Exploring Inter-Relationships between Events to Identify Strategic Technological Competencies: A Combined Approach

Cláudio Santos, Madalena Araújo, and Nuno Correia

***Abstract*—**The inherent complexity in nowadays' business environments is forcing organizations to be attentive to the dynamics in several fronts. Therefore, the management of technological innovation is continually faced with uncertainty about the future. These issues lead to a need for a systemic perspective, able to analyze the consequences of interactions between different factors. The field of technology foresight has proposed methods and tools to deal with this broader perspective. In an attempt to provide a method to analyze the complex interactions between events in several areas, departing from the identification of the most strategic competencies, this paper presents a methodology based on the Delphi method and Quality Function Deployment. This methodology is applied in a sheet metal processing equipment manufacturer, as a case study.

***Keywords*—**Competencies, Delphi Method, Quality Function Deployment, Technology Foresight.

I. Introduction

IN times when the ability to continuously innovate is an imperative to achieve competitive advantage, both academics and practitioners have great interest in the development of novel methodologies that are capable to anticipate future events, thereby helping them to define appropriate strategies. In the case of technology strategy formulation [1]-[3], companies are interested in knowing which technologies will have the greatest impact on the industry in the future, in order to guide their decisions concerning the investment in competencies and capabilities.

However, given the complexity of today's business environments, the technological evolution should not be seen in isolation. Issues related to the market, economy, competition and others should be considered together with the goal of producing more comprehensive scenarios about the future. Under the name of technology foresight, innumerous methods have been proposed and combined to yield more reliable results. Among the most popular tools is the Delphi method, based on experts' opinions, due to its practicality and holistic perspective.

Although much effort has been dedicated to develop Delphi surveys for the construction of prospective scenarios, little research has been dedicated to the interpretation of these studies to enable organizations to do a better planning of their strategic decisions. In order to fill this gap, this paper introduces a structured methodology that allows organizations to analyze and interpret the complex interactions between several events, in order to identify the most strategic technological competencies of the future. This methodology was applied in a sheet metal processing equipment manufacturer.

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II. Literature Review

A. The Role of Foresight in Technology Strategy

The strategic importance of including technology in corporate planning has been acknowledged for a long time [4]-[6]. Information about likely technological developments can be of extreme value for companies deciding on R&D priorities, thus having positive effects on the innovative capabilities of the company.

Technology foresight has been formally defined as the *"systematic process to identify future technology developments and their interactions with society and the environment for the purpose of guiding actions designed to produce a more desirable future"*[7]. Therefore, foresight demands attention to socio-economic contextual factors interacting with emerging technical capabilities that affect commercial products and services [8]. It is also less concerned with accuracy and predictability and seeks to create shared visions of the future, that stakeholders are willing to endorse by the actions they choose to take today [9]. The study of [10] concludes that the main contribution of technology foresight lies not in *predicting* the future, but rather in preparing managers to *handle* the future. Therefore, practices and techniques should aim at enhancing an organization's capability to detect changes in the environment, seize these changes and readapt its tangible and intangible assets to align with the external environment.

The upsurge of technology foresight in the last two decades has been boosted by the increasing role of innovation strategy in the competitiveness of organizations and nations, and by the emergence of information and communication technologies

(ICT). The latter provide excellent opportunities for searching large science and technology databases. They are also crucial to improve the process by which experts' knowledge are solicited and synthesized, as well as for enhancing the quality of face-to-face meetings by allowing the group members to work concurrently and to provide answers in an anonymous way on controversial issues [11].

In business environments, technology foresight can be a one-time activity or an ongoing process within the company, which can be performed by a single business, group or even a whole industry, enabling the identification and characterization of the major technology opportunities for the enterprise [12]. It also assumes different roles, depending on the size of the organization [13]. In large organizations, innovation is increasingly dependent on collaboration; it demands more external information than in the days of vertical integration, requiring careful use of technology foresight to inform technology strategy. On the other hand, small companies often argued that their limited time and resources were strong restrictions to invest in luxuries such as technology foresight. But in the early decades of the 21st century, many small companies are faced with rapid technological change, which in turn forces them to become more technologically informed. Thus, and also according to [13], there is a strong need for the development of easily comprehensible, timely and cheap sources of technology foresight for small companies.

