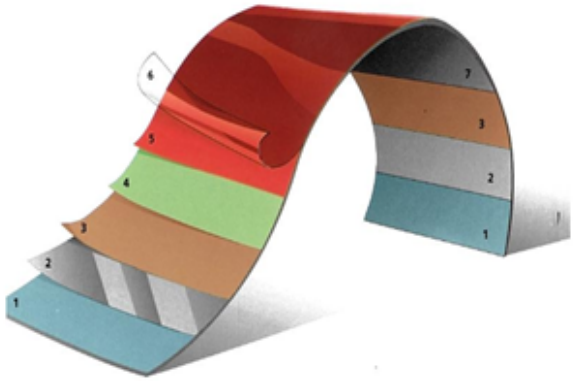
FORMAT
Forecast and Roadmapping for Manufacturing Technologies

PRE-PAINTING Case Study



Contents

Executive summary

The topic of Pre-Painting has been investigated as a case study by "Team A" of the consortium using the FORMAT methodology for Technology Forecasting. This forecast project was carried out to aid strategic decision at Whirlpool concerning investing in a coating equipment/ paint-shop. This report shows various analyses during FORMAT stages and steps, while representing the results of each stage as well as the final conclusions and recommendations.

Stages and duration:

FOR	Define forecast questions & plan project.	1,5 sessions
M	Model existing knowledge	6 sessions
A	Act to identify future traits of the system to be forecasted	5 sessions
T	Transfer conclusions to decision makers	1 session

Highlighting Stages Results:

FOR

Pre-Painting	
Main Pros*	Main Cons*
• More Environmentally friendly than paint-shop equipment.	• Limitations: ○ Bending ○ Deep drawing ○ Welding • Loss of know-how (in case of production in other company)

* other detailed Pros and Cons in full report

→ Main questions for forecast:

- **Whether** or **when** and **how** a pre-coated material will be able to be formed using the Whirlpool current technologies without compromising its original properties …
- in the coming **20 years** …
- within the context of **manufacturers** and **suppliers worldwide**?

M

The team studied coated steel sheets (CSS) and its various functions/properties and integrating important technical details of both products and process in addition to various perspectives by the team members. Alternative technologies and materials for coating steel sheets were listed and compared in terms of performance, consumption, drawbacks, etc. The perspective of different companies producing coating products has been also reported.

Note: As the team focused later on product oriented analysis, some slides are marked with X mark for being out of focus. However the slides are reported in case a future study (process oriented) shall be carried out.

System Future (original Properties of Sheets):

Visibility	-More available colours and finishing;
User interface	-More available finishing (no just vision but whole experience, e.g. touch)
Surface protection	-Long term protection; -Improved corrosion resistance
Forming process	-After process (forming), no aesthetic changes are expected
Refrigerator-related properties	-If the foam changes: properties of coated steel sheet changes; insulating agents; -Adoption of magnet forces depends on rare-earth cost.
Strength	-Coated steel sheet should support different static and dynamic loads.

Super-system Future (Appliances "Refrigerator"):

Thermal efficiency	-Higher than the past
Built-in options	-More (TBC by trend)
Colours	-More
Volume	-Stable
Number of doors	?
Specifications	-Higher specification differentiation
acoustic	-More silent
customization	-Mass customization expected

Sub-system Future: (surface layer)
"steel: RoHS 2011/65/EU"

Steel	-Quality (increased % of secondary steel) -Usually low carbon steel
Steel outer layer/substrate	-Zn/Al will be partially substituted by more effective passivation technology; -Complete ban for Cr-based passivation; -More treatments suitable for appliances
Pre-treatment	-No more Cr or Pb compounds; -less rinse pre-treatment; -pre-treatment still require acid or alkali cleaning process; -water saving for the process;
Primer changes	-No more Cr, Pb, Ni and Hg compounds allowed; -Acrylic resin primer -Binding resin: >Polyester: + 60% market share, >PVDF: less limited colour palette + lower cost, >PVC Plastisol: higher thickness and use 80°C more limited applications by law and regulations (PU, Epoxy, new better resins?) More additives available More film-based coatings will be used due to their multi-functionality
Uncoated side of steel sheet	Very rare More functionality for the inner side

A

The Act stage "A" was carried out to develop the different step to accomplish the forecasting analysis:

Extract limiting resources, define set of solutions addressing limiting resources, Fit data series, build conclusions about future traits.

Out of the analysed ones, a smaller set of prioritized functions (most relevant) was consistently defined with the main question for the forecast and the main priorities of the beneficiary. Each of the following priorities was analysed and reported:

1st priority: "*The CSS makes undesired changes, due to the bending process, prevented*".

2nd priority: "*The CSS makes chemical agents stopped (from outside)*"

3rd priority: "*The CSS makes mechanical loads held*"

4th priority: "*The CSS makes Electromagnetic fields reflected (light, colour and gloss)"*

The team therefore decided to narrow the focus of study to the first two priorities and searched for data related to what was identified as a limiting resource (both qualitatively and quantitatively). Problems and envisioned solutions have been both considered for info gathering..

Studying the differences between polymers for CSS, the team stated the following:

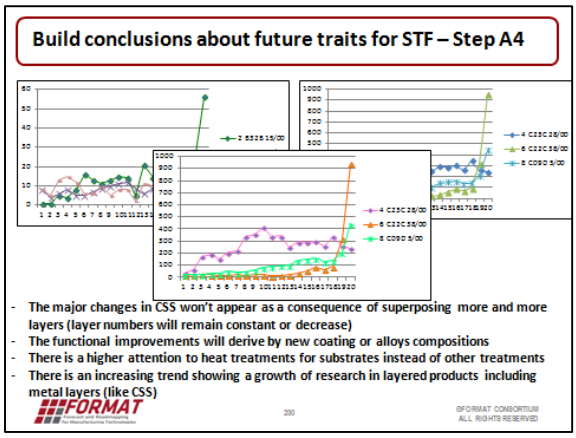
- Thermoplastic polymers (especially fluorinated) will provide the best forming characteristics
- Cost of thermoplastic polymer is (will it be?) higher than thermosetting ones (e.g.: now PVDF: 12.6 – 14 €/kg; Epoxy= 2.5 – 3 €/Kg; polyester= 1.83 – 2 €/Kg; PVC= 2.5 €/Kg.
- thermoplastic polymers satisfy more the requirements about "flexibility" rather than thermosetting polymers.
- a set of available colours for different polymers are presented.

Finally, the step A3 concludes with the analysis of limiting resources trends that comes out of the analysis of problems concerning the Sub-system level. To carry out this investigation, different data were collected from scientific papers, technical data sheets and patent databases:

- The Major changes in CSS won't appear as a consequence of superposing more and more layers (layer numbers will remain constant or decrease)
- The functional improvements will derive by new coating or alloys compositions
- There is a higher attention to heat treatments for substrates instead of other treatments.
- There is an increasing trend showing a growth of research in layered products including metal layers (like CSS)

Finally, the Step A4 was performed in order to build conclusion among the steps A1, A2 and A3. This step aims at understanding and harmonizing the different viewpoint among forecasting participants:

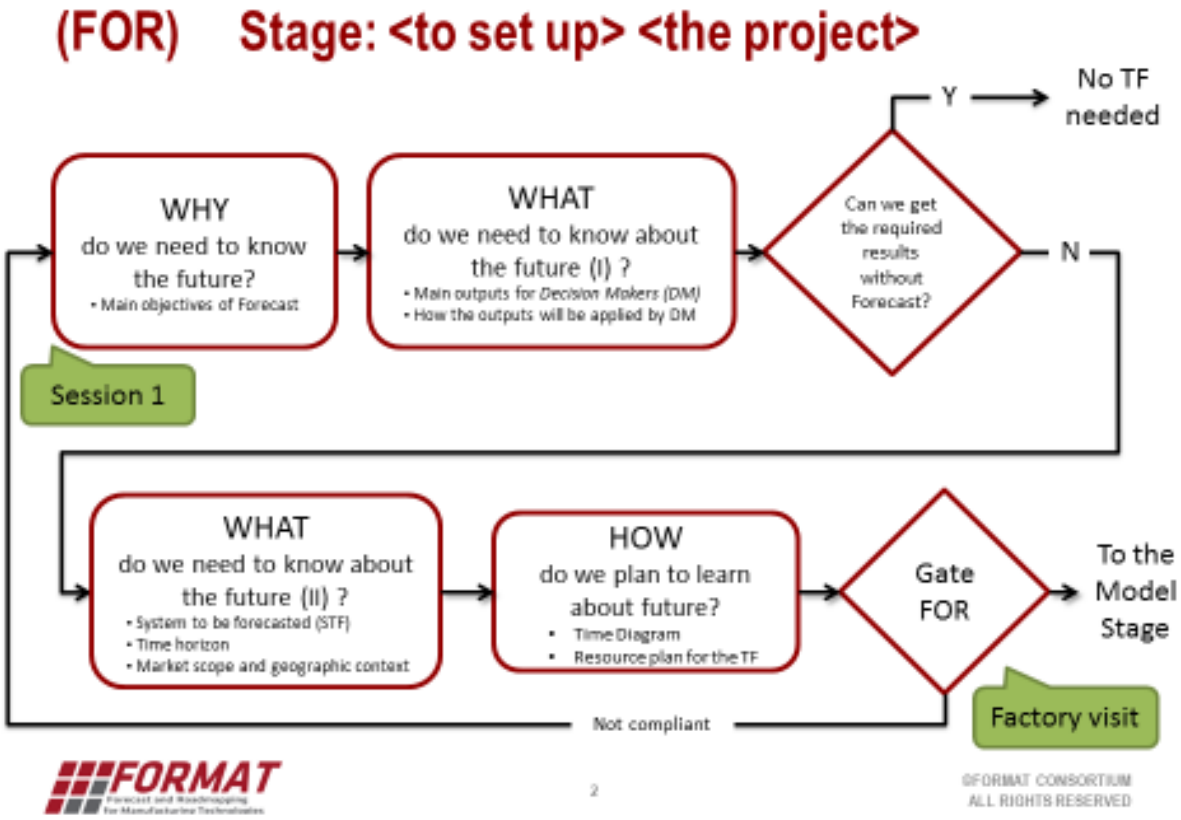
- Whirlpool suppliers in the last 12 years have improved the quality of their process for manufacturing CSS.
- Scraps are now almost constant. We still do not know if they depend on problems, on lower layer or on the forming process.
- Thermoplastic polymers provide better properties for Whirlpool requirements in terms of flexibility (bending). Therefore the further investigation of Whirlpool to define its investments should mainly focus on the CSS using thermoplastic polymers.
- A potential improvement in CSS performances won't appear, according to the historical data, because of a change in the thickness of the CSS itself, since it is unchanged in the last 20 years.
- Colours and finishing limitations will be reduced if the trend of available colours and finishing is confirmed. Actually a wide range of colours is already available for both thermoplastics (e.g. PVDF) and thermosetting polymers (e.g.: Epoxy-polyesters)
- The greatest novelties should pop up from the most active manufacturers that are currently located in Asia.



