's screens that follow.

4. The system's past.

What was the system like 20 years ago? By which parameter values was it characterized at that time? Which changes took place until the present time?

5. STF's nearest super-systems' past.

What were the nearest super-systems of the System like 20 years ago? By which parameter values were they characterized at that time? Which changes took place until the present time?

6. STF's nearest sub-systems' past.

What were the nearest sub-systems of the System like 20 years ago? By which parameter values were they characterized at that time? Which changes took place until the present time?

7. The system's future.

What will the System be like in 20 years? By which parameter values will it be characterized at that time? Which changes will take place until that time?

8. STF's nearest super-systems' future.

What will the nearest super-systems of the System be like in 20 years? By which parameter values will they be characterized at that time? Which changes will take place until that time?

9. STF's nearest sub-systems' future.

What will the nearest sub-systems of the System be like in 20 years? By which parameter values will they be characterized at that time? Which changes will take place until that time?

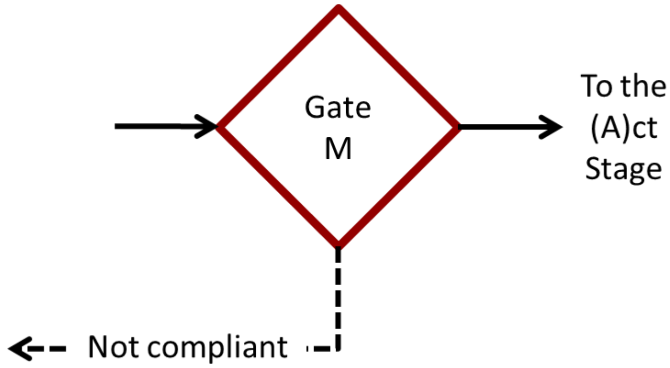
Final remark. Filling the cells 7-9 of the System Operator at this stage of the forecasting project should not be interpreted as an anticipation of the forecast to be built in stage A. As highlighted in the Tips section of this step, the core team, possibly with the support of external experts, should analyse the information about the past and the present of the STF (first two columns of the System Operator) and identify the drivers that have characterized the evolution of the STF up to now and the obstacles that prevented the STF to evolve further in that direction. The rightest column of the System Operator (Future) should be filled with the partial conclusions drawn by the core team about the recognized drivers and barriers and their expected impact.

notes

M Gate

function

<to check> <completeness and



In order to complete the M Stage and move to the next stage, you must

Complete the following:

- Model of STF at the functional level (logic similar to IDEF0)
- Description of Competitive (Alternative) technologies (solutions)
- Measure of Performance & Expenses for STF and for Competitive Solutions
- Description for STF
  - contexts=super-systems (consider TEES i.e. Technology, Environment, Economy, Social) and sub-systems;
  - past history & expected future
  - present trends

tips

⇒ It is highly recommended that you print this list out for your M gate session

⇒ This gate will serve as reference to later stages

⇒ Tick the task only after the item is 100% complete

⇒ Proceed to the next stage only after completing all items on this list

notes

FOR M A T

A Stage

notes

A Stage

The main function of Stage A is to develop a consistent set of future traits of system to forecast and prepare all needed components for answering forecasting question(s). Stage A consists of the application of four complementary studies. Step one works on problem identification and assessment of limiting resources. Step two studies the patterns of evolution regarding a system, identified problems, limiting resources and system's contexts. Beyond the first two qualitative studies, Step three introduces the quantitative assessment of the growth of selected variables by means of a logistic S-curve using regression analysis. The three steps of study are followed by a harmonization and reconciliation at Step four.

prep time

2-3 working sessions

total time

15 working days

people

2-3 analysts

ingredients

material

Access to patent databases, scientific literature, market data, repositories of statistics etc.

Datasheets and catalogues related to the STF and to the relevant subsystems and supersystems identified in stage M; data should be available in the form of time series and not just punctual values about the present.

time

5 working sessions of 4h each within 20 working days

people

2-4 analysts + Users of forecast + Invited Experts

tools

System Operator; Contradiction model; Laws of Technical system evolution; Logistic growth curves, regression analysis; ENV models

software

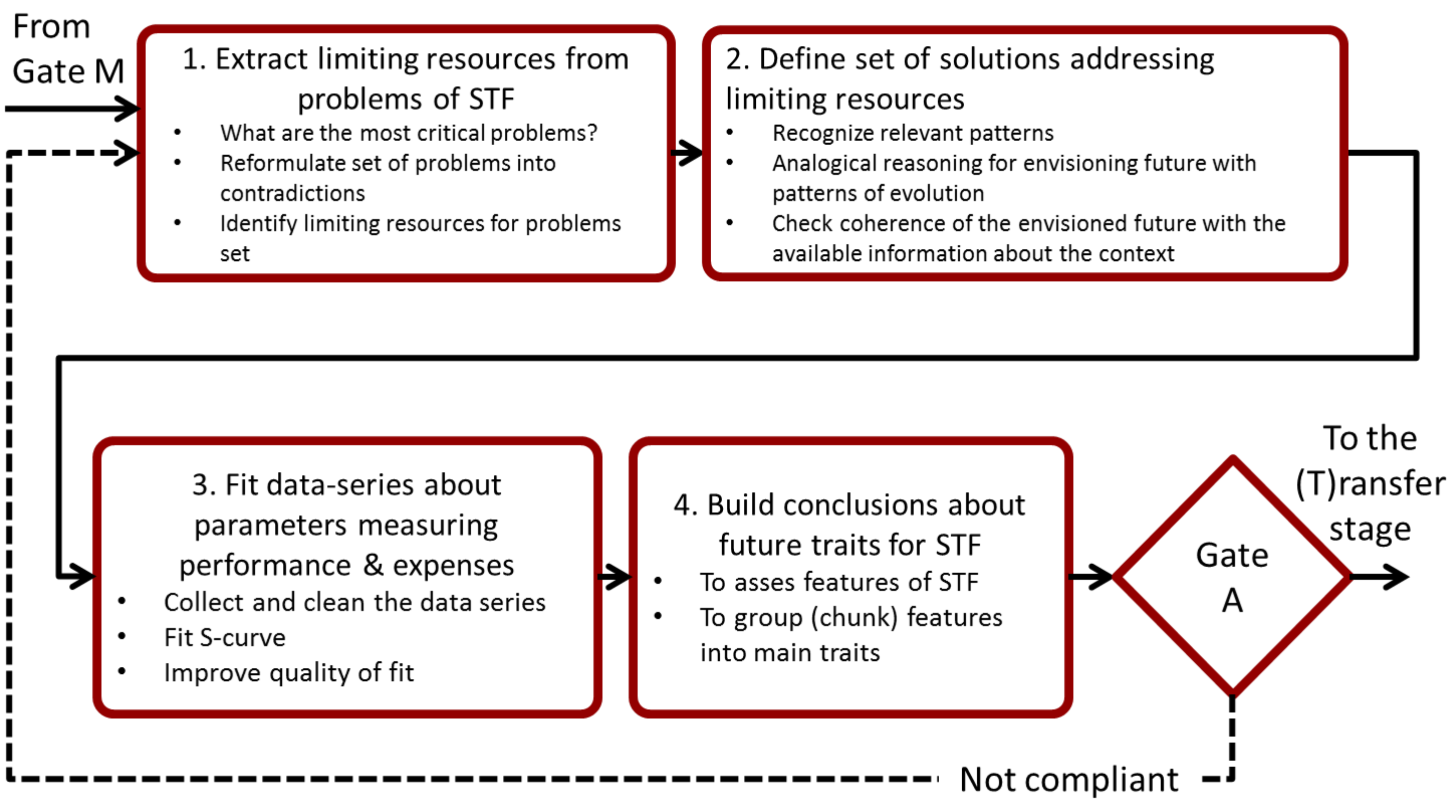
Software to work with conceptual maps, Software to work with Logistic growth curves and make regression analysis

ingredients

knowledge

Knowledge acquired within Stage FOR and Stage M is required. Understanding how to apply analytic Tools (see the list below) is necessary. Abilities to analytic work and to communicate with experts are essential.
At least one member of the core team should be familiar with analogical reasoning applied to evolutionary patterns, e.g., the application of the TRIZ Laws of Engineering Systems Evolution to envision possible evolutionary scenarios of technical systems.
Knowledge about global megatrends is welcome.

A Stage



instructions

1 Extract limiting resources from problems of STF

Identification of problems makes us focus on reasons for future change in a system. Each problem is linked to one or more resources that hinder its solution:

- What are the most critical problems?
- Reformulate set of problems
- Identify limiting resources for the formulated problems

Knowledge about limiting resources supports reliability of interpretation for results from step two and three of Stage A.

2 Define set of solutions addressing limiting resources

Explore evolution of the STF with its components and context. Use the model of the STF from Stage M, look for problems and solutions already applied to the system. Research past solutions and envision future solutions:

- Recognize relevant patterns
- Envision future technology developments with patterns of evolution and reasoning-by-analogy
- Check coherence of the envisioned future with available information about the context

3 Fit data-series about parameters measuring growth of STF or its context.

Quantitative analysis completes an understanding of the system's future after qualitative studies. Growing variables describe the system from past to present. Fitted data series together with the results of a study in problems, limiting resources and evolution trends, provide a comprehensive view into the future of the STF.

- Collect and clean the data series
- Fit S-curve
- Analyse the quality and the reliability of the fit and improve if necessary

4 Build conclusions about future traits for STF

Combine the results of the study done in Stage A. The aggregated set of data consists of problems, limiting resources through evolutionary trends and data series fits. Collective overview of this information and data provides understanding of the STF and provide a guideline of future development:

- To assess main features of future STF
- To group (cluster) features into main traits

tips

⇒ It is essential to have the latest version of outputs from Stage FOR and Stage M well-organized.

⇒ Step 1 of Stage A consists in a problem-driven anticipation of future traits of the STF: the forecast is built through a discussion about the expected problems to be addressed and the limiting resources that characterize the STF.

⇒ Step 2 approaches the definition of STF future with a solution-driven logic: possible evolutions of the STF are envisioned by analogy, triggered by generalized patterns of evolution.

⇒ The first three steps can be carried out in parallel, despite the analysis performed at Step 1 is beneficial to better focus the reasoning at Step 2. As well, the outcomes of Steps 1 and 2 are useful to identify relevant variables to analyse with quantitative models in Step 3. Step 4 is done after the final versions of three previous steps are finalized.

⇒ When performing Step 1, it is recommended to formulate problems as contradictions. However, when there is a lack of skills about modelling systems in terms of contradictions, a simplified template can be applied to express a problem: "How to <required action> when <the real-case limits>?"

⇒ When performing Step 1, the unit of measure has to be allocated to each limiting resource. It makes results of study measurable when it is appropriate.

⇒ When performing Step 2, it is recommended to provide the evidence of the identified trends with supporting information (e.g. through patent searches). This practice improves the reliability of forecast.

⇒ In a regular application of the methodology, number of sessions and duration of Stage A depend on competences of working team and availability of required data.

suggested reading

Altshuller, G. S., & Williams (transl.), A. (1984). Creativity as an Exact Science: The Theory of the Solution of Inventive Problems. New York: Gordon and Breach Science Publishers.

Becattini, N. (2013). Product and process modelling – state of the art update (p. 59). Milan. Retrieved from http://www.format-project.eu/deliverables/public-reports-and-white-papers/deliverable-2.2/at_download/file

Cascini, G., Rotini, F., and Russo, D. Networks of trends: Systematic definition of evolutionary scenarios. TRIZ Future Conference 2008, Procedia Engineering,2011, Vol-9,p. 355-367.

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Kucharavy D., R. De Guio, L. Gautier, and M. Marrony (2007) Problem Mapping for the Assessment of Technological Barriers in the Framework of Innovative Design, in 16th International Conference on Engineering Design, ICED'07.

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. Vol-61. p. 247–271.

Modis T., Natural Laws in the Service of the Decision Maker: How to Use Science-Based Methodologies to See More Clearly further into the Future. Growth Dynamics, 2013, p. 243.

suggested reading

Nikulin, C., Graziosi, S., Cascini, G., and Stegmaier, R. Integrated Model for Technology Assessment and Expected Evolution: A Case Study in the Chilean Mining Industry. Journal of Integrated Design and Process Science, 2013, Vol-17(4), p-53-80.

Nikulin, C. Technological Forecasting supported by Logistic Growth Curve analysis: software tool for increased usability (p. 4) Milan. Retrieved from http://www.format-project.eu/deliverables/white-papers/july-2013-technological-forecasting-supported-by-logistic-growth-curve-analysis-software-tool-for-increased-usability/at_download/file

Rosen C. (2000). World Resources 2000-2001 People and Ecosystems: The Fraying Web of Life, Elsevier Science, 2000, 389 pages.

Yoon, B., and Lee, S. "Applicability of Patent Information in Technological Forecasting: A Sector-specific Approach". Journal of Intellectual Property Rights. 2012. Vol. 17. p. 37–45.

Logistic Analysis: Loglet Lab 2- http://phe.rockefeller.edu/LogletLab/2.0/

Logistic Substitution Model II: http://www.iiasa.ac.at/web/home/research/researchPrograms/ TransitionstoNewTechnologies/download.en.html

Logistics Curve Software (FORMAT Prototype): http://handbook.format-project.eu/?page_id=354

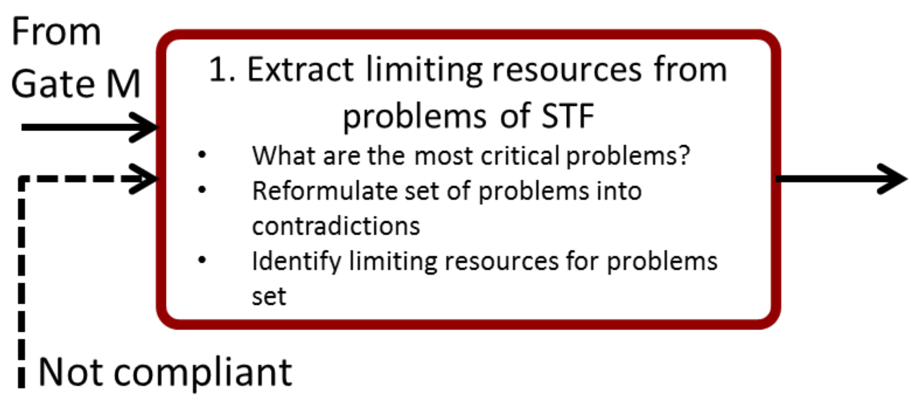
ENV Model in G. Cascini, F. S. Frillici, J. Jantschgi, I. Kaikov, and N. Khomenko, TETRIS: Teaching TRIZ at School, EN 1.0. TETRIS project and the Lifelong Learning Programme, 2009. (pp.20-24) http://www.tetris-project.org/

OTSM ENV Fractal Model in N. Khomenko, Keynote presentation for 6th TRIZ Symposium in Japan, Tokyo, September 2010 (pp.31-39).

notes

Extract limiting resources from problems of STF

Step 1



highlight

List the problems of system to forecast (STF) and identify limiting resources that are related with them.

method

Identification of problems about the STF is another way to describe the STF. Problems should be identified from the description of the system in Stage M (e.g. from results of System Operator); more precisely the team should reflect on the conflicts between drivers and barriers. Every problem is connected to a number of limiting resources. A limitation in the availability of a critical resource leads to a problem of an unfulfilled need. Identification and study of limiting resources and their dynamics clarifies the future changes about STF and its contexts.

instructions

1 What are the most critical problems?
In order to collect the list of problems, consider the results of stage M. Problems are collected for system, sub-systems and super-system levels using structured interview with specialists about STF. First, the only titles of problems are collected for building a consensus and consistent list of problems.

