Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 131 (2015) 1084 – 1093

Procedia Engineering

www.elsevier.com/locate/procedia

World Conference: TRIZ FUTURE, TF 2011-2014

FORMAT - Building an original methodology for Technology Forecasting through researchers exchanges between industry and academia

Gaetano Cascini[a], Niccolò Becattini[a], Igor Kaikov[b], Sebastian Koziolek[c], Dmitry Kucharavy[a], Christopher Nikulin[a*], Pierluigi Petrali[b], Mateusz Slupinsky[c], Mahmoud Rabie[d], Balachandar, Ramadurai[a], Luca Ruggeri[b], Katrien Vanherck[d]

[a]*Politecnico di Milano - Dipartimento di Meccanica, Via G. La Masa 1, 20156 Milano, Italy*
[b] *Whirlpool Europe, Comerio, Italy*
[c] *Wroclaw University of Technology, Wroclaw, Poland*
[d] *PNO Consultants, Diegem, Belgium*

Abstract

The paper presents an overview of the FORMAT methodology, an approach for technological forecasting capable of satisfying the need of manufacturing industries to better support decision-making processes in planning corporate strategies for R&D. The methodology has been developed within the FORMAT consortium, gathering partners from both industry and academia in a Marie-Curie EU funded project of the 7th Framework Programme - IAPP PEOPLE. The methodology is intentionally shaped as a generic one, so as to foster its adoption by the wider audience, but it suggests the adoption of several TRIZ techniques and models to support the forecast. Its exemplary application in the field of forming technologies for domestic refrigerators aims at showing its potential and viability in a real industrial context. The paper is supplemented by a case study in the white goods manufacturing (forming techniques for the inner liners of domestic refrigerators).

Peer-review under responsibility of the Scientific Committee of TFC 2011, TFC 2012, TFC 2013 and TFC 2014 – GIC

Keywords: Techological Forecasting, manufacturing technologies, laws of engineering systems evolution, S-curve analysis, logistic regression, vacuum forming

[*] Corresponding author. E-mail address: gaetano.cascini@polimi.it

1877-7058
Peer-review under responsibility of the Scientific Committee of TFC 2011, TFC 2012, TFC 2013 and TFC 2014 – GIC
doi:10.1016/j.proeng.2015.12.426

1. Introduction

The analysis of emerging technologies and their potential impact on markets, economies and societies requires reliable and repeatable methods and tools, since the related information plays a critical role for strategic decisions of private and public organizations. Frequently, these important questions are addressed by using forecasting methods and techniques, which attempt to support decision makers by anticipating information about the future [1]. However, the existing techniques reveal several weaknesses, such as limited accuracy on middle and long-term forecast, poor repeatability and poor adaptability, i.e., no universal methods are known. For this reason, complementary instruments are usually required to be integrated according to the specific goal and data availability [2, 3].

From the technological standpoint, these above-mentioned weaknesses highlight an issue related with the creation and introduction of structured methods and tools capable of supporting strategic decisions in industrial R&D activities.

The purpose of these methods and tools is to manage the multi-disciplinary complexity of current systems and to anticipate the future characteristics of products and processes [4]. For instance, this can be explained in the white good industry and generally in the manufacturing sector, where the principle of "the sooner the better" is widely accepted. In such a case, very often the lack of resources to be dedicated to R&D of new manufacturing technologies hinders the capability of the companies to meet the demands for new products. Therefore, the necessity to create a technological forecasting methodology capable to address this issue becomes more crucial, anticipating as much as possible the research and development of process technologies so as to eliminate uncertainties, problems related to the premature stage of development of a technology and related costs, and to better exploit competitive advantages in an aggressive market. On these premises, the authors have developed an innovative forecasting methodology, namely FORMAT (http://www.format-project.eu), within the boundaries of an IAPP EU funded project. FORMAT aims at supporting decision making in manufacturing industries, facing and answering 3 complementary and essential perspectives [5]:

- Product Evolution: products change to improve their performance; consequently, manufacturing technologies have to adapt to the evolving features of products. On the other hand, new manufacturing technologies allow designing new products, with renewed features.
- Technological Evolution: manufacturing technologies evolve under the pressure of improved production requirements (productivity, quality, etc.) and reduction of resources consumption (material, energy, etc.) for both economic and sustainability issues.
- Organizational Evolution: industrial strategies need to be updated according to the opportunities and constraints that the modern society offers.