T → this report and a presentation.

1. FORMULATE STAGE

Main functions of the stage are to prepare and make decision about forecasting project; to define boundaries / resource of forecasting project.



The activities of the FOR stage of the FORMAT methodology are presented in the following, consistently with the sequence of above presented steps. The Stage FOR consists of 4 steps and 2 Gates. It continued within 4 working sessions. The main function of the Stage FOR is to define the questions of the forecast and plan the whole project.

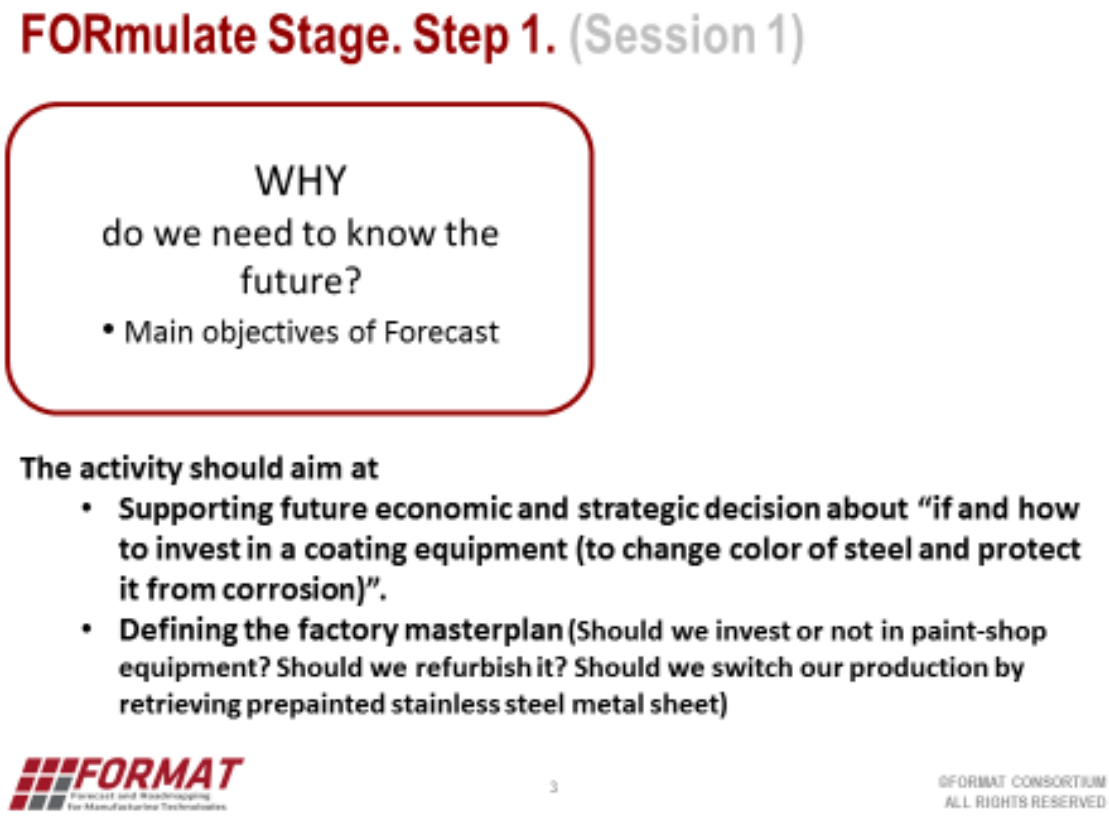
FOR_1: Formulate objectives

WHY do we need to know the future?

During the Step 1 of the Stage FOR, the core team formulated the objectives of the Case Study from various viewpoints (e.g. beneficiaries, users, technology context, marketing context). The key question to be answered in this step was “Why do we need to know the Future”?

The above slide collects two objectives:

- Supporting future economic and strategic decision.
- Defining the factory master-plan.



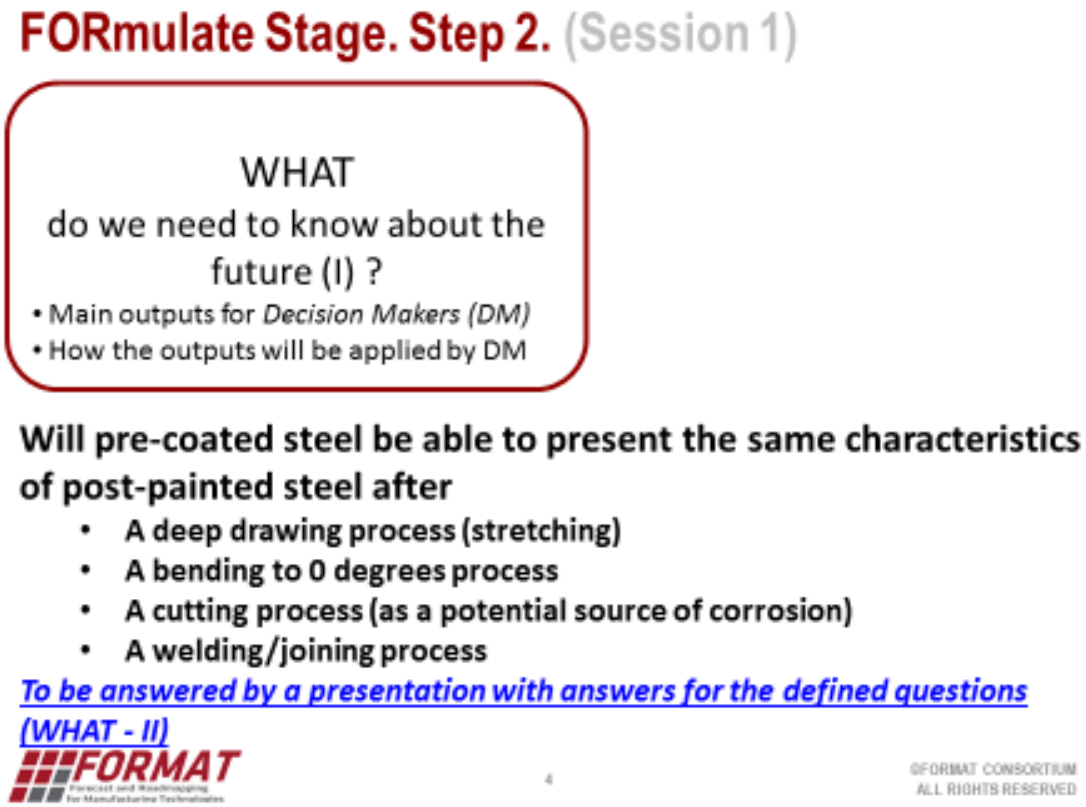
FOR_2: Define expected output

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

- Main outputs for Decision Makers (DM)
- How the outputs will be applied by DM

First, during Step 1 of the Stage FOR the core team Identified the system to be forecasted (STF).

Also during Step 2 of the Stage FOR the core team identified: What results will be required by the decision makers and how the decision makers will use the results from the forecast.

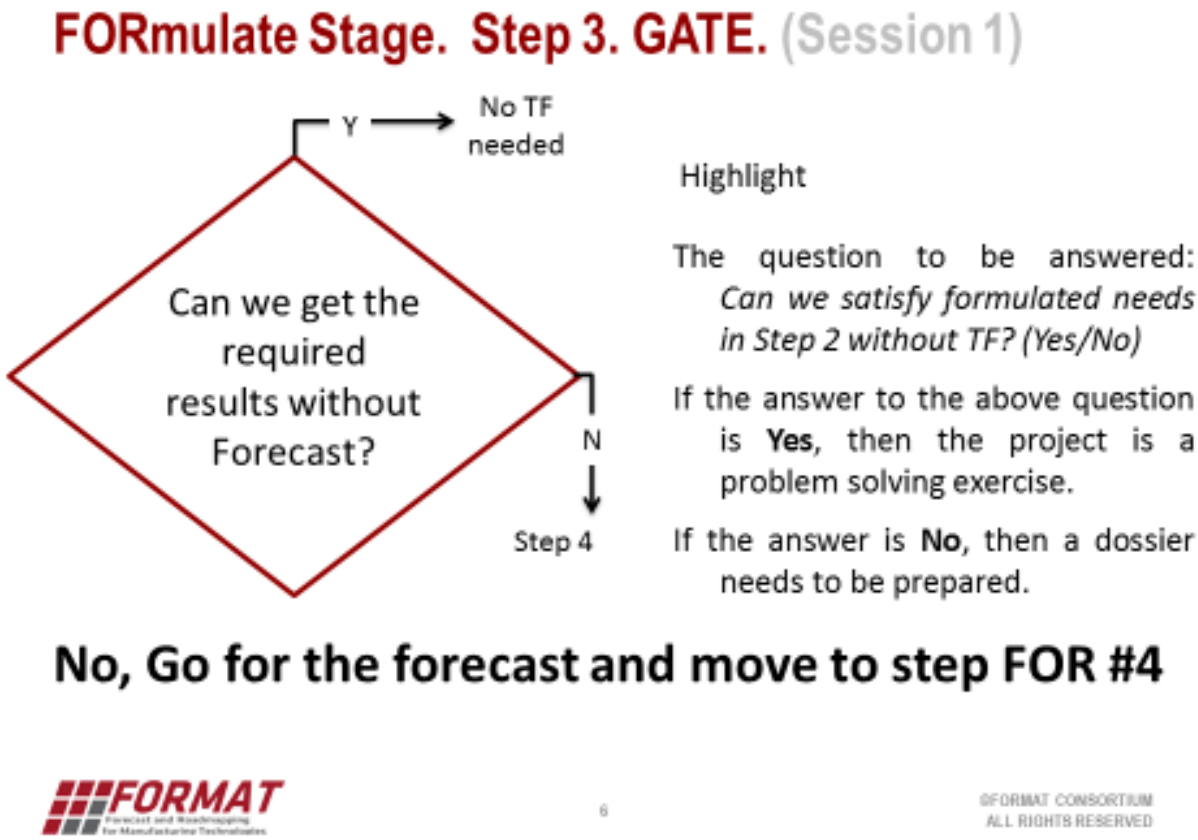


FOR_3: To forecast or not to forecast?

Can we get the required results without Forecast?

This is a decision step (more properly a gate) that differentiates forecasting and problem solving activities for formulated objectives. During the Step 3 of the Stage FOR, the core team gave an answer: We cannot satisfy the needs formulated along the Step 2 without forecasting. The conclusion was to move to the Step 4.

All these Steps (1-3) were made during Session 1.