2 Reformulate set of problems.
Second, the collected list of problem titles is disclosed using the contradiction model or using the simplified template: "How to <required action> when <the real-case limits>?"

3 Identify limiting resources for each listed problem (contradiction).
Third, for every problem the limiting resources (e.g. time, space, substances, energy, etc.) are identified using practical evidence. The unit of measure has to be allocated for each limiting resource.

4 The developed outcomes are combined in a table with four columns: (1) problem number; (2) description of problem in accordance with simplified template or using the contradiction model; (3) limiting resources; (4) measurement units.

5 Identify a subset of the most critical problems among the collected ones with help of users of forecast. Expert judgment is applied for identifying the set of most critical problems.

tips

⇒ When collecting list of problems, first focus on the main system to forecast. Meanwhile, the analysis of alternative technologies (collected within Stage M) can be useful for completing the list of problems. The study about alternative systems helps to enlighten hidden problems and peculiarities, which are not evident due to professional biases.

⇒ Techniques applied for problems identification should be operational and not time consuming. Models for description of the system (e.g. System Operator) help in guiding a systematic study in search for problems.

⇒ Getting into details in problem description may cause a tendency to revise the models built in Stage M. However, this is likely to produce delays in the fulfilment of the project and it could imply to miss the big picture. Furthermore, for a matter of coherence, changes to Stage M elements should be avoided once the gate M is closed.

⇒ Concept of limiting resources is based on the assumption that each problem is linked with consumption of a resource e.g. time, data, energy, substance. Such a resource is either limited or non-existing in particular conditions, hence a need cannot be satisfied and a problem appears.

⇒ When defining limiting resources, make them quantifiable and measurable. Measure is meant here as a unit in which a resource is quantified. Expression of specific values would be an advantage.

⇒ How to work with Contradiction models (optional):

Contradiction is a way to represent a problem. Contradiction provides a structure that facilitates the construction of a problem's model. A problem expressed in the form of a contradiction consists of the following elements (the following capital letters in brackets refer to Figure AStep1-1): feature (B) of an object (A) should assume a certain value (C) so as to achieve a desired outcome R2(+); nevertheless, the value (C) of feature (B) also implies some unwanted results (R1-). On the contrary, the feature (B) might assume an opposite value (D) that brings the latter to a desired state (R1+), but this implies an unwanted variation of the former R2(-). The opposite values (C) and (D) cause a conflict. Both positive and opposite values bring desired (+) and undesired (-) results. A single contradiction contains two of these results: R1 and R2 (Figure AStep1-1).

A contradiction is formed by describing one state of a system, for one value of a feature with an explanation of the positive R1(+) and negative R2(-) effects. Next, the opposite state of a system, for an opposite value of a feature, is described with an explanation for the positive R2(+) and negative R1(-) effects. The problem is to obtain both the desirable results R1(+) and R2(+) at the same time, although they appear at opposite values (C) and (D). A solution to a problem expressed in this way goes beyond the trade-off (a compromise between the two values).

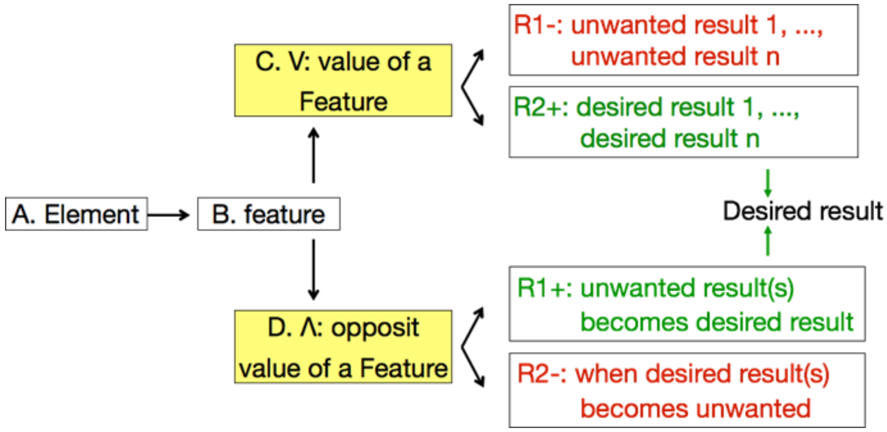


Figure AStep1-1. Model of a contradiction with A, B, C, D, R1, R2 elements referred to in the text.

Each problem from a list of problems has to be transformed into a contradiction. Using a model for a contradiction expression presented on Figure AStep1-1, one usually starts with declaration of R2(+), a first desired result. Desired result is usually clear for a current situation. R1(-) is then realized as a negative result presently observed. Then an opposite part of contradiction should be filled with R1(+) as an opposite result to the unwanted R1(-) declared earlier. It is allowed to enter more than one desired or unwanted result into a particular box.

It is a suggested method that will help you better understand problems of a system to be forecasted. Formulation of a contradiction helps also in better definition of a problem formulated from the original expression, for instance of an unsatisfied need.

suggested reading

Altshuller, G. S., & Williams (transl.), A. (1984). Creativity as an Exact Science: The Theory of the Solution of Inventive Problems. New York: Gordon and Breach Science Publishers.

Becattini, N. (2013). Product and process modelling – state of the art update (p. 59). Milan. Retrieved from http://www.format-project.eu/deliverables/public-reports-and-white-papers/deliverable-2.2/at_download/file

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Kucharavy D. and R. De Guio (2008) Technological Forecasting and Assessment of Barriers for Emerging Technologies, IAMOT 2008. Dubai, UAE, p. 20

Kucharavy D., R. De Guio, L. Gautier, and M. Marrony (2007) Problem Mapping for the Assessment of Technological Barriers in the Framework of Innovative Design, in 16th International Conference on Engineering Design, ICED'07.

examples

Project "packaging" aims at forecasting the future of materials for packaging home appliances. Previous stage, stage M delivered a description of a packaging system. A single description is recalled here in order to give a starting point for the current step of Stage A. System completeness model describes elements of a system connected in order to deliver a function performed by a system. "Every technical system should consist of four components: engine, transmission, control unit and working unit" (Salamatov, 1999). Elements of a system are predefined as: incoming energy, conversion machine, transmission machine, tool, product and control, as shown in Figure AStep1-2. The description of a system is delivered by describing each of the predefined elements with respect to the studied system.

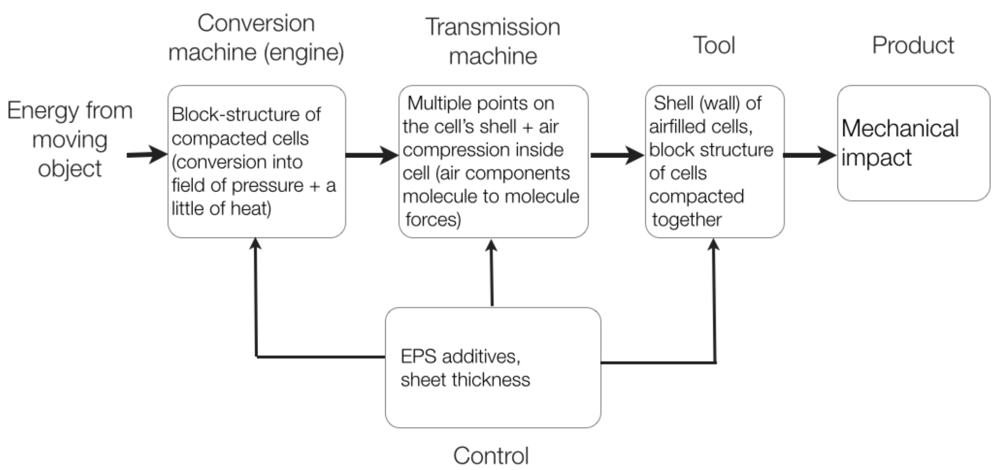


Figure AStep1-2: Model using a Law of system completeness described for 'packaging'

Figure AStep1-2 describes a 'packaging' system at work when absorbing a shock. In this case a packaging system is made of EPS (expanded polystyrene) and plastic film. The main function of packaging was defined in Stage M as "to dissipate kinetic energy during logistic operations." The problems identified following the description of the system shown in Figure AStep1-2 :

- Vector of energy hitting packaging may have different direction
- Abrasive forces
- Disintegration of EPS structure due to impact above the strength threshold of the structure
- Nature of the striking object e.g.: dust, humidity, water, dirt, clasping plates of a "forklift"
- EPS is difficult to recycle and is not currently recycled in large scale.

Alternative way of expressing the same problems is to formulate them as unsatisfied needs:

- Packaging should dissipate kinetic energy imparted from different sides of a packaged product
- Packaging should dissipate energy due to abrasive forces.
- We need packaging to protect a packaged product from multiple impacts, not only from the first. It means that packaging once impacted or maybe even de-

- It is required that packaging also protects the appliance from dust, humidity, dirt and withstands forces applied by regular logistic processes like clasping plates in a forklift.
- There is a need for a recyclable packaging.

Problems identified when studying alternative technologies. Example of alternative technology: cardboard profiles, cardboard box.

- Impact of humidity – it is required that packaging is resistant to humidity and even water e.g. rain during logistic operations, water spilled on the ground in storehouse.
- Need for compression stripes – it is desired to have as few additional elements as possible. Addition of plastic compression stripes adds to number of packaging's components.

Limiting resources (identify and declare measureable variables)

- Size of an area of packaging that is the most frequently hit i.e. edges, top, bottom [m^2]
- Size of an area of packaging that is exposed to abrasive forces [m^2]
- Thickness of packaging [m]
- Size of a standard transportation container (width x height x length) [m]
- Force applied during test on packaging [N]
- Force applied by clasping plates on forklift [N]
- Weight load during storage [kg]

Contradiction

Following example provides a contradiction built for one of the problems - a problem with the resistance of packaging. It is required that packaging be resistant to damage, but it is also required that the packaging is easy to open.

In the form of a contradiction, a problem is expressed as follows. The packaging needs to have high resistance in order to provide high energy dissipation, but then it is rigid and difficult to open. The packaging needs to have low resistance in order to be easy to open, but energy dissipation gets lower.

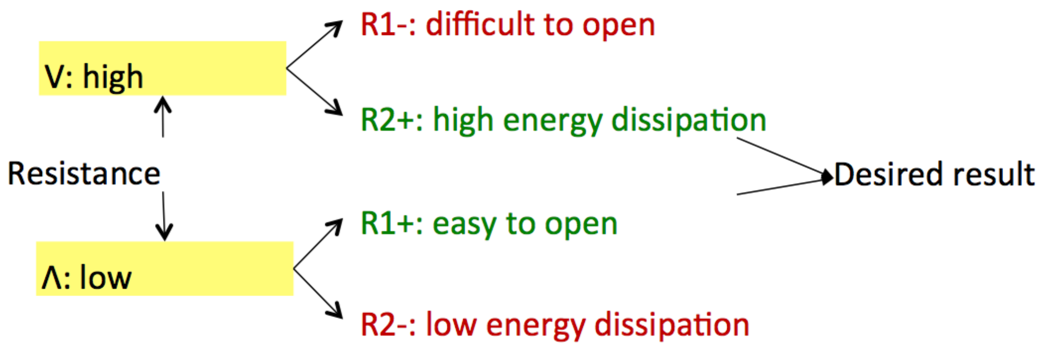


Figure AStep1-3: Contradiction for resistance of packaging

notes

Define set of solutions addressing limiting resources

Step 2

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

highlight

Identification of direction of technological development based on historical evolution of the STF.
Envisioning the characteristics of future solutions for the STF

method

Analyze the history of the STF (or some of its phases) and recognize the related evolutionary patterns according to the technological, environmental economic and social trends (STF trends). Use this pattern analysis to project what will be the future developments of the STF.

instructions

1 Recall the questions of forecast from the FOR stage

2 Also, recall the (System Operator analysis) results of Step 5 in Stage M.

3 Think about the scope of your analysis with reference to the questions of forecast. Consider if it is more important for that purpose to focus on the whole STF or on some of its critical and more promising phases prior to evolution. In case you need to focus on a specific phase of the process carried out by the STF, or on a specific subsystem. Answer the following questions in order to highlight the most relevant process phases:

   a. What are the specific operations, parts, etc., generating the bottlenecks?
   b. What are the reasons preventing the adoption of the most relevant alternative technologies?

4 Recognize the patterns driving the evolution of technical solutions for the functions or phases defined in Instruction #3. In order to help with the pattern analysis, follow these instructions:

   a. Browse the system operator on the time axis at the same hierarchical level.
   b. Compare the evolution of specific features across time screens, in order to track how the STF or its parts or the contexts have evolved.
   c. Use the above information to analyze the reason for the evolution of the STF along those paths.
   d. The reasons behind the evolution and the way evolution occurred should shed some light on the relevant patterns driving the change of the STF and its alternatives.

5 Analyze the STF using models to create an envisioned future scenario. Develop this analysis by analogical reasoning. The model of the STF has to help you to recognize patterns and directions for its evolution.

   a. Build a model of the Minimal Technical System (TRIZ Law of Engineering System Evolution#1 [5]) for each of the functions selected in Instruction #4.

b. Compare the trends emerged from the evolution of the technical systems under investigation with general patterns in technological, economic, environmental and social domains (TEES trends).
c. Match the technical system evolution, through reasoning –by- analogy, with the trends and understand which evolutionary stages have already occurred, which are now characterizing the subject of the investigation and those that still have to appear.
d. Summarize the available opportunities for further technological development i.e. all those evolutionary stages that have not already emerged for the system under investigation.

6 Check coherence of the envisioned future solutions by comparing the list of problems and beneficiary demands.

a. Recall the list of problems from the previous step in Stage A and, if needed, clarify which are the main demands behind those problems.
b. Select the further directions of evolution for the system under investigation by excluding those that are not addressing the above demands
c. Derive some conclusions and recommendations for beneficiaries by considering the potential benefits of the envisioned solutions.

tips

⇒ The Minimal Technical System (MTS) is presented in [5]. In brief, you can build the model following these instructions:

a. Recall the desired OUTPUT from the functional description of the STF (Step 1 in Stage M).
b. Identify the *Tool*, i.e. the entity which interacts directly with the object of the function thus producing the desired OUTPUT;
c. Determine which property (-ies) characterize(s) the capability of the *Tool* to deliver the function to the desired OUTPUT;
d. For each of the identified properties, define the *Engine*, i.e. the element from which the property derives;

e. Complete the model of the minimal technical system, by adding the transmission from the *Engine* to the *Tool*, the control and its interactions with the other subsystems and the external supply of the *Engine*.

⇒ A comprehensive set of technical evolutionary patterns is provided by TRIZ [2]; in [1] an operational procedure to map the evolution of the STF through the TRIZ patterns is provided.

⇒ Analogical reasoning shall involve also non-technical trends, such as social and economic mega-trends [4].

⇒ Once you have identified the relevant evolutionary trends and you have envisioned by analogy possible qualitative scenarios for the STF, it is advisable to colour the map to increase its readability; e.g. past and current solutions could be coloured in red, non-commercialized but recognized concepts (e.g. from patents, articles, publicly funded projec6ts etc.) could go yellow, while green char-

suggested reading

[1] Cascini, G., Rotini, F., and Russo, D. Networks of trends: Systematic definition of evolutionary scenarios. TRIZ Future Conference 2008, Procedia Engineering,2011, Vol-9,p. 355-367.