In order to understand how technology foresight is carried out in companies, [14] found that technology foresight practiced in companies can be divided into six generic phases: (1) formulation of information needs/selecting the search area; (2) selecting information sources, methods and instruments; (3) collecting data; (4) filtering, analyzing and interpreting the information; (5) preparing decisions and (6) evaluating proposals and decision-making at the start or financing of a project or program.

While the importance of analyzing potential future technologies remains unquestionable, this analysis should be accompanied with investigations on market trends as well [15], in order to provide a richer picture of the linkages between future technologies, products, services and their future market potential. However, expectations about the value of technology foresight to organizations should be restrained, since this is not the only factor for successful innovation [14].Notwithstanding this and according to [16], scholars agree in one point: technology foresight is a key process that generates useful information as an aid to decision making, and an effective tool to support the formulation of technology strategies [17].

B. Methodologies for Strategic Technology Identification

The body of knowledge of technology foresight includes innumerous methods and techniques generally applied to the identification, organization and extrapolation of patterns of technical development and the determination of emerging technologies [18]. Naturally, the inherent complexity surrounding this field contributes to an extensive variety of methods. Reviews can be found in [19] and in [8]. Authors have attempted to cluster and classify them according to some shared characteristics. In an attempt to establish a methodology that matches a technology forecasting technique to a technology, [17], classifies them into three types: subjective assessment, exploratory and normative methods. In [20] the proposed classification is based on the method's capability: evidence, expertise, interaction, and creativity methods.

A shared belief among technology foresight scholars and practitioners is that the development of hybrid methodologies and integrated frameworks can increase the effectiveness of the forecasts. As stated by [21, p. 602], "*one should combine the results from different methods, which would help in reducing errors arising from faulty assumptions, biases, or mistakes in the data.*"

In the multitude of frameworks, this paper is interested in the research stream that assumes a strategic and analytical perspective in finding technological opportunities. A recurrent issue in the literature on strategy and technology foresight refers to two schools of thought, the *Positioning* and *Resource Based View* schools debate to technology strategy formulation [22].

The Positioning school (an 'outside-in' perspective) basically advocates that the most successful companies are the ones able to position themselves in favorable competitive environments. Therefore, this process is mostly focused in analyzing future business environments, in which the expected technology evolution is an important element, followed by the development of internal strategies that enable companies to achieve sustainable competitive advantage [23], [24]. The Resource Based View, the 'inside-out' perspective, suggests that it is the specification of a resource profile for a firm that enables optimal product-market activities [25], [5]. Such resources should include strategic managerial capabilities and technological competencies [26], [27].

Most frameworks that link technology foresight to strategy formulation take into consideration the inside-outside dichotomy, such as the R&D planning employed by Philips described in [28]. The process initiates with the technology intelligence stage, when multidisciplinary teams are given inputs about socio-cultural trends and emerging technologies and end up developing a significant number of scenarios, which in turn are characterized by a set of new products/applications and specific technological competencies. Next, the value of each product - the metric used is potential turnover - is estimated in each defined scenario and matched with the required technological competencies. Each of these competencies is also assessed in terms of their importance for the success of each product in a given scenario, by R&D managers, specialists and marketing people. The next stage is the technology selection, when each technological competence is evaluated by two factors: their relevance and success probability. Depending on a pre-established threshold for the relevance and success probability factors, core technological competencies are then selected.

The work of [29] calls the attention for the consideration of both internal (required resources, capabilities and competencies) and external (market, industry, regulations, global developments, etc.) scenarios into the strategy foresight process. They propose a scenario matrix tool to evaluate the suitability of internal strategies with external scenarios, and a future scorecard, which combines different indicators to monitor the strategy being implemented.