FOR_4: Formulate questions

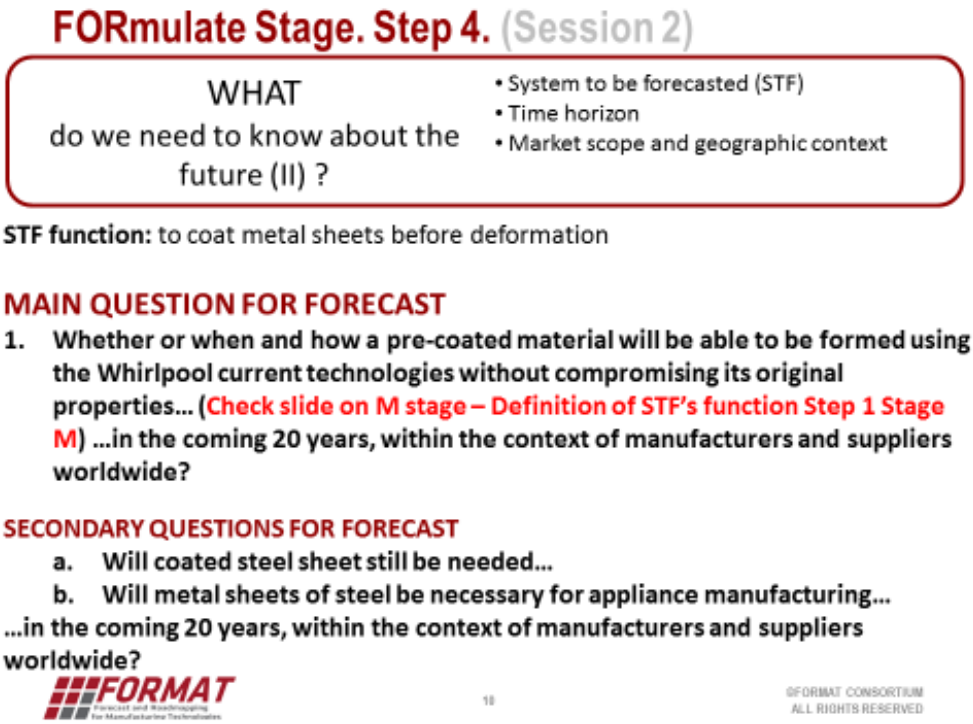
WHAT do we need to know about the future (II)?

- System to be forecasted (STF)
- Time horizon
- Market scope and geographic context

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. During Step 4 of the Stage FOR the core team reviewed results of Step 1 and Step 2 of Stage FOR and defined a main function of the system to be forecasted (STF).

- **Time horizon:** 10-20 years (2015-2035)
- **Market Scope and geographical context:** Manufactures and suppliers worldwide.

- The time horizon of the forecast reflects the amount of time in which that decision may become relevant in the perspective of Whirlpool, in order to proficiently apply its results. The target geographical area or market has been also explicitly specified even if the decision wasn't yet definitive for this facet.
- Finally, the core team integrated 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). Please note that the geographical context is changed from what defined along the previous slides.



FOR_5: Project planning

HOW do we plan to learn about future?

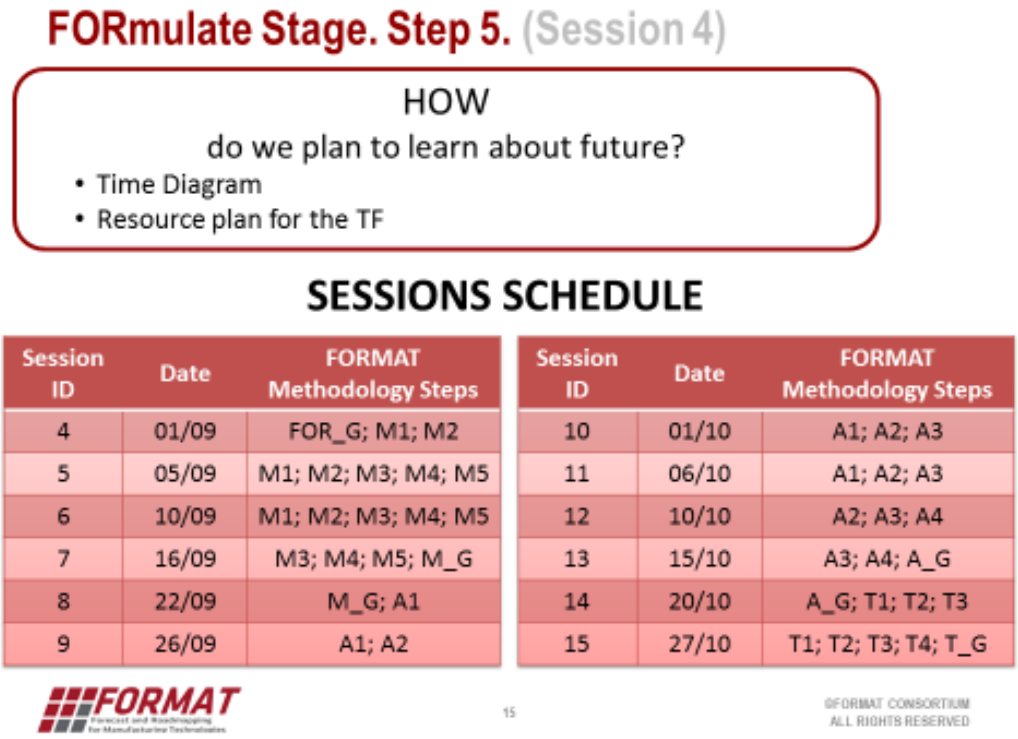
- Time Diagram
- Resource plan for the TF

While meeting beneficiaries, decisions about resources allocation – human, data, restricted access permissions were got and formalized. Participants checked the availability of human resources in advance for the period of the entire technology-forecasting project.

Resources plan for TF

- People/Knowledge
- Explicit knowledge source

- Beneficiaries and Clients
- Relevant websites
- Links for Interesting videos
- Software resources
- Rooms for meetings



FORmulate Stage. Step 5. (Session 4)

HOW

do we plan to learn about future?

- Time Diagram
- Resource plan for the TF

SESSIONS SCHEDULE

Session ID	Date	FORMAT Methodology Steps
4	01/09	FOR_G; M1; M2
5	05/09	M1; M2; M3; M4; M5
6	10/09	M1; M2; M3; M4; M5
7	16/09	M3; M4; M5; M_G
8	22/09	M_G; A1
9	26/09	A1; A2

Session ID	Date	FORMAT Methodology Steps
10	01/10	A1; A2; A3
11	06/10	A1; A2; A3
12	10/10	A2; A3; A4
13	15/10	A3; A4; A_G
14	20/10	A_G; T1; T2; T3
15	27/10	T1; T2; T3; T4; T_G

FORMAT

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Gate FOR

The main function of this Gate is to check completeness and consistency of Stage FOR.

During Step 6 of the Stage FOR the core team checked completeness and consistency of this Stage.

FORmulate Stage. Step 6. GATE "FOR".

<to set up> <the project>

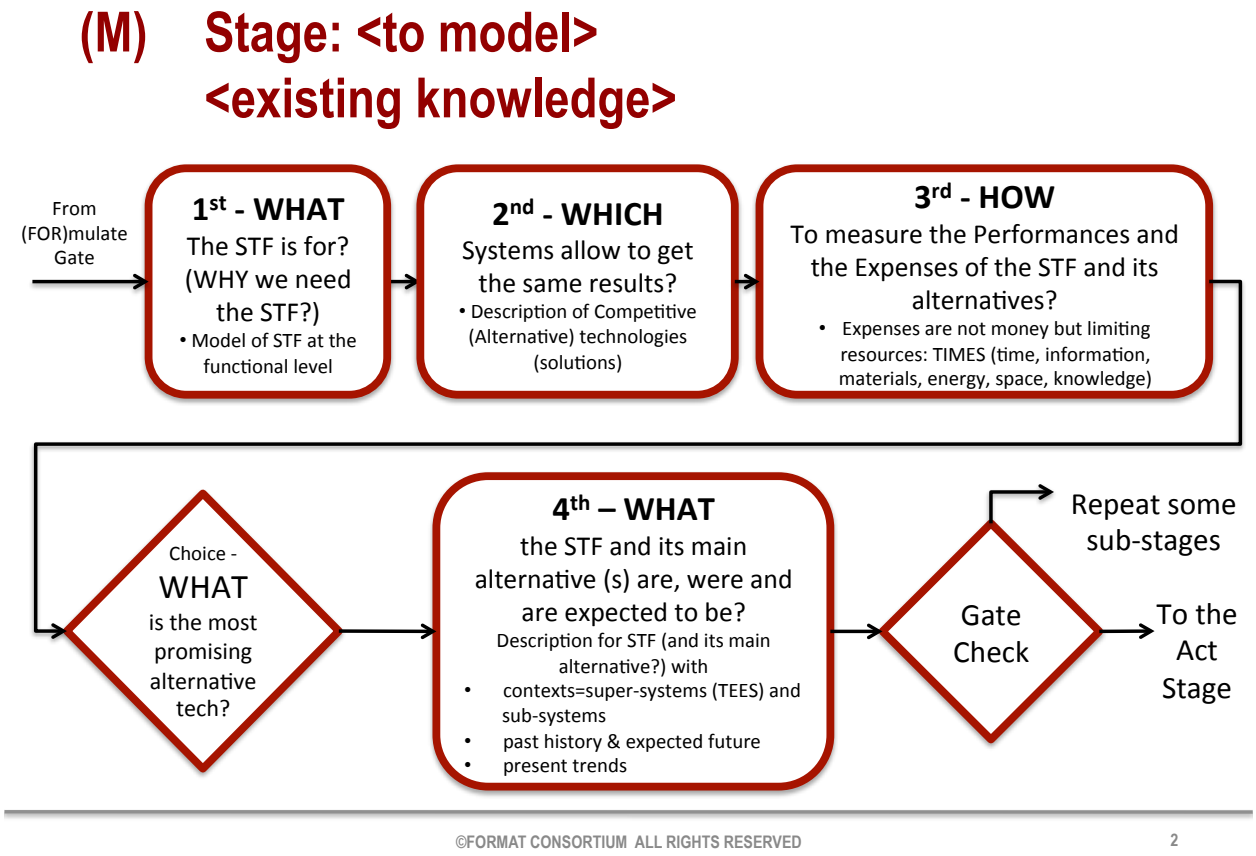
- Main objectives of Forecast (Project) (Why?) – (done)
- Definition of knowledge elements for the application of the forecasting results
  - Main outputs for *Decision Makers* (DM) (What?) - (done)
  - How the outputs will be applied by DM (link between Why-What?) – (done)
- INTERIM CHECK: Can we get the required results without Forecast?

  Go/NoGo -> to forecasting project (GO)
- Definition of Preliminary constraints for the project
  - System (Process) to be Forecasted (STF) from Technological, Economics, Environmental, Social (TEES) perspectives (What?) - (done)
  - time horizon (When?) – (done)
  - market scope and geographic context (Where?) – (done)
- Question for Forecast (Questions to be answered at the end of study) – (done)
- Plan of Project (How?)
  - Time diagram (Gantt or similar) (done)
  - Resources for the activity (People, knowledge, IT instruments,...) – (done)

2. MODEL STAGE

Main function of the stage is to review the existing knowledge about system.

The activities of the M stage of the FORMAT methodology are presented in the following consistently with the sequence of steps presented above.