[2] Cascini, G. TRIZ-based Anticipatory Design of Future Products and Processes. Journal of Integrated Design and Process Science, 2012, Vol-16 (3), p. 29-63.

[3] Nikulin, C., Graziosi, S., Cascini, G., and Stegmaier, R. Integrated Model for Technology Assessment and Expected Evolution: A Case Study in the Chilean Mining Industry. Journal of Integrated Design and Process Science, 2013, Vol-17(4), p-53-80.

[4] Rosen C. World Resources 2000-2001 People and Ecosystems: The Fraying Web of Life, Elsevier Science, 2000, 389 pages.

[5] Becattini, N. (2013). Product and process modelling – state of the art update (p. 59). Milan. Retrieved from www.format-project.eu/deliverables/public-reports-and-white-papers/deliverable-2.2/at_download/file

examples

The following example refers to the copper mining process. The process is typically made up of the following steps:

1. Drilling, blasting, cutting, and excavating
2. Ground control
3. Loading and hauling
4. Materials processing

(for a more detailed description see also www.mining-technology.com).

In the fourth step, the ore is transferred to gyratory crushers that reduce its size. This crushed ore is then conveyed to the mill grinding circuit.

The size and power production of the mill has increased significantly since its inception in the 1920's, currently reaching over 40 ft in diameter and processing about 2000 ton/h. It also involves the largest percentage of operating costs and extremely time-consuming maintenance operations in a mining company (approx. 200-hours a year). Besides, the maintenance activity requires manpower, resources and several days of detention: under normal operating conditions in a plant that processes 100 kton/day, the outage cost is approximately US$ 270,000 per day (for further details see also [5]). A mill can be considered as one of the most critical technologies of the mining process: it respectively influences its upstream and downstream activities and the overall productive capacity of the plant (in copper mining).

The main useful function of a mill is to perform the <grinding> process. This function is realized by means of the following sub-functions (Figure AStep2-2):

- Regulate Ore Quantity. It controls the quantity and the flow of mineral and water inside the mill. The belt conveyors deliver the ore to the mill. The feed rate of the mill depends on the horsepower available to rotate the mill and on the weight the mill shell can support (see also www.technology.infomine.com).
- Decrease Ore Size. It is the breaking action done by grinding the ore into fine powder. In the mill, the dry ore is combined with water and steel balls. The mill is equipped with lifters that raise the load during the mill rotation. The tumbling action causes the larger ore pieces and steel balls to grind the ore into fine particles.

- The control board of the mill's electric motor regulates the RPM and thus the mill shell rotation. The plates protect the internal part of the mill and are fixed to the mill shell. The load itself generates a mechanical pressure on the mill internal surface.
- Separate Ore. It is the activity of separating particles according to their sizes. Usually the mechanical pressure generated by the load is used to force the material passing through a grid (i.e. the screening surface), whose dimensions depend on the desired size chosen for the ore particles

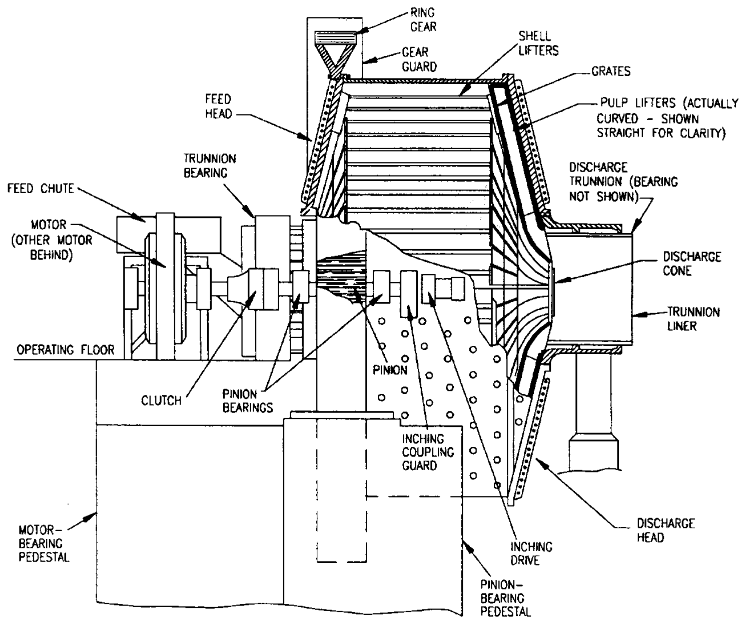


Figure AStep2-1: The general mining mill elements.

A brief investigation was performed in order to evaluate the sub-functions consuming the highest amount of resources relevant for the milling process; a qualitative evaluation was performed for each sub-function in order to understand the most

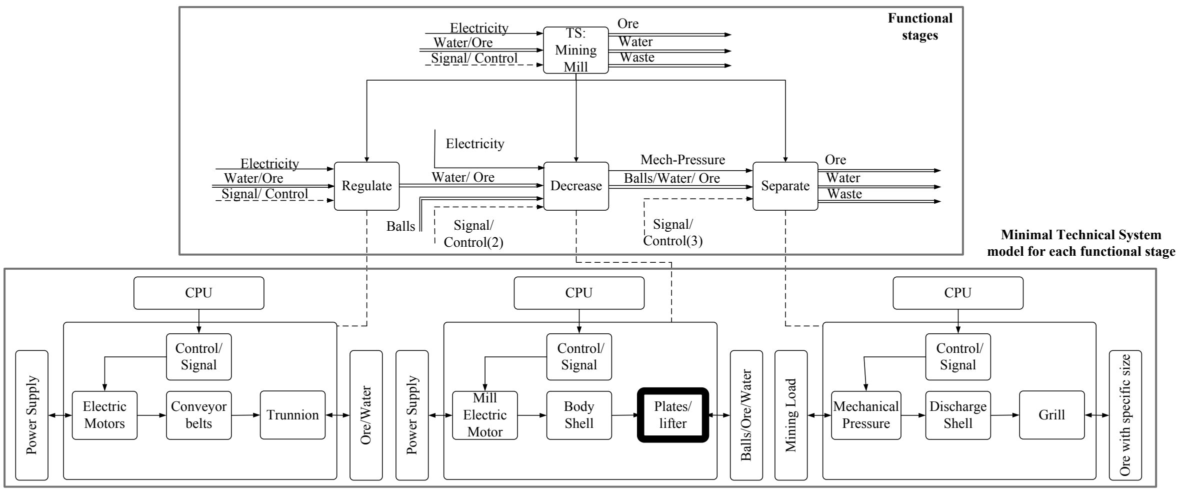


Figure AStep2-2: The chunked model of the industrial process under investigation and Minimal Technical System model for each functional phase.

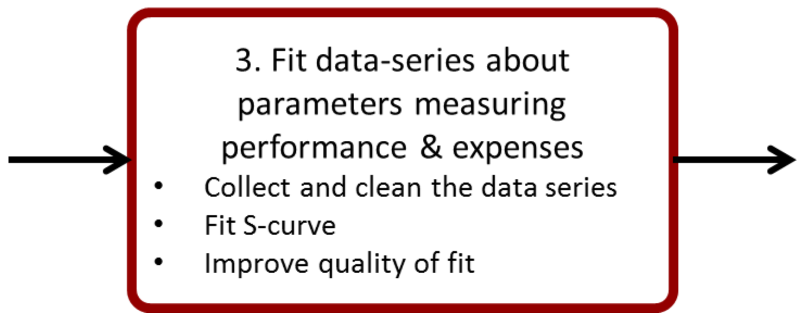
Resource	Units of measure	Regulate ore quantity	Decrease ore size	Separate ore
Maintenance time	[hrs]	Low	Medium-high	Low
Working lifetime	[hrs]	High	Medium	High
Energy consumption	[kWh]	Low	High	Low
Thickness reduction due to the wear/friction	[mm]	High	Medium	Low

Table AStep2-1: Qualitative evaluation for the identification of the most critical functional phases in the mill process

The most critical functional phase for the industrial process is the functional phase “decrease” (Table AStep2-1), because it requires the largest maintenance time and the highest energy consumption. More specifically, the maintenance involves the elements of the mill embedded in the internal cavity that is covered by plates/ lifters and that are designed to lift the load (i.e. the ore mixed with water and balls) during the mill rotation (Figure AStep2-1). Through the rotation of the mill, the load undergoes lifts and falls, with a continuous crushing effect (see also Weir Slurry Group, 2009 [6]). Besides, the internal plates have also another function, i.e. to protect the internal shell of the mill from the impacts generated by the rotating load. For these reasons, a failure occurring in these plates/lifters can determine the stop of the grinding process and the breakage of the mill-shell. In this case study, “plates/lifters” are the elements of the technical system (i.e. the mill) that will be analysed.

The evolutionary analysis was made by following the procedure described in (Cascini et al, 2008). Then, in order to check the meaningfulness of the envisioned trends, a patent search was performed focusing both on the whole system (i.e. the mill) and on the subsystem/tool (i.e. the plates/lifters). Figure AStep2-3 shows the plate/lifter evolutionary analysis. According to the approach followed in this case study, each invention (patent) is assigned to one representative TRIZ pattern of evolution. The red boxes represent inventions already patented (an indication of the patents available is provided), while green ones represent free research/design spaces and thus opportunities for new inventions.

Fit data-series about parameters measuring performance and expenses



highlight

Identify, by quantitative trend analysis, how technology-related parameters have evolved in the last years.

Forecast, by quantitative trend extrapolation, how technology is going to continue its evolution in the next years.

method

Develop a quantitative trend analysis for performance and expenses. A convenient model to perform this study is the logistic growth model, largely used for technology forecasting and relatively simple to implement. The application of the model assumes that the STF follows a logistic growth; it allows identifying the variables that will limit the STF growth in the future.

instructions

1 Recall the criteria to measure performance and expenses from Step 3 in Stage M.

2 Think about variables that can help you to understand the STF and its evolution. The variables have to be meaningful for answering to the forecast question (Step 1 in Stage FOR). Consider the following:

a. A number of variables have to be selected to develop the quantitative trend analysis; select what is meaningful for your STF.

b. Collect time data series for the selected variables from various data sources; these data sources can be internal or external.

c. Order the time data series chronologically - past to present.

3 Develop quantitative trend analysis through suitable regression models; if the variable is likely to follow a logistic growth, perform the regression by means of one of the suggested software tools.

4 (For logistic growth models only) Analyse the parameters of the regression (Figure AStep3-1):

a. K: the limit of growth, i.e. the maximum value that the variable can achieve in the future;

b. Tm: the time of maximum annual rate of growth, i.e. the midpoint of the S-curve (Only in case when one is using yearly data);

c. Δt: the time-period between the 10% and the 90% of the variable growth.

5 Assess the reliability of the regression by using statistical indicators. The main indicators to check are:

a. R-square: R-square indicates how well data fit the regression model, i.e. it is a measure of the distance between the fitted curve and the data of the time series;

b. P-value: The p-value is calculated for each parameter of the regression: a low p-value (< 0.05) indicates that the parameter is meaningful, while a larger (insignificant) p-value suggests that changes in the parameter are not associated with changes in the curve value;

6 Identify the evolution stage of the variable, i.e. estimate the degree of growth according to the following classification:
   a. Initial stage
   b. Growth stage
   c. Saturated stage

7 Identify the reasons or meaning of variable stage and drives some partial conclusions for the STF.

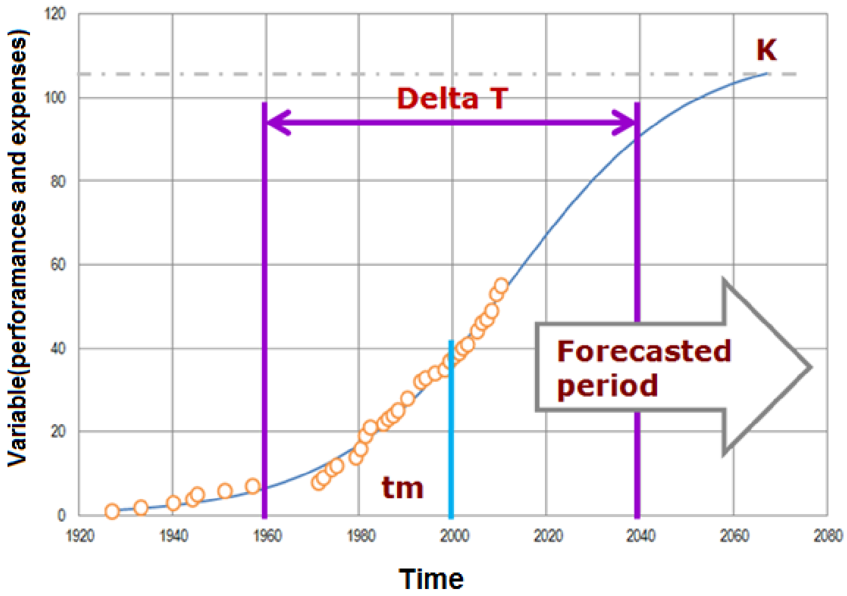


Figure AStep3-1: Graphical representation of Logistic Growth Curve based on Meyer's equation and their parameters.

tips

⇒ Before selecting the variables for forecasting, ask the beneficiaries about the availability of time data series to define the performance and expenses forecast.

⇒ In order to facilitate the regression analysis, use freely available software tools (e.g. FORMAT-prototype, Loglet, IIASA LMS). The Logistics Curve Software (FORMAT-prototype) provides complete statistical information.

⇒ Look for variables at different System Operator levels (recall the analysis carried out in Step 5 in Stage M). Sometimes the expansion of outlook allows the extension of boundaries limiting the identification of variables showing a logistic growth behaviour.

⇒ Check your results with the beneficiaries and experts in order to discuss the consistency of the regression parameters with the domain know-how and thus to derive more robust conclusions.

suggested reading

[1] 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. Vol-61. p. 247–271.

[2] Modis T., Natural Laws in the Service of the Decision Maker: How to Use Science-Based Methodologies to See More Clearly further into the Future. Growth Dynamics, 2013, p. 243.

[3] Yoon, B., and Lee, S. "Applicability of Patent Information in Technological Forecasting: A Sector-specific Approach". Journal of Intellectual Property Rights. 2012. Vol. 17. p. 37–45.

[4] Logistic Analysis: Loglet Lab 2- http://phe.rockefeller.edu/LogletLab/2.0/

[5] Logistic Substitution Model II: http://www.iiasa.ac.at/web/home/research/researchPrograms/ TransitionstoNewTechnologies/download.en.html

[6] Nikulin, C. Technological Forecasting supported by Logistic Growth Curve analysis: software tool for increased usability (p. 4) Milan. Retrieved from http://www.format-project.eu/deliverables/white-papers/july-2013-technological-forecasting-supported-by-logistic-growth-curve-analysis-software-tool-for-increased-usability/at_download/file

[7] Logistics Curve Software (FORMAT Prototype): http://handbook.format-project.eu/?page_id=354

examples

Example 1: Washing Machines

In a case study related to washing machine analysis, a meaningful indicator was described as "average capacity of washing machine" (US and Canada sales). Data was collected from an external database, California Energy Commission (http://www.energy.ca.gov/). Figure AStep3-2 presents the variable behaviour as fitted by a curve along with a plot of the residual error. The regression shows the data fitting with a projection for the next years. Table AStep3-1, in turn, collects the values of the regression parameters together with the statistical indicators concerning the statistical reliability of the analysis (Instruction #3 and #4).

