CASE STUDY "DECORATION"

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Abstract
This document is a text description of results of work performed in border of Pilot 2. Pilot 2 is an application of FORMAT methodology to a real case study provided by Whirlpool. Text description presents results of work sessions originally created as a set of slides with compiled contributions by all team members.

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1. Introduction

This document presents a working material from case study 'decoration.' The objective of case study 'decoration' was to investigate a future development in decorating technologies used on home appliances produced by Whirlpool. Particular setting of a forecasting case is presented in stage (FOR).

2. Stage (FOR)

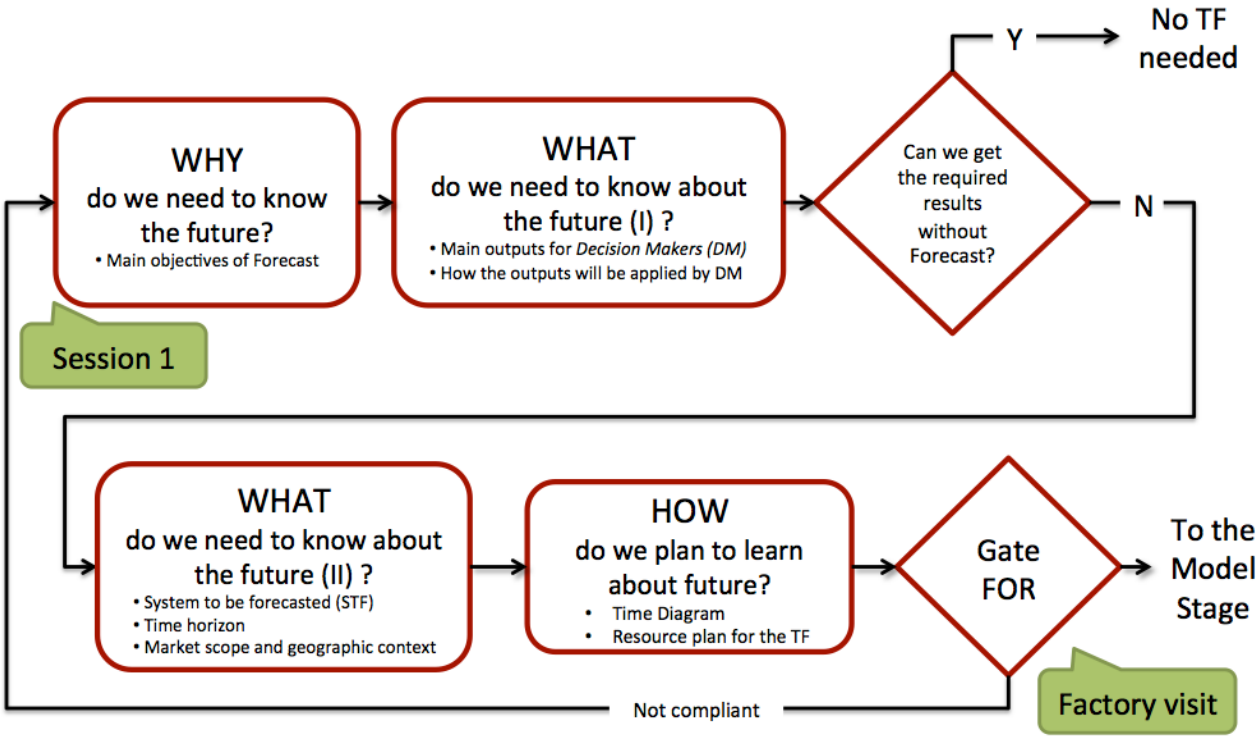

Figure 1. Steps of a stage (FOR).

Steps in stage (FOR) follow a FORMAT methodology schema presented on Figure 1. Following points 2.1 through 2.5 contain step-by-step results from execution of methodology pictured on Figure 1. Specific questions and decisions included into stage (FOR) require a high involvement of beneficiaries and users. In fact all steps included into stage (FOR) are performed basing on results of a working session with beneficiaries and users. The main objective of entire stage (FOR) is <to set up> <the project>.

Group of analysts preparing session 1.1 and 1.2 based on a preliminary description of a case study prepared at Whirlpool. This description has been used to prepare a general schema of decoration process and to learn about principle technologies currently in use at Whirlpool. The reason why two sessions number 1 were organized was coordination of an availability of beneficiaries and users. Session 1.1 was organized on 11/02/2014 i.e. before official starting date of a case study on 26/02/2014.

2.1. Main objectives of forecast

Formulation of a main objective of a forecast is to provide an answer to question "Why do we need to know the future?" In short "Why?"

The short title of a case study "Decoration" as a term requires a definition. Decoration refers to a function: <to modify> <color of> <a surface>
Where surface is understood as: plastic, metal, glass, porcelain; flat, 2D curved, 3D curved, perforated, texture. (Surface undergoes redefinition in stage (A) see slide 5)

Main objectives of forecast (project) have been formulated as follows:

- To envision: What to do to be better for Decoration process? (1st priority)
- To be aware: What will happen around in Decoration technologies (2nd priority)
- To get explicit answers for forecasting questions about future changes at Decoration processes for home appliances.

There is a continuous need to put information on the products.
In order to decide about investment for changes.
To drive differently resources to make research about particular decorations technology.
To decide about different evolution of our product design (involvement of Global Consumer Design (GCD)).
(Currently decorations are not concerned as brand distinction)
Need: faster production process, resistance to external factors (scratch, solvents, temperature),
Need to investigate: embossing, colors, textures, substrate material (glass).

2.2. Main outputs for decision makers

Main outputs for Decision Makers (DM) – an answer to question - What? – was formulated as:

- Technical parameters (e.g. cycle time) of future decoration technologies for defined time horizon and for specific markets

DM would like also to have data to support decision making using following decision criteria. In order to make a decision among technologies, following features are taken as criteria:

- Control of printing - control of the image.
- Flexibility - two or six colors, compatibility with different materials and geometry of surface.
- Maintainability - how easy and costly to perform maintenance.
- Capacity of production (cycle-time [s]).
- Feature expected in the future: print in line integration with production line.

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:

(1) Product Design,
(2) Marketing,
(3) Product Development.

This sub-stage is followed by an interim check. (Figure 1) In interim check, participants of session 1 are asked – "Can we get the required results without Forecast?" Beneficiaries and users participating in session 1 decided about "GO to forecasting project."

2.3. What do we need to know about future?

Definition of preliminary constraints for the project

During session 1.2 analysts were posing questions in order to gather data about system to be forecasted (STF). Since a case study in centered on the technological subject, a technique called TEES (Technology, Economy, Environment, Social) was used to cover by questions also other domains. Data about preliminary constraints have been collected about two principle technologies i.e. silk screening and pad printing. Discussion about each technology starts with a brief description, then, in course of discussion, strengths and weaknesses of each technology have been collected.

Decoration process
Main function: <to modify> <color of> <a surface>

Surface materials:

- plastics: PVC (thermoplastic), ABS, thermosetting polymers;
- metal: steel, stainless steel, painted steel, aluminum, chrome;
- glass: vitroceramic, soda lime glass, colored (tinted) glass;
- porcelain.

Surface shapes: flat, 2D curved, 3D curved, perforated, textured surface.

Currently at Whirlpool two main decoration technologies are used:

- Silk screening (app. 50%);
- Pad printing (app. 40%);
- Others (e.g. hot stamping, hot matrix, ceramic paste) (app. 10%)

A schema of main stages in decoration process was prepared before the session in order to support formulation of questions referring to technologies at use. (Figure 2) A schema had been prepared basing on introductory description of the case study and general information about industrial application of major decoration technologies.

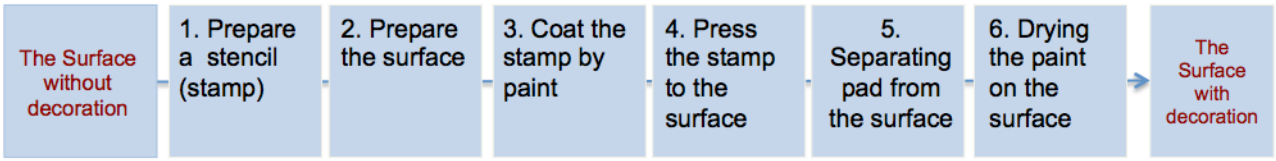

Figure 2. Schema of general decoration process

Time horizon (When?)

- 5-10 years (i.e. 2019-2024)
  Last change in decoration machines: on average was done 3-5 years ago.

Market scope and geographic context (Where?)

- Where is a decoration present? On home appliances i.e.: refrigerators; ovens, microwave ovens; dishwashers; washing machines, dryers; cooktops,
- Where are products with decoration? In: Europe, Middle East, Africa (EMEA)
  Restriction of region may change in round 2 of forecasting.

Silk screening
Main stages in silk screening decoration technology are:

1. Pre-press process: forming of a stencil – in which an emulsion is 'scooped' across the mesh and the 'exposure unit' burns away the unnecessary emulsion leaving behind a clean area in the mesh with the identical shape as the desired image.
2. Positioning. The screen is placed atop a substrate. Ink is placed on top of the screen, and a flood bar is used to push the ink through the holes in the mesh.
3. Printing. The operator lifts the screen to prevent contact with the substrate and then using a slight amount of downward force pulls the fill bar to the front of the screen. A screen is made of a piece of mesh stretched over a frame. A stencil is formed by blocking off parts of the screen in the negative image of the design to be printed; that is, the open spaces are where the ink will appear on the substrate.

Data about strengths and weaknesses of silk screening as a decoration technology applied in Whirlpool have been collected from users during session 1.2 and presented in Table 1.

Table 1. Silk screening – strengths and weaknesses

Strengths	Weaknesses
• easy and flexible to mix chemicals and prepare ink, possible to add additives; • thickness of graphics can be about 2 mm • high speed of process seconds per part (5-8s), • single pass, • covers large surface in single pass, • adequate quality and resolution of image, • possibility for making metallic effect, • appropriate for batch (50-400pcs) process	• long preparation time, • short lifetime of screen (pattern), • single color, • esthetics, it's difficult to use for small radius of substrate's surface • application is limited to flat or nearly flat surface (except. cylinders), • one color by pass, • multi-color images need several passes and drying (additional operations to add colors increase cost); • not appropriate for frequent changes of pattern (for small batch) • off line process

Pad printing

Pad printing is a wet-ink film transfer printing process. It is also known as tampography or tampo printing. The process was invented for printing finely detailed images directly onto three-dimensional objects, whereas other printing processes are generally limited to printing only onto flat objects.

Data about strengths and weaknesses of pad printing as a decoration technology applied in Whirlpool have been collected from users during session 1.2 and presented in Table 2.

Table 2. Pad printing – strengths and weaknesses

Strengths	Weaknesses
• flexible for multi-colors decoration, one machine -> multiple colors • printing on complex 3D surfaces • thickness of graphics (Up to 1mm) • Total cycle time increase 1.5 sec with each additional shot per color	• limited in size of surface, • possible failures and inadequate resolution for large surfaces, • restrictions in composition of ink, • force to transfer ink increases with size of a pad, • performance of ink system (lower than for silk screening), • resolution is lower than for silk screening, • metallic effect is not possible,

	• lower speed of process per m^2, • necessity to pre-install clichés (film), • off line process.

Question for forecast
Discussion with users about need of forecast, its utilization, application and main decoration technologies led to formulation of main question a forecast should answer to. It is a question or questions to be answered at the end of study. The main question is formulated in three parts i.e.: what, when, where. (Table 3)

Table 3. Question for forecast – questions to be answered at the end of study

What?	When? (time horizon)	Where? (market scope and geographic context)
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 all products: • Refrigerators, • ovens, • microwave ovens, • dishwashers, • washing machines, • dryers, • cooktops , at Whirlpool factories in EMEA*.
2. Will decoration technologies be needed?		
3. Which will be the expected (estimated) evolution of Main Parameters of ink-jet and laser marking?		
• When will inkjet technology be ready to substitute silk screening and pad printing for domestic appliances? • When will laser marking be able to produce colored marks in plastic?	Indefinite	→ For plastic surfaces

* EMEA - Europe, Middle Ease, Africa

2.4. How?

Time plan

Planning of tasks in case study project follows stages presented by the methodology. Each stage is composed of steps that contain tasks to be completed on associated sessions and work in-between sessions. In stage (FOR) only one session is planned. (Figure 1) Whereas other stages have up to five sessions. Overall planning was based on principle to have a case study completed in less then two months. This concept is presented in Table 4.

Case study project planning presented on Gantt chart is composed out of two categories of tasks i.e.: work in-between sessions and work on the sessions. Tasks are grouped in four stages of methodology i.e. (FOR), (M), (A), (T). It is necessary to refer to methodology in order to learn about exact topics studied in-between particular sessions. Table 4 presents a list of tasks with duration, start and finish dates for stage (FOR) and (A). A complete list of tasks is presented in Table A-1, Appendix A. Duration times are given with half day precision. Duration of tasks is presented on Gantt chart.

Beside Gantt chart, a more operational version of session planning was prepared in form of a spreadsheet. Spreadsheet version of planning is organized around sessions and work planned for and performed during each session – it contains: session number, session

date, time, duration, location, activities planned, activities performed, techniques & methods, outputs planned, outputs delivered. (Table A-2)

Table 4. Case study project – overall concept

Stage / Gates	Meetings	Work Time	Participants
(FOR) Diagnose questions and plan project	4h	2 workdays	2 analysts + 4-6 Users and Beneficiaries
(M) Define the system for forecast and study contexts	4hx4	8-10 workdays	2-4 analysts + requested experts
(A) Develop forecast for defined system and contexts	4hx5	8-10 workdays	2-4 analysts + requested specialists
(T) Prepare report and present results	4h 4h	3-5 workdays 1 workday	2 analysts 2 analysts + Users and Beneficiaries

Table 5. List of tasks in case study project "Decoration" executed by Team B: stage (FOR) and stage (M)

ID	Name	Duration [day]	Start [day, time]	Finish [day, time]
1	Session 00	1,d	11/02/14 08:00	12/02/14 09:00
2	Pilot 2	31,d	26/02/14 08:00	09/04/14 18:00
3	Stage (FOR)	2,056d	26/02/14 08:00	28/02/14 08:30
4	Before session 01	1,5d	26/02/14 08:00	27/02/14 13:30
5	Session 01	,222d	27/02/14 15:30	28/02/14 08:30
6	Gate FOR	,111d	27/02/14 16:30	27/02/14 17:30
7	Stage (M)	9,944d	28/02/14 08:30	13/03/14 18:00
8	before 02	,889d	28/02/14 08:30	28/02/14 17:30
9	Session 02	,296d	28/02/14 14:20	28/02/14 17:00
10	between 02-03	3,d	03/03/14 08:30	06/03/14 08:30
11	Session 03	,444d	06/03/14 08:00	06/03/14 12:00
12	between 03-04	1,d	07/03/14 08:00	07/03/14 18:00
13	Session 04	,333d	10/03/14 09:00	10/03/14 12:00
14	between 04+05	1,d	10/03/14 14:00	11/03/14 14:00
15	Session 05	,444d	12/03/14 09:00	12/03/14 14:00
16	after 05	1,d	13/03/14 08:00	13/03/14 18:00
17	Gate M	,222d	13/03/14 16:00	13/03/14 18:00

Resource plan for TF (copy from ppt → in table form)
Resources for the case study project have been declared during both session 1.1 and 1.2. (Table 6)

Table 6. Resources for "Decoration" case study project

Type of resources	Resources
Working team	Mateusz Slupinski (MS), Dmitry Kucharavy (DK), Christopher Nikulin (CN)
Source of knowledge	Pierluigi Petrali (PP), Fabrizio Sella (FS), Marco Urbaz (MU), Fabio Moneta (FM)
Information & data	Literature, documents, and presentations recommended by source of knowledge

IT instruments	Webex platform for VoIP meetings; Internet connection for all participants; e-mail addresses; Server for working documents and materials BSCW; PDF viewer; MS Office (Word, Excel, PowerPoint); MS Visio; MS Project.

2.5. Gate (FOR)

In FORMAT methodology gate conditions for stage (FOR) are formulated as follows:
Main function of the stage is:<to set up> <the project>

(FOR) gate conditions:

- 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/No Go -> to forecasting project
- Definition of Preliminary constraints for the project
  - System (Process) to be Forecasted (STF) from Technological, Economics, Environmental, Social (TEES) perspectives (What?)
  - time horizon (When?)
  - market scope and geographic context (Where?)
- Question 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, …)

All data required by (FOR) gate conditions have been collected and presented in point 2 of this document.

Comments to stage (FOR)

- Data required to close the gate were collected on two rounds of session #1, according to schedule.
- Conclusion about gate closure is made +1d later.
- Stage (FOR) reporting is initiated after gate closing.

3. Stage (M)

3.1. Silk screening model

Functional model of Silk Screen process for decoration was started on the basis of materials provided at the beginning of case study[4], information collected during Session #1.2 (27/02/2014), internal document BoP[5], and information retrieved from public sources of information.

The working definition of Silk Screening (also named Screen Printing) applied at the initial stages of study was based on information from open source encyclopedia[6]: "Screen printing is a printing technique that uses a woven mesh to support an ink-blocking stencil to receive a desired image. The attached stencil forms open areas of mesh that transfer ink or other printable materials which can be pressed through the mesh as a sharp-edged image onto a substrate. A fill blade or squeegee is moved across the screen stencil, forcing or pumping ink into the mesh openings for transfer by capillary action during the squeegee stroke."

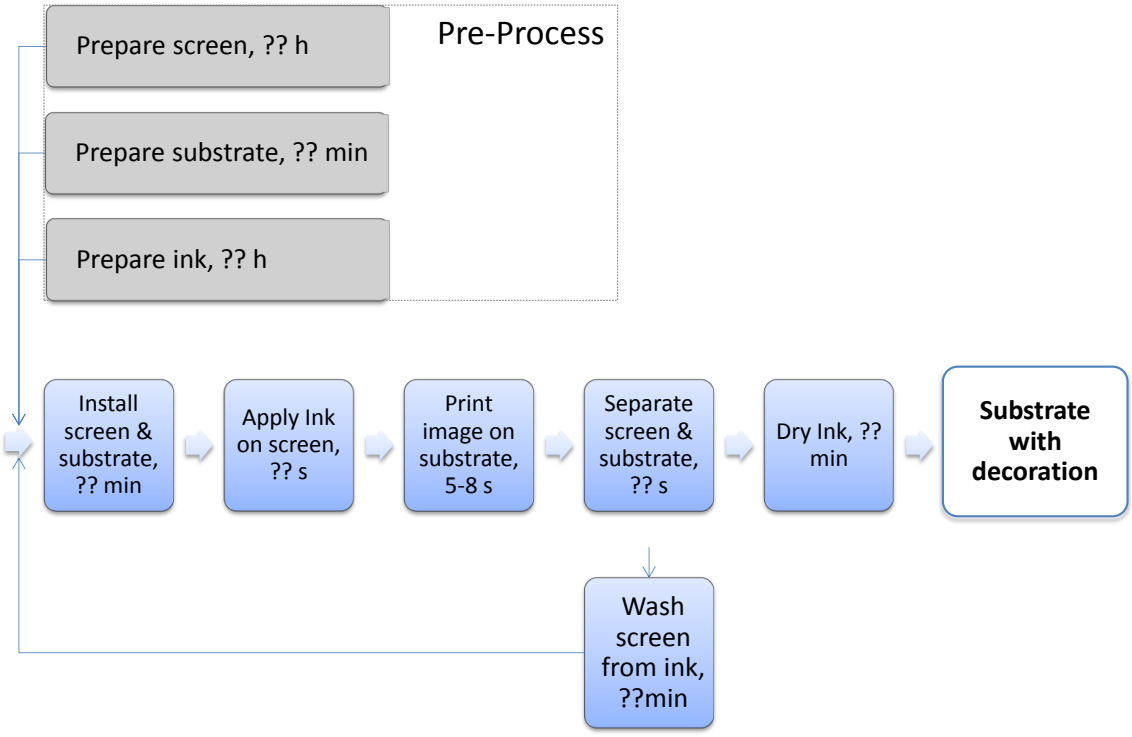

Figure 1. First draft version of Silk Screening process description

The model presented on Figure 1 was prepared for Session #3 (5-03-2014) and it was applied during first factory visit for collecting necessary information about decoration process. During factory visit (06-03-2014) two processes for silk screening were observed: static screen printing and UV screen printing. Therefore, for further study two functional models were elaborated for silk screen decoration using collected information and data (see Figure 2, Figure 3).