In the same line of direction, [30] proposes the "methodology of future coverage", diagnosis tool, aimed at analyzing the contents and coherence of a firm's vision, products and trends with relevance for the future. The methodology consists of two phases: a characteristics analysis investigates trends/megatrends (external environment), vision and products individually. Then, the coherence analysis makes pairwise comparisons (trends-vision, vision-products and trends-products), providing for each one of them a coverage index that basically addresses to what degree vision addresses trends, products reflects the vision and products reflects trends. Reference [31] decomposes the internal perspective into generic and specialized managerial capabilities and technological competencies and, through a series of six case studies, test and validate a model that assess the fit between strategic decisions made by organizations and their capabilities and competencies.

C. The Delphi Method

From the several technology foresight methodologies, the Delphi method ranks amongst the most popular ones. This method was developed at RAND Corporation in the late 1950s as a way "*for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem*"[32, p.3].

The foundations of the method rely on four principles [33]: anonymity of participants; iteration through a number of survey rounds; controlled feedback, where participants are able to comment and critique on the judgments of others made so far; and statistical group response, where descriptive statistics of the quantitative judgments are provided to participants after each round.

The last two decades have witnessed a resurgence of this methodology. Three factors have positively contributed for this: the widespread use of information technology tools to speed up communication and support of online collaborative systems [34]; its inherent capability to be easily combined with other foresight methods, such as with scenario building [35] [36], cross impact analysis [37] and technological substitution models [38]; and flexibility to adjust to different study settings, which gave rise to other variants such as the Policy Delphi [39], Disaggregative Policy Delphi [40] and the Real Time Delphi [41]-[43].

Besides these strengths, the method has the advantage of presenting holistic views about the future. In technology foresight studies, Delphi surveys may not refer to technology alone, but also to changes and likely evolutions with respect to the market and regulatory issues, for example. It is with no wonder that the Delphi method has been often combined with scenario planning [36].

Although the above principles are found in any study, there are no general recommendations concerning the questions to be included on a Delphi survey. This strongly depends on the objectives set for the study and dynamics of the industry under analysis. A comprehensive review of different types of Delphi designs is found in [44].

In foresight studies though, Delphi surveys often present some similarities. Normally, questions are related to the time of realization of a specific event. Answers are available in intervals, generally in five year steps, since single years would be too precise for a person to estimate. Time horizon varies greatly from study to study. Options such as "never" and "after (time horizon of study)" are often included.

Moreover, the impact and likelihood of the realization of such event is asked. The impact can be assessed on a single industry or many. Available answers are often in Likert scales; in the case of likelihood, interval probabilities may be asked.

Additional questions may be related to possible obstacles or constraints (economical, technological, regulatory, social, political, etc.)for the realization of the event. For the purpose of validating the sample of experts that fills the survey, a question about the self-assessment of the "expertise level" on each survey topic may also be included. Textual comments may be also available for experts to justify their assessments and/or include any additional information.

Finally, the analysis of responses is often made in terms of medians and/or averages and the convergence of opinions in terms of interval quartile ranges (IQR) and/or standard deviations (SD). The presentation of the analysis is made after each survey round or on-time in the case of Real Time Delphi.

For the purpose of illustration, TABLE I presents a brief summary of some Delphi surveys applied for technology foresight purposes.