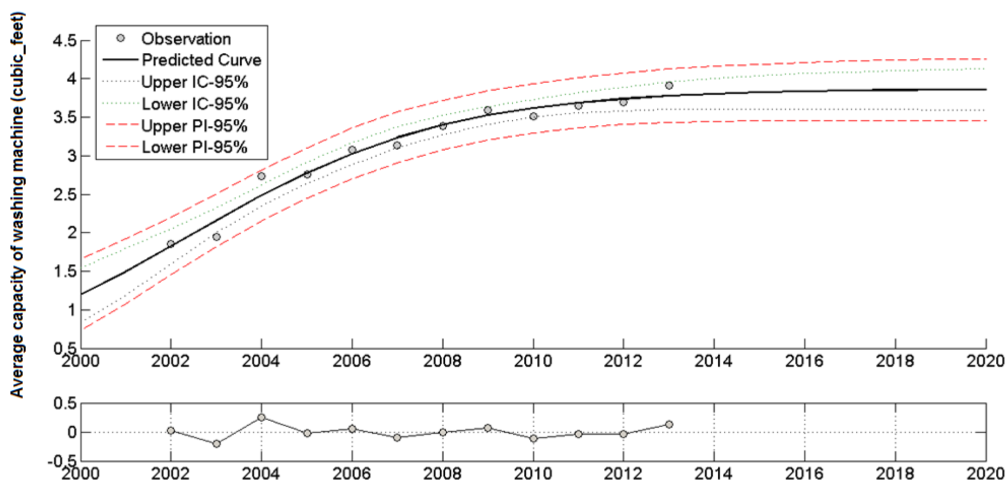


Figure AStep3-2: Average of washing machine capacity; Data source: California Energy Commission.

Table AStep3-1: Statistical results for regression analysis of washing machine capacity

Parameter	Value	Statistical significance (p)
Parameter of the regression		
Maximum for average of washing machine capacity [cubic feet]	3,86 cu ft (614,47l)	p<0,01
Period of time for 80% of the cycle [years]	12 years	p<0,01
Middle time when interior volume growth achieve his 50% [year]	2002 year	p<0,01
Results of the fit		
R-Squared [%]	96,83%	-

Conclusions driven by this analysis are that the average volume of washing machine in US and Canada is not going to radically change in the next years and it is highly probable that it will stabilize on a constant value (maturity stage) (instruction #5). As a consequence, it means that the next choices at the organizational level would avoid considering the idea of developing a bigger washing machine (Instruction #6).

Example 2: Copper Production

This step was accomplished by using a performance indicator at super-system level of the grinding process. The indicator was described as "world copper production". Data were collected from an external database, USGS mineral information and cooper worldwide. Figure AStep3-3 presents the variable behaviour as fitted by a curve along with a plot of the residual error. The regression shows the data fitting with a projection for the next years. Table AStep3-2, in turn, collects the values of the regression parameters together with the statistical indicators concerning the statistical reliability of the analysis (Instruction #3 and #4).

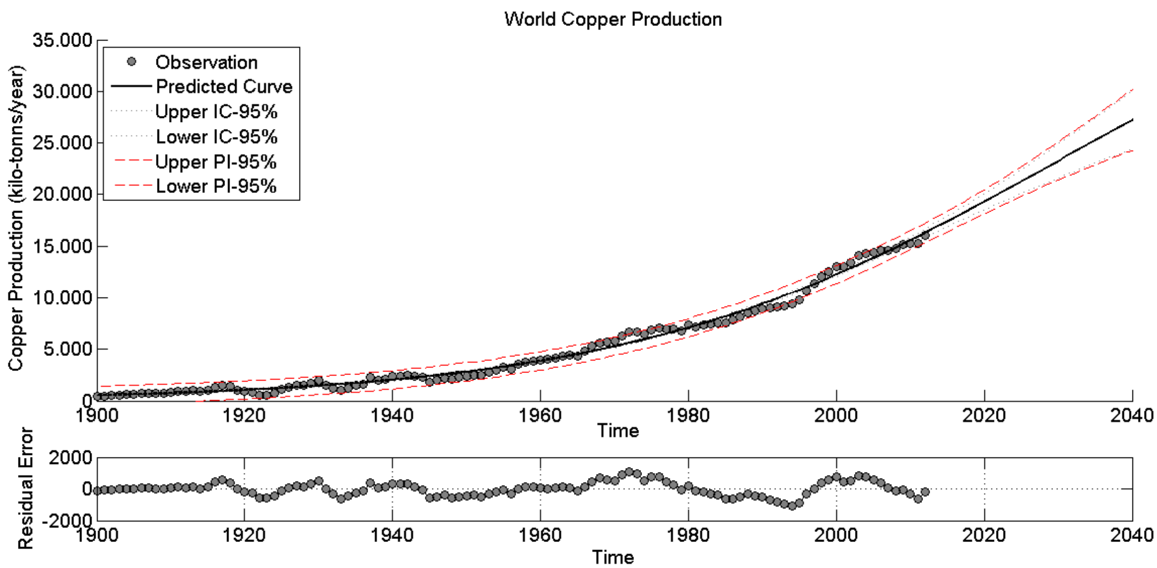


Figure AStep3-2: World copper production;
Data source: USGS mineral information and cooper worldwide.

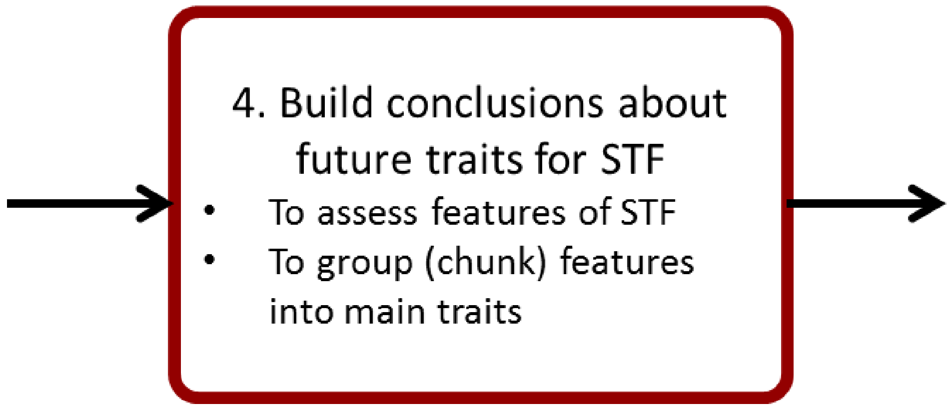
Table Astep3-2: Statistical results for regression analysis of world copper production

Parameter	Value	Statistical significance (p)
Parameter of the regression		
World copper production	46836[kilo-tonns/year]	p<0,01
Period of time for 80% of the cycle [years]	128 years	p<0,01
Middle time when achieve his 50% [year]	2030 year	p<0,01
Results of the fit		
R-Squared [%]	99,0%	-

Conclusions driven by this analysis are that the world copper production is going to continue increasing in the next years: it can be considered as a growing variable (instruction #5). As a consequence, it means that the R&D strategies should be focused on increasing the production according to the trend-demand. However, it should be also taken into account that the amount of copper inside the mine is decreasing, and a saturation point is expected to come (instruction #6).

notes

Build Conclusions about future traits for STF



highlight

Clear description of results from Stage M and Steps 1, 2, 3 of Stage A has to be prepared.

The developed results should be checked for consistency and coordinated. The consensus among members of working team should be attained for results within Step 4.

method

The fourth step in Stage A synthesizes the output of the forecast based on the elaborated results of the previous steps. The main task is to integrate the outcomes of the previous activities, check their consistency and identify the main features (traits) of the STF for the defined time horizon in specified location.

instructions

1 Examine the outcomes of Step 5 in Stage M and Steps 1-3 in Stage A.

2 Distinguish between compliant, complementary and conflicting features of the STF:

a. compliant features are those emerging as plausible future traits of the STF according to two or more steps of performed study;
b. complementary features are those identified within one step of performed study, and they are not in conflict with any other statement provided by the others;
c. conflicting features are those that derive from opposite conclusions drawn from any pair of performed steps.

3 Check measurability and assign measurement units for elaborated traits. Reformulate or regroup features for new traits, if necessary from measurability viewpoint.

4 Check consistency of formulated traits with time horizon and specified location of future STF.

tips

⇒ The compliant features clearly allow to draw the most reliable statements about the STF, while the conflicting features deserve further investigation (e.g. in a second round of the entire FORMAT process if requested by the beneficiaries).

⇒ It is recommended to group the features so as have 5-7 main traits of the future STF. This is meant to improve readability and interpretation of the forecast.

⇒ Whole set of traits is recommended to structure by three categories: (1) the features of future STF; (2) the features of future super-systems; (3) identified characteristics of sub-systems.

⇒ Traits may include sub-features. Any features and sub-features have to be accompanied with measurement units to allow comparison with alternative systems, if required.

⇒ It is necessary to check the future traits of the STF for conformity with changes on the super-system level and in the sub-system level.

⇒ Future traits of the STF have to be coordinated with features of the super-systems and harmonized with features of sub-systems of the future.

⇒ When future traits of STF are defined, they have to be checked first of all for consistency with results of Steps 1, 2, 3 of Stage A.

⇒ Participation of users of the forecast in the finalization of the outcomes of Step 4 of Stage A improves clarity of conclusions and consistency with common practices of the company.

suggested reading

[1] *ENV Model* in G. Cascini, F. S. Frillici, J. Jantschgi, I. Kaikov, and N. Khomenko, TETRIS: Teaching TRIZ at School, EN 1.0. TETRIS project and the Lifelong Learning Programme, 2009. (pp.20-24) http://www.tetris-project.org/

[2] OTSM ENV Fractal Model in N. Khomenko, Keynote presentation for 6th TRIZ Symposium in Japan, Tokyo, September 2010 (pp.31-39).

examples

While analysing technologies for the decoration for household appliances the following future trends (next 10 years) for super-systems where recognised among others not included for a matter of confidentiality:

α. Home appliances produced by complementary manufacturers (e.g. furniture maker + household appliance producer)

b. Integrated esthetically, electronically and by data- information
c. Appliances will provide more information (more sensors & data)
d. Control Panel (CP) has to deliver more information and control
e. User manipulation and control (easy to setup)
f. More touch-screen experiences.
    - New Options are attractive
    - Easy to use.
g. To attract customer the parameters:
    - aesthetic,
    - novelties,
    - smart energy consumption;
    - improved chemical resistance will be more important.
h. Recyclability of parts will be more important
i. Gradation of color in the design of CP will be more important.
j. User will be capable to create their own CP for more products
k. Most of decoration of CP with an electronic User-Interface (multi-language)
l. Company authenticity (brand, logo, look of products) will be more recognizable.

Meanwhile, future trends for sub-systems were formulated as:

a. More diversity of applied technologies for different substrates (various materials, shapes) and for diverse products.
b. Time form operator's involvement will decrease;
c. Preprocess time to prepare decoration will decrease

Consequently the **Future traits of Decoration system** (main function: <to modify> <color of> <a surface> where formulated for first version the following way:

a. Output of decoration will be more dynamic (easy to be modified when necessary)

b. Decoration process will be performed:
    - without stock,
    - in-line,
    - with increased recyclability of equipment and tools,
    - with reduced energy consumption.
c. Special investment for equipment, human resources (HR) and maintenances will be allocated.
    - Investment to new technology tends to be lower (below alternatives when delivering the same result),
    - operation cost is going to decrease,
    - environmental impact will decrease
d. Back side of Intermediate layer will be used for decoration more frequently than nowadays.
e. Full range of color management including metallic will be on demand,
f. Digital printing (no image preparation) will be wider applied:
    - change over time = 0s,
    - change over time for a part type t = 0s
g. Productivity of process [pcs/h] will be close to single color silk screening
    - no scrap during
h. Maintainability [non working, h] tends to improve due to self-maintainability
i. Cycle time of decoration process tends to be coordinated with cycle time of production line towards full integration of decoration with production line

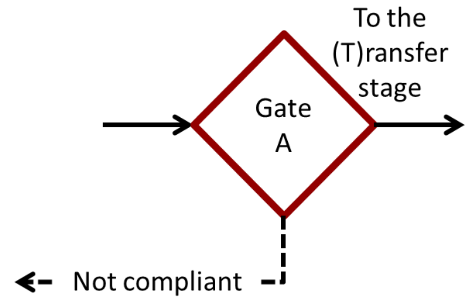
The list of future traits above is a preliminary one. A more elaborated list of traits

notes

A Gate

function

<to check> <completeness and



In order to complete the Stage A and move to the next stage, you must

Complete the following:

- ◊ List of limiting resources preventing the solutions to problems that drives evolution of STF
- ◊ Directions of development of new solutions for STF (evolutionary trends)
- ◊ Dynamics of parameter(s) measuring Performance & Expenses for STF (data series and graphs)
- ◊ Aggregated conclusions about future traits for STF

tips

- ⇒ It is required to compile the latest versions of all outcomes developed during Stage A into one document.
- ⇒ It is recommended to print out the list above for Gate A session.
- ⇒ The gate will serve as reference to later stages.
- ⇒ Tick the task only after the item is 100% accomplished.
- ⇒ Proceed to the next stage after completing all items on this list.

notes

FOR M A T

T

T Stage

notes

T Stage

The main function of Stage T is to translate conclusions about traits of STF to users and beneficiaries (decision makers - DM). It is necessary to prepare a presentation, report and present results for users and beneficiaries. Explicit answers for questions of forecast, formulated in Stage FOR have to be delivered.

prep time

2-3 working sessions

total time

3-5 working days

people

2-4 analysts plus users and beneficiaries

ingredients

materials

Meeting room equipped with videoprojector and flipchart.