[4] Materials of session #2 (28/02/2014):
[5] Bill of process, ADV. MANUFACTURING, BENTON HARBOR, MICHIGAN 49022 USA, Whirlpool. Confidential
[6] http://en.wikipedia.org/wiki/Screen_printing

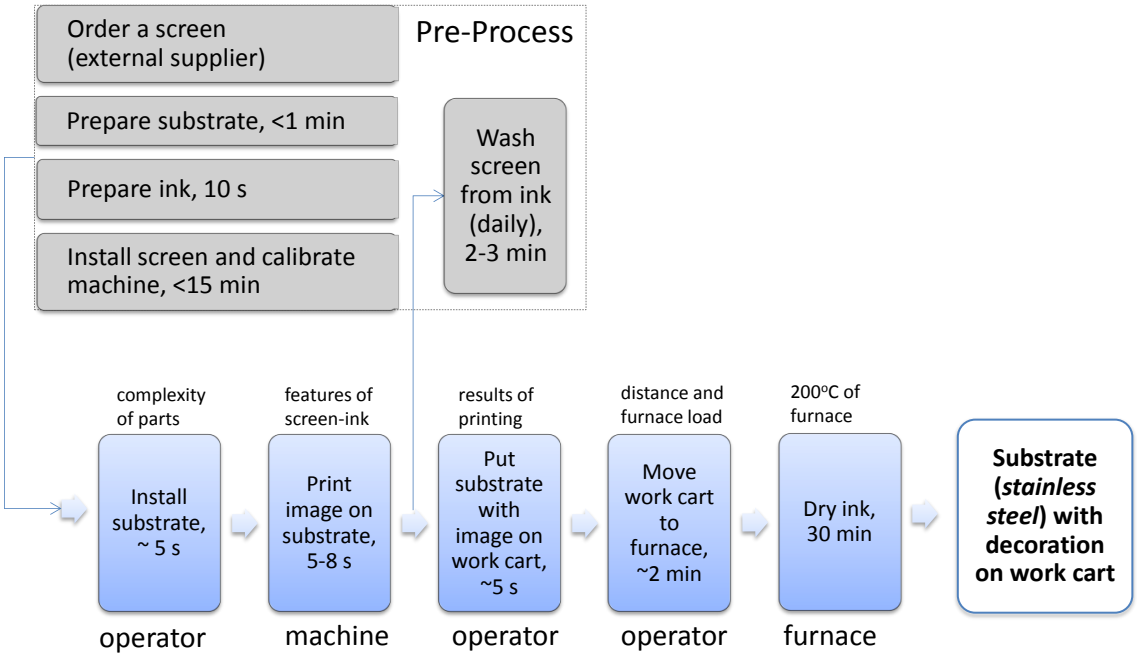

Figure 2. Functional description of screen printing static decoration process

Presented models were developed using some concepts from IDEF0[7] Functional Modeling method. A box represents a function performed during a particular operation, when an input is connected to the left side of the box and an output is connected to the right side of the box. Control that governs function performance (e.g. time, energy consumptions) is indicated on the top of a box, when mechanism of function is indicated below a bottom side of a box. Pre-process is described only on functional level without control, mechanisms and inputs-outputs syntax. The final output of the presented screen printing decoration process is an image (decoration) on stainless steel surface of a part.

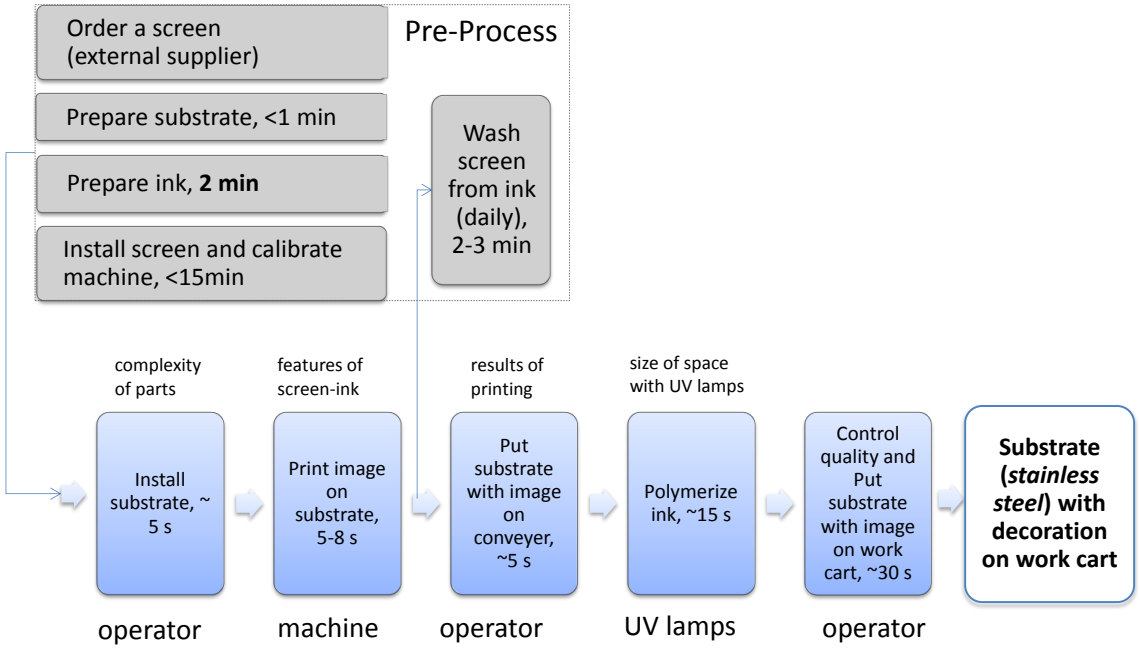

Figure 3. Functional description of screen printing decoration process using UV polymerization of ink.

[7] http://www.idef.com/idef0.htm

When comparing to the draft version of process (see Figure 1) it is necessary to notice that originally separated functions <supply the ink on screen>, <apply pressure and push the ink through the screen>, and <separate screen & surface> where aggregated into the function <print image on substrate>. This aggregation was done after observation of the decoration processes in workshop with purpose to improve clarity of model and to harmonize models with observations.

Final versions of functional models were discussed and approved during working Session #5 (12-03-2014).

3.2. Pad-Printing technology

Pad-Printing is a printing process used to transfer an image path onto a surface. It is widely applied by companies in order to communicate data to customers or users. Pad-printing process can be described in different stages; however, it depends from automation level integrated to the pad-printing process, but there are common stages such as: First, pre-process, it is useful to prepare the process tools and instruments such as cliché, pad and ink. Second, printing process, it is when the printing process occurs. Third, drying process, it is applied to attach the ink to the surface. All these stages have been observed and measured during the factory visit.

Given the interest by FORMAT partner to understand how this technology going to evolve in the future, it is needed a more detailed analysis about this technology. In order to achieve this task several activities where carry out: First, a current process description is useful to understand the partner situation regarding this technology. Second, factory visit was done in order to collect information about process stages such as number of functional stages and resources. In turn, concepts and description inspired by IDEF0 were applied in order to create the functional model of the processes.

Currently, company has two pad-printing processes in their production facilities; these processes are applied for different kind of appliances. Moreover, specific functional stages are partially different; given this situation a more detailed functional description is provided below:

- Semi-automatic, it is a process where at least one operator is needed in order to transfer the image to the substrate. As example, Figure 4 describes the functional model of semi-automatic process, it is possible identify in several stages that an operator is required.
- Automatic, it is considered as a process where an operator is not needed to transfer the image to the substrate (Figure 5), however there is a quality check performed by human.

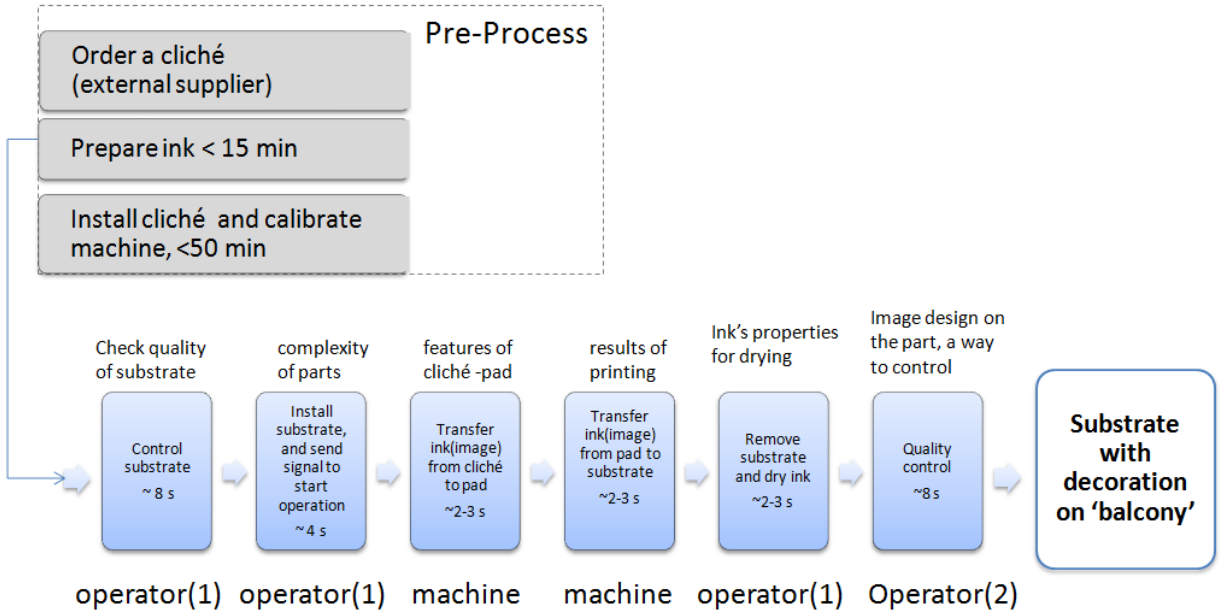

Figure 4. Functional description of the semi-automatic pad-printing process.

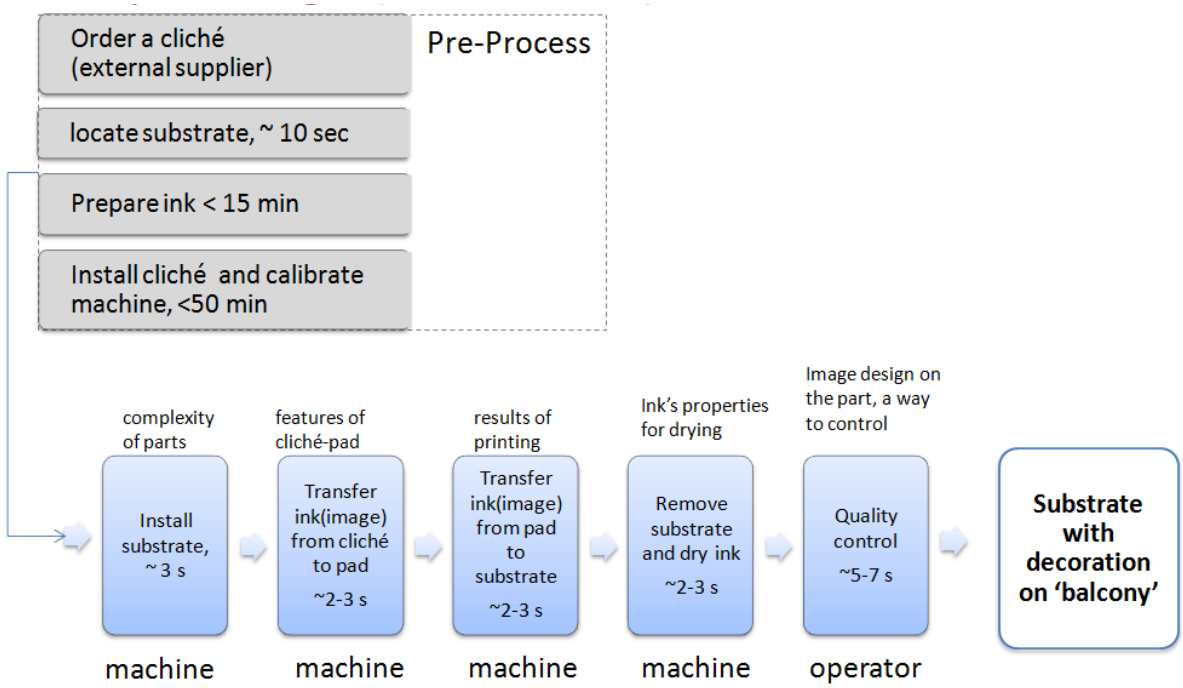

Figure 5. Functional description of the automatic pad-printing process.

From methodological point of view, the final functional model description was developed after several sessions, the models were updated iteratively until to obtain a meaningful functional description according partner point of view.

3.3. Alternative technologies – remaining set

Fraction of particular decoration technologies, being currently at use at Whirlpool or considered to be used, is 50%+40%+10%. Beside two major players, remaining 10% is occupied by a group of technologies. The technologies listed by users during session 1.2

(27/02/2014) are presented in Table 7 together with indication of origin for parts decorated by the means of a particular technology. Origin of decoration depends on where does a particular decoration solution come from. Possible options are:
IN – it is produced inside Whirlpool factory,
OUT – it is delivered by supplier,
NO – it is not currently applied.

Table 7. Remaining 10% of decoration technologies considered by Whirlpool

#	Decoration technology	Origin of decorated piece
1.	Hot stamping	IN/OUT
2.	Laser marking	IN
3.	Chemical etching	OUT
4.	Inkjet printing	NO

It has been decided that remaining set of decoration technologies will be described by the means of main features and Pros/Cons. Sources used for these descriptions are coming from Whirlpool with exception of information about chemical etching. Functional models for technologies in Table 7 have not been done with exception of laser marking.

Hot stamping (Herreria, 2011)("Hot stamping," n.d.)
Hot stamping is a dry printing method of lithography in which pre-dried ink or foils are transferred to a surface at high temperatures. For pros and cons see Table 8.

Main features of hot stamping at WH:

- applied for making a metal gloss decoration on substrate;
- hot stamp pressing;
- pressed cliché;
- controllable pressing force;
- applicable on plastics such ABS, polypropylene, enameled steel;
- initial set up is complex.

Table 8. Pros and Cons of hot stamping application (Herreria, 2011)

Pros	Cons
• Change over time is under 5 min • Cycle time • Non-polluting process because paint is dry • Durability, chemical resistance, abrasion resistance • Relative low investment • Chrome/metal appearance • Resolution • Environment friendly green	• Impractical for reworking • Low operation cost effectiveness • High scrap rate • Long change over under 1 cycle • Not easy for maintenance • Control of pressure power • Requires a cliché • Initial set up is complex • 0.2 mm raised geometry is recommended for optimum hot stamping transfer

Laser marking

The laser beam modifies the material surface, creating permanent marks without removing material or impacting surface integrity ("Universal Laser Systems," n.d.). At WH it is applied for making digitally processed decoration with zero change over time. For pros and cons see Table 9.

Thanks to the visit of the laser marking decoration process at cooking factory in Cassinetta, it was possible to build a functional model for laser marking process basing on a real application case. (Figure 6) Logic to formulate functions has been adapted from IDEF0 removing strict IDEF0's syntax constraints. Figure 6 consists of two sections. In top part, separated by dashed-line frame, a pre-process's components are presented. Bottom part of Figure 6 presents a horizontal line of boxes describing consecutive stages of decoration process. Horizontal direction of flow marked by arrows pointing to right represents a consecutive order of stages. Function of each stage is described by text inside boxes together with timing. Timing was measured during the visit at silk screening and laser marking processes at cooking factory in Cassinetta on 06/03/2014. Text on top of a box describes a control applied to each stage. Description located beneath a box describes a mechanism that is being used to achieve a function.

For instance, description of stage "Polymerize ink" (Figure 6) should be read as follows. Stage "Polymerize ink" has an on-site measured time of 15s. This stage is controlled, limited by a size of space with UV lamps used in curing process (control: indicated on top of a box). The mechanism to perform ink curing is based on UV lamps (mechanism: indicated beneath a box).

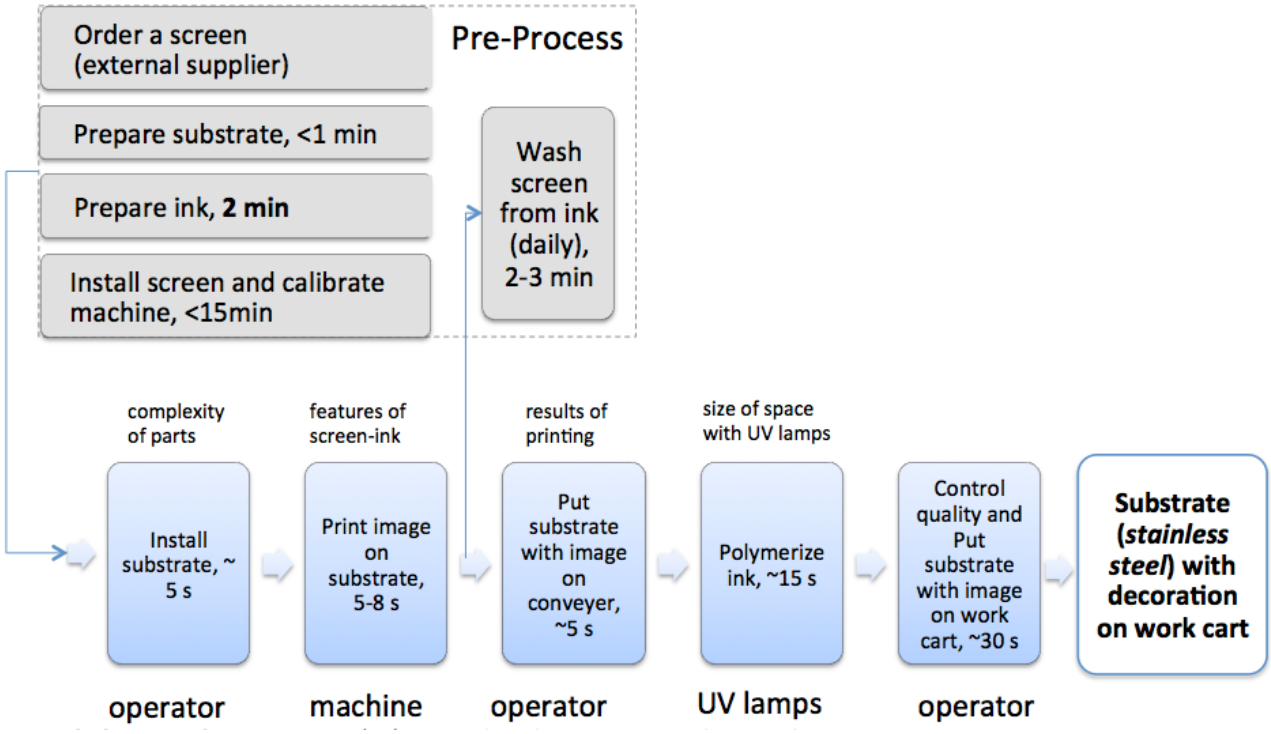

Figure 6. Functional model of laser marking process

Table 9. Pros and Cons of laser marking application (Herreria, 2011)

Pros	Cons
• zero change over (no tooling change required) – 1/1 principle in manufacturing possible to apply • Durability • Lower scrap rate • Environment friendly green • Range of application from small to large • Resolution • Change over over one cycle	• Costly maintenance • Costly utilities • high cycle time • Higher level of expertise for maintenance • Exchange pieces (spare parts) are unique for particular application • **Chemical resistance worse** then silk screening • Low operation cost effectiveness • No color complexity management • No chrome/metallic appearance

Chemical etching

Etching refers to the technique of creating decoration on the surface of metal or glass by applying acidic, caustic, or abrasive substances.