TABLE I
EXAMPLES OF DELPHI SURVEYS APPLIED IN TECHNOLOGY FORESIGHT

Reference	Context	Delphi survey questions
[45]	Technology foresight undertaken in the Indian electronics and information technology industry.	Experts were asked to reveal: time of realization, major constraints for realization, prioritization of given topics, collaboration with multinational institutions, investment areas, how to cash in on the opportunities for the Indian environment and their individual level of expertise. Timeframe: 25 years.
[46]	A Delphi survey conducted in South Korea government on 1200 technological topics.	Experts were asked to reveal for each survey statement: degree of expertise, degree of importance, forecast time of realization, probability of realization, current level of R&D, method of performing R&D and constraints of realization. Timeframe: 20 years.
[47]	Foresight on the future of sensor technology (electromagnetic, mechanical, electrical, magnetic, chemical and nuclear).	Experts were asked to reveal their level of expertise, time of occurrence, technological feasibility, potential market value, market sectors most heavily impacted, and barriers for realization for each of the Delphi statements. Respondents were also asked about their area of occupation; type of organization and their country of work.Timeframe: 15 years.
[35]	A regular Delphi survey conducted by the Japan government about future societal needs and technological developments.	Experts were asked to provide assessments on each survey statement about: degree of importance, expected effect, forecasted realization time, current leading countries, effective measures that the government should adopt and potential problems. Timeframe: 10 years.
[48]	Indicate development directions in the Polish energy and fuel sectors identify key technologies of strategic importance.	Experts were asked to qualify their expertise level, time of occurrence, the impact on five elements (wealth creation, environment, life quality, energy supply safety and increase in the number of innovative enterprises) and which actions to take for each statement contained in the Delphi survey. Timeframe: up to 2030.
[49]	Indicate likely future scenarios for the logistics service industry in the year 2025.	Experts assessed each projection in terms of its probability, impact on the industry and desirability for the year 2025.
[50]	A Delphi survey to anticipate probable and wildcard scenarios on the future of aviation in 2025.	Expertswere asked to provide probability estimations and impact values for each projection, as well as written justifications for each of their estimates.
[51]	A web-based real time Delphi study on the factors which will influence the future development of the transport infrastructure until the year 2030.	Experts were asked to provide their assessments for expected probability of occurrence, impact and desirability for each survey projection.

D. Quality Function Deployment

Quality Function Deployment (QFD) is a matrix type of tool extensively used in product design specification, based on translating customers' requirements into technical and engineering characteristics. For this analysis of complex relationships, matrix type of tools have been largely employed by consultants and managers in business, as well as by academics, for its simplicity in communication, flexibility and easiness to integrate, thus satisfying the generic requirements of a "good" tool for technology management, as mentioned by [52]. QFD has also been used in technology foresight studies to analyze the relationship the demands from Smart City[1] [53] demands and specific devices, services and technologies [54]. In this paper, an adapted QFD matrix is used to analyze the inter-relationships between events from a Delphi survey.

Given the above considerations, the amount of information that can be collected from a Delphi survey can be overwhelming. In line with the aforementioned propositions favoring robust; economic and practical to implement; integrated; and flexible technology management tools, there is a need for novel ways to synthesize such information in useful ways. And, although it has become rather consensual how important future studies has become to strategy making, few studies have gone this far. Contributing to fill this gap, this paper proposes a structured methodology to facilitate the interpretation of the results from a Delphi survey in the process of strategic technological competency identification, based on an adapted QFD to analyze complex events relationships.

III. PROPOSED METHODOLOGY

This section describes a practical methodology that enables the management of a company to identify opportunities to invest in the most strategic technological competencies. This methodology combines the Delphi method with the Quality Function Deployment (QFD).

A flowchart of the methodology is presented in Fig. 1, followed by a description of each stage.

[1] The Smart City is a concept based on the development of modern (ICT) communication infrastructure, investment in human and social capital to provide a high quality of life, a wise management of natural resources and participatory governance.

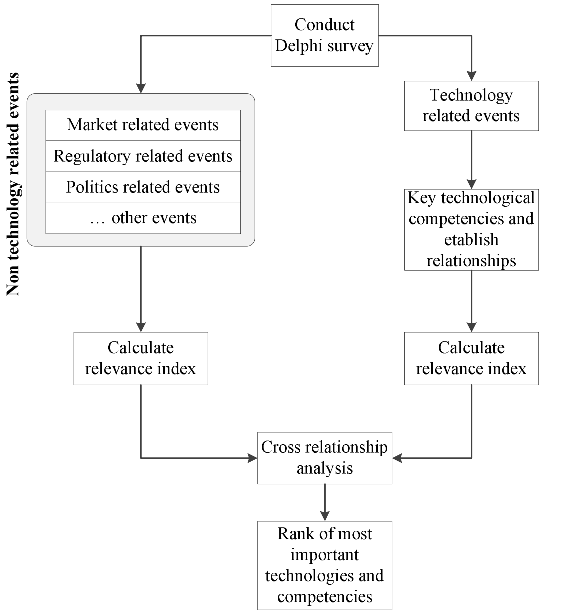

Fig. 1 Methodology to identify strategic technological competencies

As mentioned earlier, Delphi surveys applied in technology foresight studies usually include events that are not only related to technology, but also to market, regulatory, politics and other areas of interest. Hereinafter, these will be referred as *nontechnology related events* and will be treated separately from the *technology related events*.