tools

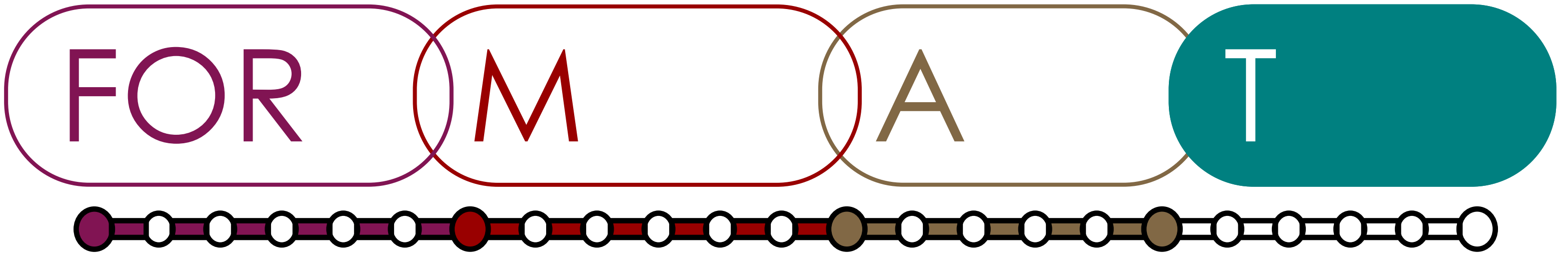
none

knowledge

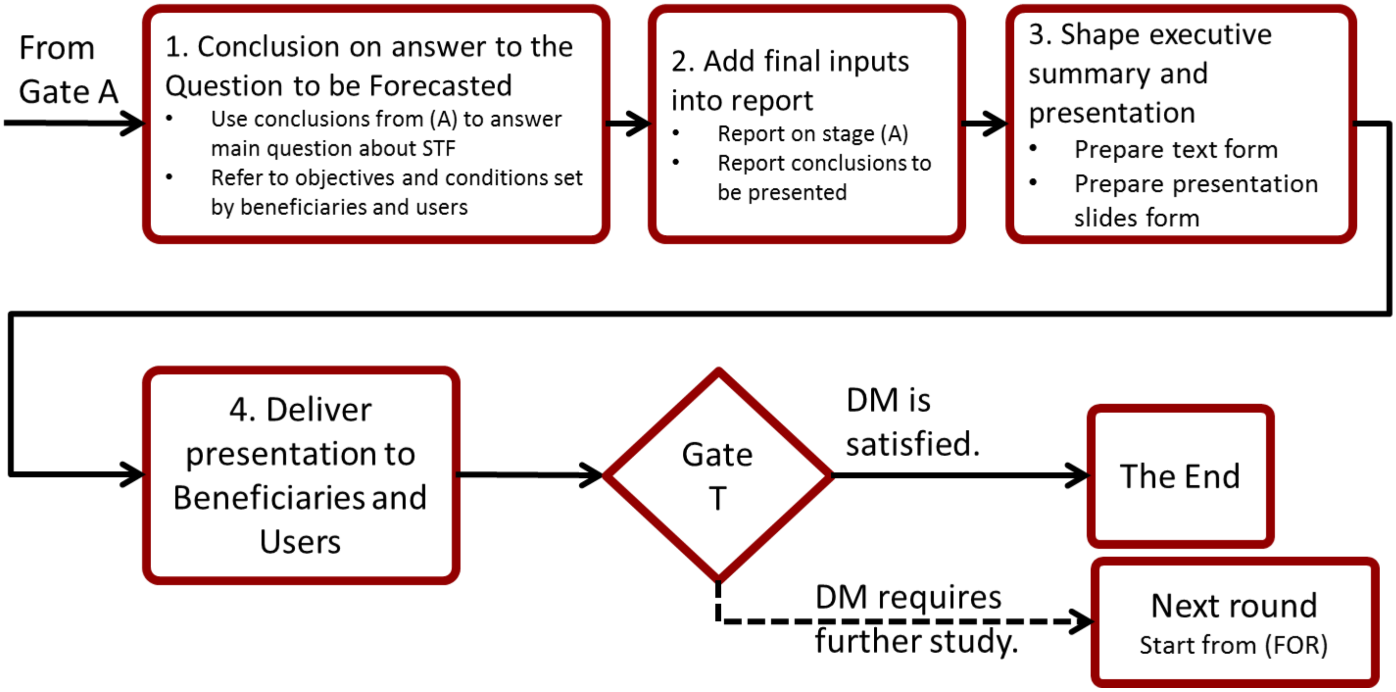
Knowledge learned within study about STF are required. Skills to develop a report and to deliver presentation are essential.

software

Office software, collaboration software



T Stage



instructions

1 Build answers to the questions for forecast formulated at Stage FOR

a. Use list of traits of STF and features of super-systems and sub-systems from Stage A (A_4) for answering main question and sub-questions.

b. Refer to objectives (FOR_4 - Why?) and conditions set by beneficiaries and users

2 Review and update the final outputs in accordance with requirements from users and beneficiaries:

a. Build the first version of the executive summary

b. Develop and provide a preliminary version of the final presentation for the working team with invited specialists and users

c. Collect feedback on this preliminary presentation and the executive summary.

3 Develop the final presentation:
   a. Prepare short conclusions of study
   b. Develop the final version of presentation of the forecast for users and beneficiaries

4 Deliver presentation to beneficiaries and users and submit the report with the executive summary.

5 Make a decision on the developed results:
   a. Decision makers, users and beneficiaries are satisfied (or not) and project is concluded.
   b. Further study is required to improve the reliability of the forecast and/or to update its scope or the level of detail

tips

⇒ In order to improve clarity of answers for the forecasting question, it is strongly recommended to collaborate with users and beneficiaries of forecast in steps 1, 2 of Stage T.

⇒ When developing the report and the presentation, a reduced working team of two analysts is more efficient than a bigger team. Contribution from other members of team may be collected to build slides and documents in advance (during Stage A).

⇒ Report and executive summary should be made consistent with standards of the organization of the users and beneficiaries. It is recommended to enquire about required reporting form prior to Stage T.

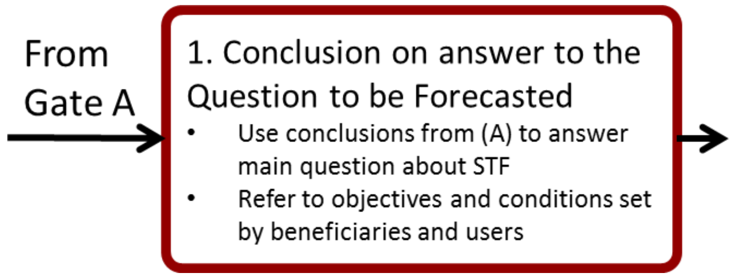
suggested reading

1. Playlist (8 talks) Before public speaking…
   http://www.ted.com/playlists/226/before_public_speaking
2. Organizational guidelines for writing project reports.

notes

Conclusions on answers to the questions to be forecasted

Step 1



highlight

The final results of Stage A have to be described with the consensus of all team members.

This step requires active participation from users of forecast in order to ensure clarity of answers.

method

The first step of Stage T produces the explicit answers to the forecasting questions defined at stage FOR. The main task of this step is to aggregate qualitative and quantitative results of the study into comprehensive and useful (for users and beneficiaries) answers to the three main questions of forecast: What? When? Where?

instructions

1 Use results from Stage A (A_4) for building answers to the forecast questions

2 Use results from Stage M and A for building answers for sub-questions.

3 Check consistency of suggested answers with objectives and conditions set by beneficiaries and users within Stage FOR.

tips

⇒ Answers to the questions of forecast should be short, visionary, measurable and unambiguous. On the other hand, the answers have to be clear to people who had not participated in the forecasting project.
The practice of using diagrams, graphics and references is recommended.

⇒ Answers to sub-questions should support and reinforce the answer to the main forecasting question.

⇒ Often, the answer to a forecasting question may not be plausible, but it should be consistent with the logic and results of the study.

⇒ Plausible answers for forecasting question might indicate
   a. that there were not many new things learnt during the forecast study;
   b. hidden biases influenced the results of the study;
   c. obtained results were adjusted to common ideas.

suggested reading

1. Public reports of FORMAT project case studies.
   http://www.format-project.eu/deliverables/public-reports-and-white-papers

2. Description of Case studies.

examples

While analysing technologies for the decoration of household appliances the main question for the forecast was formulated as follows:

Which is the most promising decoration technology for achieving present and future product need (quality, flexibility, cost effectiveness) in the future 5 to 10 years (2019-2024) for home appliances products at Europe, Middle East, and Africa markets?

Based on the output of the previous stages, the following answer was built:

In the future 5 to 10 years (2019-2024) main technologies for decoration for home appliances products at Europe, Middle East, and Africa markets will be improved silk printing in combination with digital displays. Performed study recognized the following traits of future decoration technologies:

- *for informative parts the decoration on home appliance will be dynamic (e.g. display, e-ink technologies for multi-language)*
    - *for aesthetic parts (e.g. brand name) the decoration will provide*
    - *more variability for colours (including metallic) and*
    - *more texture effects;*
- *digital image processing will be more in use;*
- *decoration process will be accomplished in line - cycle time of decoration process tends to be coordinated with cycle time of production line*
    - *with reduced energy consumption,*
    - *more recyclable parts and*
    - *minimum stock.*
- *Back side of transparent parts of home appliance will be used more frequently to improve abrasive and chemical resistance of decoration.*

- *Next decorations technologies will provide on the level of production process "0 time" for change over, and for change over for a part type, when productivity of process (pcs/h) will be close to single colour silk screening (in 2013).*
- *Maintainability [non working, h] of used equipment tends to improve due to self-maintainability.*
- *Special investment for equipment, human resources (HR) and maintenances will be allocated.*
    - *Investment to new technology tends to be lower (below alternatives when delivering the same result);*
    - *operation cost is going to decrease;*
    - *environmental impact is going to decrease*

Further sub-questions were also addressed:

1) Will decoration technologies be needed?
   Yes. *Decoration technologies will be within predicted time horizon for delivering information to users and for improving aesthetic experience.*

2) Which will be the expected (estimated) evolution of Main Parameters of ink-jet and laser marking?
   a) in the upcoming ten years, ink-jet technology will evolve towards improvement of controllability of printing process (chemical resistance, abrasion resistance and metallic appearance); ease of maintenance; increasing operation cost effectiveness.
   b) in the upcoming ten years, laser marking technology will evolve in the direction of ease of maintenance; increasing operation cost effectiveness and decrease initial investments.

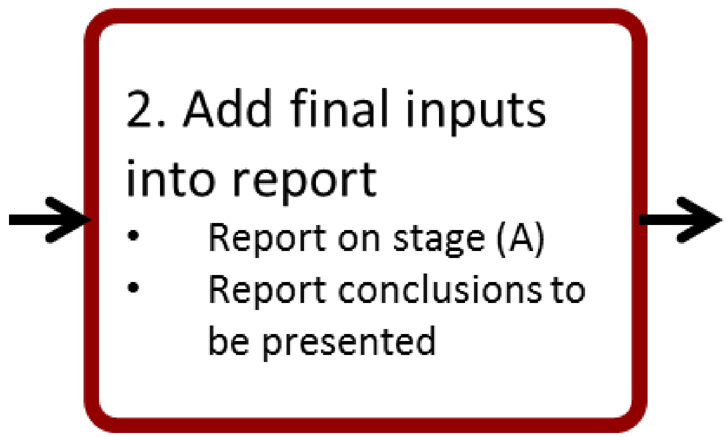
3) When will ink-jet technology be ready to substitute silk screening and pad printing for domestic appliances?
in the upcoming ten years ink-jet technology will not substitute silk screening and pad printing for mass home appliances products at Europe, Middle East, and Africa. However, this technology will grow considerably as complementary one in the second part of next decade.

4) When will laser marking be able to produce coloured marks in plastic?
Performed study has not recognized any signs than laser marking will be able in the upcoming 10 years to produce coloured marks for mass home appliances products at Europe, Middle East, and Africa.

notes

Add final inputs into report

Step 2



highlight

Complete the report of the project.

method

T Step 2 delivers conclusions that will be reported to beneficiaries and users at the final session of the technology forecasting project.

instructions

1 Collect results from preceding stages: for instance, the slides developed during case study (Stage FOR, Stage M, Stage A).

2 Build the first version of the executive summary: report the results of last steps in stage A (A_4) to users and beneficiaries.

3 Compile and discuss a preliminary version of the final presentation within working team with invited specialists and users of forecast.

4 Collect feedbacks on this preliminary presentation and the executive summary.

5 Write the report.

tips

⇒ Collect all slides from preceding stages and group them into three sets: FOR, M, A.

⇒ Check consistency in language, references and edition layout among reports prepared by different members of the analyst team.

⇒ Dedicate time to improve clarity of reports – pay attention to the specific terms.

⇒ Structure the report with headlines to improve readability and conformity with requirements from users and beneficiaries.

suggested reading

A. B. Badiru, Project Management for Research: a guide for engineering and science, First. London: Chapman & Hall, 1996, p. 224.

Felmley, James C. "Analyzing and Reporting Forecast Performance." The Journal of

Cabri, Anthony, and Mike Griffiths. "Earned Value and Agile Reporting."AGILE. Vol. 6. 2006.

examples

Building a report from a forecasting case study depends on a way how the work on each stage was organized. If FORMAT template has been applied then results from each working session are the most likely recorded in the form of presentation slides.

Any additional content assisting the slides is put in the form of presenter notes. In this case, preparation of a report can be done by simply printing all presentations assembled for each gate in the form of handouts. Handouts format provides on each page a picture of a slide with presenter notes under each slide. Using handouts format limits the editorial tasks to scaling of the slide's picture in order to maintain their readability.

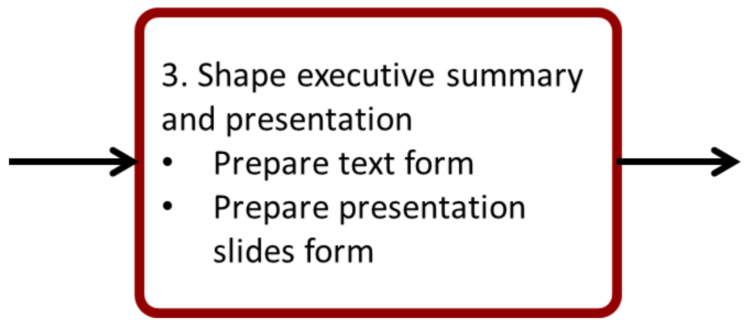
Reporting of step 4 in stage A, as a step right before a gate A, may be still in the process of refining. Similar situation is for immediately preceding step, step 1 in stage T. In order to complete reporting, slides should be finished and integrated in their latest form.

An example of a report from case study can be seen in the 'Case Studies' section

notes

Shape executive summary and presentation

Step 3



highlight

Describe the answers to the questions of the forecast and provide measurable supporting arguments.

method

The executive summary is shaped as a brief conclusion of the technology forecasting process. A presentation with extended Question and Answers provides clear understanding of forecast.

instructions

1 Indicative structure of the Executive summary – an overview of results of the forecasting study:

a. Questions addressed by the forecast and related answers
b. Qualitative and quantitative evidences of the forecast
c. How the study was performed
d. Where the forecast might be used
e. Presentation of the team involved in the project

2 Develop a presentation on the forecasting project, i.e. slides, animation, video, including:

- Supporting qualitative and quantitative data
- The reasoning that was applied for building the forecast

3 Discuss and update the first version of the executive summary and presentation with the working team.

tips

⇒ Aim for a short presentation approach i.e. 10 slides, 20 minutes, big font size (this implies strong visuals with reduced text per slide)

⇒ Presentation can be based on the material accumulated throughout the study

⇒ In your presentation, pay attention to the following:

⇒ present the main questions of the forecast and the explicit answers to those questions

⇒ add a description of the system under study (STF)

⇒ add conclusions for whole study

suggested reading

1. Raynolds, G. (2011). Presentation Zen: Simple Ideas on Presentation Design and Delivery (2nd ed., p. 312). New Riders.
2. Duarte, N. (2011). slide:ology (p. 296). O'Reilly Media.
3. Kawasaki, G. (2005). The 10/20/30 Rule of PowerPoint, http://blog.guykawasaki.com/2005/12/the_102030_rule.html

examples

Here you can find an executive summary prepared for a case study "decoration.' Decoration case study was investigating technologies that produce markings on home appliances that deliver data to the user. Construction of this executive summary follows an outline proposed above, however it was adjusted to fit form of obtained results. For instance, questions are followed directly by answers together with identified evolutionary developments, what improves readability.

Executive summary for case study "decoration"

1. Main and sub-questions answered (this point is using a material prepared for step T_1)

Which is the most promising decoration technology for achieving present and future product need (quality, flexibility, cost effectiveness) in the future 5 to 10 years (2019-2024) for home appliances products at Europe, Middle East, and Africa markets?