Besides, the methodology has to help driving technological investments, research activities and product design processes and draw the path of technological evolution. A key objective of the methodology is the usability by company's staff. Furthermore, it has to be reliable, repeatable, resource- efficient, adjustable and transferable at different company levels.

This paper, therefore, overviews the partial results of the FORMAT project after two years of activity. In details, section 2 reviews the state of the art of techniques associated with technological forecasting, as well as the scientific basis that has inspired the FORMAT methodology, presented in section 3. Section 4 reports a real case study in the field of cabinet manufacturing for domestic refrigerator at Whirlpool Company. This case study gives a preliminary demonstration of the potential and the viability of this methodology. Section 5 presents the technical outcomes from an application, together with methodological strength and weaknesses

Nomenclature

FORMAT	Forecast and Roadmapping for Manuf. Tech.
IAPP	Industry-Academia Partnerships and Pathways
STF	System To be Forecasted
TF	Technological Forecasting
VF	Vacuum Forming

2. Brief Review of TF Methodologies and Approaches

Technological Forecasting (TF) methodologies have received much attention in the recent years due to the potential benefits for companies, for instance, at anticipating information about the technology future, but at the same time helping the decision makers to accomplish their company's goals [1, 6]. Currently, a large number of different TF methodologies and techniques are available in literature, with complementary characteristics, strengths and weaknesses. In an effort to orient analysts in the identification of the most suitable approach, researchers in the field of TF have proposed different classification schemes. However, a wide number of categories have emerged, sometimes even more complicating the selection process.

In order to summarize the knowledge in the TF field, the FORMAT Consortium developed an exhaustive literature review by indexing techniques and classifications of TF methodologies. Table 1 illustrates the accounted techniques and categories. References, meanings and more detailed descriptions are available in [3].

Table 1. Number of methodologies extracted by different authors in the forecasting field.

#	Name of the source	Method.	Categories
1	A.L. Porter *et al*. "Technology futures analysis: Toward integration of the field and new methods" 2004 [1]	51	9
2	Makridakis *et al.* "Forecasting methods and applications" 1998. [7]	19	19
3	J.Scott Armstrong *et al.* "Principles of forecasting" 2002. [8]	10	10
4	Vanston, "Technology futures", 2005 [9]	28	11
5	FOR-LEARN [10]	26	9
4	J.P. Martino "Technological forecasting for decision making", 1993. [6]	39	11
7	Futures Research Methodology Version 2.0, Millenium Project, 2002. [11]	27	-
8	Futures Research Methodology Version 3.0, Millenium Project, 2011. [12]	35	-
9	Technological Forecasting and Social Change, Special issues since 2004	9	-
10	International Journal of Forecasting, Special issues and sections since 2000	4	-
11	M3 competition, [13]	24	6
12	A.L. Porter – presentation, 2005. [14]	19	13

The analysis proposed in [3] highlighted the multiplicity of techniques and classification schemes, also showing that significant overlaps exist between techniques entitled to different authors and named differently in diverse sources.

In an effort to be practical in use, the original categorization created by Kucharavy *et al.* [2] seems to be suitable to categorize all the techniques in a manageable number of classes:

Causal models (*e.g.* analogy, morphological analysis, laws and patterns of system evolution);

Phenomenological models (e.g. extrapolations of time series data, regressions);

Intuitive models (*e.g.* Delphi surveys, structured and unstructured interviews);

Monitoring and mapping (*e.g.* scanning of literature and published sources, scenarios, mapping existing information).

A historical analysis allowed understanding the complete theoretical framework of the techniques and their evolution. In more detail, by counting the publications in two of the most acknowledged scientific databases (namely Scopus and Google Scholar) it was possible to analyze trends of development and application of TF methodologies. Within a globally increasing trend of publications in the field, Figure 1 presents the relative amount of publication, demonstrating the changing interest in the categories in time. Generally speaking, causal models and monitoring and mapping revealed to get a growing share among the TF techniques.

The authors adopted the outcome of this analysis as the starting point to build the FORMAT methodology.