Because technological related events may embody one or more technical knowledge areas or competencies, these need to be identified and their link with the respective technology related event(s) made clear. Fig. 2 shows a schematic diagram of these relationships.

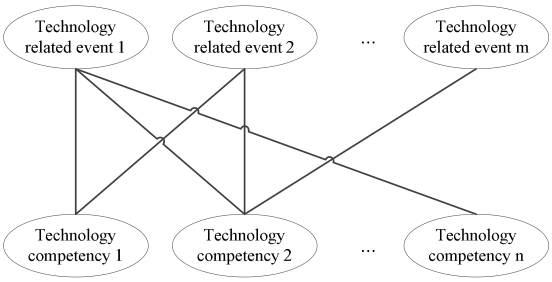

Fig. 2 Relationships between technology events and competencies

Next, attempting to synthesize the results of a typical Delphi survey, a metric indicating the relevance for each event is proposed. Typically, an event is evaluated on three vectors: *impact*, *likelihood of occurrence* and *urgency*.

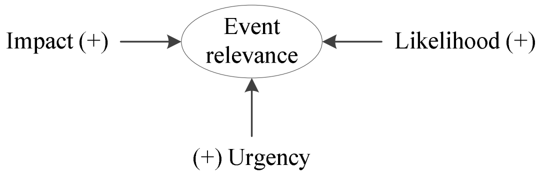

Fig. 3 Vectors influence on the relevance of an event

Fig. 3illustrates the influence of each vector. It is reasonable to say that greater impact and likelihood contribute positively to the relevance of an event. Events that are expected to occur in the short term should receive special attention by organizations, while events expected to occur in a more distant future guarantee more time for preparation. For this reason, it is considered that the greater urgency of an event, the greater its relevance too.

As mentioned earlier, Delphi survey results are usually analyzed using statistics such as median, averages, IQR and SD. It is fairly reasonable to say that most relevant events are the ones that received the highest scores and where experts converged more, or where the uncertainty about the event is minimal. In other words, the most relevant events are the ones where scores' central tendency is higher and dispersion is lower. Therefore, the mean divided by the standard deviation (the inverse of the coefficient of variation[2]) can be used as an indicator for the relevance of an event.

For the impact and likelihood, the calculation is made easy since Likert scales are usually employed, but the case of urgency requires additional transformation: available answers for time of realization are provided in interval years; a conversion is needed to a corresponding Likert scale range. An example of such transformation is illustrated in section IV.

Finally, the event relevance index is calculated using the following formula:

$$\text{Relevance index} = \frac{\left[\left(\frac{\text{Mean}_{(\text{impact})}}{\text{SD}_{(\text{impact})}}\right) + \left(\frac{\text{Mean}_{(\text{likelihood})}}{\text{SD}_{(\text{likelihood})}}\right) + \left(\frac{\text{Mean}_{(\text{urgency})}}{\text{SD}_{(\text{urgency})}}\right)\right]}{3} \quad (1)$$

The relevance index is then normalized for technology and nontechnology related events to provide a differentiated idea of importance, similar to using "weights."

The self-assessment expertise level is often included in Delphi surveys. If included in the survey, the organization may decide to filter the answers to only include the highest self-rated experts, in order to get more accurate predictions.

Having established the relationships between technology related events and competencies and the relevance index, the next step of the methodology is related to analyzing the inter relationships between technology and nontechnology related events. In other words, how market, regulatory, economy and

[2] In statistics, the coefficient of variation is a normalized measure of dispersion of a sample of numbers. It is defined as the ratio of the standard deviation to the mean.

other events may create the conditions for greater adoption of certain technologies.

Building a matrix like the one shown in Fig. 4, an adapted QFD matrix, one can analyze the relationships between nontechnology and technology related events more directly.