Table 10. Pros and Cons of chemical etching

Pros	Cons
• cheap [1] • relative low investment [3] • lower scrap rate [3] • ease of maintenance [3] • almost no damage due to purely chemical nature [1] • highly selective [1] • durability, chemical resistance, abrasion resistance [3] • relative quick change over [3] • range of application small to large [3]	• inadequate anisotropy [1] • inadequate process control (temperature sensitivity) [1] • inadequate particle control [1] • high chemical disposal costs [1] • difficult to use for small parts [1] • no color complexity management [3] • no chrome/metallic appearance[3] • limited substrate application[3] • no environment friendly green [3] • long cycle time [3] • long change over under one cycle [3]

Isotropic[2] – etching proceeds at equal rates in both horizontal and vertical direction.
Anisotropic[2] – etching proceeds faster in one plane than in another.
Selectivity[2] – the ability of the etch process to distinguish between the layer to be etched and the material not to be etched.
[1] (Doolittle, 2008)
[2] (Center, 2010)
[3] (Herreria, 2011)

Inkjet printing

Inkjet printing is a type of computer printing that creates a digital image by propelling droplets of ink onto paper, plastic, or other substrates.

Expected application at WH: To make digitally processed decoration in wide scale of color with up to photorealistic resolution.

Inkjet printing as a decoration technology is not yet applied at Whirlpool. However it is a technology that is under study by Whirlpool for possible future applications. For pros and cons see Table 11.

Table 11. Pros and cons of laser marking (Urbaz, 2013)

Pros	Cons
• Graphics resolution (Photorealistic) • Entire surface can be covered • It is possible to apply on small surface • Digital image process (pre-process) is less than 30 min • customization of image with real-time data • Different kind of thickness for graphics • Diversity of colors applied on one surface • Gradient effect is possible • High flexibility for different types of images • Adequate cycle time [s/pcs] • Adequate change over time	• Relatively high process time for long surface. • Number of colors is constrained by cartridge from suppliers (It is not possible to create a new colors) • Ink performance is not adequate for corrosion • It's not possible to make the metallic colors

3.4. System Operator (SO)

With the information about the current state of technologies applied by FORMAT partner, a further analysis is needed in order understand how have been changed the requirements and contexts for the main process function (<modify> <colors> <of surface>). With this perspective, SO analysis seems a suitable TRIZ tool to understand and combine all the information collected in the previous sections. Moreover, it allows at understanding and comparing historical changes. SO analysis started defining at system-level the main function process, requirements and characteristics Figure 7. At sub-system level were defined the technologies currently applied by FORMAT partner and their estimated application in terms of percentages. With this information, super-system description is accomplished taking into consideration four contexts: technological, environmental, economic and social. Additionally, in order to obtain a feasible envision of the future, it is suggested to develop a sort of horizontal comparison from the present to the past, this comparison allows analyst at understanding how has been changed the requirement and/or context. As results of this activity, several remarks emerged from the analysis which helps to the teamwork driving a more precise envision of the future. These remarks are presented in details in Figure 8 for decoration case study. Finally, the SO future screens are accomplished with the knowledge learned from the past.

According to the case study, the main process function can have two main goals: i) decoration has to deliver information to customers and ii) esthetical image has to trigger customer attention. Different technologies are described at sub-system level such as Silk-screening, Pad-printing and others. Super-system describes main requirements and characteristics from different context such as: WH appliances, recyclability of home appliance, control pane production and use, etc.

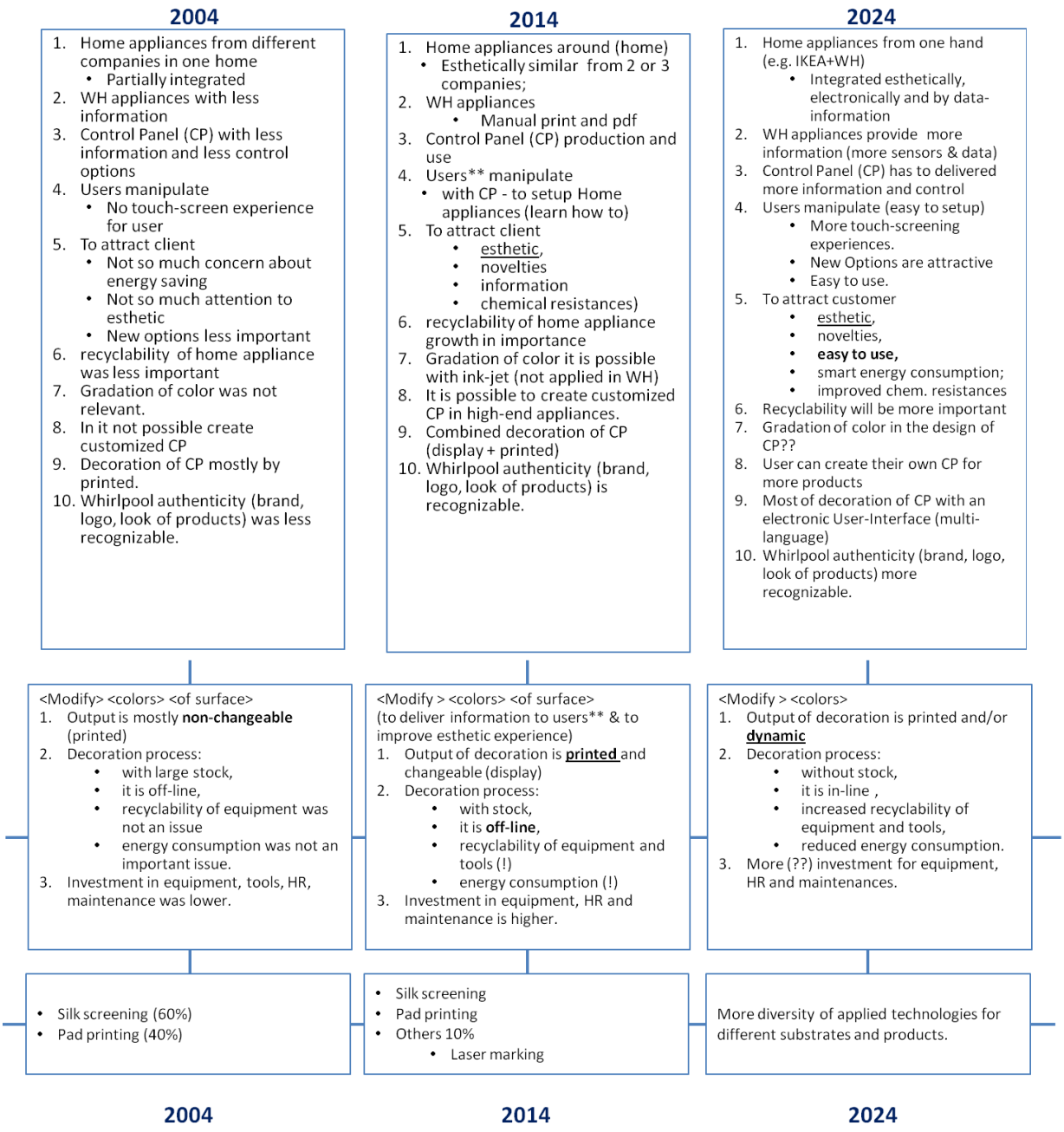

Figure 7. System Operator (SO) according to main function process.

3.5. Decision criteria

Definition of Decision criteria for decoration technologies at WH was initiated during session 1.2 (27-02-2014) through structured interview with invited experts. In scope of study about future of manufacturing technologies the **decision criteria** defined as *set of factors on which decision about implementation (or not implementation) of a particular technology is taken*.

After treating information collected during session 1.2 the following list of Decision criteria for decoration technologies was identified:

1. Controllability of printing process: more control on image
   - to be adaptable for complex images;
   - Resolution, Esthetic, Effects [quality of final image].

2. Flexibility:
   - ink composition and number of colors (two and more);
   - time to add new color to process line
   - diversity of substrates (plastic, metallic, glass, porcelain; flat, 2D, 3D, perforated, texture).
3. Productivity of process (pcs/h):
   - cycle time of machine (second);
   - cycle time for new colors/design/substrates should not increase.
4. Maintainability (non-working, h):
   - how easy and complex to maintain the machine on work;
   - user interface;
   - necessary efforts to maintain the machine;
   - time and cost to repair the machine when it is necessary;
   - availability and cost of spare parts.
5. Integration level with production line:
   - how much time is required to start a new part/substrate/design for printing;
   - it is preferable to have the decoration process in-line, but not off-line (current situation).
6. Price of machine (EUR)
   - installation cost;
   - operation cost and cost of exclusion (retirement).

Identified Decision criteria were integrated with decision factors, extracted from internal document BoP[8] when alternative technologies for decoration process were analyzed. Eighteen decision factors were grouped in accordance with identified decision criteria. The result of integration was discussed and approved during session #5 (12-03-2014).

Decision criteria	Decision factors
1. Controllability of printing process: more control on image	1. Color complexity management 2. Chrome/ Metallic appearance 3. Resolution 4. Chemical resistance 5. Abrasion resistance 6. Durability
2. Flexibility	1. Multiple substrate application 2. Curved / Non flat surface application 3. Range of application small to large 4. Quick Change Over (when compared between the alternatives)
3. Productivity of process (pcs/h)	1. Cycle time 2. Lower Scrap Rate
4. Maintainability (non-working, h)	1. Ease of maintenance
5. Integration level with production line	1. Possible for continuous flow to assembly 2. Change over under one cycle (40-60 sec)
6. Price of machine (EUR)	1. Low investments (when compared between the alternatives) 2. Operation cost effectiveness 3. Environment friendly Green

Figure 8. Results of integration for decision factors and Decision criteria

[8] Bill of process, ADV. MANUFACTURING, BENTON HARBOR, MICHIGAN 49022 USA, Whirlpool. Confidential

Decision criteria were applied as a guideline to summarize results of study for known alternative technologies for decoration process. The study of alternative technologies has been performed on the basis of materials provided at the beginning of case study[9], data collected during Session #1.2 (27/02/2014), from internal document BoP[10], Inkjet technology[11], and information retrieved from public sources.

In order to build our final assessment of competitive technologies the qualitative values were assigned to each technology in accordance with the list of decision factors. When a technology provide an *adequate* performance for selected decision factor the assigned value is 1, when it is *neutral* the assigned value is 0, when it is inadequate the assigned value is -1. The values for six decision criteria were obtained as an average of evaluations for decision factors in groups. Final score for each technology is an average of values for six decision criteria.

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Figure 9. Assessment of competitive (alternative) technologies for decoration process

In order to improve clarity of assessment of alternative technologies the radar diagram was elaborated using data from the table (see Figure 9) above.

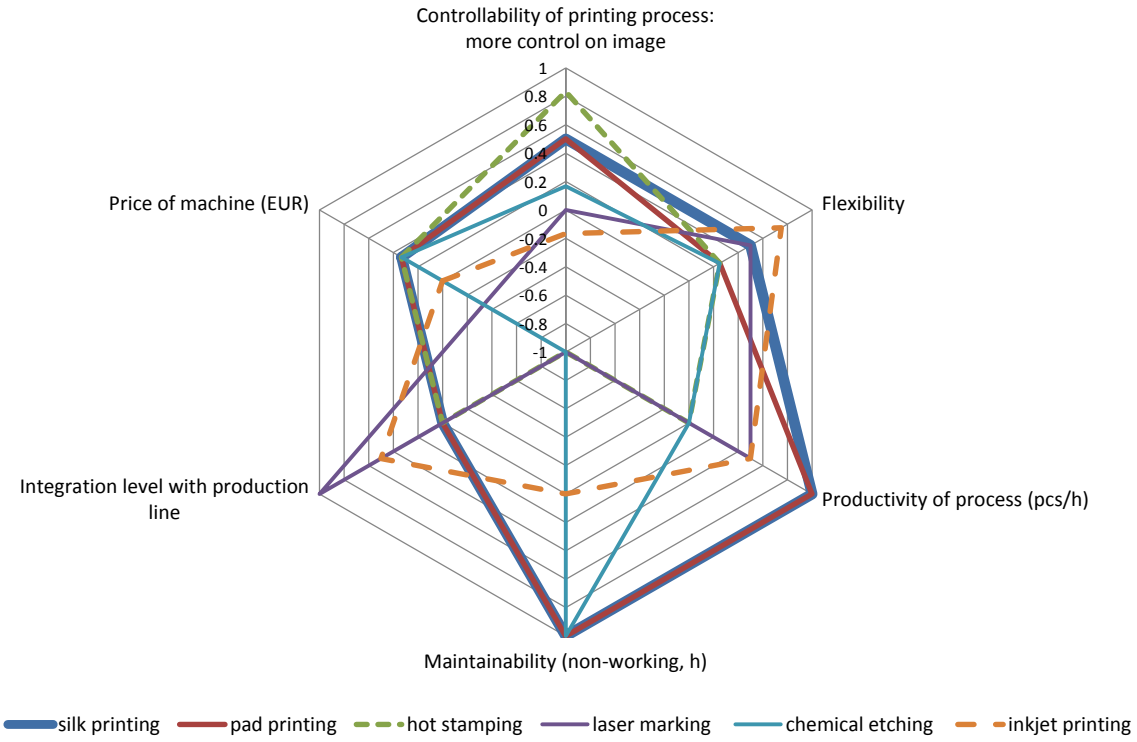


Figure 10. Assessement of competitive (alternative) technologies vs. decision criteria

A summarizing conclusion can be drawn from radar diagram presented on the Figure 10: in order to substitute the existing solutions for decoration process at WH, the future decoration technology has to provide controllability of printing process alike hot stamping; when flexibility has to be alike inkjet printing; without degradation of productivity and maintainability compared to silk printing and pad printing; including integration level of

[9] Materials of session #2 (28/02/2014):
[10] Bill of process, ADV. MANUFACTURING, BENTON HARBOR, MICHIGAN 49022 USA, Whirlpool. Confidential
[11] Ubraz M. Inkjet technology, Whirlpool Cassinetta October, 2013

decoration into production line alike laser marking (digital printing); price of technology has to be comparable or lower than present values for silk printing or pad printing.

The gaps between actual values for analysed technologies and desired values presented on periphery of radar diagram indicate the amount of problems to be solved for each alternative technology towards a desired one in future. The larger area of a diagram for a particular technology indicates higher level of adequacy for decoration process. For instance, pad printing has score 0.51 (see Figure 9) and the second largest area among analysed technologies.

3.6. Context

Identification and classification of constraints is relevant in order to understand how technological system can evolve, because allows to define boundaries and requirements for the evolution. Moreover, the classification should enrich and facilitate description of problems and their analysis.

Given this point of view, TEES classification method was used to identify current company constraints. Hence, the TEES approach was used with the goal of an all-around analysis and to detect problems of the STF (STF – System to be forecasted) that are of most current interest.

Four aspects of viewing the system have been determined: Technological, Economic, Environmental and Social. From the one hand, these aspects sufficiently give the possibility to cover the most significant connections and problems of the system. With this classification, a table has been made for the decoration technologies existing in Whirlpool based on its functional model. (Table 12) As results, 21 constraints have been formulated. In turn, the classification of constraints needs to be iteratively modified to obtain understandable results for all the team work and beneficiaries. As results of the agreement activity, the final classification is provided: 7 – with the Technological aspect, 7 – with the Economic, 2 – with the Environmental and 5 – with the Social. (Table 12) From the other hand, the classification has to be in accordance with System Operator (SO) (Figure 7) analysis; the analyst has to understand in which level of SO the constraints emerge and how these can influence the company state. In the Table 12, next to each problem, references to the corresponding screen of the SO have been given. (Figure 7)

Table 12. TEES constraints to STF (sub-system, system, super-system are references to System Operator on Figure 7)

Technological	Environmental
• Accessible to produce different kind of look and surfaces. (super-system) • Automation of production, less supplementary operations (such as prepare the ink and so on). (super-system) • Time to make decoration. (sub-systems) • Ambient conditions (temperature, humidity, level of UV, conditions of CP surface …) should be stabile during production of decoration. (sub-systems) • Production of decoration should be integrated with main production line (e.g. automation). (super-system) • Performance of modified color	• Recyclability of equipment, tools, area, HR. (system) • Material and substances has to be compatible with production process, home environment and HR, H&S (Health & Safety) ([1], page 14). (super-system)

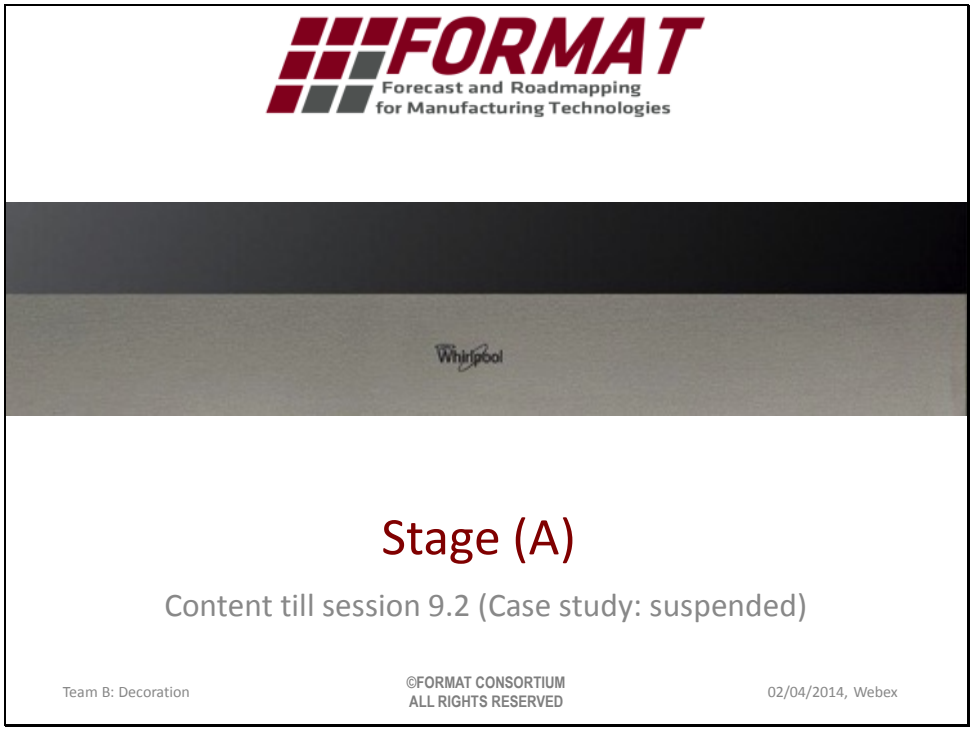
(abrasion, chemical resistance, durability). (super-system) • Material of cliché causes environmental impact. (super-system)	
Economic	Social
• Initial investment in equipment, tools, area, human resources (HR). (system) • Overall cost of running equipment (normative cost, before called SIC – S. Industrial Cost). (system) • Investment for training HR. (system) • Low production cost. (super-system) • Amount of energy used for entire production process of WH appliance. (super-system) • Investment for maintenance. (system) • How much energy is consumed to modify colors? (system)	• Result of decoration understandable for different groups of users (affordance). (super-system) • Results of decoration has to be customizable (super-system) • Whirlpool authenticity has to be recognizable.(super-system) • Education of operator in production process (adjustments, pre-installment). (super-system) • Quality of the image has to be attractive for users. (super-system)