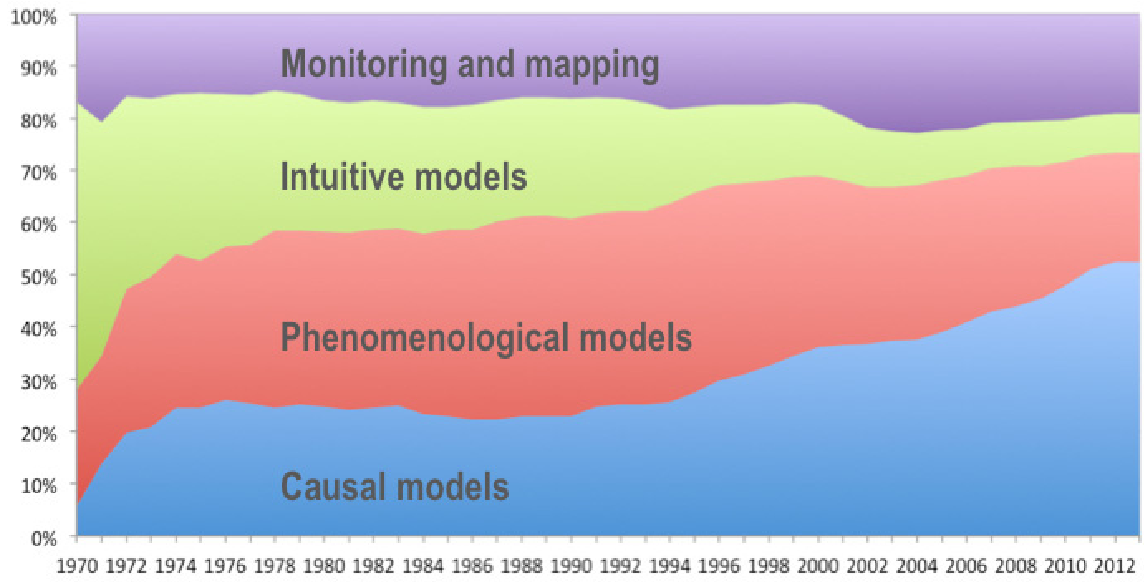

Figure 1: Percentage of papers' category cumulative appearance per year.

Given the domain of activity of the industrial partner of the FORMAT consortium and the large number of techniques that already exist, the crucial points to consider while developing an innovative forecasting methodology are linked with:

- Satisfaction of methodological requirements by the industrial partners (and most of all, manufacturing companies in white good industry), considering product, technology and organization evolution.
- Flexibility of techniques used to achieve the forecasting goals, by creating or combining techniques that already exist.
- Repeatability and adaptability of the methodology, so as to systematically drive the forecasting process for developers (e.g. attempting to avoid an expert methodology advisor). Moreover, it has to be easy to be used at different organizational levels.
- Robustness and reliability of methodology, by adopting four main elements that are considered as essential to correctly forecast a technology [6]: i) technology being forecast; ii); the statement of the characteristics of the technology; iii) the time of forecast; iv) the statement of the probability associated with the forecast.

For this purpose, the FORMAT methodology has been created to support decision makers in manufacturing industry.

3. The FORMAT Methodology

The FORMAT Methodology has been conceived adopting the "Researching Future" methodology (RFm) by Kucharavy et al. [15] as a reference, for what concerns the integration of qualitative and quantitative approaches to Technology Forecasting (TF). Moreover, the methodology seems to cover the four elements requested by [6] and also joins techniques from the adopted categories. However, RFm cannot be adopted, as it is, within the FORMAT methodology, for several reasons: i) it needs to be customized to gain maximum effectiveness,; ii) RFm appears as very effective under the guidance of an expert methodology advisor, but it appears as not adequately replicable by industry analysts without a significant training investment; iii) RFm with respect to other Technology Forecasting methods shows a careful attention to the management of the TF project.

The FORMAT methodology has been conceived as a Stage-Gate process (Figure 2) in order to exploit its intrinsic capabilities to keep control over step-based projects, regardless its out-of-the-scope strength and weaknesses in supporting innovation process involving the development of ideas [22].