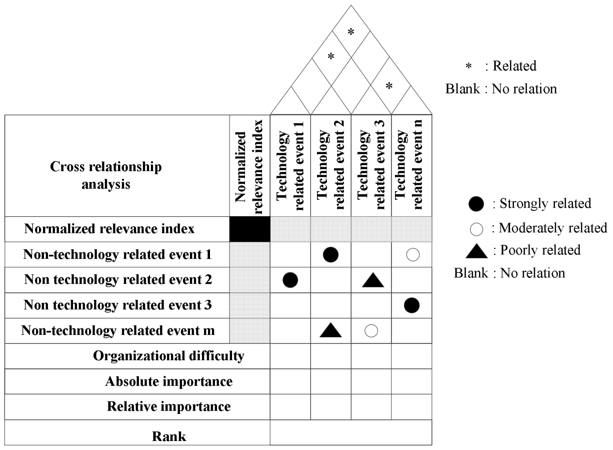

Fig. 4 Adapted QFD matrix

The nontechnology related events are placed in the rows while the technology related events in the columns. The normalized relevance index for each nontechnology related event is placed in the first column and in the first row is placed the normalized relevance index for the technology related event (the grey area in Fig. 4). On the top of the matrix (the "roof") the experts establish the existing relationships between technology related events, if they share common technological competencies.

In the intersecting cells, the relationships between technology and nontechnology related events are assessed using an appropriate scale. On the bottom of the matrix, the *organizational difficulty* assesses how difficult would it be for the organization to develop such technology, based on their existing bundle of capabilities and competencies. The *absolute importance* per technology related event is the sum product of the normalized relevance indexes and the relationship score. The *relative importance* is calculated in terms of percentage of the total sum of scores and the rank indicate the importance position of each technology related event.

Finally, a list of the most strategic technological competencies can be made by summing the absolute scores of the corresponding technology related events.

This approach differs from Cross Impact Analysis [55] by incorporating a multi-dimensional perspective about the relevance of an event (impact, likelihood and urgency) instead of simply estimating probabilities of occurrence of an event given the occurrence of another set of events. Moreover, the proposed method is linked with the technology strategy formulation process, since it is focused on the effects of events that may cause greater technology adoption.

In order to illustrate the application of such methodology, an implementation case study is presented in the next section.

IV. Case Study

The case study presented here was carried out in2012 in a European medium sized manufacturer of capital intensive equipment for sheet metal processing. During a period of approximately three months, and with support of the company's top management, experts from the industry and academia were interviewed and a thorough literature review was carried out, resulting in the identification of twenty seven events for the sheet metal industry. For reasons of confidentially and space, only a reduced number of events and their survey statistics are portrayed in this study, see TABLE II.

TABLE II
Delphi Survey Events Analyzed in the Case Study

No	Event	Type
1	Machine orders from low-labor-cost countries involve greater automation.	Market
2	Europe implements stricter machine tool market surveillance as a consequence of more stringent environmental regulations.	Regulations
3	Imported and low-cost machinery faces difficulties entering the European market.	Regulations
4	Hybridization (multiple processes in a single machine) is massively adopted in sheet metal processing equipment.	Technology
5	Massive adoption of active monitoring technologies and intelligent machines with self-learning capabilities.	Technology
6	Forming forces in hybrid engines (servo motors and hydraulic systems) exceed the forces of large hydraulic machines of today.	Technology

These events fed a Real Time Delphi survey[3] which was administered to a panel of sixty four experts. For each event, experts were expected to answer four questions:

1) What is your knowledge level in this subject? (available answers: from 1(low) to 4 (high))
2) What is the expected impact of this event? (available answers: from 1(low) to 4 (high))
3) When will it happen? (available answers: < 5 years, 5-10 years, 10-20 years, > 20 years, Never)
4) How likely is it to occur? (available answers: from 1(low) to 4 (high))

Experts were also able to provide their textual comments at will. In the end, twenty seven experts completed the survey, providing seventy comments. The average and standard deviations of each event was calculated. Moreover, scores and assessments do not reflect the opinion of the company, since the purpose here is only to demonstrate the application of the proposed methodology.

TABLE IIIIII includes each event's means and standard deviations, collected from the experts' assessments.

[3] The platform used was the Surveylet provided by the Calibrum Corporation (http://calibrum.com/).