In the future 5 to 10 years (2019-2024) main technologies for decoration for home appliances products at Europe, Middle East, and Africa markets will be improved silk printing in combination with digital displays. Performed study recognized the following traits of future decoration technologies:

- for informative parts the decoration on home appliance will be dynamic (e.g. display, e-ink technologies for multi-language)
- for aesthetic parts (e.g. brand name) the decoration will provide
  - more variability for colours (including metallic) and
  - more texture effects;
  - digital image processing will be more in use;
- decoration process will be accomplished in line - cycle time of decoration process tends to be coordinated with cycle time of production line
  - with reduced energy consumption,
  - more recyclable parts and
  - minimum stock.
- Back side of transparent parts of home appliance will be used more frequently to improve abrasive and chemical resistance of decoration.
- Next decorations technologies will provide on the level of production process "0 time" for change over, and for change over for a part type, when productivity of process (pcs/h) will be close to single colour silk screening (in 2013).
- Maintainability [non working, h] of used equipment tends to improve due to self-maintainability.
- Special investment for equipment, human resources (HR) and maintenances will be allocated.
  - Investment to new technology tends to be lower (below alternatives when delivering the same result);
  - operation cost is going to decrease;
  - environmental impact is going to decrease

1) Will decoration technologies be needed?
Yes. Decoration technologies will be within predicted time horizon for delivering information to users and for improving aesthetic experience.

2) Which will be the expected (estimated) evolution of Main Parameters of ink-jet and laser marking?
a) During coming ten years, ink-jet technology will evolve towards improvement of controllability of printing process (chemical resistance, abrasion resistance and metallic appearance); ease of maintenance; increasing operation cost effectiveness.
b) During coming ten years, laser marking technology will evolve in the direction of ease of maintenance; increasing operation cost effectiveness and decrease initial investments.

3) When will ink-jet technology be ready to substitute silk screening and pad printing for domestic appliances?
During coming ten years ink-jet technology will not substitute silk screening and pad printing for mass home appliances products at Europe, Middle East, and Africa. However, this technology will grow considerably as complementary one in the second part of next decade.

When will laser marking be able to produce colored marks in plastic?
Performed study has not recognized any signs than laser marking will be able in coming 10 years to produce colored marks for mass home appliances products at Europe, Middle East, and Africa.

2. How was this study prepared?

Main question was formulated in cooperation with Whirlpool (WH) beneficiaries. The decoration system was described as a manufacturing process with its components and context. The same was done for selected group of alternative technologies that are important for WH. Data about technologies have been collected from provided documentation, during factory visits and from invited WH experts.

Alternative technologies have been studied for problems. Limiting resources that linked with problems have been listed. Observation of evolutionary changes gave an idea about future development of system's elements. In this case study it was not possible to perform the quantitative analysis and forecast conclusions were built basing on the results of qualitative studies.

3. Where will the forecasting results be used?

Utilization of forecast after delivery was described as follows:

- For reasoning about investment in modification or change in decorations (e.g. currently a budget amount involved is difficult to assess – business case should be prepared each time),
- For Factory Master Plan (it is influenced by decision on decoration technologies).
- To communicate to people – first client:
    - Product Design,
    - Marketing,
    - Product Development.

4. What were competitive technologies considered inside forecasting study?

The top group of competitive technologies consisted of: silk screening, pad printing and laser marking. Extended group included also: ink-jet printing, chemical etching, hot stamping.

5. Present the team working on the project

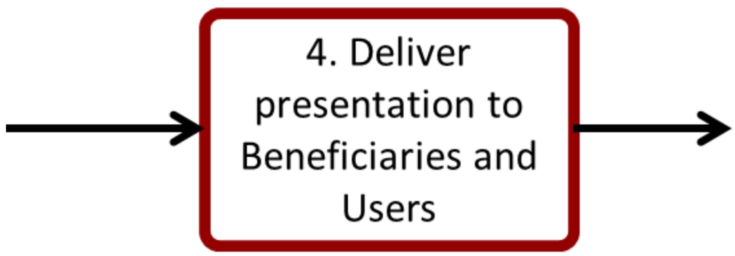
The forecasting team was composed of: a four-person core team (FORMAT project developers). WH beneficiaries and experts contributed at first and concluding working sessions. Two WH experts contributed also to the individual working sessions and guided the factory visits.

Presentation

Presentation that was delivered to beneficiaries and experts at the concluding working session can be downloaded from the following link.

Deliver presentation to beneficiaries and users

Step 4



highlight

The results of the forecasting study should be presented to users and beneficiaries.

method

The outcome of the technology forecasting project is presented in a live meeting with users and beneficiaries to ensure the proper delivery of the project outcomes.

instructions

1. Prepare meeting room and equipment for the meeting:
   - sound-isolated room, table, chairs, power sockets, electric extenders
   - video-projector and necessary equipment if remote participants attend the presentation (quality of Internet connection)
   - laser pointer, voice recorder, white board, markers
   - comfortable conditions for attendees
2. Agree before starting the meeting about time available for participants.
3. Deliver the presentation, paying attention to the allocated time for the meeting.

tips

⇒ Before presentation: similar to other meetings, go ahead of time to the venue to make sure that the equipment are working fine.

⇒ Materials for presentation include slides to be shown and slides which may be shown to support answers for questions.

⇒ Encourage users and beneficiaries for questions from first minutes of presentation. Go to participative mode, rather than to 'lecturing' mode.

⇒ During presentation: recordings of the meetings is highly recommended for future analysis.

⇒ After presentation: meeting minutes with the actions items and people responsible to be sent to the users and beneficiaries; send only presented materials to attendees.

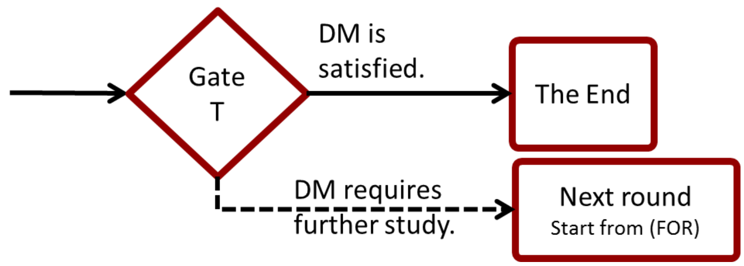
suggested reading

1. Atkinson, Cliff. 2011. Beyond Bullet Points, 3rd Edition: Using Microsoft PowerPoint to Create Presentations That Inform, Motivate, and Inspire. Pearson Education.
2. Ramadurai, B. 2014, How to Present Outcomes from a Technology Forecasting Project, http://www.format-project.eu/deliverables/white-papers/january-2014-how-to-present-outcomes-from-a-technology-forecasting-project/at_download/file
3. Reports about case studies performed during FORMAT project
4. Melissa Marshall: Talk nerdy to me http://www.ted.com/talks/melissa_marshall_talk_nerdy_to_me

notes

T Gate

function



<to check> <completeness and

Complete the following:

- ◊ Answer the Question to be Forecasted (from (FOR) Gate)
- ◊ Write an executive summary
- ◊ Write a report
- ◊ Prepare a presentation of results
- ◊ Deliver the presentation

instructions

1. If Users and Beneficiaries are Satisfied → The End of project
2. If it is required further study → Decision about the next round. Start from Stage FOR

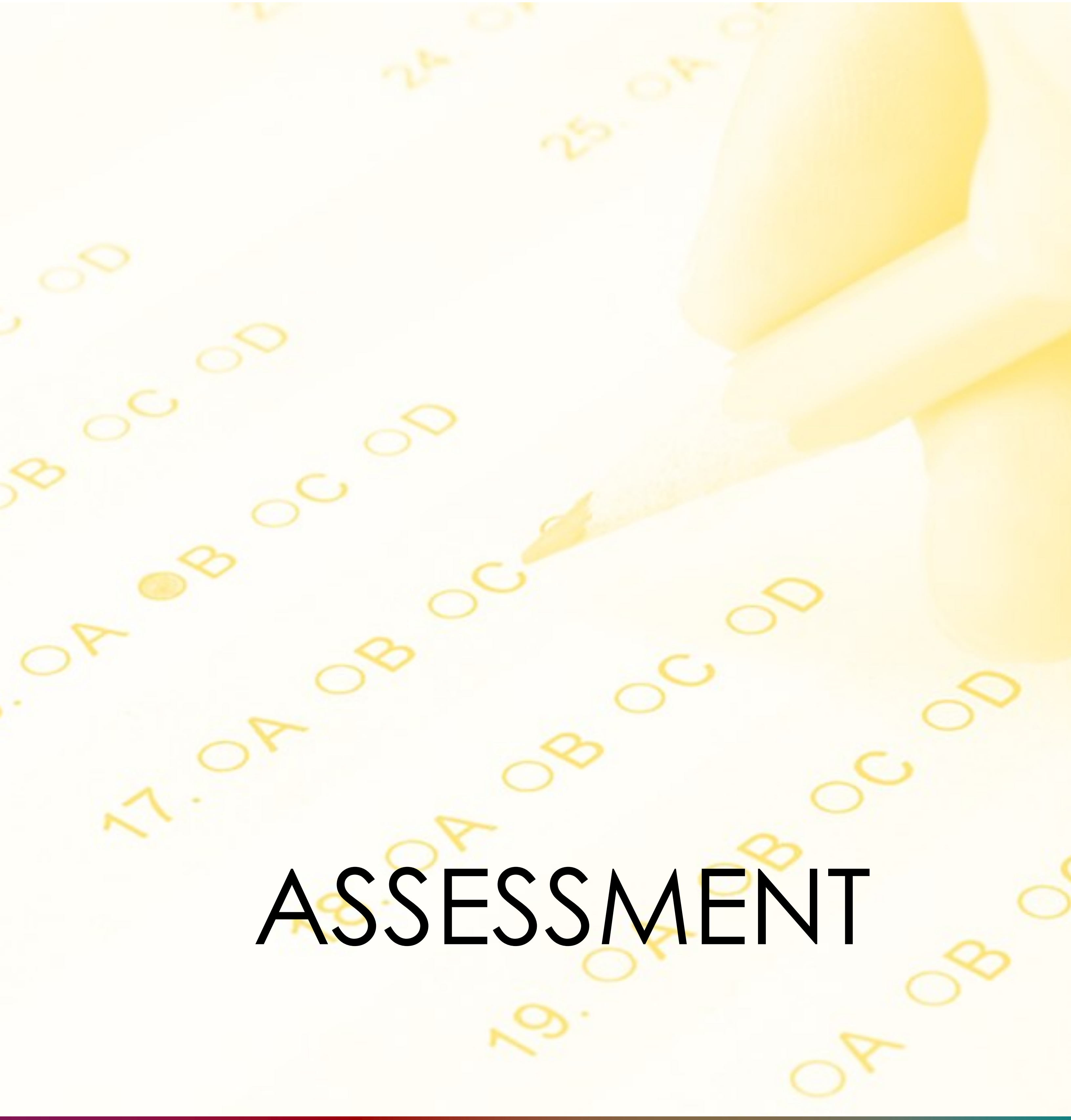
tips

⇒ It is recommended that you print this list out for your T gate session.

⇒ Tick the task only after the item is 100% complete.

notes

FOR M A T



ASSESSMENT

Assessment

The main method of evaluation guidelines depends on the evaluation metrics developed in the project [1]. These evaluation metrics depends on information extracted from users and beneficiaries of the project. Interviews and/or questionnaires can be used.

prep time

3 working sessions

total time

4-7 working days

people

1-3 analysts plus all users and beneficiaries

ingredients

materials

Deliverable 4.1

tools

Structured interviews;
Questionnaire
Final report and presentation

knowledge

Interviewing skills
Questionnaire building skills

software

Office software available for all participants of project (e.g. word processors, spreadsheets, for slides, pdf converters); collaboration software to support VoIP meetings (necessarily including screen sharing features, preferably with recording option)

instructions

1 Collecting information:
- Case study sessions
- Reports
- Evaluate time spent on the case study by users and summarize the outcome

2 Interviews: use evaluation metrics (annex in Deliverable 4.1) to interview the participants. Add extra questions to ask about feedback for developing the case study.

3 Send questionnaires to beneficiaries to ask them about the questions in the scoring card (annex in Deliverable 4.1)

4 Collect information and classify it into a SWOT analysis (strengths, weaknesses, opportunities and threats).

5 Qualitatively evaluate interviews and questionnaires with respect to the following criteria:
- the practical use of the methodology,
- the detected gaps,
- the value of the outcomes and
- the reliability of the methodology.

6 Evaluate the answers of the questionnaires qualitatively following the annex of Deliverable 4.1 (the scoring card):
- 1 = definitely no
- 2 = more no
- 3 = more yes
- 4 = definitely yes

7 Calculate the average of each answer and the standard deviation

8 Represent the results of team experience (the interviews with users) and beneficiaries satisfaction (the questionnaire and the interviews with beneficiaries)

tips

⇒ During the interviews, aim at a feedback that can support your later analysis into strengths, weaknesses, opportunities and threats. However, avoid mentioning these terms.

⇒ Carry out interviews individually

⇒ Questionnaires should be anonymous among participants.

⇒ Record sessions if possible.

⇒ Take notes and make sure information is explained clearly to participants.

⇒ Identify who is doing what during the case study and ask more questions about his/her personal evaluation of this part.

⇒ Always ask for suggestions for improvement.

suggested reading

[1] Deliverable 4.1,: http://www.format-project.eu/deliverables/public-reports-and-white-papers/evaluation-metrics/at_download/file

[2] Deliverable 4.5 (to be finalized by the end of November 2014)

examples

Deliverable 4.3 represents the assessment of the case study of vacuum forming in the FORMAT project based on investigating the team experience through interviews, a questionnaire and a preliminary monitoring of similar/related non-FORMAT studies. The FORMAT builders and user participated in an online questionnaire and individual online-interviews which were a direct application of the evaluation metrics and scoring card previously published in deliverable 4.1.

Each participant extended his/her answers to give recommendations for the improvement of the methodology, case-studies and deliverables. These participations were clustered by the researcher into main four categories according to SWOT analysis to represent the strengths, weaknesses, opportunities and threats. Although in SWOT analysis opportunities and threats are external due to the environment, most of the participant recommendations and warnings were directly related to the case-study activities. Therefore, other two categories of external opportunities and threats were added to recommendations based on preliminary study of similarly related studies in thermoforming, plastic machinery and appliances manufacturing.