A Stage-Gate structure for the FORMAT methodology is expected to ensure several benefits:

- Ease of adoption by manufacturing companies already familiar with the same model for managing their product development cycle;
- Possibility to control the advancement of the TF project and the opportunity to keep investing efforts and resources in its development through a careful monitoring of the process gates;
- Flexibility of the TF process, since different methods and tools can be adopted at each stage, as far as their outcome fits the expected information to achieve the corresponding gate;
- Possibility to exploit existing competences in the company, by embedding suitable known models and techniques into the FORMAT stages.

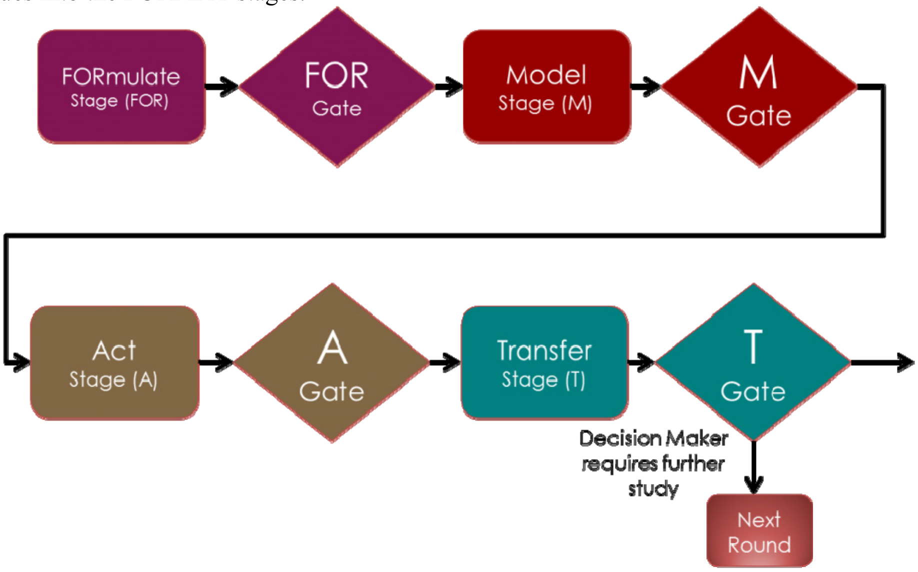

Figure 2: Stage-Gate Process Model for Technology Forecasting Methodology (FORMAT)

Moreover, it overcomes the above limitations of RFm by a customized procedure for the investigation of industrial processes by dedicated guidelines. Besides, the Stage-Gate structure allows a more procedural approach that, with appropriate instructions, reduces the need for investments on training the forecasters/analysts. Moreover, it also makes the process more repeatable in various industrial contexts.

Each stage is described by means of two items, in order to give a similar internal structure to the stages. The first item is a description of the stage goal, by using a functional syntax: it allows the analysts to have a clear description of the goal to be accomplished. The analysts have to address the functional description to move on to the next stage. The second item is a more detailed checklist of questions to be addressed, so as to fulfil the main function of the stage. Then, each stage is followed by a gate, depicting the detailed requirements (in terms of information needs) that prescribe what should be checked before deciding whether to continue with the following activities of the TF project.

Table 2 describes the main functions, questions and requirements for each stage-gate pair. Four stages constitute the TF process: the stages are split according to the FORMAT acronym: FORmulate, Model, Act and Transfer.

Firstly, Stage FOR is related with the motivation of the forecasting analysis. This stage has to check whether the forecast is really needed or not. Moreover, at this stage the analysts needs to agree on: i) the description of the main objectives and the expected outputs of the forecasting project;

ii) a clear statement about how the forecast will be applied within the decision making process; iii) the possibility to satisfy the formulated needs with or without TF. Additionally, the resources to address the forecasting project have to be defined and the activities suitably planned.

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

The activities of Stage A consider both a qualitative and a quantitative perspective to forecast the future. The qualitative approach is further detailed into a problem- and a solution- focused generation of knowledge about future. The former defines critical problems and resources that limit the technological development (e.g. by using the TRIZ concepts of contradictions and resources). The latter aims at envisioning by analogical reasoning the potential evolutions addressing both the identified problems and the lack of system resources (e.g. as with the Network of Evolutionary Trends (NET) [16]). The quantitative approach is based on data-series analysis for performance and expenses (e.g. by applying regression analysis as logistic growth curve [15, 17]).