TABLE III
NORMALIZED RELEVANCE INDEX CALCULATION FOR NONTECHNOLOGY EVENTS

No	Event	Impact		Likelihood		Urgency		Normalized
		Mean	SD	Mean	SD	Mean	SD	relevance index
1	Machine orders from low-labor-cost countries involve greater automation.	2.8	0.8	2.6	0.9	3.3	0.8	0.31
2	Europe implements stricter machine tool market surveillance as a consequence of more stringent environmental regulations.	3.2	0.8	3.0	0.9	3.5	0.7	0.38
3	Imported and low-cost machinery faces difficulties entering the European market.	2.7	1.1	2.2	1.2	3.7	0.7	0.30
4	Hybridization (multiple processes in a single machine) is massively adopted in sheet metal processing equipment.	3.0	0.8	2.7	1.0	3.2	0.7	0.34
5	Massive adoption of active monitoring technologies and intelligent machines with self-learning capabilities.	3.2	0.7	2.8	0.9	3.3	0.7	0.37
6	Forming forces in hybrid engines (servo motors and hydraulic systems) exceed the forces of large hydraulic machines of today.	2.8	1.1	2.7	1.1	3.3	0.7	0.29

By applying (1), the relevance index is calculated for each event, and then normalized for technology and nontechnology related events, see TABLE III. The conversion of time of realization intervals into urgency scales is shown inTABLE IV. No filter was used to select the highest self-rated experts.

TABLE IV
INTERVAL CORRESPONDING LIKERT SCALES

Time interval	Corresponding Likert scale (urgency vector)
Before 2017 (< 5 years)	4
Between 2017 and 2021 (5 – 10 years)	3
Between 2022 and 2031 (10 – 20 years)	2
After 2032 (> 20 years)	1

The next step is to identify and establish the relationships between events and competencies. After a careful analysis on the products, technologies and systems reflected in each technology related event, the following competencies were identified: *machine design*, *sensing*, *robotics*, *mechatronics*, *process automation and integration* and *information and communication technologies (ICT)*. The relationships between events and competencies are portrayed in Fig. 5.

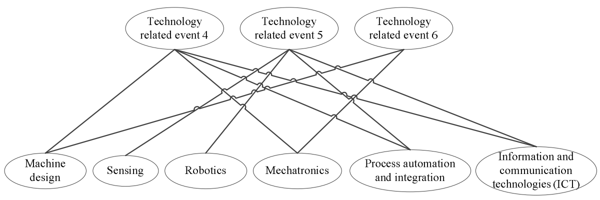

Fig. 5 Technology related events and their corresponding competencies

The following text provides the justification for the relationship assessment between events. Consider that the justifications that follow are the results of an analysis done by researchers, whose knowledge about the sheet metal industry is limited to what was acquired during the development of this study.

Technology related event number 4 (*"Hybridization (multiple processes in a single machine) is adopted massively in sheet metal processing equipment")* is strongly favored by events number 1 and 3 *("Machine orders from low-labor-cost countries involves greater automation"* and *"Imported and low-cost machinery faces difficulties entering the European market"*). It is expected that with a demand increase for automation by countries with low labor costs that the market potential for machines capable of performing multiple manufacturing processes, thus reducing the need for operators, will also increase. Moreover, from the perspective of a company having Europe as one of its main markets(as in the case study here discussed), greater restrictions on the entry of low-cost competitors in this market, strongly favors the market for hybrid machines incorporating more traditional sheet forming processes.

Event 5, in turn, is strongly favored by the event 1, because a higher request for automation will increase demand for machines with active monitoring and capacity for self-learning processing. Regarding event 2, this type of technology is only poorly favored because its ability to substantially reduce process waste still needs to be thoroughly demonstrated.

Event 6 is strongly favored by event 2, since machines with hybrid engines (servo motors and hydraulic systems) have demonstrated their ability to substantially save energy during operation. On the other hand, this technology is moderately favored by event 1. Despite the possibility of working with larger forces in the future, and therefore compete with hydraulic machines (which are cheaper), the acquisition cost of such machines is still higher. It will only be strongly favored if this cost decreases to a level that can compete with more traditional engines.