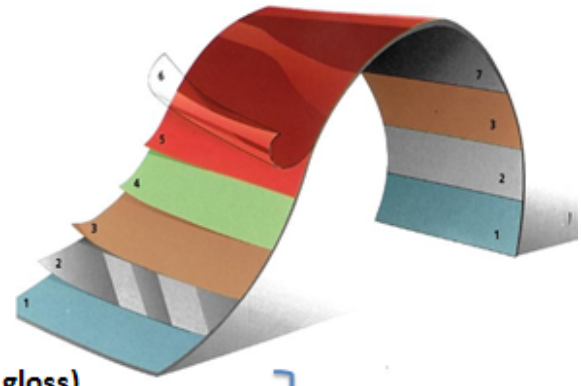
M_1: Define system to forecast

WHAT the System to Forecast (STF) is for? (WHY we need the STF?)

- Model of STF at the functional level

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

1- steel
2- metal coating
3- passivating layer
4- primer
5- topcoat
6- strippable film
7- reverse side coating



STF: coated steel sheet

STF function: the coated steel sheet makes

1. **Electromagnetic fields reflected (light, color and gloss)**
2. **The user pleased by touch, visible and thermal feelings**
3. **Chemical agents stopped (from outside)**
4. **Undesired changes, due to the bending process, prevented**
5. The foam held (internally, for refrigerators)
6. The insulant agents enclosed in the foam (internally, for refrigerators)
7. Mechanical loads held (e.g. for washing machines)
8. Magnets attracted (e.g. refrigerator gaskets)

ORIGINAL PROPERTIES (See slide 17)

During the Step 1 of the Stage M the core team defined the System To be Forecasted (STF) and its function consistently with what was stated along the FOR Stage of the methodology, and in particular with reference to the questions for the forecast that have been formulated along the Stage 4 of the FOR Stage.

The earliest approach to the functional modelling for the STF has been done with reference to the manufacturing process involving the Coated Steel Sheets. The process has been considered starting from the fabrication of the steel Sheets to the manufacturing process involving their mechanical deformation (e.g.: bending, deep drawing, welding,…). The core team decided to overlook the fabrication phase, considering it not relevant to the purposes of the forecasting activity.

On the basis of the textual description, the core team managed to define a description of the coating process, so as to continue defining its appropriate functional description (EMS/IDEF0-like model).

M_2: Identify alternatives

WHICH systems allow to get the same results?

- Description of Competitive (Alternative) technologies (solutions)

Alternative technologies

Coating Technology	Material	Anti-microbial surface	Chemical resistant	Adhesion	Reflection of light	Water resistant	UV- absorbtion	Abrasion resistant	Anti-corrosion	Anti-scratch	Deformation availability (T0,T1,T2)
PGS	Polyester	Medium	Medium	High		Medium		Medium	Medium		Medium
PCM	Polyester	High	High	High		High		High	High	High	High
PVDF	Polivinylidene fluoride	High	High	High		High		High	High	High	High
PSS	Super-Polyester	Medium	Medium	High		High		Medium	Medium		Medium
PVS	Plastisol	Medium	High	High		High		Medium	High	High	High
PCS1	High Polymeric Polyester	High	Medium	High		High		Medium	Medium	High	High

Reference:
http://www.nilsmalmgren.com/epoxy-chemistry/epoxy-plastics-general-chemical-and-physical-properties/
http://www.sciencedirect.com/science/article/pii/S0300944001002557

In order to reduce the wide set of alternatives, the core team tried to cluster them in a smaller but representative set (first two columns of the table).

The other cells collect just qualitative evaluations of the specific performances the diverse technology assures with reference to the criteria there reported. This activity has been carried out in order to also support the selection of the most suitable alternative technology, which has to be done during the intermediate gate of the Stage M.

Nevertheless, with a clearer view about the alternative technologies and with the awareness that the overall performances of a CSS depend on the superposition of different layers, the core team decided to study the thicknesses, the sequence and the and composition of layers for the main available coatings.

M_3: Measure performance

HOW to measure the Performances and the Expenses of the STF and its alternatives?

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

In the third step of Stage M, the Core Team have recalled the questions of the forecast defined in Stage FOR in order to formulate the main Performances of the STF and its alternatives. Next, the criteria for measuring the performance of the STF and its alternatives have been defined in terms of

i. Achievement of threshold values (values added in brackets for the this and the next slide)

ii. Versatility/Flexibility,

iii. Robustness (of results),

iv. Controllability, and

v. Capability to work in different conditions.

Along with performance, a structured list of needed resources (expenses) for the systems to work has been defined. Expenses here are not strictly costs, but are the reasons behind the costs to keep the system working. In order to explore what is required by the alternatives, the Core Team has considered the following general resources:

i. Time resources,

ii. Information and knowledge resources,

iii. Material resources,

iv. Energy resources,

v. Space resources.

Expenses (resources) required by the STF or its alternatives

Time

- Process time (Welding time? Curing time? …?)
- Inlet stock time
- Outlet stock time

Information/Knowledge

- Maintenance knowledge
- Installation/decommission kn.
- Knowledge for running the process

Material

- Wastes
- Water
- Primer
- Cleaner
- Painting/coating material
- Degreaser
- Layer for lamination (depending on the application)

Energy

- Manpower
- Energy for cleaning
- Energy for curing
- Energy for moving sheet metals

Space

- Manufacturing Space
- Stocks for inlet
- Stocks for outlet

M_Gate: Select alternatives

WHAT is the most promising alternative technology?

Consistently with the previous analysis of alternative technologies (Step 2) and once defined the main criteria to carry out comparisons among them (Step 3). The core team identified the most promising alternative technology with reference to the main question for the forecast.

- The most promising alternative technology to the currently used Epoxy-Polyester coatings/paintings is represented by
  - PVDF

M_5: Study context

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

Description for STF (and its main alternative?) with

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

In this step the team has produced a harmonized and holistic description of the STF and its alternatives. The identified technology alternatives have been overviewed in the evolution from the past, through the present to a first description of their expected future. In this step the multi-screen description of the STF has been built according to the logic of System Operator (Altshuller, 1984). STF described on the level of system, super-system and sub-system has been analysed from the present time perspective. This description has been formulated with reference to the functional model identified in Stage FOR.

SYSTEM OPERATOR ANALYSIS

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

Description for STF (and its main alternative?) with

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

Past: 1994	**Present: 2014** APPLIANCES (Refrigerator, dishwasher, washing machine & tuble drier, cooktop, conventional oven, MW oven)	**Future: 2035**
Past: 2004	**Present: 2014** ORIGINAL PROPERTIES (EM field reflection, pleasantness for users, chemical resistance, formability, appliance-related properties)	**Future: 2035**
Past: 2000/2004	**Present: 2014** LAYERS (Steel, passivation layer, pre-treatment, primer, top coat, uncoated side of the steel)	**Future: 2035**

System

System, PRESENT: 2014

1. Electromagnetic fields reflected (light, color and gloss)
    1. Forming and stamping may alter the color and the texture of the coated steel sheet [1]
    2. Available colors: **various colors**, grays, whites, and some pastel with desired corrosion-resistant [1], [2]
2. The user pleased by touch, visible and thermal feelings
    1. Coatings can be modified with acrylics, silicones, and other resins to improve their aesthetic appeal. [1]
    2. Zinc-rich coatings tend to mud crack if applied at higher thickness. [4]
3. Chemical agents stopped (from outside)
    1. Thermosetting and zinc-rich coatings providing firm long-term protection, but they are more difficult to touch up or repair in the event of physical damage or localized failure.
4. Undesired changes, due to the bending process, prevented
    1. The reduction of heavy metals in paints and substrates may reduce the formability of coated steel sheets
5. Refrigerator-related characteristics

    The foam held (internally, for refrigerators)

    The insulant agents enclosed in the foam (internally, for refrigerators)

    Magnets attracted (e.g. refrigerator gaskets)
6. Mechanical loads held (e.g. for washing machines)
    1. High strength and good formability. This conflict was resolved. [3]
    2. Smaller thickness than in the past, less weight. [3]

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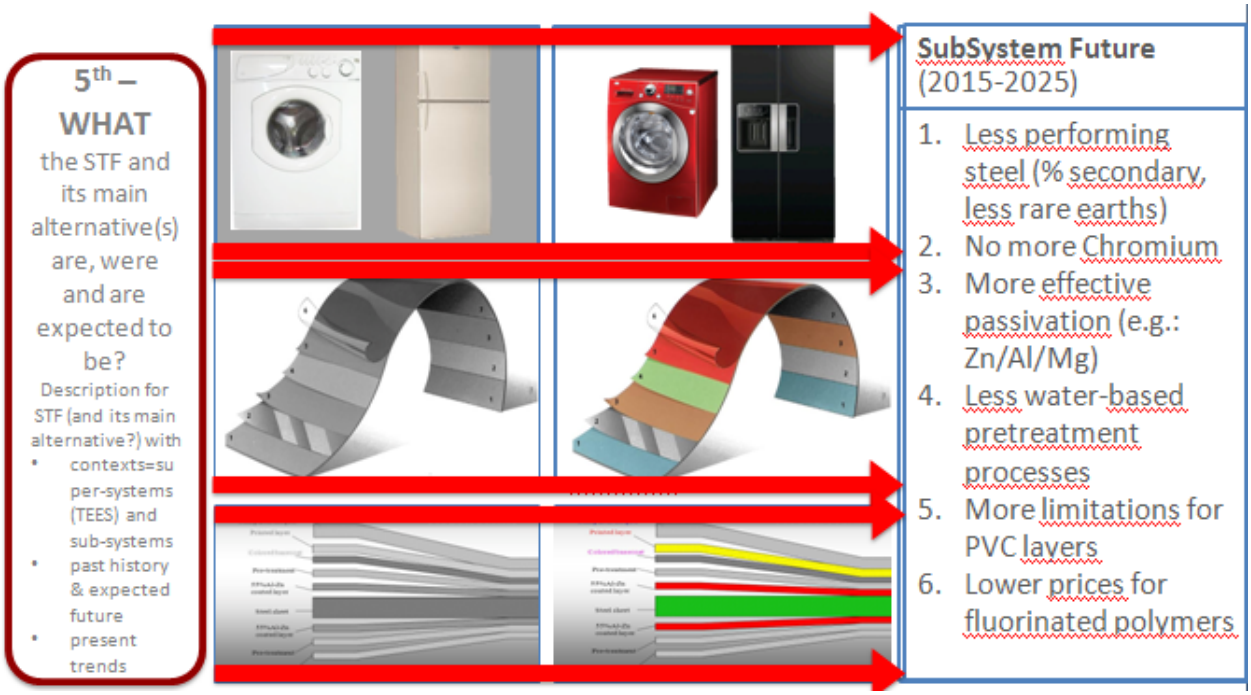
In the above slide the Core Team has described the STF in the present term. It presents a current behaviour of the system with reference to the functional model of the STF defined in Stage FOR. In this

step of System Operator analysis, the measurable and meaningful parameters of the system have been formulated in order to depict changes of the system as intuitive projections in the future, based on the current and past characteristics and the related emerging trends.