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

4. A FORMAT Application in the White Industry Sector

A real case study is presented in order to provide an example of application of the FORMAT methodology, and show its applicability and viability in an industrial context. The case study has an industrial interest for the industrial partner that operates in the business of white goods production. In detail, it is about the forming techniques for the inner liners of domestic refrigerators.

During the FOR Stage, the analysts and Whirlpool's experts agreed on a set of questions (WHAT do we need to know about future?) whose answers may be conveniently used in order to plan future R&D strategies (WHY do we need to know the future?) in the selected context (time span 20 years, 2013-2033; location, factories of Europe, Middle East and Africa): i) Will vacuum forming (VF) technologies be needed in the future? ii) What will be the most available forming technologies in the future? iii) What will be the evolution of the main parameters of vacuum forming technologies?

A TF analysis is necessary to address these questions. Therefore an appropriate resource planning was set to accomplish the forecasting project, including analysts teamwork sessions, company experts' time availability and schedule. Therefore, the requirements (i.e. gate) to move on to the next stage were accomplished.

Along stage M, the analysts have to describe the current technological situation. FORMAT has been conceived as a flexible methodology, such that different specific tools can be applied to fulfill the same task, based on the specific competences of the analysts. In this case, the current inner- liner manufacturing process was modeled by using a functional description: <to make> <open polymer 3D-form (box-form)> <from granules>. The current process phases were described by using an adapted Energy-Material-Signal model [23], considering polystyrene granules as the input flow. A sequence of functions were elicited to further characterize both the process of transforming granules into a 2D polymer sheet (melt, form, size and quality check, stabilize and store) and its final transformation into an open 3D plastic form (soften, shape, size and quality check).

In order to obtain a complete overview of the manufacturing process, the main function of the production process was analyzed by using the System Operator considering a period of time of ±20 years from present. As a result, it produced a list of features, requirements, drivers and barriers from past, present and potential future at different levels: super-system (e.g. refrigerator and company context), system (e.g. current process), sub-system (e.g. sub- process or process phases). Several alternative technologies were identified by analysts to produce the inner-liner, specifically with a specific focus after the extrusion of the granules. The relevant alternative technologies considered in this study are: molding, casting, injection molding, blow molding and rotational molding. They all compete with vacuum forming, but none of them is currently capable of satisfying technical and organizational requirements, such as: cycle time of forming, low energy consumption, environmental impact, complexity of the 3D form, investment, etc. Consistently with the above elicited knowledge, the main parameters about performances and expenses have been defined.

Table 2: Brief description of the stages of the FORMAT Methodology.

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

Especially during Stage A, the authors have considered TRIZ techniques viable to address the different requirements of the related gate. The qualitative (problem- and solution- focused) and quantitative (S-curves and data regressions) approaches have been followed to obtain a complete perspective of the technology:

1. The extraction of limiting resources from problems identified in the system is carried out according to the logic of TRIZ contradictions. More than 20 contradictions (*e.g.* Figure 3) have been identified preventing the technological evolution of forming technologies for refrigerators. These contradictions emerged by analyzing the results of stage M, meanwhile the validation of contradictions relied on interviews with company's expert. A list of main problems was identified by combining results of contradiction analysis and decision makers' priorities; some of the main problems are: i) distance between heater and sheet; ii) dependence on crude oil of a raw material; iii) setups' frequency; iv) cooling equipment complication; v) dimension of 3D form (thickness); vi) initial thickness of 2D sheet.
2. In order to define a set of solutions addressing the limiting resources, the NET [16] was adopted as a technique to create a technological envision of possible futures. This approach aims at developing a set of potential technical scenarios based on the TRIZ Laws of Engineering Systems Evolution. For instance, Figure 4 shows a

part of the NET diagram, where box-color describes the technological state: black box: obsolete; red box: mature, yellow box: emerging; green box: envisioned and future projection of the technology evolution.