[1] Bill of process, ADV. MANUFACTURING, BENTON HARBOR, MICHIGAN 49022 USA, Whirlpool.
[2] Meeting 27-02-2014, Whirlpool Cassinetta.
[3] Inkjet technology Marco Urbaz, Cassinetta, October 2013

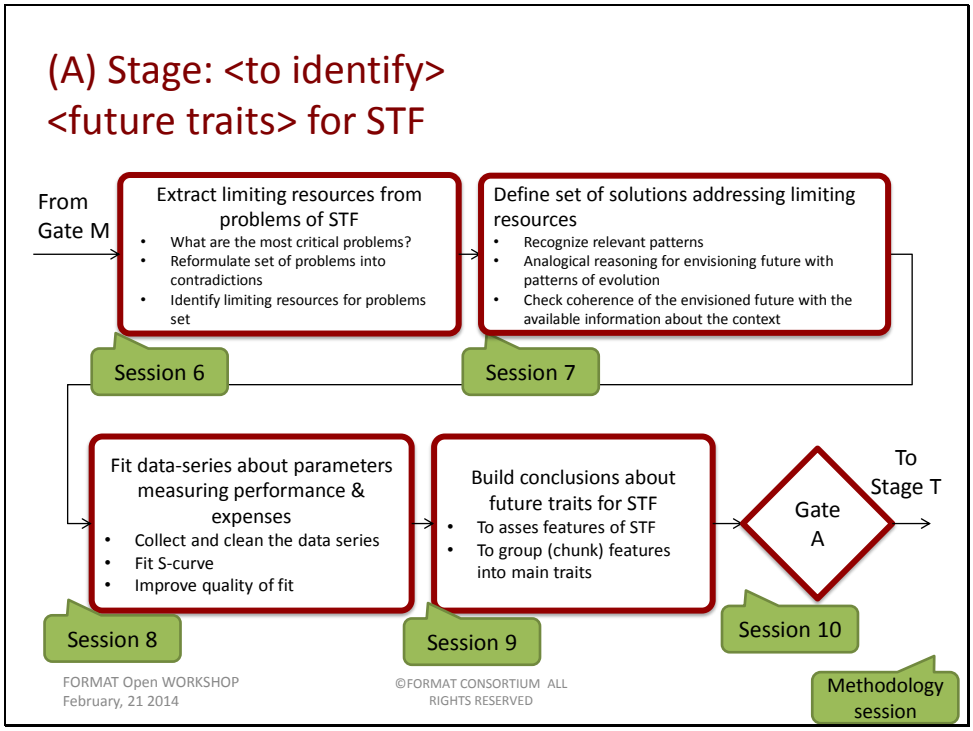
4. Stage (A)

Results of a forecasting study in stage A are presented in the form of slides from working sessions. Some of the slides are completed with comments put under the slide.

Slide 1



Slide 2



Slide 3

(A) Gate

<to identify> <future traits> for System to be Forecasted (STF)

- 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

 3

Slide 4

List of limiting resources preventing the solutions to problems that drives evolution of STF.

Team B: Decoration 4

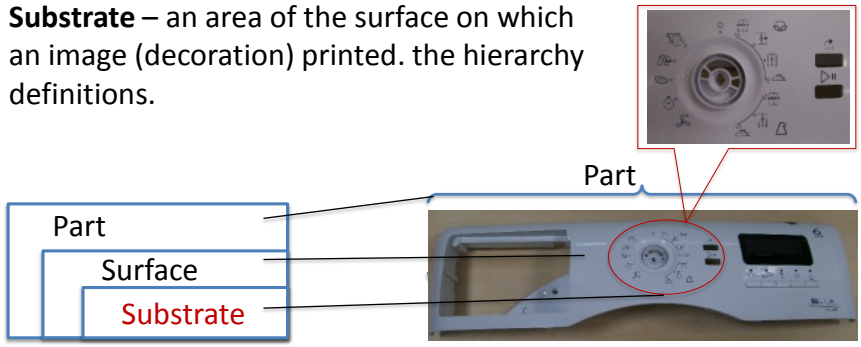
Slide 5

Definition of surface and substrate

Part – A part of something is one of the pieces, sections, or elements that it consists of. [Collins COBUILD dictionary]

Surface – it is a layer on the part where substrate is located.

Substrate – an area of the surface on which an image (decoration) printed. the hierarchy definitions.



The hierarchy of defined subjects **The front panel of washing machine**

 5

Slide 6

Critical problems of STF and limiting resources[1]

Common for all:	Multi-colors: <Modify> <colors> of substrate			
- Decoration process is off-line - time of process to modify the color	**Flat** *problems and resources common in rows for particular substance*	**2D curved**	**3D curved**	**Perforated/ texture**
Plastic	- time consumption of total cycle time is high (it is off-line) - time for ink drying	- pad printing is an only solution for non-flat surface (inside 90% decoration done in WH) - size of the image is small (due to the pressing force limits) - Radius of substrate's surface	- pad printing is an only solution for non-flat surface (inside 90% decoration done in WH) - size of the image is small (due to the pressing force limits) - Radiuses of substrate's surface	- ink is distributed on surface of unequal height (texture) - ink is distributed on discontinuous surface (perforations, holes) - Area of contact between ink and substrate
Metallic	- time of drying is long - drying emits odors - time to clean the surface in pre-process is required - time of decoration process (common) - The oxidation time of the metal surface.	- size of the image is small (due to the pressing force limits) - cycle time for drying, curing, quality control is a bottleneck - Radius of substrate's surface (size of the substrate per image applied by single pad) - The oxidation time of the metal surface.	- size of the image is small (due to the pressing force limits) - Force applied to the substrate is unequally distributed - Radiuses of substrate's surface (size of the substrate per image applied by single pad) - The oxidation time of the metal surface.	- Unequal adhesion conditions for the ink due to difference in surface height - Surface of ink to dry is higher (in case of texture) - Area of contact between ink and substrate - The oxidation time of the metal surface.
Glass	- High resistance of substance of a substrate causes low ink's attachment - Ink resistance to grease and cleaning products is low - extent of ink's ability to attach to substance*	- Number of colors is limited - Long time consumed (for drying) - extent of ink's ability to attach to substance*		- (Area of contact between ink and substrate is small (for textured)) - extent of ink's ability to attach to substance*
Porcelain (substance hardly used)	- High resistance of substance of a substrate causes low ink's attachment - Ink resistance to grease and cleaning products is low - extent of ink's ability to attach to substance*	- Ink resistance to grease and cleaning products is low - extent of ink's ability to attach to substance*	- Ink resistance to grease and cleaning products is low - extent of ink's ability to attach to substance*	

Legend: cell content in black – problems; content in red – limiting resources; content in grey – comments;*ink performance = adhesion forces, ink, number of colors, resistance in time, extent of ink's ability to attach to substance;
[1] meeting of teamwork at session 6 on 14/03/2014

Team B: Decoration 6

Slide 7

List of problems for STF

1. Which of described problems are relevant for WH?
   - No flexibility in choice of colors
   - The same technology can not be used for different shapes of surface
   - The same technology can not be used for different substrates
   - A need for frequent change overs, production in small batches (multi-language EU issue)
2. Which of the described limiting resources are relevant for WH?
   - Ink's ability to attach to substance
   - Time of ink solidification
   - Substrate's substance (e.g. ABS, PS)
   - Change over time (CN)
   - Shape of surfaces
   - Time of decoration process
3. According to the materials: what is the main problem? What are the main limiting resources?
   - Substrate's substance requires preparation
   - Limited attachment forces of a decoration to substrate (i.e. glass)
   - On glass - for strong performance ink should be applied before tempering, when for bright colors ink has to be applied after tempering
4. According to the substrate shapes: what is the main problem? what is the main limiting resource?
   - Curvature dimensions (2D and 3D)
   - Size of a decoration

Content based on results of the meeting with Fabio Moneta – an invited expert, on 25/03/2014

Team B: Decoration 7

Slide 8

Directions of development of new solutions for STF (evolutionary trends).

Team B: Decoration 8

Slide 9

Indications for - evolution

1. Recognize relevant patterns (use SO) – *take into consideration below bullets*
   - What is (are) the specific operation(s) generating bottlenecks? (slowest, consume most resources – energy, time, materials, information)
   - Identify potential further developments of the critical operations (use SO, level of sub-system).
2. What are the reasons preventing the adoption of the technology with features from stage (M) (competitive alternatives)?
3. Analysis of the functional models (stage M) using Law of ideality increase [TRIZ]: ideal machine, ideal process *(self acting process, function performed by itself)*, ideal substance.

SO – System Operator

Team B: Decoration 9

Slide 10

Bottlenecks

Alternatives	Bottlenecks [time, energy, materials]	Potential further developments	Relevant patterns
Silk screening (static)	Drying (time), pre-process (time)	Time for drying ink decreases, automation level increase (to make it in-line)	• decoration dynamization and customization, • control time reduced, • amount of information increase (Surface size is the same it means more information appear on the same size of surface, more colors) • interaction with user by touch (improved controllability) • Resistance of decoration increases during use and decrease for disposal
Silk screening (UV)	Polymerization (time), control (time), pre-process (time)	Time for polymerization and control decreases, to make it in-line	
Laser marking	Form image (time), pre-process (time)	Form image time will decrease, energy consumption will decrease	
Pad printing (automatic)	Pre-process (time), Quality control (time), Energy for process	Energy for process will decrease (in additional operations, shorter movements?)	
Pad printing (semi-automatic)	Pre-process (time), Control substrate (time), Quality control (time)	automation level increase (to make it in-line)	

Team B: Decoration 10

Slide 11

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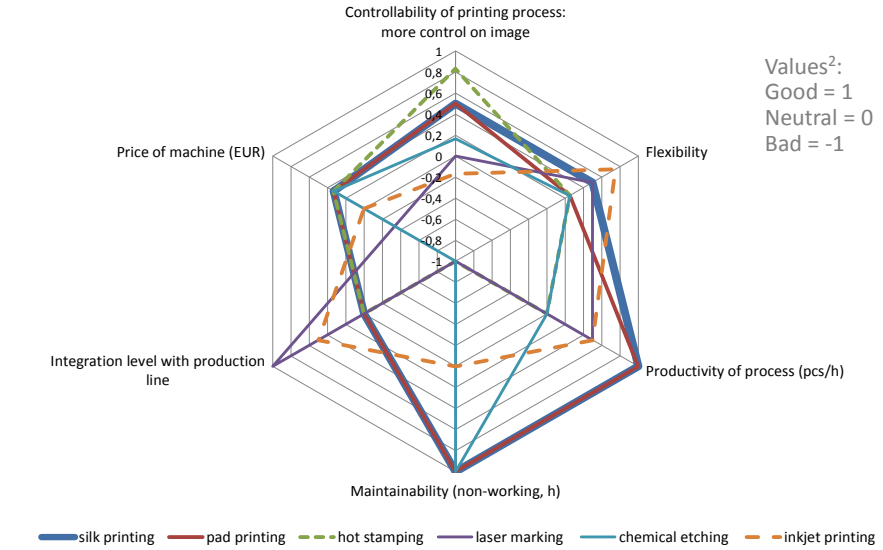
Slide 12

Content removed for confidentiality reasons.

Slide 13

Summary for Competitive (Alternative)



[2] Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: Advanced Manufacturing, Whirlpool. Confidential

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Slide 14

What are the reasons preventing the adoption of the technology with features from stage (M) (competitive alternatives)?

1. **Diversity of performed decorations** demands different characteristics for applied technologies. Therefore, from business perspectives it is unlikely to satisfy all diversity of decorations by just one technology.
2. **Replacement of technologies** is long-term improvement process; it has to be done in accordance with plan of renewal of equipment and production plans of Home appliance.
3. In order to run *innovative technologies* for decoration (e.g. like inkjet printing with "flexible" ink on 3D substrates) **long-term investments into HR** are required.
4. Requirements to perform **decoration in many languages** (particularity of EU market) put *Flexibility* and *Integration level with production line* to the first-importance places for future products of WH.
5. Decision about investments into **In-house technologies** and **Out-sourcing** production is difficult to predict without knowing long-term strategy about production and development of WH.

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The reason for something is a fact or situation which explains why it happens or what causes it to happen. [Collins Cobuild Dictionary]

Slide 15

See slide's notes too.

Analysis of the functional models (stage M) using Law of ideality increase [TRIZ]: towards ideal machine and ideal process

Features, (**functionalities in bold;** expenses in regular)	
Controllability of printing process, more control on image	Full range of color management including metallic, performance maintained during entire time of use by users of a final appliance,
Flexibility	Digital printing (no image preparation), change over t=0s, change over time for a part type t=0s
Productivity of process [pcs/h]	Cycle time close to single color silk screening, no scrap
Maintainability [non working, h]	No down time for maintenance like laser marking, towards self-maintaining
Integration level with production line	Cycle time of decoration should be coordinated with cycle time of production line
Price of machine [EUR]	Investment to new technology should be lower, below alternatives (delivering the same result), operation cost should decrease, environmental impact should be minimized

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Slide 16

Solutions addressing limiting resources

Limiting resources	Solutions
Time of process to modify the color	Time below cycle time of production line
Time for ink drying	UV curing with capacity for large size (or many) parts, time below cycle time of decoration
Radius of substrate's surface	Decoration tool maintains a fixed distance to any surface shape;
Area of contact between ink and substrate	Decoration and substrate are (tightly linked → are unified → are one)
Extent of ink's ability to attach to substance	Deep attachment, on back surface, inside substance
The oxidation time of the metal surface.	

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Slide 17

System operator: super-systems

2004

1. Home appliances from different companies in one home
   - Partially integrated
2. WH appliances with less information
3. Control Panel (CP) with less information and less control options
4. Users manipulate
   - No touch-screen experience for user
5. To attract client
   - Not so much concern about energy saving
   - Not so much attention to esthetic
   - New options less important
6. recyclability of home appliance was less important
7. Gradation of color was not relevant.
8. In it not possible create customized CP
9. Decoration of CP mostly by printed.
10. Whirlpool authenticity (brand, logo, look of products) was less recognizable.

2014

1. Home appliances around (home)
   - Esthetically similar from 2 or 3 companies;
2. WH appliances
   - Manual print and pdf
3. Control Panel (CP) production and use
4. Users[5] manipulate
   - with CP - to setup Home appliances (learn how to)
5. To attract client
   - esthetic,
   - novelties
   - information
   - chemical resistances)
6. recyclability of home appliance growth in importance
7. Gradation of color it is possible with ink-jet (not applied in WH)
8. It is possible to create customized CP in high-end appliances.
9. Combined decoration of CP (display + printed)
10. Whirlpool authenticity (brand, logo, look of products) is recognizable.

2024

1. Home appliances from one hand (e.g. IKEA+WH)
   - Integrated esthetically, electronically and by data-information
2. WH appliances provide more information (more sensors & data)
3. Control Panel (CP) has to delivered more information and control
4. Users manipulate (easy to setup)
   - More touch-screening experiences.
   - New Options are attractive
   - Easy to use.
5. To attract customer
   - esthetic,
   - novelties,
   - **easy to use,**
   - smart energy consumption;
   - improved chem. resistances
6. Recyclability will be more important
7. Gradation of color in the design of CP??
8. User can create their own CP for more products
9. Most of decoration of CP with an electronic User-Interface (multi-language)
10. Whirlpool authenticity (brand, logo, look of products) more recognizable.

[2] Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: Advanced Manufacturing, Whirlpool. Confidential
[3] Session 1.2, 27-02-2014, Whirlpool Cassinetta.
[4] Inkjet technology Marco Urbaz, Cassinetta, October, 2013
[5] Man, woman, elderly people, teenagers, kids

 17

Slide 18

System operator: system and sub-systems

Super-systems for 2004	Super-systems for 2014	Super-systems for 2024
<Modify> <colors> <of surface> 1. Output is mostly **non-changeable** (printed) 2. Decoration process: • with large stock, • it is off-line, • recyclability of equipment was not an issue • energy consumption was not an important issue. 3. Investment in equipment, tools, HR, maintenance was lower. 4. Front surface used for decoration	<Modify > <colors> <of surface> (to deliver information to users[5] & to improve esthetic experience) 1. Output of decoration is **printed** and changeable (display) 2. Decoration process: • with stock, • it is **off-line**, • recyclability of equipment and tools (!) • energy consumption (!) 3. Investment in equipment, HR and maintenance is higher. 4. Rear surface is used for decoration	<Modify > <colors> 1. Output of decoration is printed and/or **dynamic** 2. Decoration process: • without stock, • it is in-line , • increased recyclability of equipment and tools, • reduced energy consumption. 3. More (??) investment for equipment, HR and maintenances. 4. Back side of Intermediate layer used for decoration
• Silk screening (60%) • Pad printing (40%)	• Silk screening • Pad printing • Others 10% • Laser marking	• More diversity of applied technologies for different substrates and products. • Time form operator's involvement will decrease; • preprocess time decrease
2004	**2014**	**2024**

[5] Man, woman, elderly people, teenagers, kids

 18

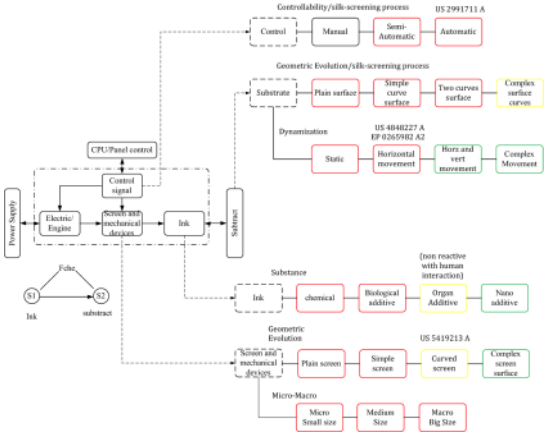
Slide 19

Application to pad-printing and silk-screening technology

- **Recognize relevant patterns and analogical reasoning for envisioning future with patterns of evolution.**
  - Definition of Minimum Technical System for pad-printing and silk-screening
  - Recognize patterns for Tools, transmission, control and object.
- **Check coherence of the envisioned future with the available information about the context.**

Slide 20

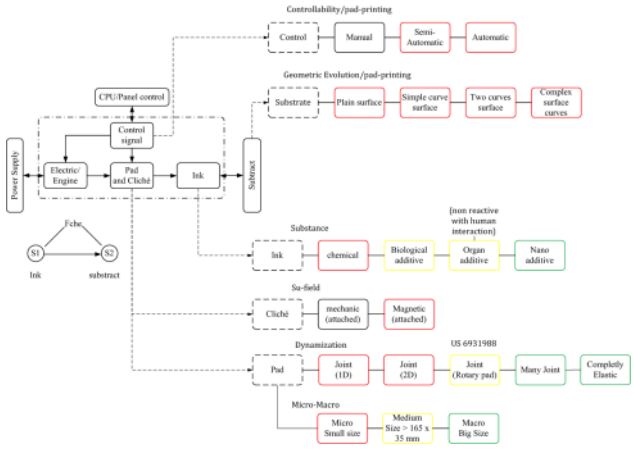
Analogical reasoning for envisioning future with patterns of evolution: Silk-Screening



[1] Patent nº US 5419213 (A)(1993) "Apparatus and method for the silk-screen printing of multiple curved peripheral surfaces of an article defined by multiple curved peripheral surfaces"
[2] Patent nº US 2991711 (A) (1954) "Fully automatic silk-screen printing machine movement of surface"
[3]Patent nº EP 0265982 (A2) (1986) "Machine for the multi-colour silk-screen printing of cylindrical containers in general"
[4]Patent nº US 4848227 (A)(1981) "Device for the silk-screen printing of cylindrical objects having an elliptical cross-section"
[5] Inkcups Now(March-2014), http://www.inkcups.com/
[6] http://www.triz.co.kr/TRIZ/frame.html
[7] Glenn Prestwich(2007). Instant insight: Organ printing, Highlights in Chemical Biology, 5.