We recognize the "parameter X" as a relevant characteristic of the current STF/Pre-Coated Steel Sheet. Its current value has been recorded and historical data have been searched in available sources. The parameter X of the STF is now (quantitative/qualitative value it has now), while in the past it was (quantitative/qualitative value in the past). Intuitively, if the trend continues, it is expected that the parameter X of the STF will be (quantitative/qualitative value in the past). This will require confirmation in subsequent steps.

Gate M

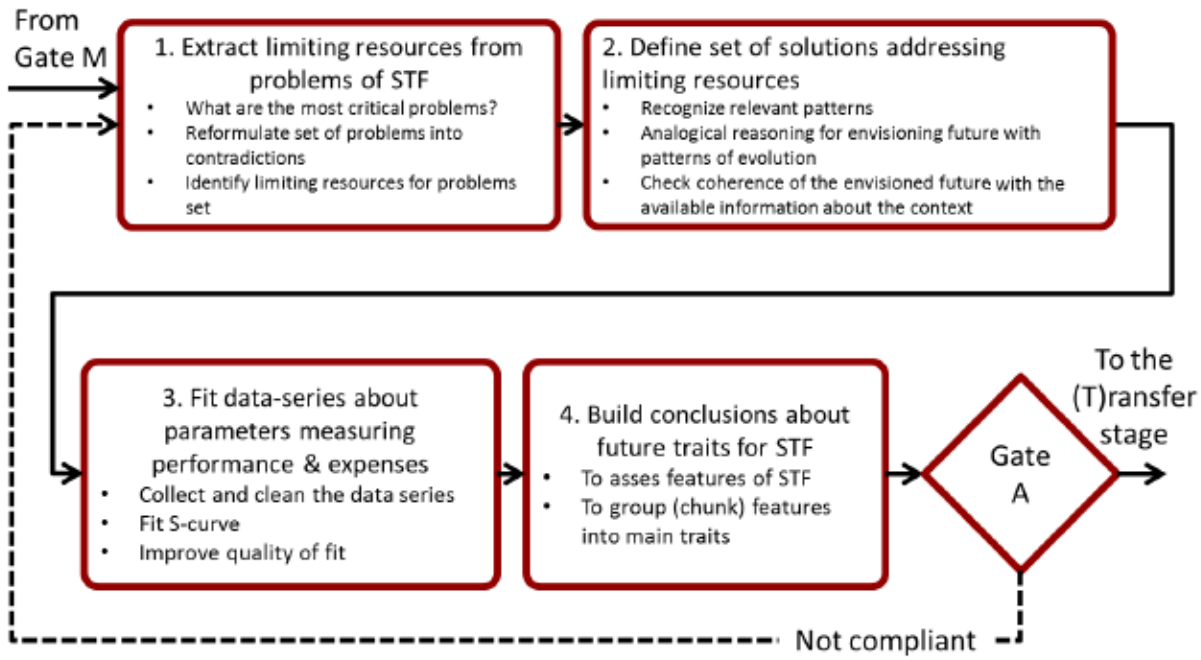
- Model of STF at the functional level
- Description of Alternative technologies.
- A measure of Performance & Expenses for STF and for Alternative technologies.
- Description for STF (logic as System Operator).

3. ACT STAGE

Main functions of the stage are

- 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

The Stage A is composed, as for the other stages, by several sub-steps. They need to be accomplished before checking the consistency with the conditions stated for the final Gate check.

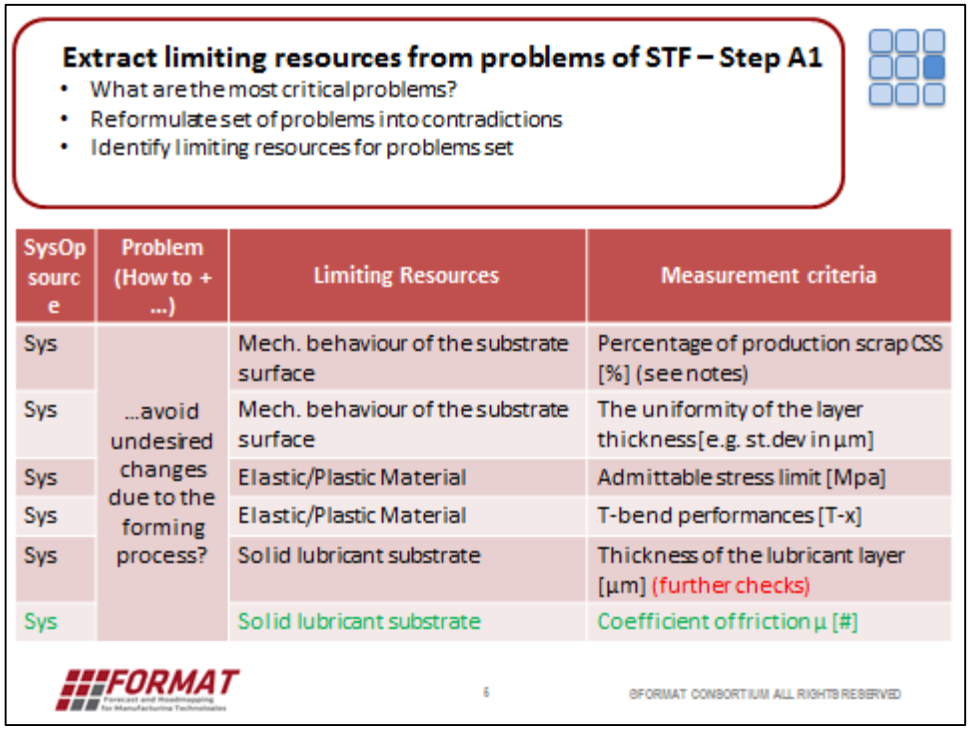


A_1: Identify limiting resources

During the Step 1 of the Stage A, the problems have been defined as situations for which it is not clear how to attain a certain goal. With the problem definition (2nd column) the core team and the experts have tried to consider what are the limiting resources (3rd column) needed to solve those problems (e.g.: to improve the capability of the CSS to avoid undesired changes due to the forming process a limit can be seen in the mechanical (elastic/plastic) behaviour of the material to be used). Several criteria have been defined. (4th column) in order to measure the current state of resources consumptions. These tables present a clear reference to the items developed during the System Operator analysis carried out during the stage M (1st column).

Noteworthy, this degree of development has been achieved after several iterations and refinements. The following slides disclose the actual process the core team have followed during the activities. Nevertheless, the set of final slides for the Step 1 of the Stage A is available at the end of this section.

List of problems and limiting resources



Extract limiting resources from problems of STF – Step A1

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

SysOp source	Problem (How to + ...)	Limiting Resources	Measurement criteria
Sys	...avoid undesired changes due to the forming process?	Mech. behaviour of the substrate surface	Percentage of production scrap CSS [%] (see notes)
Sys		Mech. behaviour of the substrate surface	The uniformity of the layer thickness [e.g. st.dev in µm]
Sys		Elastic/Plastic Material	Admittable stress limit [Mpa]
Sys		Elastic/Plastic Material	T-bend performances [T-x]
Sys		Solid lubricant substrate	Thickness of the lubricant layer [µm] (further checks)
Sys		Solid lubricant substrate	Coefficient of friction µ [#]

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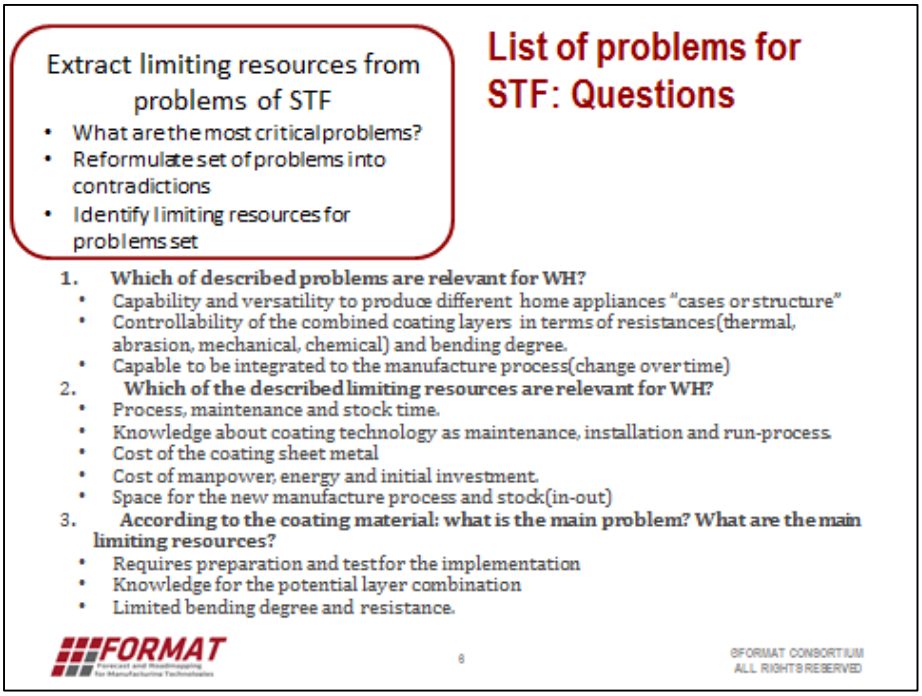
Consistently with the indications provided in the handbook, the core team started Step 1 by developing a first attempt of extracting limiting resources by following the 3 main proposed issues (relevant problems, limiting resources, ranking). As results, a list of limiting resources was elicited.

From the below slide, the list of limiting resources seems to not be completely adequate to support the overall Step goal. This issue emerged from the lack of clarity in the handbook for the identification of meaningful and properly formulated limiting resources related to the STF as they come out from problems. Consequently, this activity required to be iterated in order to obtain a more precise and adequate list of problems that the limiting resources can be inferred from. In order to obtain a clear identification of the limiting resources, a question-answer approach was developed as presented in Figure 8. This can be considered as the second attempt of extracting limiting resources from a list of problems. Moreover, this further attempt took into consideration also the TEES (Technological, Economic, Environmental or Social) categories in order to clarify and understand the context of the identified limiting resource. Since those four categories were not explicitly mentioned during the M stage, it could potentially lead to coherence issues.