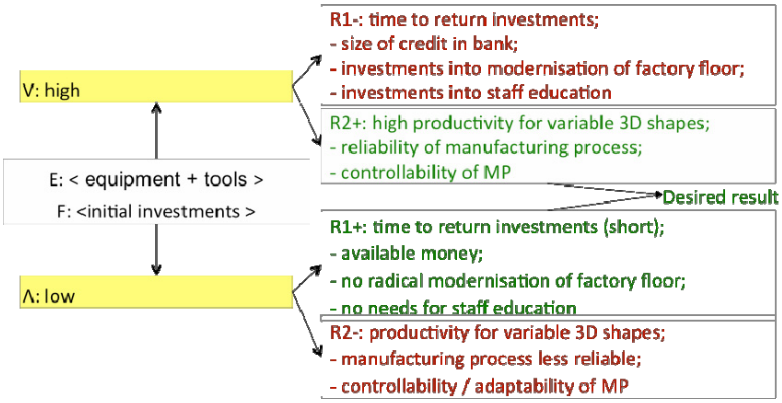

Figure 3: Example of contradiction used at Stage A. Red descriptions are for undesired results (Ri-); green descriptions are for desired results (Ri+) according to the OTSM-TRIZ contradiction model

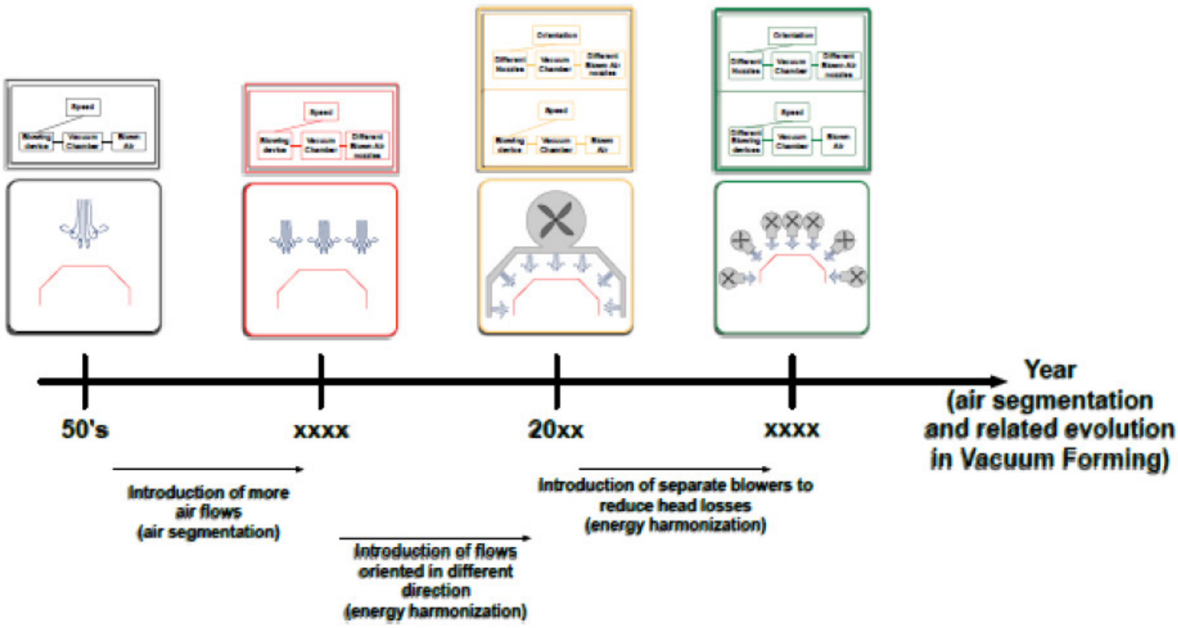

Figure 4: part of NET developed for VF technology trend of segmentation for the air used for cooling the 3D form (hardening).

3. Data-series regressions for the main parameters measuring performance and expenses addressing the limiting resources were developed and interpreted by adopting the assumption of logistic growth (S-curve). Figure 5 presents the trend analysis for the average volume of refrigerators, data available at [18, 19]. According to the regression, the maximum expected interior volume for refrigerator is 614,4 liters (p<0,01), the middle time of growth happened in 1953 (p<0,01) and the period to achieve the 80% of the cycle is 52 years (p<0,01) [17].