Slide 21

Analogical reasoning for envisioning future with patterns of evolution: Pad-Printing



[1]Dongguan Ruida Machinery And Equipment Co., Ltd.(March-2014) /http://dgnewman.en.alibaba.com/
[2] Inkcups Now(March-2014), http://www.inkcups.com/
[3]CarePrint (March-2014) http://www.padprinting.in/pad-printing-machine/
[4] Patent nº US 6931988 (2004) "Rotary head pad printer"
[5] http://www.triz.co.kr/TRIZ/frame.html
[6] Glenn Prestwich(2007). Instant insight: Organ printing, Highlights in Chemical Biology, 5.

Slide 22

Check coherence of the envisioned future with the available information about the company context

Technology	Minimum Technical System	Description of the past solution and patterns	Expected benefits
Both technologies	ink	Increase the ink performance using different additive: Biological-ink is a ink that not produce environmental damage; Organ-ink is a ink that non-react with human interaction, nano-ink are possible future ink with new properties.	Drying time, quality of image
Both technologies	Substrate	Geometric evolution: Complexity of the shape surface has been increased given customers' demands.	Flexibility of the process
Silk-screening	control	Controllability: currently, there are automatic silk-screening, but process can still reducing the time consumption.	Process and pre-process time
Silk-screening	Substrate	Dynamization: There are some silk-screening machines capable to move the substrate in order to improve the decoration process.(e.g. moving the substrate is possible to print curve surface)	Flexibility of the process

Slide 23

Check coherence of the envisioned future with the available information about the company context

Technology	Minimum Technical System	Description of the past solution and patterns	Expected benefits
Silk-screening	Screen	Dynamization: Some silk-screening machines have a dynamic screen capable to track specific movement(e.g. horizontal).	Flexibility of the process
Pad-printing	Pad	Dynamization: Some pad-printing machines have a dynamic pad capable to track specific movement(e.g. vertical, horizontal and angles).	Flexibility of the process
Pad-printing	Pad	Micro-Macro: Size of the pad has been increased in the last year, however there some limitation in terms of ink performance.	Flexibility of the process
Pad-Printing	Cliché	Substance-Field involvement: In the past, the cliché was attached at the machine using different types of nuts and bolts , now the cliché is magnetic in order to reduce the pre-process time.	Flexibility of the process

Team B: Decoration 23

Slide 24

Dynamics of parameter(s) measuring Performance & Expenses for STF (data series and graphs)

Not completed – Case study is suspended.

Team B: Decoration 24

Slide 25

This slide is copied from Stage (M) in order to recall a data availability question.

Measure of Performance & Expenses for STF and for Competitive Solutions

Six decision criteria (3 for performance and 3 for expenses):

1. Controllability of printing process: more control on image
2. Flexibility
3. Productivity of process (pcs/h)
4. *Maintainability (non-working, h)*
5. *Integration level with production line*
6. *Cost of equipment, operation and human resources (EUR)*

It is suggested to measure the growth and competition of decoration technologies by **number of parts** produced (decorated) **per Quarter** with a particular technology starting from 2004 (2009 at least) at European factories.

Reference documents for required data:
1. DoP – Declaration of Production,
2. OEE – Overall Equipment Efficiency

 25

This slide is a copy from stage (M).

Slide 26

Alternative Measure of Performance & Expenses for STF and for Competitive Solutions

1. Development history of decoration technologies in industry (not only in WH also in other EU companies)
2. Numbers of purchased machines (from: industry or suppliers)

Team B: Decoration 26

Proposition made after encountering difficulty in obtaining of data that availability had been originally investigated.

Slide 27

Searching data outside of the factory

It is suggested to measure the growth and competition of decoration technologies by **number of parts** produced (decorated) **per Quarter** with a particular technology starting from 2004 (2009 at least) at European factories.

There are tree possible ways :

1. From the all Whirlpool factories (internal information)
2. From the produces of decorating machines (external information)
3. From books, reports in which compared decorating technologies and provides statistics (external information)

The Sources:

- Eurostat web site
- Google books web site
- E-Libraries
- Magazine "Plastics Decorating"
- Search the Internet

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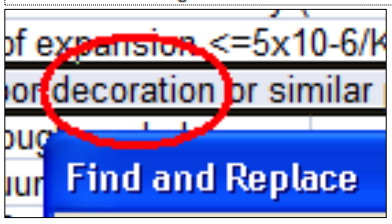
Slide 28

Searching data outside of the factory

Decoration and Assembly of Plastic Parts books.google.com

books.google.com
Edward A. Muccio - 1999 - Страниц: 253
Table 6.1 provides suggestions for troubleshooting **pad printing** operations. Vertical Printing Technology Figure 6.7 compares three **pad printing** methods. Vertical-acting applications, similar to the one described in the section "**Pad Printing** ...



Website_snapshot_2012_created_2014-03-12_N2

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Slide 29

Searching data outside of the factory

It is suggested to measure the growth and competition of decoration technologies by **number of parts** produced (decorated) **per Quarter** with a particular technology starting from 2004 (2009 at least) at European factories

Why the direct question to the produces of decorating machines not possible?

- There are many companies
- These data are very sensitive
- Some machines are importing from others countries
- Some machines are exporting to others countries

The conclusion. In these available sources the necessary data were not found. The possible reason is that these data are hidden in more general groups.

Team B: Decoration 29

Slide 30

Aggregated conclusions about future traits for STF

Not started yet - Case study is suspended.

Case study had been suspended for a while but then it was restarted to provide a conclusion of a first round of FORMAT methodology application. Conclusion will be presented in stage T.

Slide 31

Gate (A)

Status: open

Comments:

- *Recognizable patterns in technological evolution – performed using guidelines adapted from methodology v.2 and NB's ToK presentation*
- *System Operator was used also in pattern recognition*
- *Recognized patterns bind thinking to current solutions.*

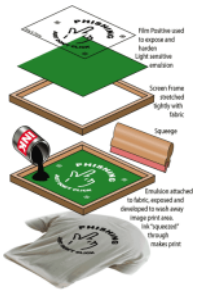
Note!
In this case study step 3 in stage A was not concluded successfully. Data required to perform tasks in step 3 of stage A were not available. Due to the lack of results from step 3 in stage A quantitative results of a forecasting study are not delivered. It was decided to proceed to next stage without quantitative forecast and to present a forecast based on qualitative study. This conclusion, however only qualitatively is enough to pass the gate A and proceed to stage T.

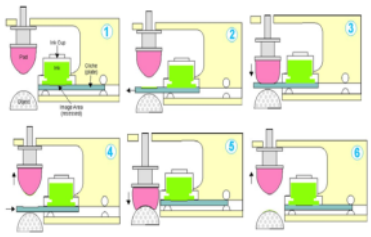
5. Stage (T)

Transfer of results from 'decoration' forecasting case study to the decision makers and practitioners was performed by the means of presentation that is reproduced in the following pages in the form of slides' pictures.

Slide 1

DECORATION





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Slide 2

Decoration

Main function: [to modify] [color of] [a surface]

SURFACES

Plastics: PVC (thermoplastic), ABS, thermosetting polymers

Metal: steel, stainless steel, painted steel, aluminum, chrome

Glass: vitroceramic, soda lime glass, colored (tinted) glass

Porcelain

Surface's shape: flat, 2D curved, 3D curved, perforated, textured surface

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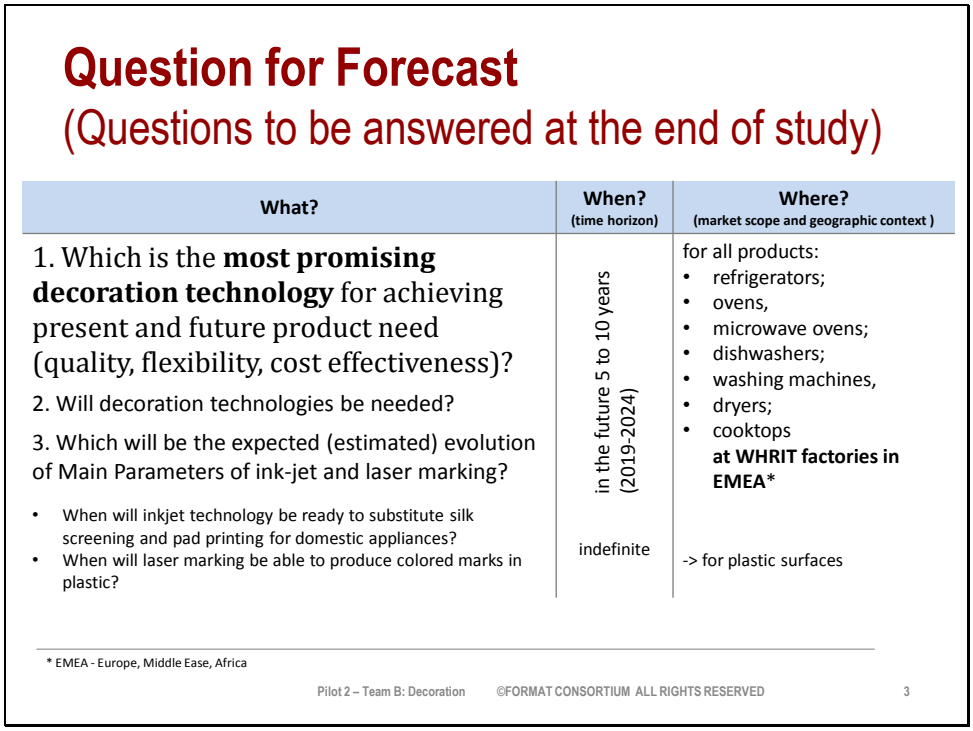
Slide 3



Question for Forecast
(Questions to be answered at the end of study)

What?	When? (time horizon)	Where? (market scope and geographic context)
1. Which is the **most promising decoration technology** for achieving present and future product need (quality, flexibility, cost effectiveness)? 2. Will decoration technologies be needed? 3. Which will be the expected (estimated) evolution of Main Parameters of ink-jet and laser marking?	in the future 5 to 10 years (2019-2024)	for all products: • refrigerators; • ovens, • microwave ovens; • dishwashers; • washing machines, • dryers; • cooktops **at WHRIT factories in EMEA***
• When will inkjet technology be ready to substitute silk screening and pad printing for domestic appliances? • When will laser marking be able to produce colored marks in plastic?	indefinite	-> for plastic surfaces

* EMEA - Europe, Middle Ease, Africa

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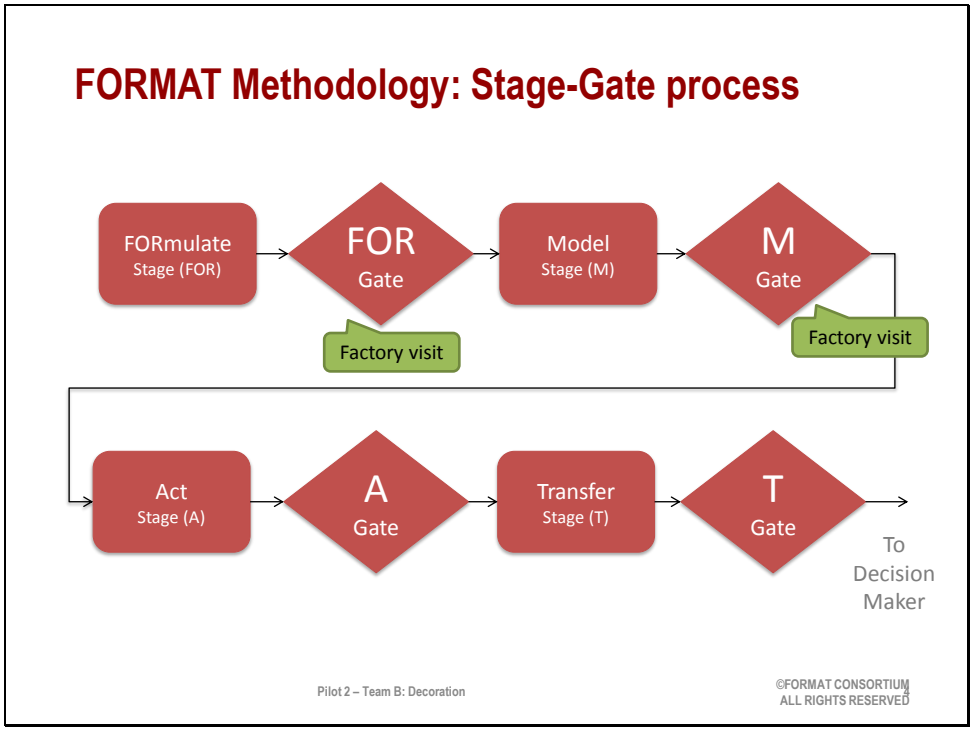
[**Decoration is a part of human-machine interface**]

- It depends on substrate, number of colors and required resolutions: Decoration will become more dynamic (changing with time, see e-ink), less 'crowded' (needed decoration at needed time) a few of permanent decoration;
- Yes, it will be needed
- See the radar diagram

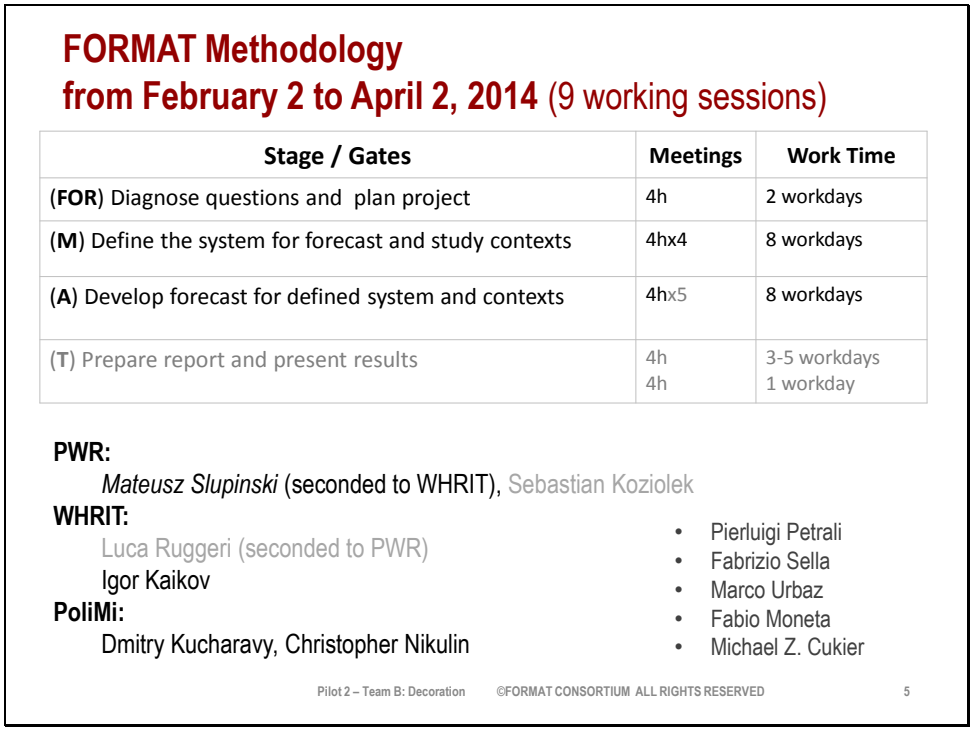
  3.1. It will not substitute in 5 years, but it will be a complementary technology in 10 years for specific substrates when colors are required (no detail answer with time series)

  3.2. It will not happen on industrial level in 5 years.

Slide 4



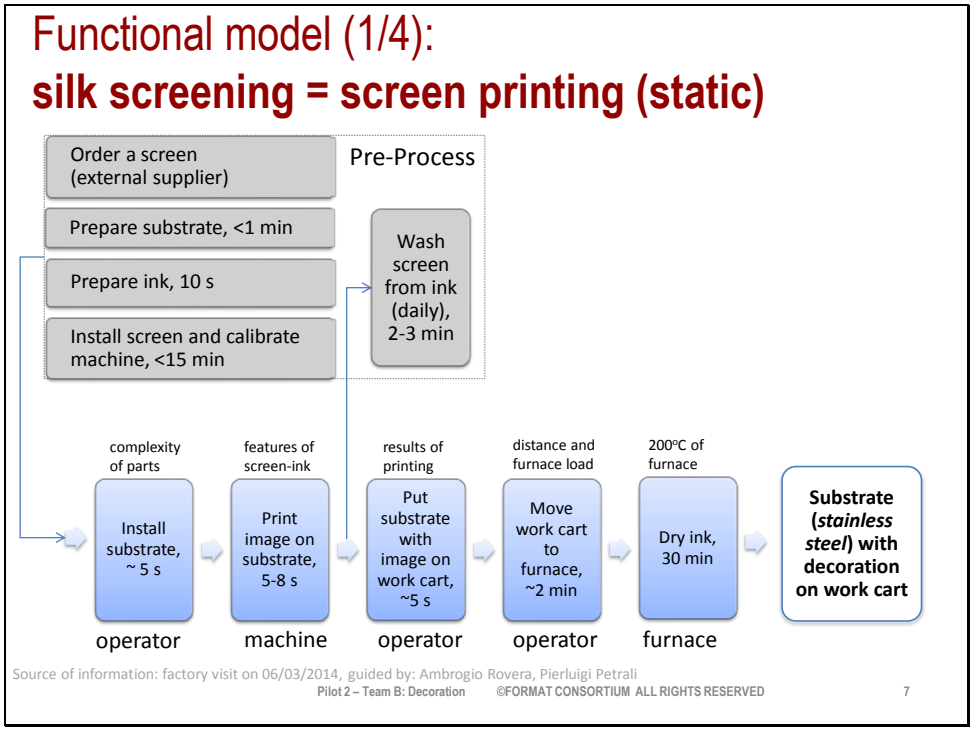
Slide 5



Slide 6

Model of STF at the functional level

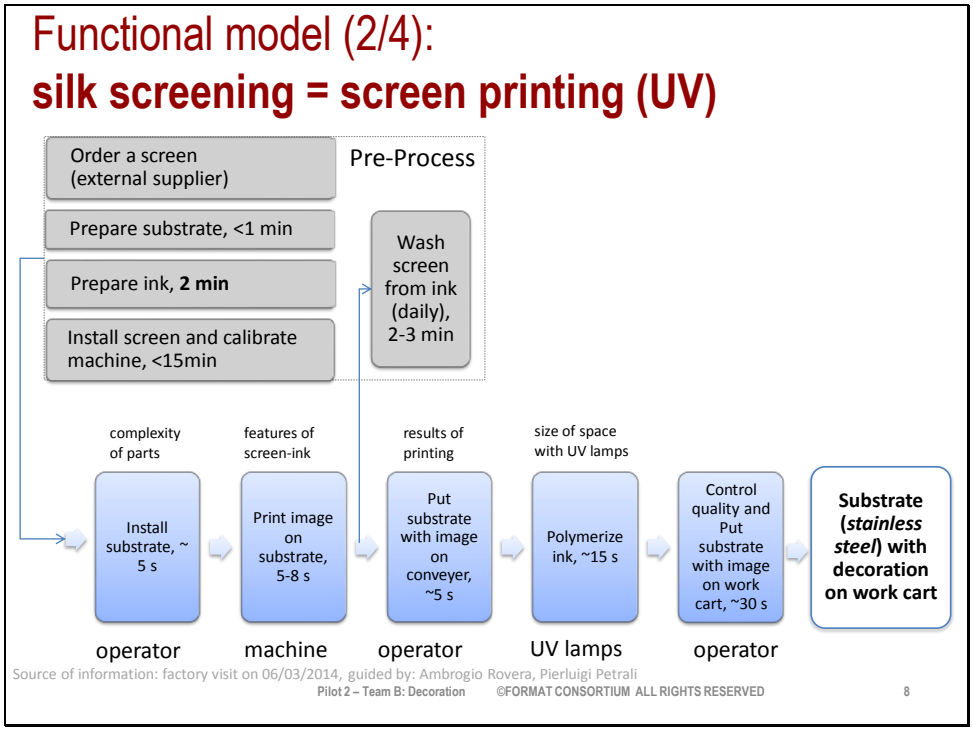
Slide 7



By DK for session 04 - Print image on screen:
- Supply the ink on screen (using machine);
- Apply pressure and push the ink through the screen (using the edge of the squeegee)
- Separate screen & surface (using machine)