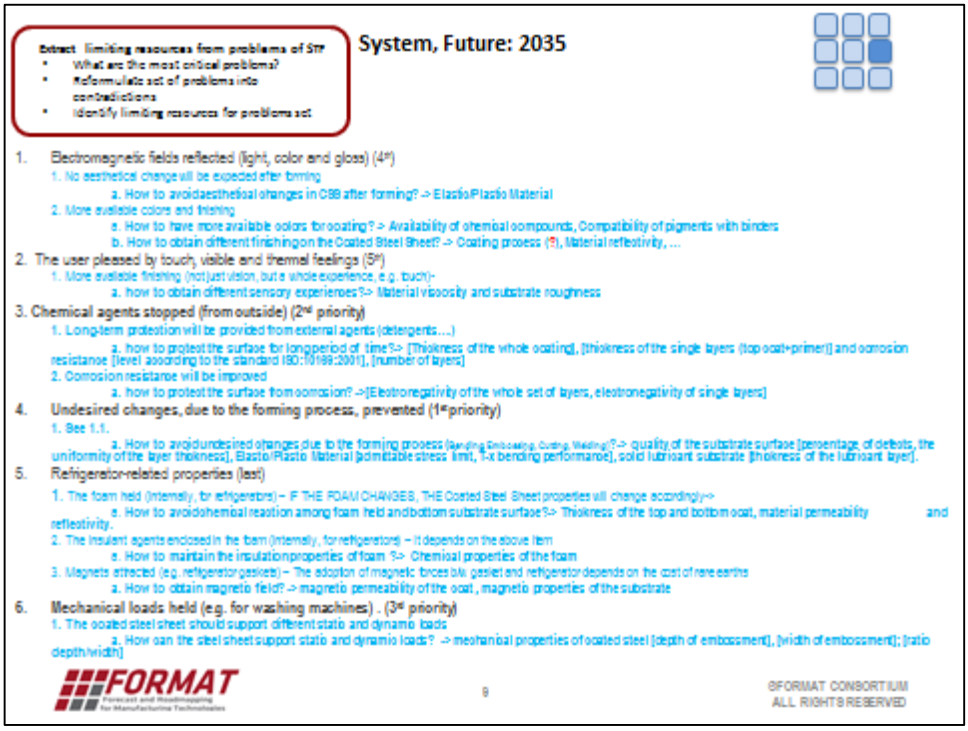
As results of this second round for StepA1, the core team recognized the usability of the question-answer approach to obtain a more meaningful list of limiting resources. Given this positive results, the analysis of limiting resources was extended to the different future screens of the System Operator.. In order to accomplish this overall analysis of SO a set of instruction has been proposed:

i) Formulate the main question to be answered (e.g. what are the resources that limit the fulfilment of the functions?)

ii) By each SO's element is recommended to formulate a question related to the element, it is suggested to formulate the questions by using a simple word structure as for example: how to…?

iii) Identify and extract the limiting resources that prevent the fulfilment of the SO's element.

System



As it came to light during step A1, the simplest way to extract liming resources from the problems of the STF, is through the expected states (future of the System Operator). The question to be answered was “what are the resources that limit the fulfilment of the functions?” In this phase was added the hierarchy in the list of functions.

Along the Step 1 of the Stage A the core team noticed that the System Operator analysis (Stage M, step 4), deserved an improved investigation in order to integrate an intermediate level between the STF (i.e. the Coated Steel sheets) and the Super System level (i.e. the appliances). This level of investigation focused on the forming processes involved in the manufacturing of appliances with CSS. Starting from the state of the art (investigation of the present state), also the past and the future states were analysed.

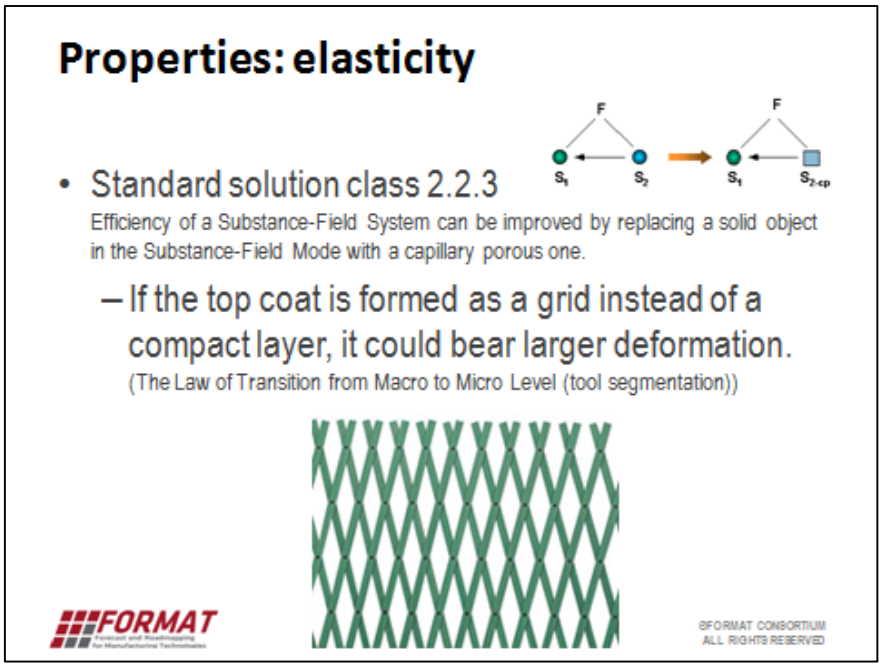
A_2: Recognize evolution patterns

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

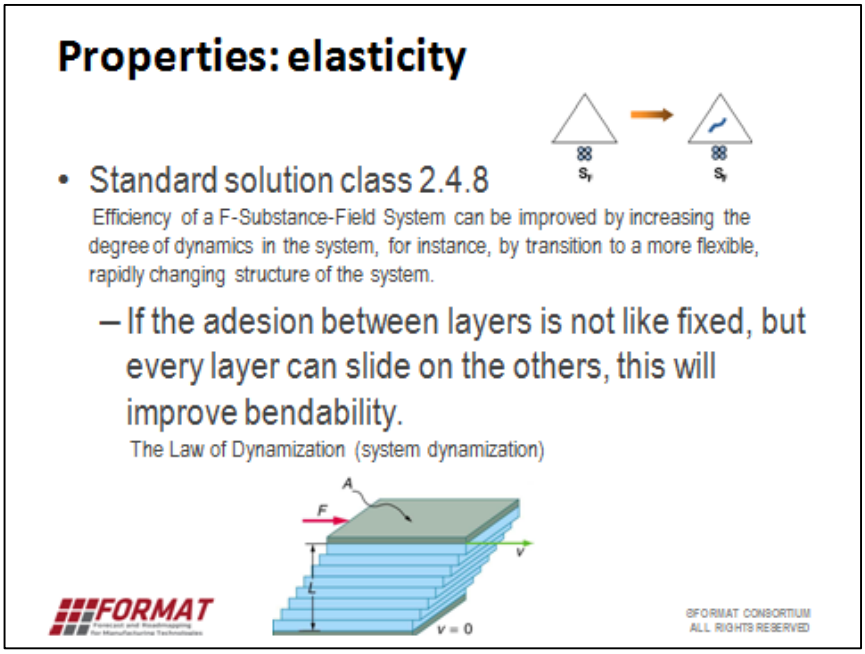
Once the different MTS models have been prepared as a propaedeutic activity to envision future solutions, the core team decided to reduce the scope of solution envisioning by just focusing on the first two priorities.

Indeed, considering the intrinsic simplicity of the CSS as technical systems, the core team decided to start envisioning solutions by using both the TRIZ Laws of Engineering System Evolution, as well as the set of 76 Standard Solutions to define future opportunities of development.

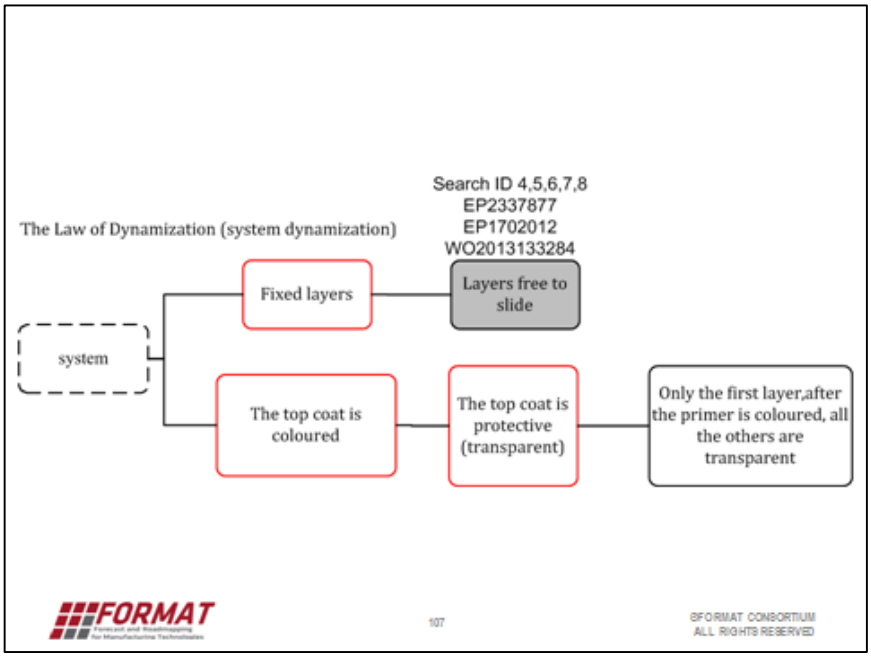


Moreover, whenever the envisioned solution comes from the application of set of 76 Standard Solutions, later on they have been conveniently organized in a network of trends, consistently with the patterns of evolution (e.g., every solution was juxtaposed to a TRIZ Law of Technical System Evolution (LESE)). No solution was censored or neglected, even if visionary or unlikely, for delivering as many suggestions as possible to the team, for further investigations.

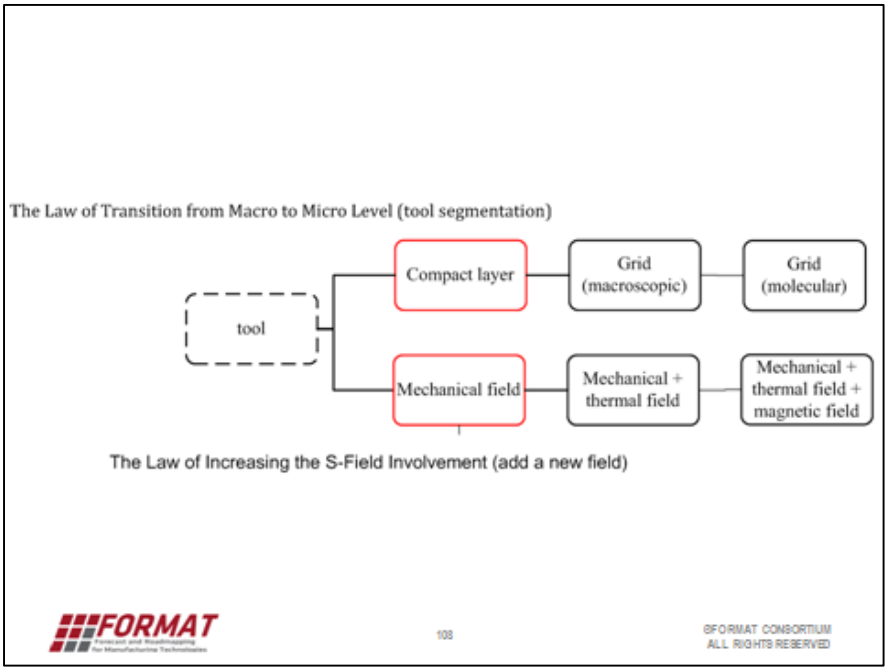
The next slides present the envisioned directions for the development of future solutions. The slide presents a clear reference to the standard (e.g. 2.2.3) used to generate the solution concept and its brief description. The concept of solution is presented with a textual description and it is sometimes clarified with a representative picture.