FOR M A T

notes

TUDIES

CASE S

SE STUDIES

CAS

CASE STUDIES

Case Studies

Vacuum Forming, ed. FORMAT team

Decoration, ed. Dmitry Kucharavy

Pre-coated steel, ed. Niccolo Becattini

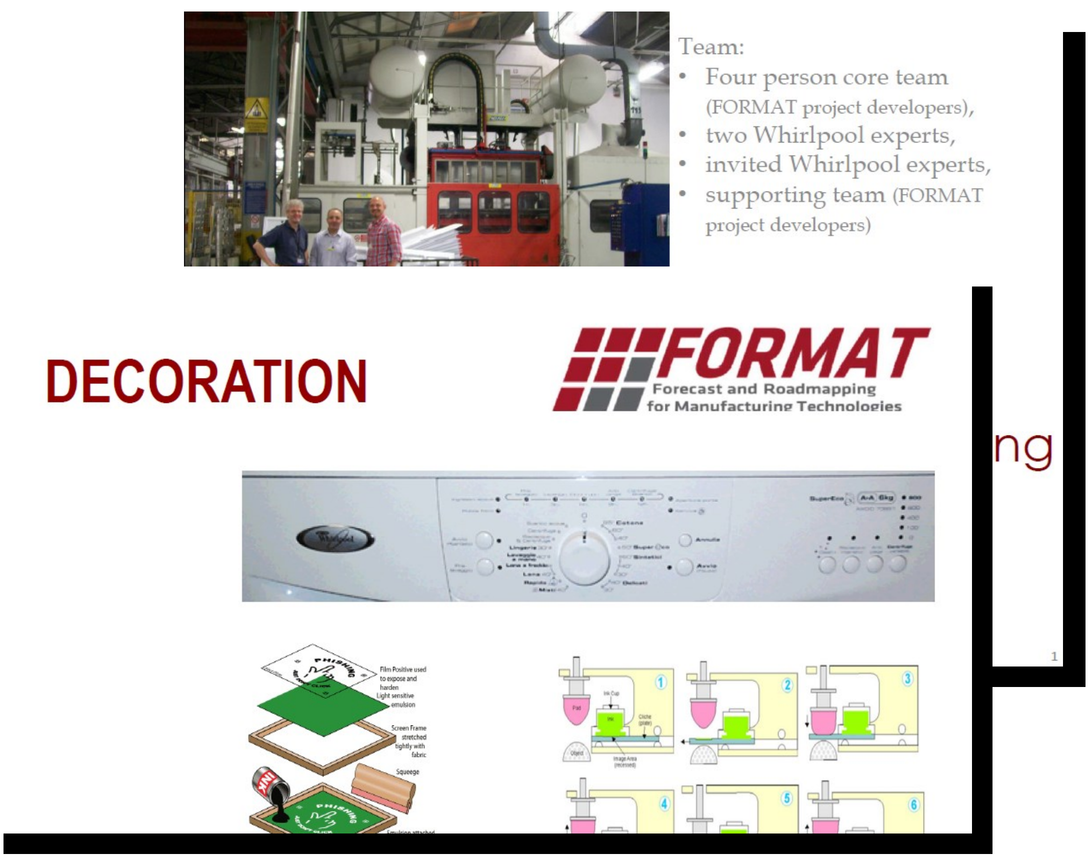
Konin 2050—forecasting for the city of Konin, Poland, ed. Justyna Król

Vehicle 2030, ed. Sebastian Koziołek

Domestic ovens, ed. Gaetano Cascini

Interior of a car, ed. Niccolo Becattini

Case studies can be downloaded here.



Case studies can be downloaded at http://handbook.format-project.eu

FOR M A T

GLOSSARY

Glossary

Alternative technology

A form of technology that is regarded by some stakeholders as preferable to conventional technology [adapted from Collins Dictionary]
When the main function of one technology is close to another, but its working principle is different, the first can be used instead of the second.

In particular, an alternative Manufacturing Process (MP) has to start with the same raw materials (e.g. granules & scrap of high impact polystyrene) as the current MP; and to finish with the identical product (e.g. Open polymer 3D-form - open box). Additionally, an alternative MP has to allow its integration into existing super-systems (e.g. fabrication of home refrigerator in particular industrial conditions).

Context: FORMAT methodology

Barriers

A barrier is something such as a **rule**, a **law** (of nature, or of society), or a **policy** that makes it difficult or impossible for something to happen or be achieved; **factors** that hinder and decelerate development of a certain system along evolution. The identification of barriers is the starting point for identifying problems and contradictions.

Context: Drivers & Barriers / FORMAT methodology

Contradiction

In the context of TRIZ (Theory of Inventive Problem Solving), system evolution implies the resolution of contradictions, i.e., conflicts between a system and its environment or between the constituting elements of the system itself. The inventive solutions bringing a major contribution to the development of a technical system do not compromise between opposite requirements. Overcoming contradictions is thus a driving force behind technology evolution and their identification is the first step of any invention process.

The complete model of a contradiction comprehends three elements:
- Two (2) Evaluation Parameters (EP) constituting a measure of system requirements satisfaction
- One (1) Control Parameter (CP) whose value impacts, with opposite results, both the Evaluation Parameters.

A contradiction occurs when two evaluation parameters are coupled in such a way that the attempt of improving any of them (by acting on the control parameter) determines the worsening of the other. Classical TRIZ literature often distinguishes between Technical/Engineering and Physical contradictions, the former expressed just taking into account the Evaluation Parameters, and the latter focused only on the opposite requirements for a same Control Parameter.

Context: TRIZ

Driving contradiction
The driving contradiction is the Contradiction that determines evolution of a system within time.

For instance, the weight of transportation system has to be high for large-capacity vehicles to provide necessary strength and energy to move weighty cargo; but weight of transportation system has to be low for large-capacity vehicles to increase the portion of payload in overall weight of transportation system. In the other words, payload has to be greater than weight of transportation system.

Context: Researching Future

Contexts (Technological, Economic, Environmental, Social – TEES)

The surroundings, circumstances, environment, background or settings that determine, specify, or clarify the meaning of an event or other occurrences [http://en.wiktionary.org/]

Technological[1]

Technological context includes the following frameworks: Technological changes; Industrial structure; Machines and infrastructures used for specific purposes; Methods to design, produce, operate and decommission (getting rid of) machines and infrastructures; relating to the application of scientific knowledge for practical purposes, especially in industry.

Economic

Economic context includes the following frameworks: Production context; Consumption issue, Transfer of wealth context; Economic Growth issue; Cost of products; relating to the production and consumption of goods and services and the supply of money, but also relating to the careful management of available resources

Environmental

Environmental context includes the following frameworks: Occupied space use; Natural resources use (material (air, water, soil, etc.), energy (fossil, renewable)); Environmental awareness (contaminations (air, water, soil), global warming, noise issues, light issues, odor); Safety for environment (plants, wild life, bio-diversity). Relating to the natural world and the impact of human activity on its condition

Social

Social context includes the following frameworks: Public acceptance (safety issues, public opinion, etc.); Political issues (Security, Independence, Fiscal and Regulatory policies, Local and Global policies); Educational context (availability of information, available skills, knowledge, manpower capacity); Employment context. Related to the development, structure, and functioning of human society

Context: Drivers & Barriers / FORMAT methodology

Competing technology

See Alternative Technology

Context: FORMAT methodology

Core team

Group of 4-6 specialists (analysts, users) that develop the forecast from the beginning until the end. Members of core team participate in all working sessions and coordinate activities with requested specialists and experts.

Context: FORMAT methodology

Data

Data is a description of facts from a certain viewpoint organized for analysis or used to reason or make decisions. They can be derived from scientific or industrial experiments. In other words, it is a description (e.g. measurement) of facts through a comparison with something known (size, color; strength). Data acquisition is limited by examples to compare and selected measurement units (e.g. how does one measure a personal value?). It is important to underline that the same facts can be described by different datasets.

Context: Components of knowledge acquisition process / Researching Future

Decision Maker

Decision maker is someone entrusted in an organization to make financial or organizational decisions using the process described in "Decision making". Sometimes, the final decision may be made by one or a group of decision makers (possibly a committee).

Context: FORMAT methodology

Description of Manufacturing Process (MP) "AS IS"

Working description(s) of a currently existing industrial process.

Context: Stage M / FORMAT methodology

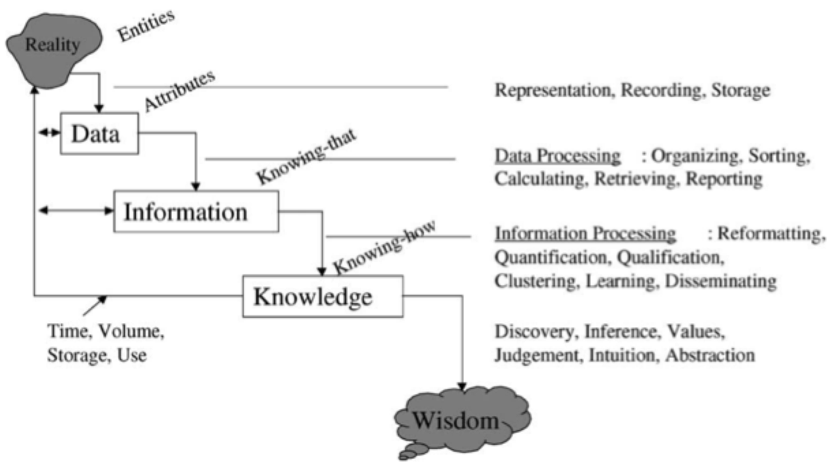
Decision making

Decision making can be regarded as the cognitive process resulting in the selection of a course of action among several alternative scenarios. Every decision making process produces a final choice (James Reason, 1990). The output can be an action or an opinion of choice [Wikipedia].

Context: FORMAT methodology

DIKW Hierarchy (Data - Information - Knowledge - Wisdom)

All the symbols representing a property of entities, as well as events, should be considered as **Data**. It turns into **Information** once such data gets selected according to the relevance of its content. Therefore, the terms hierarchy is not properly used in this context, since the relationship that binds Data and Information is not merely "structural". In other word such a transformation concerns a process of inference. **Knowledge**, indeed, is represented as the result of the transformation of Information into know-how, which means that the relevant content is also interpreted and organized in a way that is reusable according to the meaning that has been conferred to Information. As well, also the relationship between Information and Knowledge is not strictly hierarchical, rather relational. According to this definition of Knowledge, it is evident that this is the level that allows to transfer elsewhere some content organized according to the meaning of a previous interpretation. At last, **Wisdom** pertains to the sphere of judgment and it is in relationship to Knowledge because it assigns values to the know-how (Ackoff, 1989).



Context: Knowledge Management

Drivers

A driver is something such as a need, rule, law, or policy that makes it possible and probable for something to happen or be achieved; the factors that reveal and accelerate (pull & push) the development of a certain system along evolution. Drivers can provide necessary resources for solving problems. A factor which causes a particular phenomenon to happen or develop.

Context: FORMAT methodology / Drivers & Barriers

ENV model

Element_Name-of-feature_Value-of-feature model that allows describing any element or system through its traits. For instance:

What is it that looks **like a ball**,
But stands still and **does not fall**
Off its thin and **graceful legs**?
Children like to **turn it round**,
Rivers, **mountains**, **lakes** are found,
Countries, **states** and **their** towns
Can be seen all around

In bold we can collect features of an element. As result of this gathering one can recognize what it is (globe) [Khomenko, 2001].

ENV model allows, without a specific name, to describe and identify any element of material and non-material realms.

Context: OTSM-TRIZ

Expert

An expert is a person who is very skilled at doing something or who knows a lot about a particular subject. (specialist) [Collins Cobuild Dictionary]

Experts are widely recognized as a reliable source of technique or skill whose faculty for judging or deciding rightly, justly, or wisely is accorded authority and status by their peers or the public in a specific well-distinguished domain. [adopted from wikipedia]

In the context of the FORMAT methodology, experts are referred as the people in the company having specialist's skills and competences about a certain technology.

Context: Knowledge management

Evaluation metrics

Qualitative or quantitative indicators to assess the usefulness of the forecast, the benefit-to-effort ratio, an opinion about the representation of the results, etc.

The metrics are organized in three levels, to be able to evaluate the FORMAT methodology from the viewpoint of:

The beneficiaries of the Technology Forecast:

The person(s) to whom a Technology Forecast may be beneficial, e.g. by supporting them in decision-making, by helping them gain knowledge on a technological system… The beneficiaries are mainly the "end-users" of the forecast, usually the people in the company that are involved in decision-making.

The users of the Technology Forecast:

The person(s) who are using results of or Technology Forecast study in practice. For instance, Users consider results of forecast when developing new technologies or preparing specifications for new equipment acquisition.

The analyst = the user of the FORMAT methodology:
The person(s) that follows the stage-gate FORMAT methodology to prepare and execute a Technology Forecast, using the indicated methods in each stage to get a required output for each gate. Using the methodology includes data and information collection, analysis, synthesis, and the formulation of the presentation and report of the results.

The builders of the FORMAT methodology:
The FORMAT researchers, who selected the methods in and carried out the testing of the FORMAT methodology, who can describe the methods in terms of needed efforts and expertise.

Context: FORMAT methodology

Information

Information can be defined as a structured representation using data and interpretations from a certain viewpoint. It is structured, articulated, codified, and stored in certain media. The most common forms of information are manuals, documents, and audio-visual materials. Information is not related to individuals but it has an interpretative content. By watching the daily news from different countries it is easy to witness how different information can be about the same facts and events [Kucharavy, De Guio, 2009]
Applied meaning is close to "explicit knowledge[3]".
How does one get it? Facts, data and sets of data + Interpretation. Information is what we learn.

Context: Components of knowledge acquisition process / Researching Future

Function-behavior analysis

It is an approach through which a technology/technical system can be studied. The functional analysis deals with the identification of the purpose of the technical system (what the system is for). The behavioral analysis deals with the identification of the way a technical system carries out its function (how the system works).

Context: FORMAT methodology

Function definition

In order to formulate function of a system it is suggested to use the following 3 steps procedure:

Describe a function using common words and expressions:

Example: pen – to write, drawing

Reformulate the function defined at (1) in accordance with the pattern:

<verb> + < object> (+ <attributes>)

Example: <draw> <letters>

Reformulate the function(s) defined at (2) by expressing the action described by the <verb> with the pattern:

[change] + <features (values) of the object>

Example: [change] + <information content of the writing support>

GO back to (2) and review formulated function for consistency with results of step 3

Final definition of the function of a system is taken from results of Step 2 after revision the consistency with Step 3.

Context: OTSM-TRIZ

Gate

Gates are the control points to check what was done and make decision about next stages of the process.

Gates are check points, not phases of the process: in a gate, no activities are performed, but checking the completeness, the consistency and the appropriateness of the information required at gate.

Context: Stage-Gates description of FORMAT methodology

Industrial Process

An industrial process is the complex set of operations that result in the transformation of raw materials, energy and signal (data/information) into a final product which, in turn, can be a material object, as well as energy or signal or a combination of them).

Context: FORMAT methodology

Knowledge

Personal experience to apply information, data, and facts for coping with practical tasks.

Knowledge belongs to individual. Knowledge cannot be placed on the carrying medium. It is dynamic i.e. permanently changing. First of all it is 'Personal Knowledge'. Applied meaning is close to "tacit knowledge[4]" [Michael Polanyi, 1951]

Context: Components of knowledge acquisition process /Researching Future

Manufacturing Technology

A manufacturing technology is one of the elementary technologies that are employed along an industrial process. In other words, the complex set of Manufacturing Technologies describes the industrial process. Such definition is susceptible of interpretation, according to the level of detail of the investigation: an industrial process can be considered a Manufacturing technology by itself, when used in a wider context (e.g. a broader manufacturing process, a business process).

In general terms, Manufacturing Technologies should be intended as the elementary elements carrying out the functional phases of an Industrial Process.

Context: FORMAT methodology

Maturity (Technological Maturity)

It describes the degree of maturity of a technology, consistently with its stage of development. In this reference the following definition becomes relevant

*Obsolete technology***:** a technology that appeared on the market a long time ago and that has been largely substituted by new ones that are more performing (even if

*Mature technology***:** a technology currently available on the market that is capable to obtain a satisfactory performance level (largely optimized) and for which there still exist a small number of issues to be solved (e.g.: about the consumption of resources or side effects).