(Altered after visit in Cassinetta factory on 06/03/2014)

Slide 8

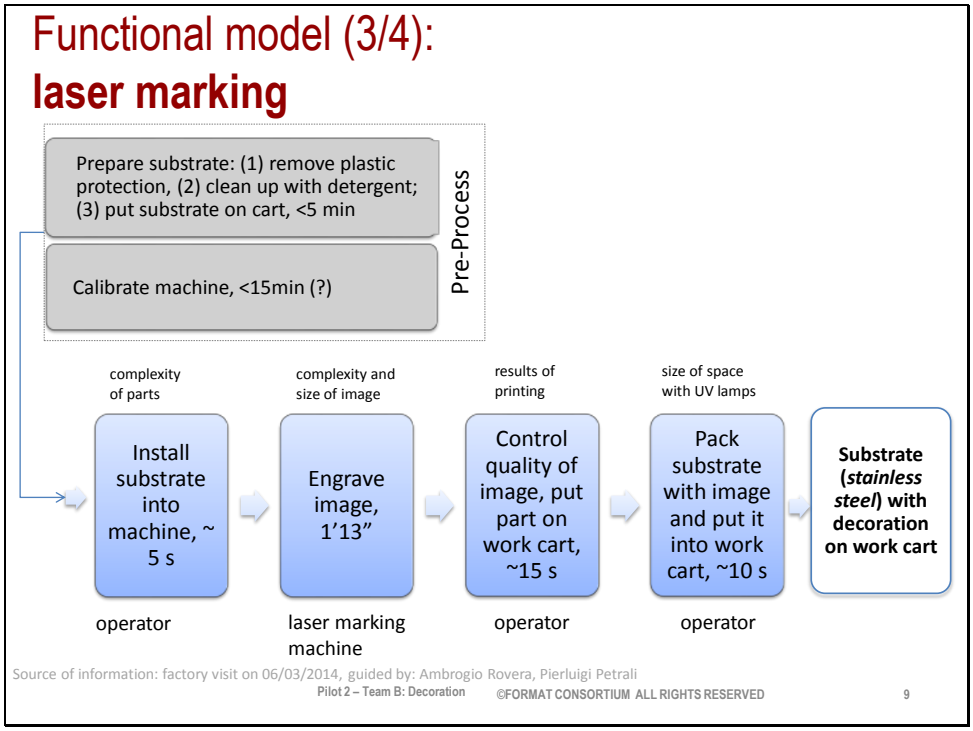


By DK for session 04 - Print image on screen:

- Supply the ink on screen (machine);
- Apply pressure and push the ink through the screen (the edge of the squeegee)
- Separate screen & surface (machine)

(Altered after visit in Cassinetta factory on 06/03/2014)

Slide 9



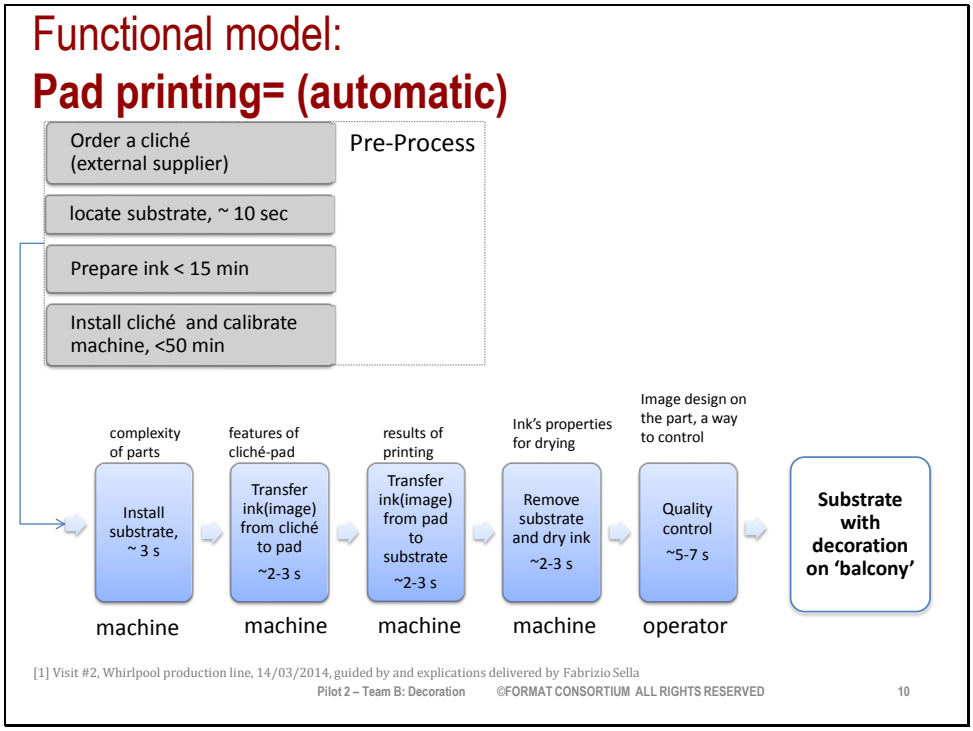
By DK for session 04 - [http://en.wikipedia.org/wiki/Laser_marking]
Laser engraving, and laser marking, is the practice of using lasers to engrave or mark an object. The technique does not involve the use of inks, nor does it involve tool bits which contact the engraving surface and wear out. These properties distinguish laser engraving from alternative engraving or marking technologies where inks or bit heads have to be replaced regularly.

The impact of laser engraving has been more pronounced for specially designed "laserable" materials. These include laser-sensitive polymers and novel metal alloys.

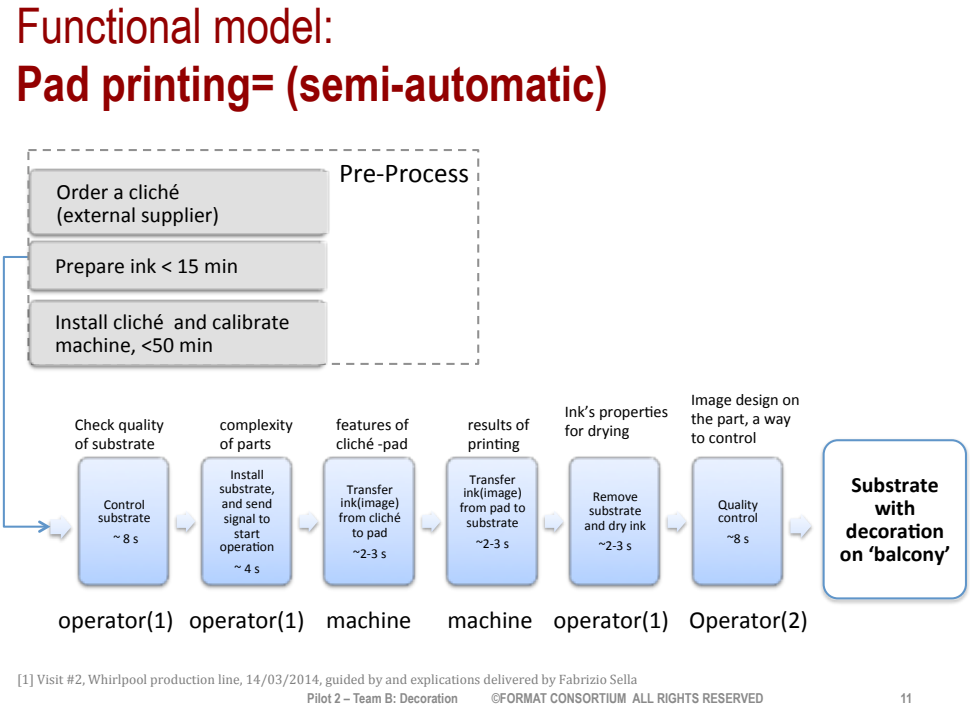
The term laser marking is also used as a generic term covering a broad spectrum of surfacing techniques including printing, hot-branding and laser bonding. The machines for laser engraving and laser marking are the same, so that the two terms are usually interchangeable.

(Added after visit in Cassinetta factory on 06/03/2014)

Slide 10



Slide 11



Slide 12

Description of Competitive (Alternative) technologies and solutions

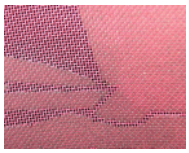
List of decoration technologies considered at WH:

1. silk screening (screen printing); IN/OUT
2. pad printing (tampography); b) multi-stations, c) with semi-automation; IN/OUT
3. hot stamping; IN/OUT
4. laser marking (laser graphic imaging); IN
5. chemical etching (etching on metals; etching on glass); OUT
6. Ceramic paste; OUT
7. Inkjet printing; NOT YET USED

IN/OUT refers to utilization of a particular technology IN Whirlpool factories or only as an element bought OUT side of Whirlpool.

Slide 13

Competitive (Alternative) (1/7): silk screening (screen printing)



A macro photo of a screen print with a photographically produced **stencil**. The ink will be printed where the stencil does not cover the substrate*.

Screen printing is a printing technique that uses a woven mesh to support an ink-blocking stencil to receive a desired image.

Disadvantages identified for silk screening

1	It is difficult to apply for curved surfaces, when radius is small
2	High time consumption for pre-process (create design, molds, films, etc)
3	Only one color can be printed at the same time
4	Multiple stages to add additional color in the image (one color more = one machine more)

[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential
[2] Session 1.2, 27-02-2014, Whirlpool Cassinetta.
[3] http://en.wikipedia.org/wiki/Screen_printing#Screen_printing_press

Slide 14

Competitive (Alternative) (2/7): **pad printing**

Pad printing is a printing process that can transfer a 2-D image onto a 3-D object. This is accomplished using an indirect offset (gravure) printing process that involves an image being transferred from the cliché via a silicone pad onto a substrate.

Disadvantages identified for pad printing

1	Inadequate resolution and esthetic for large surface cause by pressure of the machine.
2	No metallic effect (may be an important factor for customer decision), limited flexibility to prepare colors.
3	It is necessary pre-install films and clichés according each new image.
4	Waste of films and clichés due to iterations for each new image.

[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential
[2] Session 1.2, 27-02-2014, Whirlpool Cassinetta.
[3] Pad-printing, description process: available :http://www.teca-print.ch/eng/Padprinting/Tampondruckverfahren_E_706-000-240.pdf
[4] http://en.wikipedia.org/wiki/Pad_printing

Slide 15

Competitive (Alternative) (3/7): **hot stamping**

Hot stamping is a dry printing method of lithography in which pre-dried ink or foils are transferred to a surface at high temperatures.

Main feature of hot stamping at WH: – applied for making a metal gloss decoration on substrate; – hot stamp pressing; – pressed cliché; – controllable pressing force; – applicable on plastics such ABS, polypropylene, enameled steel; – initial set up is complex.

Pros	Cons
Change over time is under 5 min	impractical for reworking
Cycle time	Low operation cost effectiveness
Non-polluting process because paint is dry	High scrap rate
Durability, chemical resistance, abrasion resistance	Long change over under 1 cycle
Relative low investment	Not easy for maintenance
Chrome/metal appearance	Control of pressure power
Resolution	Requires a cliché
Environment friendly green	Initial set up is complex
	0.2 mm raised geometry is recommended for optimum hot stamping transfer

[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential
[2] Wikipedia http://en.wikipedia.org/wiki/Hot_stamping

Slide 16

Competitive (Alternative) (4/7): **laser marking**

The laser beam modifies the material surface, creating permanent marks without removing material or impacting surface integrity[2]. At WH it is applied for *making digitally processed decoration with zero change over time.*

Pros	Cons
• zero change over (no tooling change required) – 1/1 principle in manufacturing possible to apply • Durability • Lower scrap rate • Environment friendly green • Range of application from small to large • Resolution • Change over over one cycle	• Costly maintenance • Costly utilities • high cycle time • Higher level of expertise for maintenance • Exchange pieces (spare parts) are unique for particular application • **Chemical resistance worse** then silk screening • Low operation cost effectiveness • No color complexity management • No chrome/metallic appearance

[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential
[2] http://www.ulsinc.com/

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Slide 17

Competitive (Alternative) (5/7): **chemical etching**

Etching refers to the technique of creating decoration on the surface of metal or glass by applying acidic, caustic, or abrasive substances.

Pros	Cons
• Cheap, [1] • Relative low investment [3] • Lower scrap rate [3] • Ease of maintenance [3] • almost no damage due to purely chemical nature, [1] • highly selective [1] • Durability, chemical resistance, abrasion resistance [3] • Relative quick change over [3] • Range of application small to large [3]	• Inadequate anisotropy, [1] • inadequate process control (temperature sensitivity), [1] • inadequate particle control, [1] • high chemical disposal costs, [1] • difficult to use for small parts. [1] • No color complexity management [3] • No chrome/metallic appearance[3] • Limited substrate application[3] • No environment friendly green [3] • Long cycle time [3] • Long change over under one cycle [3]

Isotropic[2] – Etching proceeds at equal rates in both horizontal and vertical direction
Anisotropic[2] – Etching proceeds faster in one plane than in another
Selectivity[2] – The ability of the etch process to distinguish between the layer to be etched and the material not to be etched

[1] For wet chemical etching by Alan Doolittle, PhD, Georgia Tech, http://users.ece.gatech.edu/~alan/ , Lecture 11 Etching Techniques Reading: Chapter 11
[2] Isotropic, Anisotropic, Selectivity – from: Maricopa Advanced Technology Education Center, part of the Academic Affairs Division, Maricopa Community College District
[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential

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Slide 18

Competitive (Alternative) (6/7): inkjet printing

Inkjet printing is a type of computer printing that creates a digital image by propelling droplets of ink onto paper, plastic, or other substrates.

Expected application at WH: To make digitally processed decoration in wide scale of color with up to photorealistic resolution.

Pros	Cons
• Graphics resolution (Photorealistic) • Entire surface can be covered • It is possible to apply on small surface • Digital image process (pre-process) is less than 30 min • customization of image with real-time data • Different kind of thickness for graphics • Diversity of colors applied on one surface • Gradient effect is possible • High flexibility for different types of images • Adequate cycle time [s/pcs] • Adequate change over time	• Relatively high process time for long surface. • Number of colors is constrained by cartridge from suppliers (It is not possible to create a new colors) • **Ink performance is not adequate for corrosion** • It's not possible to make the metallic colors

[1] Ubraz M. Inkjet technology, Whirlpool Cassinetta October, 2013

Slide 19

Description for STF

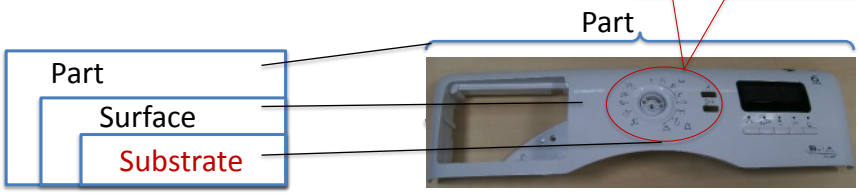
Slide 20

Definition of surface and substrate

Part – A part of something is one of the pieces, sections, or elements that it consists of. [Collins COBUILD dictionary]

Surface – it is a layer on the part where substrate is located.

Substrate – an area of the surface on which an image (decoration) printed. the hierarchy definitions.



The hierarchy of defined subjects **The front panel of washing machine**

Slide 21

System operator: super-systems

2004

1. Home appliances from different companies in one home
   - Partially integrated
2. WH appliances with less information
3. Control Panel (CP) with less information and less control options
4. Users manipulate
   - No touch-screen experience for user
5. To attract client
   - Not so much concern about energy saving
   - Not so much attention to esthetic
   - New options less important
6. recyclability of home appliance was less important
7. Gradation of color was not relevant.
8. In it not possible create customized CP
9. Decoration of CP mostly by printed.
10. Whirlpool authenticity (brand, logo, look of products) was less recognizable.

2014

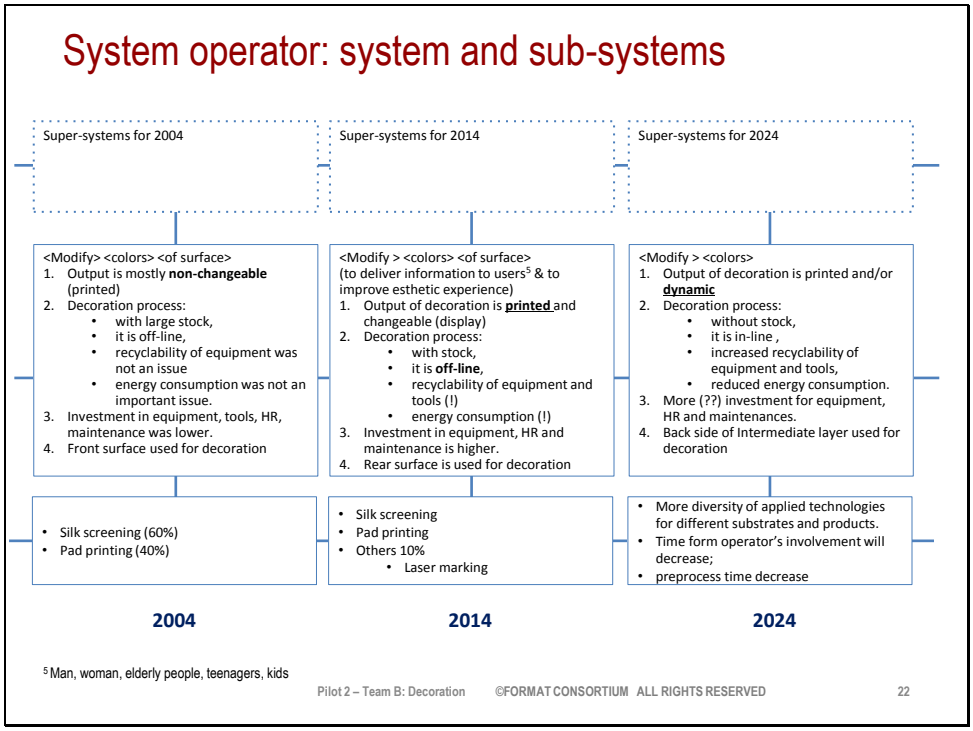
1. Home appliances around (home)
   - Esthetically similar from 2 or 3 companies;
2. WH appliances
   - Manual print and pdf
3. Control Panel (CP) production and use
4. Users[5] manipulate
   - with CP - to setup Home appliances (learn how to)
5. To attract client
   - esthetic,
   - novelties
   - information
   - chemical resistances)
6. recyclability of home appliance growth in importance
7. Gradation of color it is possible with ink-jet (not applied in WH)
8. It is possible to create customized CP in high-end appliances.
9. Combined decoration of CP (display + printed)
10. Whirlpool authenticity (brand, logo, look of products) is recognizable.