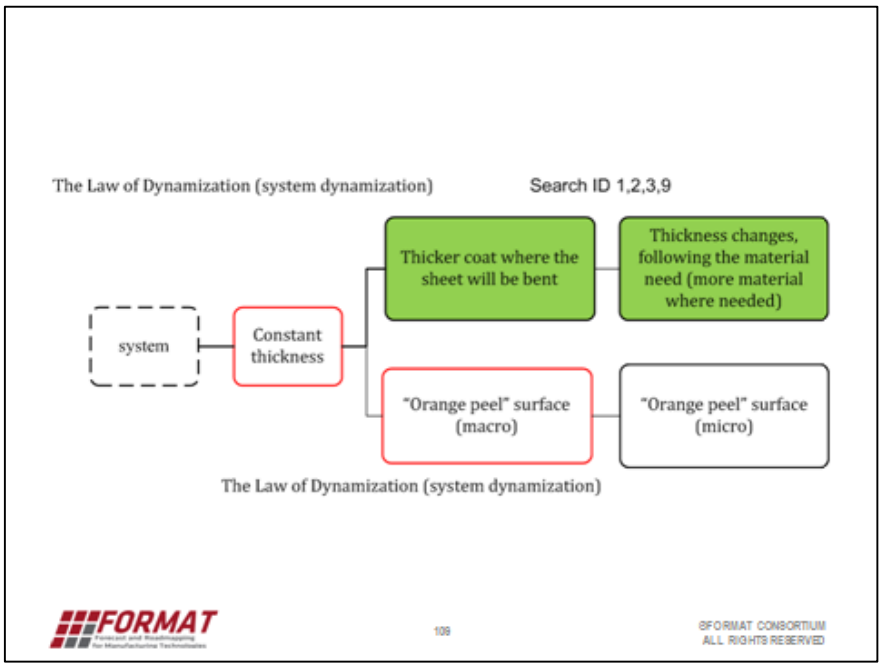
In the following slides, the envisioned trends of evolution are presented one by one, considering the whole system or a part of it as the evolving subject. They are characterized by a dashed contour, while the envisioned evolutions comes in different colours. The red boxes indicate already available solutions, grey boxes indicate solutions whose patent/paper search led to relevant results, white boxes indicate solutions whose patent/paper search didn't led to any relevant results, green boxes indicate free space for investments. As briefly mentioned above, the different patterns are supported by different patent searches.



Property: elasticity. Subject of the evolution: the whole system (Coated steel sheet).



Property: elasticity. Subject of the evolution: the tool (The top coat and potentially the other layers). The lower branch (increase S-Field involvement) relates to the capability of those part of the system to have a better interaction with the forming machine by introducing substances that are "field-sensitive" in order to reduce the emergence of undesired effects in the top coat and in the other layers.



Property: thickness. Subject of the evolution: the whole system (Coated steel sheet).

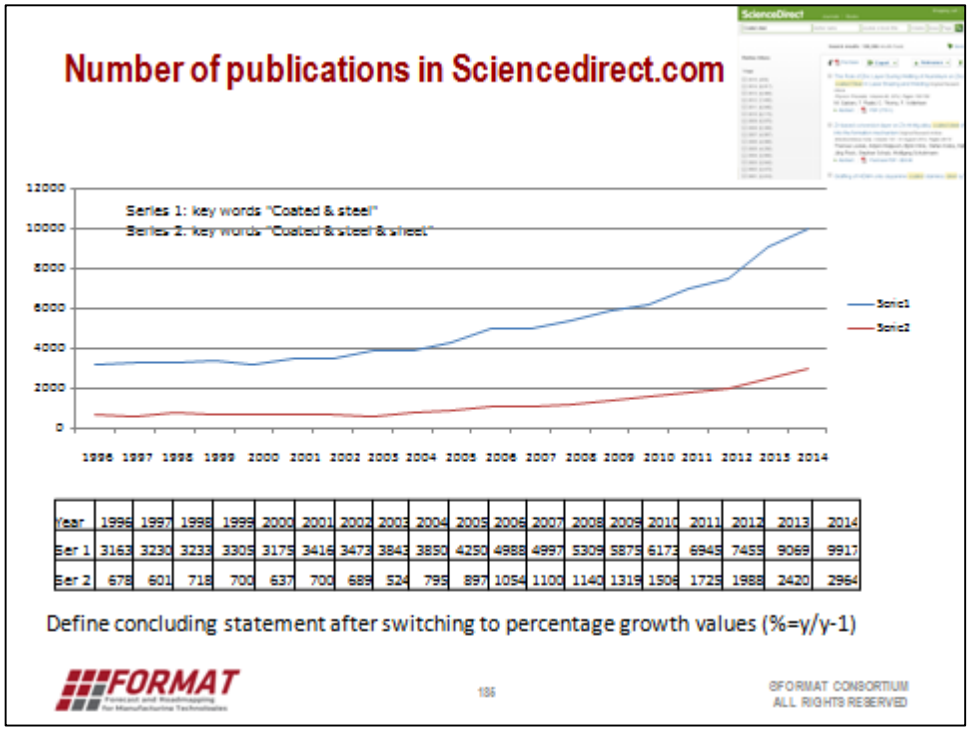
A_3: Fit time series

Fit data-series about parameters measuring performance & expenses

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

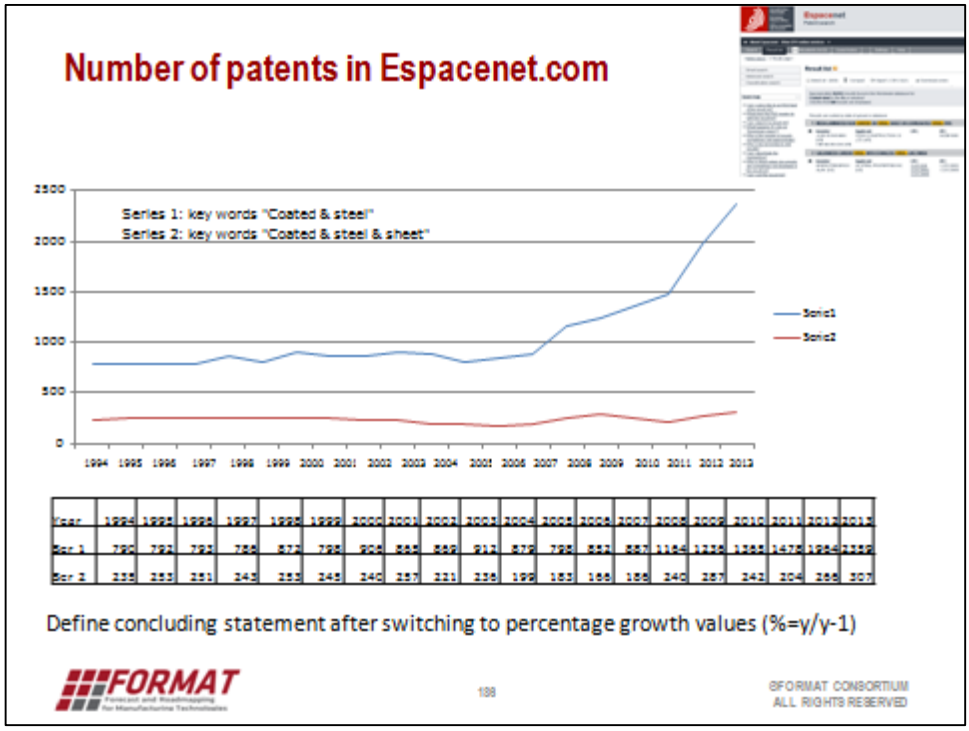
Number of publications on Sciencedirect.com

A frequency analysis was carried out, as well, for what concerns the publishing of scientific papers in the field of CSS. The above graph shows that there is a growing trend of publication.



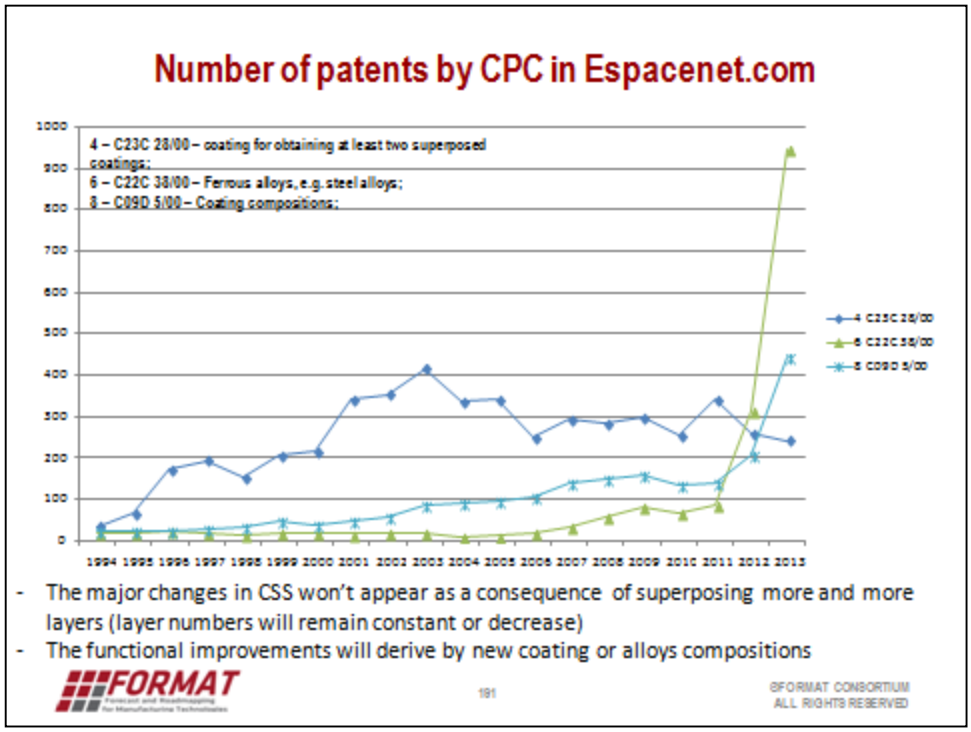
Number of patents on Espacenet.com

Differently from what happens in the scientific publications (where the trend of publication frequency is similar between “coated steel” and “coated steel sheet”), an analogous search in patent databases showed differences. The rate of growth of CSS patent appears as constant if compared to the one generally referring to steel coating.



Number of patents by CPC on Espacenet.com

On the basis of the above patent searches, especially with reference to the patent classification, an overall analysis of patent trends has been carried out. The following slide presents aggregated about patenting activities in specific classes (Cooperative Patent Classification-CPC), so as to infer the R&D trends in industry.



A_4: Define future traits

Build conclusions about future traits for STF

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

Finally, the Step A4 was performed in order to build conclusion among the steps A1, A2 and A3. This step aims at understanding and harmonizing the different viewpoint among forecasting participants. The harmonization of knowledge have to be useful to bring new conclusion to the beneficiaries.Moreover, it has to allow the core team to gain a deeper understanding about the STF. The conclusions are developed by combining both quantitative and qualitative viewpoint. Different types of conclusion were driven according to the different SO levels.