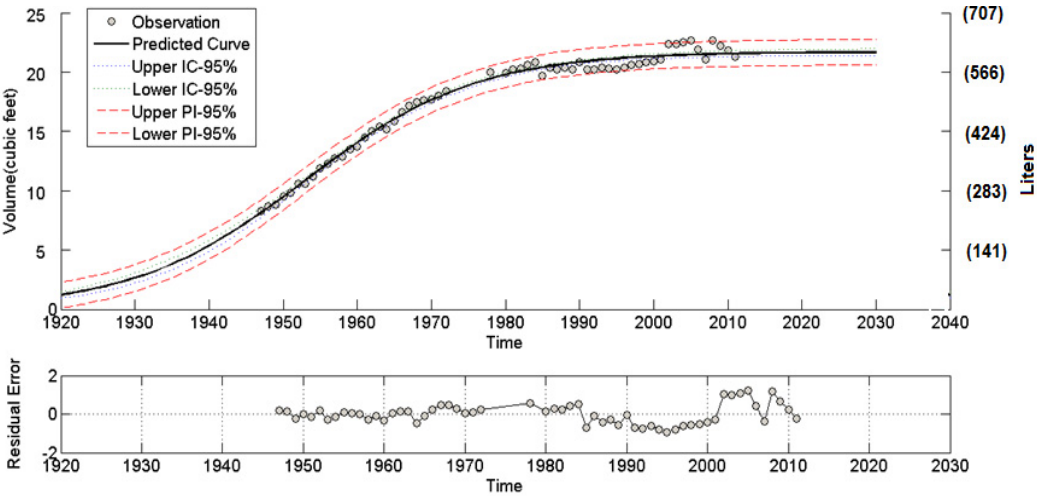

Figure 5: Trend analysis based on logistic growth assumption (i.e. average interior volume of refrigerator by every year)

More about the knowledge produced along stage A, as well as the other stages, can be found at (http://www.format- project.eu/). For instance, in the next years a projection of the technology is mainly linked with the reduction of cycle time for manufacturing process, energy consumption and recycling of the parts. With the same view, more elements of fridge system will be integrated in order to increase the food preservation time. In terms of polymer forming technologies, the complexity of the mold will increase in order to satisfy new customer demands, but also the footprint (plant size in sqm) of the Manufacturing Process (MP) should decrease. It is expected that the degree of integration of future MP with other phase's production will increase, also considering the still relevant trend of lean-manufacture. Moreover, Figure 5 has shown that the average volume of refrigerators is not going to radically change in the next years, therefore it is highly probable that it will stabilize on a constant value. As a consequence, it means that the next choices at the organizational level would avoid considering the idea of substituting their forming machines just because the old ones are not capable of producing bigger refrigerators. The fourth, Stage T is related to the way in which analysts will transfer their conclusions to the beneficiaries. The results were transferred to the beneficiaries by using comparison tables between main problems and decision maker parameters.

5. Preliminary assessment and conclusions

An innovative forecasting methodology was introduced in order to satisfy an emerging need for companies as the anticipation of reliable information about the future of technologies. The FORMAT methodology was built by using a Stage-Gate structure to address several requirements emerged by the manufacturing industry. Four stages define the complete methodology; each stage is described in terms of functions, questions and requirements to be accomplished. Every stage can be accomplished by using different techniques, selected among those who are more promising to satisfy the gate requirements.

A preliminary assessment of the FORMAT methodology was developed, according to the metrics defined in the project deliverable [20]. The assessment was carried out according to objective criteria, in order to produce as much constructive feedback as possible [21]. For this reason, a partner not involved in the case study was asked to carry out the assessment. PNO consultants applied the evaluation metrics; being acknowledged about the activity, but also not biased by the way the case study was implemented. The assessment showed the FORMAT methodology has several advantages that make it unique in comparison with other state of the art of technology forecasting methods. The builders, users and assessment reporters provided various recommendations to improve the efficiency and contents of the case studies. The main recommendations were:

- The need of reducing time consumption and using more economic expertise and variables. All the participants of the assessment have expressed this need.
- The balance between quantitative and qualitative techniques is expected to be improved upon more availability of data about the past.
- The case study has provided effective replicable results using various techniques.
- More efforts are required to summarize the results in stage T.