2024

1. Home appliances from one hand (e.g. IKEA+WH)
   - Integrated esthetically, electronically and by data-information
2. WH appliances provide more information (more sensors & data)
3. Control Panel (CP) has to delivered more information and control
4. Users manipulate (easy to setup)
   - More touch-screening experiences.
   - New Options are attractive
   - Easy to use.
5. To attract customer
   - esthetic,
   - novelties,
   - **easy to use,**
   - smart energy consumption;
   - improved chem. resistances
6. Recyclability will be more important
7. Gradation of color in the design of CP??
8. User can create their own CP for more products
9. Most of decoration of CP with an electronic User-Interface (multi-language)
10. Whirlpool authenticity (brand, logo, look of products) more recognizable.

[2] Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: Advanced Manufacturing, Whirlpool. Confidential
[3] Session 1.2, 27-02-2014, Whirlpool Cassinetta.
[4] Inkjet technology Marco Urbaz, Cassinetta, October, 2013
[5] Man, woman, elderly people, teenagers, kids

Slide 22



Slide 23

Slide 24

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Slide 25

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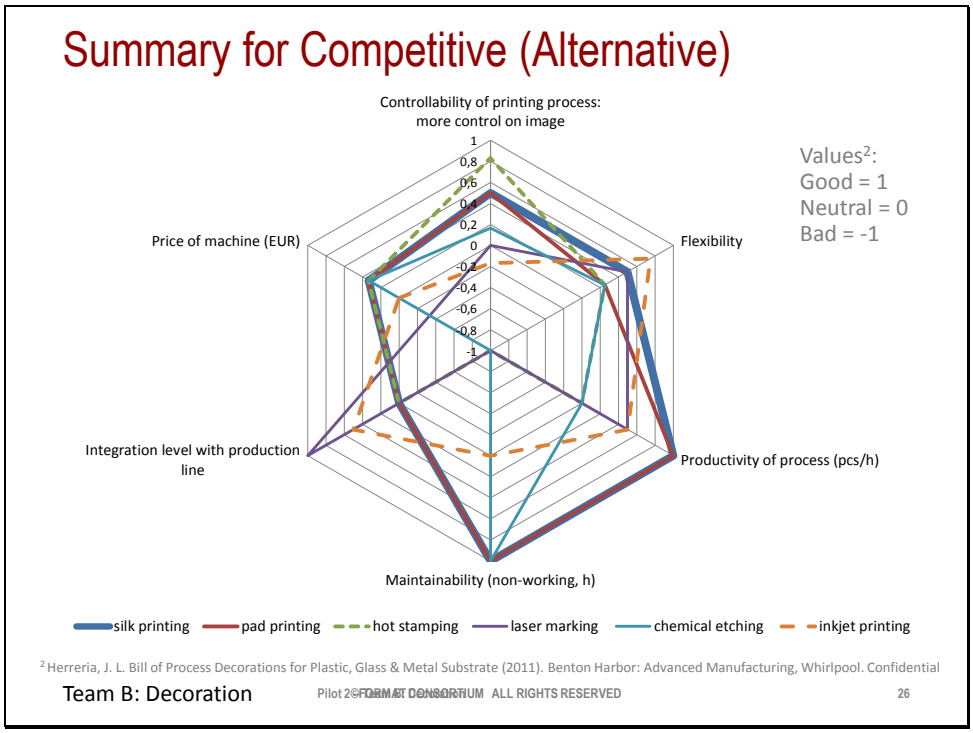
Slide 26



Slide 27

TEES-constraints to STF

TEES = Technological, Economic, Environmental, Social

TECHNOLOGICAL	ENVIROMENTAL
- Accessible to produce different kind of look and surfaces. (super-system) - Automation of production, less supplementary operations (such as prepare the ink and so on). (super-system) - Time to make decoration. (sub-systems) - Ambient conditions (temperature, humidity, level of UV, conditions of CP surface …) should be stabile during production of decoration. (sub-systems) - Production of decoration should be integrated with main production line. (e.g. automation). (super-system) - performance of modified color (abrasion, chemical resistance, durability). (super-system) - material of cliché causes environmental impact. (super-system)	- Recyclability of equipment, tools, area, HR. (system) - material and substances has to be compatible with production process, home environment and HR, H&S (Health & Safety) ([1], page 14). (super-system)
ECONOMIC	**SOCIAL**
- Initial investment in equipment, tools, area, human resources (HR). (system) - overall cost of running equipment (normative cost, before called SIC – S.. Industrial Cost). (system) - Investment for training HR. (system) - Low production cost. (super-system) - Amount of energy used for entire production process of WH appliance. (super-system) - Investment for maintenance. (system) - How much energy is consumed to modify colors? (system)	- Result of decoration understandable for different groups of users (affordance). (super-system) - Results of decoration has to be customizable (super-system) - Whirlpool authenticity has to be recognizable.(super-system) - Education of operator in production process (adjustments, pre-installment). (super-system) - Quality of the image has to be attractive for users. (super-system)

[1] BoP, Herreria, J. L. Bill of Process Decorations for Plastic, Glass & Metal Substrate (2011). Benton Harbor: ADVANCED MANUFACTURING, Whirlpool. Confidential
[2] Meeting 27-02-2014, Whirlpool Cassinetta.
[3] Inkjet technology Marco Urbaz, Cassinetta, October 2013

Slide 28

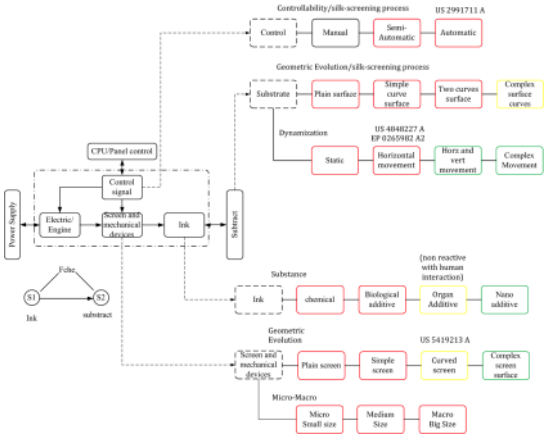
Application to pad-printing and silk-screening technology

- **Recognize relevant patterns and analogical reasoning for envisioning future with patterns of evolution.**
  - Definition of Minimum Technical System for pad-printing and silk-screening
  - Recognize patterns for Tools, transmission, control and object.
- **Check coherence of the envisioned future with the available information about the context.**

Team B: Decoration

Slide 29

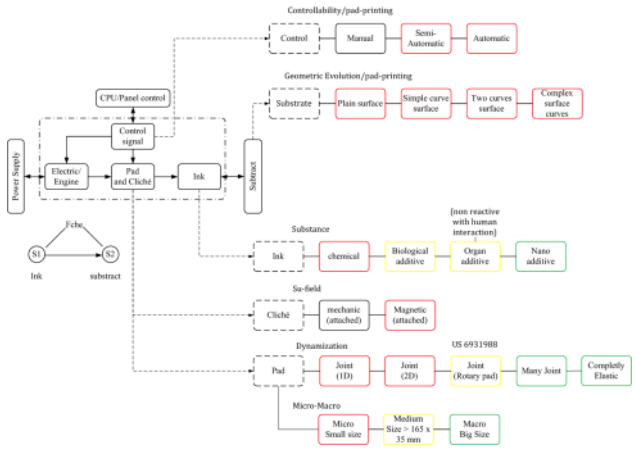
Analogical reasoning for envisioning future with patterns of evolution: Silk-Screening



[1] Patent nº US 5419213 (A)(1993) "Apparatus and method for the silk-screen printing of multiple curved peripheral surfaces of an article defined by multiple curved peripheral surfaces"
[2] Patent nº US 2991711 (A) (1954) "Fully automatic silk-screen printing machine movement of surface"
[3]Patent nº EP 0265982 (A2) (1986) "Machine for the multi-colour silk-screen printing of cylindrical containers in general"
[4]Patent nº US 4848227 (A)(1981) "Device for the silk-screen printing of cylindrical objects having an elliptical cross-section"
[5] Inkcups Now(March-2014), http://www.inkcups.com/
[6] http://www.triz.co.kr/TRIZ/frame.html
[7] Glenn Prestwich(2007). Instant insight: Organ printing, Highlights in Chemical Biology, 5.

Slide 30

Analogical reasoning for envisioning future with patterns of evolution: Pad-Printing



[1]Dongguan Ruida Machinery And Equipment Co., Ltd.(March-2014) /http://dgnewman.en.alibaba.com/
[2] Inkcups Now(March-2014), http://www.inkcups.com/
[3]CarePrint (March-2014) http://www.padprinting.in/pad-printing-machine/
[4] Patent nº US 6931988 (2004) "Rotary head pad printer"
[5] http://www.triz.co.kr/TRIZ/frame.html
[6] Glenn Prestwich(2007). Instant insight: Organ printing, Highlights in Chemical Biology, 5.

Slide 31

Check coherence of the envisioned future with the available information about the company context

Technology	Minimum Technical System	Description of the past solution and patterns	Expected benefits
Both technologies	ink	Increase the ink performance using different additive: Biological-ink is a ink that not produce environmental damage; Organ-ink is a ink that non-react with human interaction, nano-ink are possible future ink with new properties.	Drying time, quality of image
Both technologies	Substrate	Geometric evolution: Complexity of the shape surface has been increased given customers' demands.	Flexibility of the process
Silk-screening	control	Controllability: currently, there are automatic silk-screening, but process can still reducing the time consumption.	Process and pre-process time
Silk-screening	Substrate	Dynamization: There are some silk-screening machines capable to move the substrate in order to improve the decoration process.(e.g. moving the substrate is possible to print curve surface)	Flexibility of the process

Team B: Decoration Pilot 2 – Team B: Decoration 31

Slide 32

Check coherence of the envisioned future with the available information about the company context

Technology	Minimum Technical System	Description of the past solution and patterns	Expected benefits
Silk-screening	Screen	Dynamization: Some silk-screening machines have a dynamic screen capable to track specific movement(e.g. horizontal).	Flexibility of the process
Pad-printing	Pad	Dynamization: Some pad-printing machines have a dynamic pad capable to track specific movement(e.g. vertical, horizontal and angles).	Flexibility of the process
Pad-printing	Pad	Micro-Macro: Size of the pad has been increased in the last year, however there some limitation in terms of ink performance.	Flexibility of the process
Pad-Printing	Cliché	Substance-Field involvement: In the past, the cliché was attached at the machine using different types of nuts and bolts , now the cliché is magnetic in order to reduce the pre-process time.	Flexibility of the process

Team B: Decoration Pilot 2 – Team B: Decoration 32

Slide 33

See slide's notes too.

Analysis of the functional models (stage M) using Law of ideality increase [TRIZ]: towards ideal machine and ideal process

Features, (**functionalities in bold;** expenses in regular)

Controllability of printing process, more control on image	Full range of color management including metallic, performance maintained during entire time of use by users of a final appliance,
Flexibility	Digital printing (no image preparation), change over t=0s, change over time for a part type t=0s
Productivity of process [pcs/h]	Cycle time close to single color silk screening, no scrap
Maintainability [non working, h]	No down time for maintenance like laser marking, towards self-maintaining
Integration level with production line	Cycle time of decoration should be coordinated with cycle time of production line
Price of machine [EUR]	Investment to new technology should be lower, below alternatives (delivering the same result), operation cost should decrease, environmental impact should be minimized

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Slide 34

Solutions addressing limiting resources

Limiting resources	Solutions
Time of process to modify the color	Time below cycle time of production line
Time for ink drying	UV curing with capacity for large size (or many) parts, time below cycle time of decoration
Radius of substrate's surface	Decoration tool maintains a fixed distance to any surface shape;
Area of contact between ink and substrate	Decoration and substrate are (tightly linked → are unified → are one)
Extent of ink's ability to attach to substance	Deep attachment, on back surface, inside substance
The oxidation time of the metal surface.	

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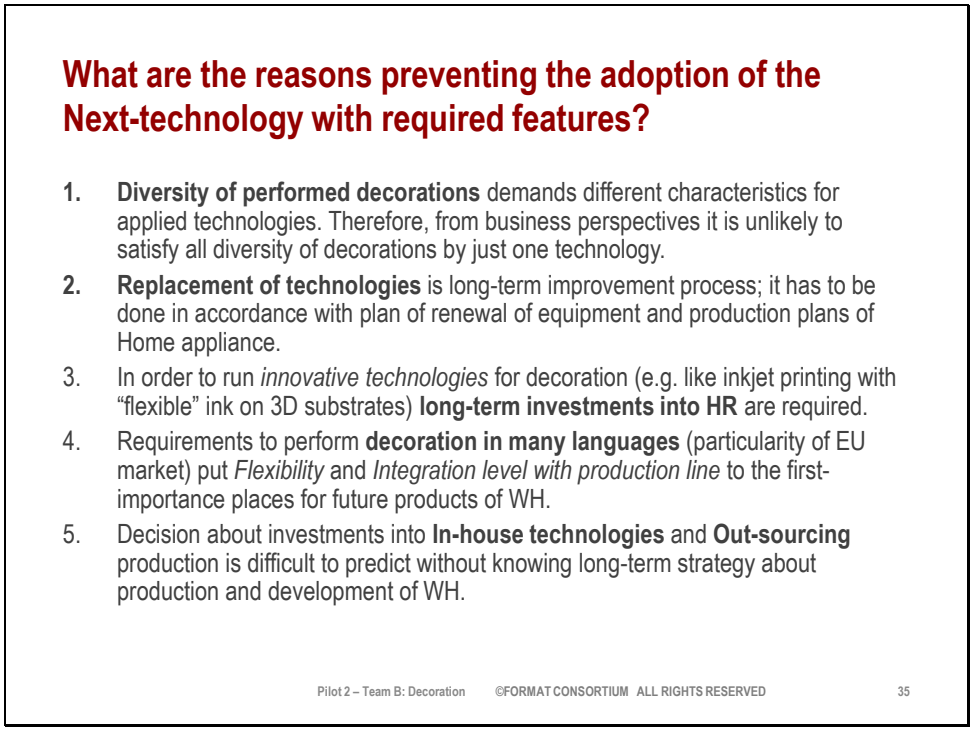
Slide 35



The reason for something is a fact or situation which explains why it happens or what causes it to happen. [CollinsCobuild Dictionary]
examples:

- e-ink technology;
- tactile sensation of decoration;

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Appendix A.

Table A-1. List of tasks in case study project "Decoration" executed by Team B

ID	Name	Duration	Start	Finish
1	Session 00	1,d	11/02/14 08:00	12/02/14 09:00
2	Pilot 2	31,d	26/02/14 08:00	09/04/14 18:00
3	Stage (FOR)	2,056d	26/02/14 08:00	28/02/14 08:30
4	Before session 01	1,5d	26/02/14 08:00	27/02/14 13:30
5	Session 01	,222d	27/02/14 15:30	28/02/14 08:30
6	Gate FOR	,111d	27/02/14 16:30	27/02/14 17:30
7	Stage (M)	9,944d	28/02/14 08:30	13/03/14 18:00
8	before 02	,889d	28/02/14 08:30	28/02/14 17:30
9	Session 02	,296d	28/02/14 14:20	28/02/14 17:00
10	between 02-03	3,d	03/03/14 08:30	06/03/14 08:30
11	Session 03	,444d	06/03/14 08:00	06/03/14 12:00
12	between 03-04	1,d	07/03/14 08:00	07/03/14 18:00
13	Session 04	,333d	10/03/14 09:00	10/03/14 12:00
14	between 04+05	1,d	10/03/14 14:00	11/03/14 14:00
15	Session 05	,444d	12/03/14 09:00	12/03/14 14:00
16	after 05	1,d	13/03/14 08:00	13/03/14 18:00
17	Gate M	,222d	13/03/14 16:00	13/03/14 18:00
18	Stage (A)	12,889d	14/03/14 09:00	01/04/14 18:00
19	Session 06	,444d	14/03/14 09:00	14/03/14 14:00
20	between 06-07	2,d	14/03/14 14:00	18/03/14 14:00
21	Session 07	,222d	18/03/14 14:00	18/03/14 16:00
22	between 07-08	1,5d	19/03/14 08:30	25/03/14 14:00
23	Session 08	,296d	25/03/14 13:00	25/03/14 15:40
24	between 08-09	1,d	26/03/14 08:00	26/03/14 18:00
25	Session 09	,296d	27/03/14 13:00	27/03/14 15:40
26	between 09-10	1,5d	28/03/14 08:30	31/03/14 14:00
27	Session 10	,296d	31/03/14 14:00	31/03/14 16:40
28	after 10	1,d	01/04/14 08:00	01/04/14 18:00
29	Gate A	,222d	01/04/14 16:00	01/04/14 18:00
30	Stage (T)	6,d	02/04/14 08:00	09/04/14 18:00
31	Session 11	,296d	02/04/14 08:00	02/04/14 10:40
32	between 11-12	4,d	02/04/14 14:00	08/04/14 14:00
33	Session 12	,444d	08/04/14 13:00	08/04/14 17:00
34	after 11	1,d	09/04/14 08:00	09/04/14 18:00
35	Gate T	,333d	09/04/14 14:00	09/04/14 17:00
36	Report writing	30,889d	26/02/14 08:00	09/04/14 17:00
37	Report writing	24,833d	26/02/14 08:00	09/04/14 17:00
38	Report submission to interim internal review	,889d	18/03/14 08:00	18/03/14 17:00
39	Report submission to final review	,889d	08/04/14 08:00	08/04/14 17:00