*Growing Technology***:** an available technology that emerged on the market in a recent time. Its performance can be further improved and/or it has still a large number of issues to be solved.

*New or Emerging Technology***:** a technology developed in a few prototypes or for which experimental studies are running to achieve satisfactory level of performance.

Context: FORMAT methodology

Network of evolutionary trends (NET)

It is a network describing the historical evolution of a given technical system, as well as its potential directions for further development. The nodes of such network are the different states in which the technical system has been, is or could be in the future. The links of the networks are trends that drive the transition from a generation to another.

Evolutionary tree (or Phylogenetic tree)

It is a concept derived from biology, where it shows the relationships among living species in hierarchical terms. The branches of the tree describe the pattern of evolution (from less evolved - ancestors- to more evolved species - offsprings). The same logic can be applied for describing the evolution of technical systems.

Context: FORMAT methodology

Overall Performance Index

It represents the level of exploitation of a certain technical system. The Overall Performance Index is a ratio between the actual performance expressed by the technical system in an industrial process and the maximum potential of the technical system (e.g. as measured in laboratories). An Overall Performance Index equal to

100% means that the technical system is exploited to its full potential. Lower values mean that the technology can be further exploited, but for some reasons it does not happen (e.g. because of the emergence of undesired side effects, excessive consumption of resources, …)

Context: FORMAT methodology

Performance characteristic

Performance characteristic represents ratio of benefits to expenses. It is applied explicitly or intuitively to understand the evolution of a system in time (to recognize why a system A replaced a system B). Performance characteristic is close by its meaning to concept of Ideality from TRIZ[5].

Context: Researching Future

Product

The product is the final result of an industrial process, which can be expressed in terms of a material entity, a specific kind of energy or signal/information.

Context: FORMAT methodology

Resources

A stock or supply of necessary material and immaterial things in order to function effectively[6]
Resources can be classified into five main categories: Energy, Time, Space, Material, Information (data)/Knowledge.

A limiting resource limits the growth or development of an organism, population, or process [adopted from Wikipedia].

Context: TRIZ / FORMAT Methodology

Stage

Literally, a stage is a level, degree, or period of time in the course of a process. The FORMAT methodology follows a stage-gate process, i.e. its activities are organized in stages, while gates represent the checkpoints distributed along the TF process. Stage can be performed using various techniques of methods, but it should produce a required output which is checked at Gate. Stage is represented by a rounded rectangle and a gate is represented by a diamond.

Context: Stage-Gates description of FORMAT methodology

System

A System is a group of interacting, interrelated, and interdependent elements/ components performing a certain function.

The key idea of describing a system is that once the boundary has been described (a system is identified), then one describes: (a) the features of the system; (b) the features of the environment without the system which affect the system; (c) the interactions between system and environment.

In order to know anything, one has to make a distinction. Therefore, system is an artificial model to facilitate the learning process.

Sub-systems
A system in border of some larger system. Sub-systems are parts (components) of a parent system.

Super-systems (context, holon)
A system that includes the analyzed system as a part. In other words, a super-system is a parent system for the examined system. For instance, the transport infrastructure is a super-system for a particular type of transport system.

Practical expression or relation between super-system and system:

> Super-system is a system that in order to work requires an existence of a system. There is a demand to a system that comes from a super-system.

Context: System operator, Law of system completeness

S-curve models

Simple logistic S-curve model

Simple (symmetric) logistic S-curve model is an equation suggested first time in 1838 by Pierre-Francois Verhulst as a model of population growth. The initial stage of growth is approximately exponential; then, as saturation begins, the growth slows, and at maturity, growth stops [http://en.wikipedia.org/wiki/Logistic_growth]. There are several logistic curves, one of the most popular equations is described below:

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

Where,
α – growth rate parameter, time required for growth trajectory from 10% to 90% of limit κ
characteristic duration (Δt); β – parameter specifies the time (tm) when the curve reaches 0.5κ midpoint of the growth trajectory (tm); κ – is the asymptotic limit of growth (κ) [Weisstein, E.W. Logistic Equation. (MathWorld A Wolfram Web Resource, 2003)].

This model describes a dynamics of 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 ability of a 'species' to multiply inside finite 'niche capacity' through time period.

For socio-technical systems the three-parameter S-shaped growth model is applied for describing "trajectories" of growth or decline through time.

Fisher-Prey transform

Fisher-Prey transform is a change of variables that normalizes a logistic curve and renders it a straight line.

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

Where,
t – time; N(t) – size of population at t; κ – is the asymptotic limit of growth [P. S. Meyer, J. W. Yung, and J. H. Ausubel, "A Primer on Logistic Growth and Substitution: The Mathematics of the Loglet Lab Software," Technol. Forecast. Soc. Change, vol. 61, no. 3, pp. 247–271, 1999].

This transform facilitates comparison to other logistic growth processes, as soon as all the curves are normalized to limit of growth κ, more than one logistic can be plotted on the same chart. Therefore, competition of multiple systems over time can be simulated and analyzed.

Bi-logistic (component logistic models)
Bi-logistic is a model applied for a system that experiences growth in two discrete phases. In this model, growth is the sum of two discrete curves, each of which is a three-parameter logistic [P. S. Meyer, J. W. Yung, and J. H. Ausubel, "A Primer on Logistic Growth and Substitution: The Mathematics of the Loglet Lab Software," Technol. Forecast. Soc. Change, vol. 61, no. 3, pp. 247–271, 1999].

Multiple logistic (component logistic models)

Multiple logistic are models where growth is the sum of n simple logistics [P. S. Meyer, J. W. Yung, and J. H. Ausubel, "A Primer on Logistic Growth and Substitution: The Mathematics of the Loglet Lab Software," Technol. Forecast. Soc. Change, vol. 61, no. 3, pp. 247–271, 1999].

Logistic substitution model
"The logistic substitution model describes the fraction of the niche or market share of the competitors . The life cycle of a competitor can be partitioned into three distinct phases: growth, saturation, and decline. The growth and decline phases represent logistic growth processes, which as we will see, influences the saturation phase[7]."

The assumptions behind the logistic substitution model, as developed by Nakicenovic and Marchetti [Marchetti, C., and Nakicenovic, N.: The dynamics of energy systems and the logistic substitution model. IIASA Research Report RR-79-13. International Institute for Applied Systems Analysis, Laxenburg, Austria, 1979] are:

New technologies enter the market and grow at logistic rates.

Only one technology saturates the market at any given time.

A technology in saturation follows a non-logistic path that connects the period of growth to its subsequent period of decline.

Declining technologies fade away steadily at logistic rates uninfluenced by competition by new technologies.

Lotka-Volterra competition model

The Lotka–Volterra equations, also known as the *predator–prey equations*, are a pair of first-order, non-linear, differential equations frequently used to describe the dynamics of biological systems in which two species interact, one as a predator and the other as prey. They were proposed independently by Alfred J. Lotka in 1925 and Vito Volterra in 1926, neither of whom were biologists [http://en.wikipedia.org/wiki/Lotka-Volterra_equations].

Context: FORMAT methodology

Technology forecasting team

The team responsible for the execution and delivery of the technology forecasting results to the decision makers or stakeholders of the technology forecasting project. The team may comprise 2 components – Core Team and Extended Team. Core Team consists of people who will follow the process in the methodology end to end. The Extended Team will comprise of people who are included on a need basis depending on the stage or gate involved.

Context: FORMAT methodology

Users (of forecast)

See Evaluation metrics.

Context: FORMAT methodology

footnotes for the glossary

1 Technology - Technology refers to methods, systems, and devices which are the result of scientific knowledge being used for practical purposes [Collins Cobuild]
2 Economic means concerned with the organization of the money, industry, and trade of a country, region, or society [Collins Cobuild]
Economy - an economy consists of the economic system, comprising the production, distribution or trade, and consumption of limited goods and services between two agents, the agents can be individuals, businesses, organizations, or governments. [Wikipedia]

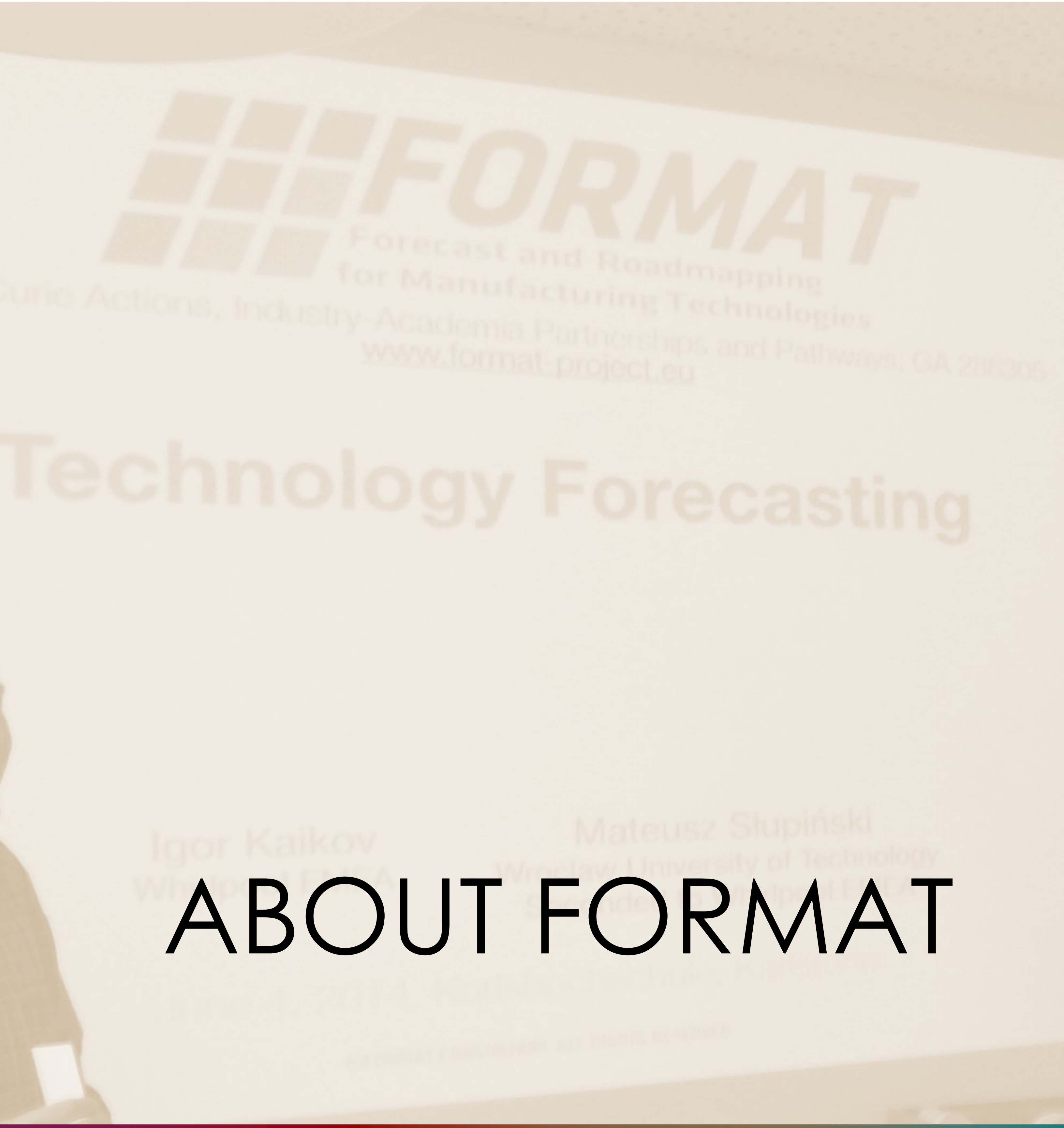
3 Explicit knowledge is knowledge that has been or can be articulated, codified, and stored in certain media. It can be readily transmitted to others. The most common forms of explicit knowledge are manuals, documents and procedures. Knowledge also can be audio-visual. Works of art and product design can be seen as other forms of explicit knowledge where human skills, motives and knowledge are externalized. [Wikipedia]

4 Tacit knowledge is knowledge that people carry in their minds. Tacit knowledge is considered more valuable because it provides context for people, places, ideas, and experiences. Effective transfer of tacit knowledge generally requires extensive personal contact and trust.

5 In TRIZ the degree of ideality is defined as a ratio between the system performance and the expenses required to perform these performances. The higher performance for lower expenses means the greater ideality.
In practice of inventive problem solving, the concepts of Ideal machine, Ideal process, and Ideal substance [Altshuller, 1979] guide direction of problem solving process.

6 (very raw definition)

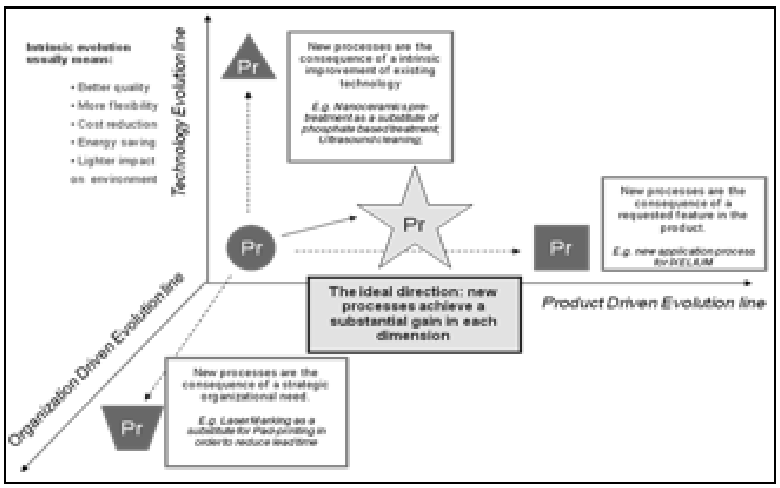
7 [P. S. Meyer, J. W. Yung, and J. H. Ausubel, "A Primer on Logistic Growth and Substitution: The Mathematics of the Loglet Lab Software," Technol. Forecast. Soc. Change, vol. 61, no. 3, pp. 247–271, 1999.]



ABOUT FORMAT

The FORMAT project aims at **developing of an innovative forecasting methodology supporting decision making in Manufacturing Industries**, facing and answering the 3 previous perspectives:

1. *Product Evolution:* the design of new products can require new process technologies for the product itself to be manufactured.
2. *Technological Evolution* is the technological pressure, intrinsic technological evolution leads to changes and improvements in the manufacturing processes that must not be let unexplored.
3. O*rganizational Evolution*: to fulfill some industrial strategies, new processes with improved performance can be necessary.



The ideal direction to be pursued in developing the FORMAT innovative forecasting methodology is that new processes in Manufacturing Industries achieve a substantial gain in each dimension.

In the current common approach for *White Good Industry* and, generally in the manufacturing sector, manufacturing is involved at different stages of product development. Although the principle of "the sooner the better" is widely accepted, <u>very often manufacturing is unprepared to address product driven technological changes due to limited resources to be dedicated to R&D of manufacturing processes</u>. So *there are other two industrial needs*:

- to **anticipate as much as possible the research and development of process technologies** so as to eliminate uncertainties, infancy problems and related costs, and to better exploit competitive advantages in an aggressive market such as the White Goods one.
- to **focus R&D resources on those technologies,** which are the most promising along the above -mentioned three axes of evolution.

The final result of the project will be the development of an innovative Forecasting Methodology, backed by a web semantic IT tool, supporting decision making in Manufacturing Industries.

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