Some limitations may emerge, since the FORMAT methodology leverages already available tacit or explicit knowledge, as well as the intuition skills of experts in the field of study. It means that new scientific discoveries that are not conceivable or counter-intuitive to that knowledge may largely affect the validity of the forecast produced by the FORMAT methodology.

The FORMAT methodology is currently under further application and validation both within the Consortium and by other SMEs beyond the white good industry domain.

Acknowledgments

FORMAT is a project funded by the European Commission under the 7th Framework programme-IAPP Marie Curie Actions (PIAP-GA-2011-286305).

References

[1] Porter, A. L. et al. Technology Future Analysis: Toward integration of the field and new methods. Technological Forecasting and Social Change. 2004. Vol-71, p. 287-303.
[2] Kucharavy, D., De Guio, R. Problems of forecast. En Proceeding of conference ETRIA TRIZ Future 2005., 2005. p.219-235.
[3] Slupinski M., TECHNOLOGY FORECASTING – STATE OF THE ART UPDATE, available at http://www.format-project.eu/deliverables/public- reports-and-white-papers/deliverable-2.3/view
[4] Cascini, G. (2012). TRIZ-based anticipatory design of future products and processes. Journal of Integrated Design and Process Science, 2012, vol. 16, no 3, p. 29-63
[5] Becattini, N., Cascini, G., Petrali, P., Pucciarini, A. Production processes modeling for identifying technology substitution opportunities. In Proceedings of the 11th TRIZ Future Conference. 2011. p. 17-33.
[6] Martino, J.P., Technological Forecasting for Decision Making. 3 ed. Engineering and Technology Management, ed. M.K. Badawy. 1993: McGraw-Hill, Inc.
[7] Makridakis, S., S.C. Wheelwright, and R.J. Hyndman, Forecasting methods and applications. 3 ed. 1998: John Wiles&Sons, Inc.
[8] Scott Armstrong, J., PRINCIPLES OF FORECASTING: A Handbook for Researchers and Practitioner. 2002, Boston / Dordrecht / London: Kluwer Academic Publishers.
[9] Vanston, J.H., Better forecasts, better plans, better results. Research Technology Management, 2003: p. 47-58.
[10] Comission-JRC-IPTS, E. FOR-LEARN. 2007 [cited 2010; Available from: forlearn.jrc.ec.europa.eu.
[11] Glenn, J.C. and T.J. Gordon, Futures Research Methodology – Version 2.0. 2002, American Council at United Nations University.
[12] Glenn, J.C. and T.J. Gordon, Futures Research Methodology – Version 3.0. 2011, The Millennium Project, United Nations University.
[13] Makridakis, S. and M. Hibon, The M3-Competition: results, conclusions and implications. International Journal of Forecasting, 2000. 16(4): p. 451-476.
[14] Porter, A.L., New Methods for "FTA": Future-oriented Technology Analyses 2005, Search Technology, Inc. & Georgia Tech
[15] Kucharavy, D., De Guio, R. Application of S-shaped curves. En 7th ETRIA TRIZ Future Conference. 2007. p. 81-88.
[16] Cascini, G, Rotini, F, Russo, D (2011) Networks of trends: systematic definition of evolutionary scenarios. Procedia Engineering 9, p. 355-367.
[17] Meyer, P. S., Yung, J. W. and Ausubel, J. H. "A Primer on Logistic Growth and Substitution The Mathematics of the Loglet Lab Software". Technological Forecasting and Social Change. 1999. Vol-61. p. 247–271.
[18] Association of Home Appliance Manufactures (AHAM) http://www.aham.org/
[19] Appliance Standards Awareness Project (ASAP) http://www.appliance- standards.org/
[20] Vanherck, K. EVALUATION METRICS. http://www.format-project.eu/ deliverables/public-reports-and-white-papers/evaluation-metrics/view
[21] Rabie, M. SMALL PROJECT: ASSESSMENT – TEAM EXPERIENCE; FORMAT project deliverable 4.3
[22] Cooper, Robert G. 2008. Perspective: The Stage-Gate® Idea-to-Launch Process - Update, What's New, and NexGen Systems. Journal of Product Innovation Management 25, no. 3: 213-232.
[23] Pahl, G., Beitz, W., Feldhusen, J., & Grote, K. H. (2007). Engineering design: a systematic approach (Vol. 157). Springer.