ID	Task Name	Duration	Start	Finish
1	**Case_2.1**	**42 days?**	**Tue 11/02/14 08:00**	**d 09/04/14 18:00**
2	**FOR**	**12,89 days**	**Tue 11/02/14 08:00**	**u 27/02/14 17:00**
3	Before session 01	1,5 days	Wed 26/02/14 08:00	u 27/02/14 13:30
4	Session 00	0,8 hrs	Tue 11/02/14 08:00	e 11/02/14 08:48
5	Session 01	1,5 hrs	Thu 27/02/14 15:30	u 27/02/14 17:00
6	Gate FOR	2 hrs	Thu 27/02/14 15:30	u 27/02/14 17:30
7	**M**	**9,94 days?**	**Fri 28/02/14 08:30**	**u 13/03/14 18:00**
8	before 02	0,89 days?	Fri 28/02/14 08:30	ri 28/02/14 17:30
9	Session 02	2,67 hrs	Fri 28/02/14 14:20	ri 28/02/14 17:00
10	between 02-03	3 days	Mon 03/03/14 08:30	u 06/03/14 08:30
11	Session 03	2,67 hrs	Thu 06/03/14 08:00	u 06/03/14 10:40
12	between 03-04	1 day	Fri 07/03/14 08:00	ri 07/03/14 18:00
13	Session 04	2,67 hrs	Mon 10/03/14 08:00	n 10/03/14 10:40
14	between 04+05	1 day	Mon 10/03/14 14:00	e 11/03/14 14:00
15	Session 05	2,67 hrs	Wed 12/03/14 08:00	d 12/03/14 10:40
16	after 05	1 day	Thu 13/03/14 08:00	u 13/03/14 18:00
17	Gate M	**2 hrs**	**Thu 13/03/14 16:00**	**u 13/03/14 18:00**
18	**A**	**13 days?**	**Fri 14/03/14 08:00**	**e 01/04/14 18:00**
19	Session 06	2,67 hrs	Fri 14/03/14 08:00	ri 14/03/14 10:40
20	between 06-07	2 days	Fri 14/03/14 14:00	e 18/03/14 14:00
21	Session 07	2 hrs	Tue 18/03/14 14:00	e 18/03/14 16:00
22	between 07-08	1,5 days	Wed 19/03/14 08:30	e 25/03/14 14:00
23	Session 08	2,67 hrs	Tue 25/03/14 13:00	e 25/03/14 15:40
24	between 08-09	1 day	Wed 26/03/14 08:00	d 26/03/14 18:00
25	Session 09	2,67 hrs	Thu 27/03/14 13:00	u 27/03/14 15:40
26	between 09-10	1,5 days?	Fri 28/03/14 08:30	n 31/03/14 14:00
27	Session 10	2,67 hrs	Mon 31/03/14 14:00	n 31/03/14 16:40
28	after 10	1 day	Tue 01/04/14 08:00	e 01/04/14 18:00
29	Gate A	2 hrs	Tue 01/04/14 16:00	e 01/04/14 18:00
30	**T**	**6 days**	**Wed 02/04/14 08:00**	**d 09/04/14 18:00**
31	Session 11	2,67 hrs	Wed 02/04/14 08:00	d 02/04/14 10:40
32	between 11-12	4 days	Wed 02/04/14 14:00	e 08/04/14 14:00
33	Session 12	3,43 hrs	Tue 08/04/14 13:00	e 08/04/14 16:26
34	after 11	1 day	Wed 09/04/14 08:00	d 09/04/14 18:00
35	Gate T	3 hrs	Wed 09/04/14 14:00	d 09/04/14 17:00
36	**Report writing**	**30,89 days?**	**Wed 26/02/14 08:00**	**d 09/04/14 17:00**
37	Report writing	24,83 days?	Wed 26/02/14 08:00	d 09/04/14 17:00
38	Report submissio	0,89 days	Tue 18/03/14 08:00	e 18/03/14 17:00
39	Report submissio	0,89 days?	Tue 08/04/14 08:00	e 08/04/14 17:00

Figure A-1. Gantt chart; part 1/2 (till session 06)

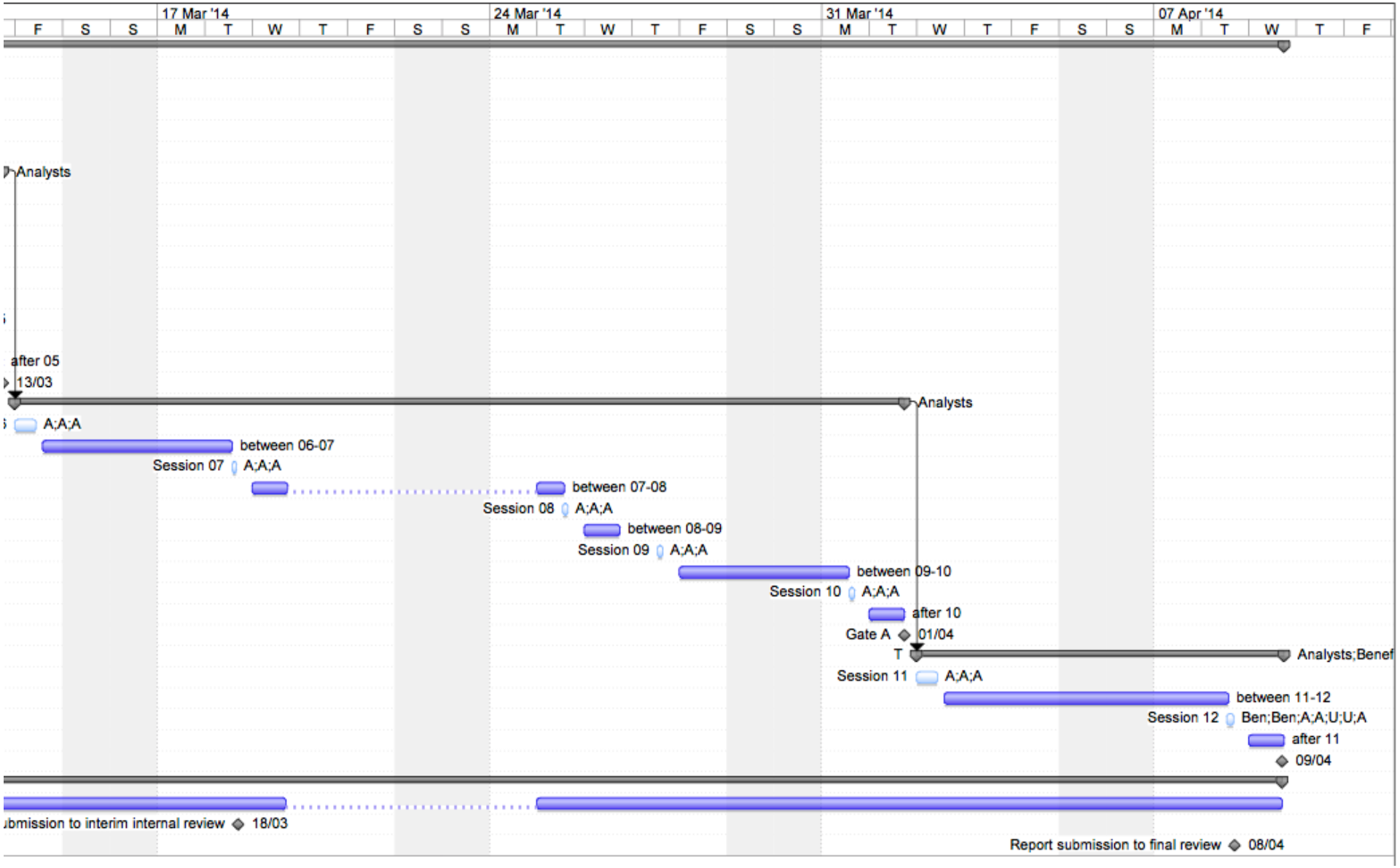

Figure A-2. Gantt chart; part 2/2 (from session 06)

Table A-2. Case study project planning – an operational version used during execution (WH - Whirlpool)

Session	When	hours	Where	Activities planned	Activities performed	Techniques & methods	Outputs planned	Outputs delivered
#1.1	11/02/14 09:00	1	WH	*<to set up> <the project>* Define Main objectives of Forecast (Project) (Why?) Formulate Main outputs for Decision Makers (DM) Clarify: How the outputs will be applied by DM? Identify the System to be forecasted (STF) Define the Time horizon Define the Market scope and geographic context(s)	*<to set up> <the project>* Define Main objectives of Forecast (Project) (Why?) Formulate Main outputs for Decision Makers (DM) Clarify: How the outputs will be applied by DM? Define the Time horizon Define the Market scope and geographic context(s)	Structured Interview Presentation of slides Question & Answers Recording session	Initial information on: *<to set up> <the project>* Define Main objectives of Forecast (Project) (Why?) Formulate Main outputs for Decision Makers (DM) Clarify: How the outputs will be applied by DM? Identify the System to be forecasted (STF) Define the Time horizon Define the Market scope and geographic context(s)	Initial information on: *<to set up> <the project>* Define Main objectives of Forecast (Project) (Why?) - partially Formulate Main outputs for Decision Makers (DM) Clarify: How the outputs will be applied by DM? Define the Time horizon Define the Market scope and geographic context(s)
#1.1	27/02/14 15:30	2	WH	*<to set up> <the project>* Collect data and information for - Planning project - Model of STF at the functional level; - Description of Competitive (Alternative) technologies - About limiting resources: TIMES (time, information, materials, energy, space, knowledge)	*<to set up> <the project>* Collect data and information for - Planning project - Model of STF at the functional level; - Description of Competitive (Alternative) technologies - About limiting resources: TIMES (time, information, materials, energy, space, knowledge) Define the Market scope and geographic context(s) Definition of Preliminary constraints for the project: - System (Process) to be Forecasted (STF) from Technological,	Structured Interview Sharing relevant documents Studying the documents Presentations of slides Question & Answers Recording session	**Gate (FOR)** **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?) Definition of **Preliminary constraints** for the project - System (Process) to be Forecasted (STF) from Technological, Economics, Environmental, Social (TEES) perspectives (What?)	**Gate (FOR)** **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?) Definition of **Preliminary constraints** for the project - System (Process) to be Forecasted (STF) from Technological, Economics, Environmental, Social (TEES) perspectives (What?)

Session	When	hours	Where	Activities planned	Activities performed	Techniques & methods	Outputs planned	Outputs delivered
					Economics, Environmental, Social (TEES) perspectives (What?)		- time horizon (When?) - market scope and geographic context (Where?) **Question 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,…)	- time horizon (When?) - market scope and geographic context (Where?) **Question for Forecast** (Questions to be answered at the end of study) **Plan** of Project (How?) - Time diagram (Gantt or similar) - session planning in Excel, Gantt not issued - Resources for the activity (People, knowledge, IT instruments,…) Output listed above have been obtained however it was not yet recorded in a stable form.

Session	When	hours	Where	Activities planned	Activities performed	Techniques & methods	Outputs planned	Outputs delivered
				<to set up> <the project> 1. Gate FOR -Time planning 2. Concept for M 3. List of alternative technologies 4. Initial inputs to list of problems (optional)	Decision on organization of notes from session 01 Presentation of results referring to gate FOR - decision on desired layout and form of FOR gate Decision and concept of sessions' planning organization Decision on list of alternative technologies Distribution of work in 1st substages of stage M Decision on collection of inputs to the list of disadvantages	Sharing relevant documents: off session Studying the documents: off session Presentations of slides: on session Question & Answers: on session	**Gate (FOR)** **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?) Definition of **Preliminary constraints** for the project - System (Process) to be Forecasted (STF) from Technological, Economics, Environmental, Social (TEES) perspectives (What?) - time horizon (When?) - market scope and geographic context (Where?) **Question 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,…)	**Gate (FOR)** **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?) Definition of **Preliminary constraints** for the project - System (Process) to be Forecasted (STF) from Technological, Economics, Environmental, Social (TEES) perspectives (What?) - time horizon (When?) - market scope and geographic context (Where?) **Question for Forecast** (Questions to be answered at the end of study) **Plan** of Project (How?) - Time diagram (Gantt or similar) - session planning in Excel, Gantt not issued - Resources for the activity (People, knowledge, IT instruments,…) List of alternative
#2	28/02/14 14:00	2	Webex					

Session	When	hours	Where	Activities planned	Activities performed	Techniques & methods	Outputs planned	Outputs delivered technologies
#3	05/03/14 09:00	4	WH	*<to model> <existing knowledge>* 1. To develop the answer for question: The STF is for? (WHY we need the STF?) 2. To define: What are the systems allow to get the same results? 3. To develop the answer for question: How to measure the **Performances** and the **Expenses** of the STF and its alternatives? 4. **Visit #1** the production process	Review pros & cons in FOR To develop the answer for question: The STF is for? (WHY we need the STF?) Alternations and reconstruction of STF functional models To define: What are the systems allow to get the same results? – partially done Construction of System Operator for STF	Recording session Presentations of slides: on session Question & Answers: on session Structured discussion - construction of System Operator	1. **Model of STF at the functional level** 2. Description of **Competitive** (Alternative) **technologies** (solutions) 3. **Performance and Expenses** (when expenses are not merely money but limiting resources: TIMES (time, information, materials, energy, space, knowledge)	What STF is for? When? Where? STF functional models after alternations: on session System Operator: on session Updated and improved sessions' planning in Excel: off session

Session	When	hours	Where	Activities planned	Activities performed	Techniques & methods	Outputs planned	Outputs delivered
				<to model> <existing knowledge> Do develop the answer for question: WHAT the **STF** and its main **alternative** (s) are, were and are expected to be?	Answer for question: WHAT the STF and its main alternative (s) are, were and are expected to be? (main part done on session 03 in Ssystem Operator, some alternations added) To define: What are the systems allow to get the same results?	Presentations of slides: on session Question & Answers: on session Discussion structured around agenda and schema of Stage M	Description for STF (like System Operator) contexts=**super-systems** (TEES) and **sub-systems** **past** history & **expected future** present **trends**	System Operator built at session 03, improvements defined as a to-do task Contexts=super-systems (TEES) - defined as a to-do task Performance characteristic - under discussion Systems that allow to get the same results - Defined Decision criteria compilation - discussed and defined as a to-do task Improved functional models of STF + alternative i.e. laser marking
#4	10/03/14 09:00	4	Webex	*<to model> <existing knowledge>* - to review developed materials - **Visit #2** to production process	- review of developed materials - improvement of expressions in TEES - improvements of materials developed for stage M - check up on conditions to close gate M	Presentations of slides: on session Question & Answers: on session Discussion structured around agenda and Gate M Broadcasting by Webex to Luca Ruggeri recording session (audio+ video (partially))	**Gate (M)** **Model** of STF at the **functional** level Description of **Competitive** (Alternative) **technologies** (solutions) A measure of **Performance & Expenses** for STF and for Competitive Solutions - Measures may be presented using ENV model - The measure can be applied as Y axis for S-curves.	**Gate (M)** **Model** of STF at the **functional** level Description of **Competitive** (Alternative) **technologies** (solutions) A measure of **Performance & Expenses** for STF and for Competitive Solutions - Measures may be presented using ENV model - The measure can be applied as Y axis for S-curves.
#5	12/03/14 09:00	4	PoliMI face-to-face obligatory				**Description for STF** (logic as System Operator) - contexts=super-	**Description for STF** (logic as System Operator) - contexts=super-

Session	When	hours	Where	Activities planned	Activities performed	Techniques & methods	Outputs planned	Outputs delivered
							systems (TEES) and sub-systems - past history & expected future - present trends	systems (TEES) and sub-systems - scheduled to be integrated before next session - past history & expected future - present trends Decision making criteria - rviewed and integrated with decision factors matrix from BoP for Decorations
				<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	Extract limiting resources from problems of STF - What are the most critical problems? - Identify limiting resources for problems set - Visit #2 to production process	Presentations of slides: on session Question & Answers: on session Discussion structured around agenda and stage (A) recording session Presentation and discussion with invited user (Gigi)	list of major problems for examined MP(s) list of contradictions for identified major problems list of limiting resources which cause the problems	list of major problems for examined MP(s) list of limiting resources which cause the problems photos from factory visit updated, upgraded functional model for pad printing reporting layout constructed and explained to team context: super-systems (TEES) and sub-systems integrated Assesment of alternative technologies - work started and advanced
#6	14/03/14 10:00	4	WH					

Session	When	hours	Where	Activities planned	Activities performed	Techniques & methods	Outputs planned	Outputs delivered
#7	19/03/14 09:00	4	Webex	*<to identify> <future traits> for STF* **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	Define set of solutions addressing limiting resources - work partially perfomed at previous session, required improvement. - Recognize relevant patterns - performed using indications from NB's presentation: recognition of bottlenecks, identification of further developments of critical operations - Analogical reasoning for envisioning future with patterns of evolution - modifications introduced into System Operator (it becomes a technique used also at stage A) - Check coherence of the envisioned future with the available information about the context - inputs have been checked with System Operator Additional: - Identification of bottlenecks Answer to: What are the reasons preventing the adoption of the technology with features from stage (M) (competitive alternatives)? (Question adapted from NB) - answer delivered by evaluation of	Presentations of slides: on session Question & Answers: on session Discussion structured around agenda and schema of Stage A	1. What is (are) the specific operation(s) generating bottlenecks? (slowest, consume most resources – energy, time, materials, information) 2. What are the reasons preventing the adoption of the most relevant alternative technologies? 3. Build a model of model of the critical operations (1-2) using Law of System Completeness. 4. Analysis of the models (3) using Laws of Evolution (from TRIZ). 5. Identify potential further developments of the critical operations (1-2) according (4). Collected from other slides (content in parenthesis is an addition helping to grasp an idea - from MS): • (recognition of) patterns of evolution (slide 11) • (controlling activity) check envisioned future with evolution of the context (slide 12 NB ToK) • trends characterizing the context (slide 13 of NB ToK)	From planned output, real output has been restructured into: 1. Recognize relevant patterns (use SO) – take into consideration below bullets -- What is (are) the specific operation(s) generating bottlenecks? (slowest, consume most resources – energy, time, materials, information) - identified from timing in functional descriptions -- Identify potential further developments of the critical operations - done in System Operator 2. What are the reasons preventing the adoption of the technology with features from stage (M) (competitive alternatives)? - done by the means of comparison of competitve alternatives

Session	When	hours	Where	Activities planned	Activities performed	Techniques & methods	Outputs planned	Outputs delivered
					competitive (alternative) technologies.			
#8	25/03/14 15:00	4	WH	*<to identify> <future traits> for STF* **Fit data-series** about parameters measuring performance & expenses	Questions about problems and limiting resources to invited expert - Analysis of the functional models (stage M) using Law of ideality - data series requested as a to-do of session 4 on 10/03/2014 have not been delivered therefore data-series fitting could not take place.	Presentation of stage (M) to invited expert (Fabio Moneta) - question & answers - session structured around agenda	logistic S-curves to describe growth/decline and substitutions of examined MP(s)	Confirmation by invited expert of critical problems and limiting resources. Stable version of gate (M) closed

Session	When	hours	Where	Activities planned	Activities performed	Techniques & methods	Outputs planned	Outputs delivered
				<to identify> <future traits> for STF Build **conclusions** about future traits for STF - To asses features of STF - To group (chunk) features into main traits	Case study (Pilot 2-Team B) is being suspended in wait for data -- proposition of alternative main performance measure -- proposition of alternative data sources -- Analysis of the functional models (stage M) using Law of ideality increase [TRIZ]: towards ideal machine and ideal process	Presentations of slides: on session Question & Answers: on session Discussion structured around agenda	list of features for STF set of traits for STF	-- Stable version of stage (M) improved --Improvement in quality of elements prepared for previous sessions --Analysis of the functional models (stage M) using Law of ideality increase (TRIZ): towards ideal machine and ideal process
#9.1	27/03/14 14:00	4	Webex	*<to identify> <future traits> for STF* - To review the developed results	Case study - suspended - Review of to-do - State of data acquisition - Alternative data sources – a note on activity - Reporting activities – making an advance - Methodology meeting – preparing questions	Presentations of slides: on session Question & Answers: on session Discussion structured around agenda	**Gate (A)** - 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 - description of the answer for forecasting question - first draft of report of study - first draft of executive summary	- Points of discussion for methodology meeting - Planning of reporting of stage (A) - initial list of "Solutions addressing limiting resources"
#9.2	02/04/14 09:00	2	Webex	*<to translate> <conclusions about traits for STF> to DM* - Conclusion on answer to the Question to be Forecasted - Add final inputs into report - Shape executive summary and presentation				
#11		4						

Session	When	hours	Where	Activities planned	Activities performed	Techniques & methods	Outputs planned	Outputs delivered
				<to translate> *<conclusions about traits for STF> to DM* - review prepared materials and check their readiness to be presented			- reviewed materials for presentation	
#12.1		4		*<to translate>* *<conclusions about traits for STF> to DM* - Deliver presentation to Beneficiaries and Users - Question and Answers session + Discussion - Make decision about Go/NotGo for next round			**Gate (T)** - Answer the Question to be Forecasted (from (FOR) Gate) - Executive summary - Report - Presentation	
#12.2		4						
	total, h	47						