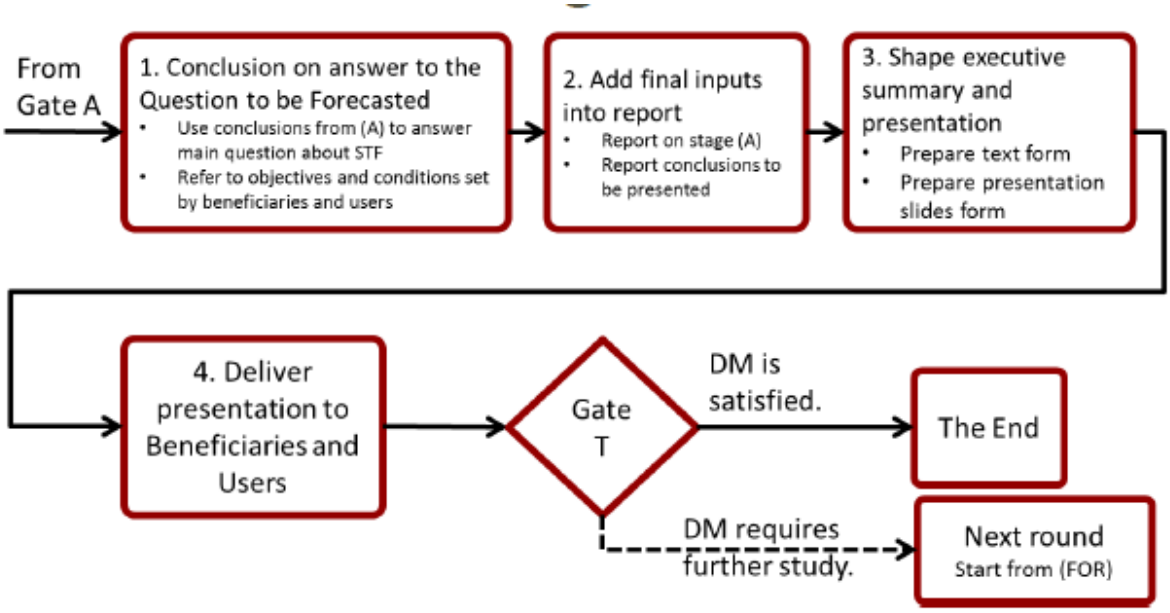
- CSS will be used more flexibly for manufacturing in order to confer specific colors to appliances (Slide 11)
- The overall amount of alternatives, ranging the different polymers, will make them more suitable than now for appliance manufacturing (Slide 9/10/11)
- The coating thickness didn't change in the last 20 years and it is expected it won't change (Slide 9)
- The amount of layers didn't change significantly (different manufacturers, different layers). Macroscopic layers potentially may appear to confer better formability to current coatings (Slide 8)
- The data about the relative difference between alternative technologies seems to remain constant along time (uniform development process for the different polymers) (Slide 9)
- Thermoplastic polymers (especially fluorinated) will provide the best forming characteristics (Slide 8 & 10)
- The major changes in CSS won't appear as a consequence of superposing more and more layers (layer numbers will remain constant or decrease) (Slide 12/13)
- The functional improvements will derive by new coating or alloys compositions (Slide 13)

Gate A

The Gate A have been implicitly explored and its requirements checked as the development of the activity proceeded.

4. TRANSFER STAGE

Main function of the stage is to transfer results of study to the users and beneficiaries of the Technology Forecast.



T_1: Answer questions

Conclusion on answer to the Question to be Forecasted

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

MAIN QUESTION FOR FORECAST

1. **Whether or when and how a pre-coated material will be able to be formed using the Whirlpool current technologies without compromising its *original properties*…in the coming 20 years, within the context of manufacturers and suppliers worldwide?**

- It is already possible to find coated steel sheets for which manufacturers claim 0T bending properties (http://www.chromadek.com/Web_datasheet_c1.7.pdf)
  - PVC is currently applied as a paint or a film
  - PVF is usually applied as a film
  - PVDF is applied as a paint
- The "next generation" coating will likely be based on a thermoplastic polymer which will be available in a wide range of colors (poor limitations).
- The "next generation" coating will be characterized by new chemical composition (new/modified polymers or integration of exogenous substances to confer desired characteristics)

T_2: Report results

Add final inputs into report

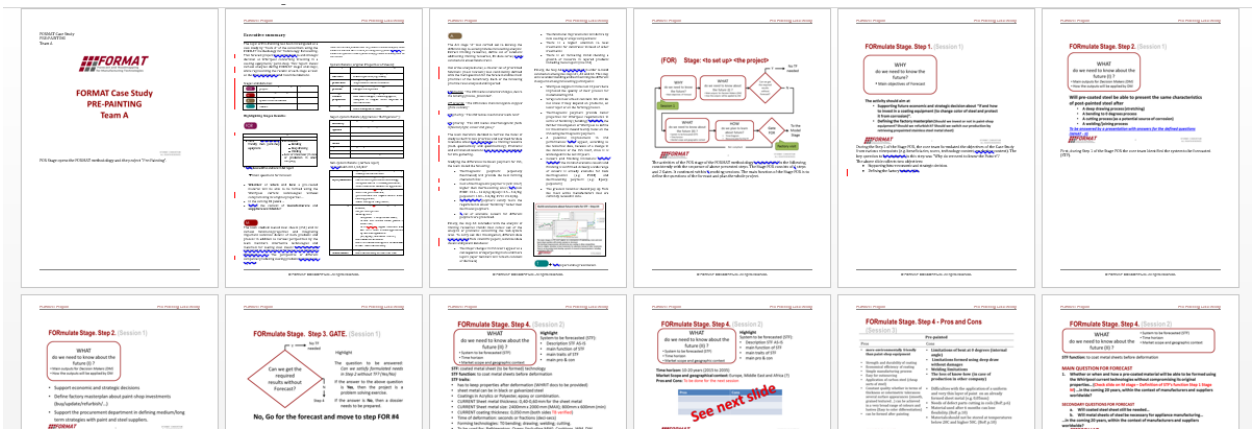
- Report on stage (A)
- Report conclusions to be presented

T_3: Develop reports

Shape executive summary and presentation

- Prepare text form
- Prepare presentation slides form

Report was shaped in accordance with demand of users and beneficiaries of case study about Decoration. Final report included 185 pages and set of slides developed during study (Results of stages FOR, M, A, T).



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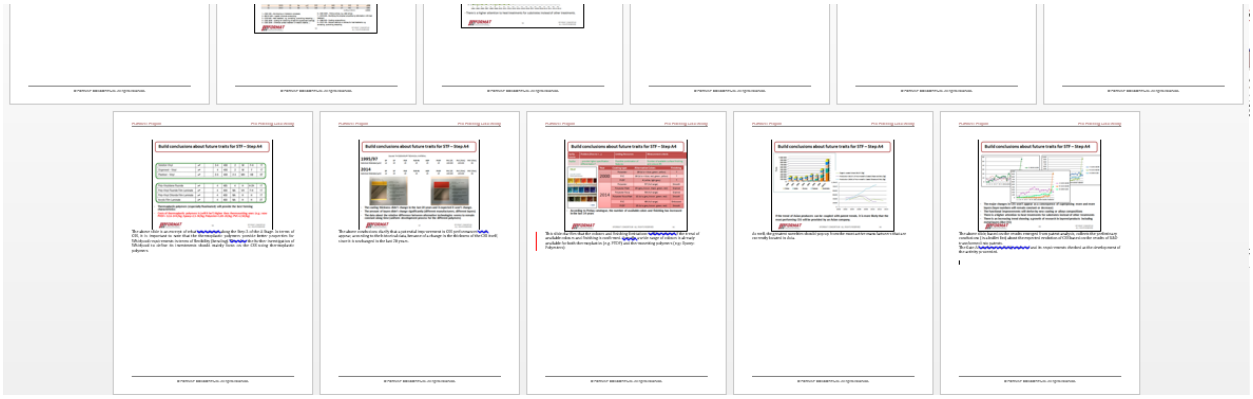
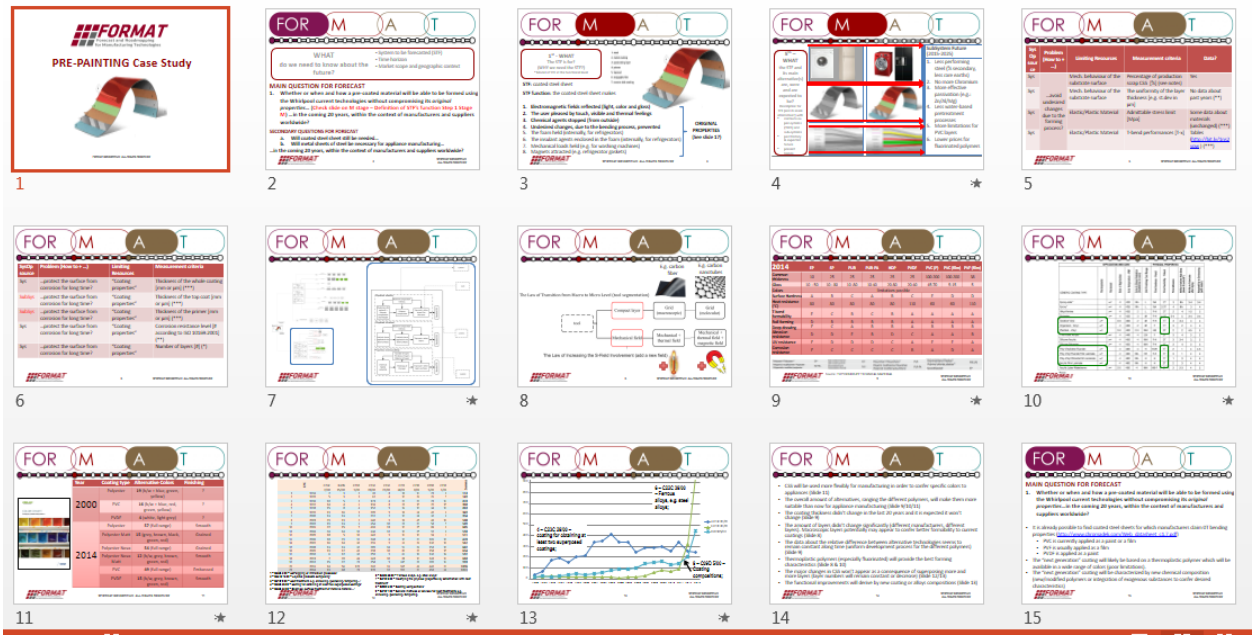


T_4: Deliver presentation

Deliver presentation to Beneficiaries and Users

It was delivered 15 slides of presentation for facilitating the discussion during one hour. All members of working team participated in presentation and discussion. Collected questions were clarified in final report about case study.



Gate T

- Answer the Question to be Forecasted (from (FOR) Gate)
- Executive summary
- Report
- Presentation

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