Fig. 6 presents the assessments and the calculations of the absolute and relative importance. A score of 9 points was used for a strong relationship, 4 points for moderate and 1 point for poor relationship. The absolute importance for each technology related event is calculated by summing the multiplication of the normalized relevance index of the technology, nontechnology related events –the "interaction effect"- and the assessment relationships. The relationships marked on the "roof" of the adapted QFD matrix reflect shared technological competencies among technology related events. The organizational difficulty is assessed on a scale from 1 (easy) to 5 (difficult). According to these inputs, the most important technology related event is *"Hybridization* *(multiple processes in a single machine) is massively adopted in sheet metal processing equipment."*

Cross relationship analysis	Normalized relevance index	Event 4	Event 5	Event 6
Normalized relevance index	■	0.34	0.37	0.29
Event 1	0.31	●	●	○
Event 2	0.38		▲	●
Event 3	0.30	●		
Organizational difficulty		3	5	1
Absolute importance		1.9	1.2	1.4
Relative importance		43.0%	26.4%	30.6%
Rank		1	3	2

Fig. 6 Cross relationships analysis results

Finally, and according to the defined relationships, TABLE V presents the rank of most important technological competencies and their respective scores, simply calculated by summing the absolute importance of related technology related events. Machine design and mechatronics appear to be the most strategic technology competencies, followed closely by process automation and integration and ICT.

TABLE V
TECHNOLOGICAL COMPETENCIES SCORES

Technology competencies	Total score
Machine design	3.3
Mechatronics	3.3
Process automation and integration	3.1
ICT	3.1
Sensing	1.2
Robotics	1.2

V. CONCLUSION

The field of technology foresight is continuously giving birth to new methodological developments. Given its strategic importance, we expect a great evolution in the coming years. The Delphi method is one of the most popular technology foresight methods, being able to provide holistic views about future developments. Delphi surveys are useful for identifying overall events in technologies, markets and regulations, etc., but this information inevitably needs to be complemented with deeper analysis, for that purpose resorting to other technology foresight methods (patent analysis, data mining, etc.). But, in situations when, either for financial or other relevant reasons, complementary studies can't be done, organizations still need structured ways to identify strategic opportunities derived from an analysis on the data collected from these surveys.

Although the significant practicality of the Delphi method, it does not allow the interactions between events to be assessed together. This may lead to incomplete analyses, being made without a proper understanding of events' inter-relationships. In order to overcome this deficiency, a matrix type of tool is proposed to analyze the influence of external events in technology adoption. Moreover, substantial amount of data can be collected from a Delphi survey, so there is a strong need for information to be synthesized into appropriate metrics, to support organizations in the identification of technology development opportunities.

The assessment of the relationships between technology and nontechnology related events proposed in the adapted QFD matrix may not seem obvious at a first sight. However, it is expected that even this apparent difficulty will be largely offset by (or even reinforce) the major benefits envisioned by the application of the proposed methodology - the generation of an intense organizational debate about the direction of the industry's technology evolution, and about the identification of strategic opportunities for future technological developments. This approach could also be integrated directly on the Delphi survey, i.e., after providing their best guesses concerning the impact, likelihood of occurrence and time of realization, experts could provide, on a second stage, their assessment on the inter-relationships between events.

Still, some recommendations for the application of the technique are suggested:

1) special attention should be dedicated to the identification and inclusion of nontechnology related events in the surveys, in order to portray the main contextual factors and enable the analysis of the relationships with the technology related events;
2) if the organization desires to know the opinion of experts in the analysis of relationships matrix (as suggested earlier), this could be done after they have filled their best guesses concerning the impact, likelihood of occurrence and time of realization, as in a second round of a typical Delphi, in order to avoid overloading experts with long surveys;
3) a proper taxonomy of technological competencies should be searched in order to provide a common platform of understanding. Although some taxonomies have been proposed in literature, still there is no one widely accepted.

We believe that the proposed technique for identifying strategic opportunities is a positive contribution in this direction. Further developments are expected resulting from the application of this technique in other case studies.

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