Experience of Effective Technological Forecasting

Retrospective Analysis of an Actual Project

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Abstract

The history of forecasting TRIZ-based projects is still too short to give us a number of real examples that would make it possible to look back and analyze their results. All the more, a rare opportunity to analyze such a case would be of great interest.

Certain errors of the project, which was conducted about 15 years ago quite successfully under the author's leadership and aimed at forecasting the evolution of toothbrushes, are analyzed in the article. This period allows to see, what forecast came true and what didn't. For the confidentiality reasons, the author uses only those concepts in his case studies, which have appeared to be disclosed to public as a result of commercial or patent activity of various companies.

Some specific problems of forecasting projects are analyzed. The author conducts an analysis of major reasons for errors in forecasting the evolution of engineering systems. The author also proposes approaches for preventing forecasting errors and emphasizes the importance of thorough work with patent information.

Key words*: technological forecasting, concept development, S-curves, error analysis, patent data.*

1. Gordian Knot of Problems Inherent to Forecasting Projects

A number of in-depth studies devoted to forecasting was published at different times - for example, [1-6], and others. Within the range of reference sources studied by the author, one can draw two conclusions: a) a large body of knowledge on evolution of systems and potential possibilities of forecasting this evolution has been accumulated, analyzed and developed, and b) the said knowledge are lacking the most important element necessary in practical activity – namely, instrumentality. By instrumentality the author means practicality of approaches, which allow formulating quite **reliable forecasts during an acceptable period of time** (with a special emphasis upon "reliability"), which would be different from obvious forecasts.

It was shown in [6] that many forecasting problems are rather complex, even when taken individually. When taken together, they form a Gordian knot, which one has often to cut in the real time mode. The author's experience shows that in this case a set of different methodological approaches, on the one hand, and experience as well as "art", on the other hand, serve as a sword (i.e. a tool). Though in this case methodologies represent a foundation, but according to author's

estimate, under the conditions of usual lack of time, experience and "art" account for up to 80% of the obtained results. What is this estimate based on? There are many specialists, who know the methodology. However, there are only a few successful projects with non-obvious results verified in the course of time.

The goal of the present paper consists in developing the both parts of this complex tool. Recognizing the utmost importance of experience and "art", the author believes that methodological vision is required to improve them both, because it is difficult to swing a sword that doesn't have a handle.

One of the most serious problems inherent to forecasting projects, which was not identified in [6], consists in the necessity of "fan-shaped" information-and-analytical studies aimed at investigation into evolution of a system proper and a field, to which it belongs, as well as tendencies in a number of other fields. In this case these "other" fields include not only the ones, which are close to one under investigation, but also some others that could be quite far from it. The main Gordian knot turns out to be surrounded by additional ones. They are less complicated, but there are a lot of them. The volume of information-and-analytical work to be done becomes rather high. A possible solution, in author's opinion, consists in intensive application of modern approaches to work with information - especially patent information [8, 9, 10].

According to author's opinion, critical analysis of errors is exceptionally useful for training in any field. At the same time, though the majority of previously published works devoted to this issue were characterized by in-depth study and width of coverage, the author failed to find materials, in which the actually conducted forecasting studies were analyzed with sufficient degree of criticism.

For example, one of specific tools for forecasting projects – namely, analysis of system evolution by S-curve – often appears to be unreliable due to a number of problems. Sometimes they turn out to be so difficult to formalize, that any attempts to solve them strictly methodologically don’t lead to reliable and consistent results. These problems are mainly associated with:

- Selection of parameters characterizing the evolution of a system,

- Determination of limit for system evolution,
- Selection of operation principle, for which the limit of evolution is to be determined, and
- Combining the results of analysis carried out for different parameters, etc.

Besides, evaluation of potential, volatility, segmentation and other characteristics of consumer's market is of great importance for correct forecasting. All this imposes additional requirements upon project results and can degrade their reliability.

Many of specific difficulties inherent to forecasting retain their significance and influence at presence, while other gradually become less significant. For instance, much more powerful information-and-analytical set of tools is available nowadays as compared to the situation 15 years ago; the methodologies have been developed further; and certain experience has been accumulated since then. Nevertheless, the main reasons for errors still remain in force. The goal of the present article is to decrease the probability of occurrence of similar errors.

The content of the present article represents a result of thorough analysis of a real project that was quite successful on the whole. The author tries to learn from his own mistakes and offers the others to learn from these mistakes as well.

Very few specialists in the field of innovative designing had an opportunity to acquire similar experience.

2. Subject Matter of Analysis. Goals and Objectives of Analyzed Project

The present article was written as a result of critical analysis of a particular forecasting project, which is 15 years old. 15 years is a significant part of several dozens of years that constituted a formal forecasting period according to project work specification.

So, in 1995 a project was carried out, which was aimed at forecasting the evolution of the engineering system "Toothbrush".

The following constraints were imposed on this project: all brushes having cleaning heads of ordinary type that are set into motion by means of electro-mechanical drive fell outside the scope of analysis. It was required to give both a

short-term and long-term (for dozens of years) forecasts for the evolution of this system. The number of worked out forecasting concepts (as well as their quality) should have enabled the client to evaluate the degree of perspectiveness of this industrial direction on the whole.

In terms of this principle client's goal, it was necessary to concentrate efforts on solutions and products that would have sufficient potentialities for market success. Besides a forecast for already existing sub-directions, of special interest was a forecast for products with supposedly

- significant improvement of the level of main function performance, and
- new functions, which are characterized by high consumer/customer value.

At the moment of project performance, a number of systems were offered at the market that employed different operation principle as compared to the conventional toothbrush, for example:

- electromechanical brushes,
- vibro- and ultrasonic brushes, and
- water jet devices for mouth cavity care.

Besides, a number of new directions and operation principles (as compared to a conventional toothbrush) existed at that moment at the level of at least patented solutions. For example:

- toothbrushes with ion-exchange resins and toothbrushes using electrophoresis-based methods for introducing medications into the mouth cavity;
- toothbrushes that combined teeth cleaning with effective massage;
- chewing toothbrushes;
- devices in the form of tray put on teeth capable of feeding a cleaning solution or other substance into the tray;
- devices intended for disinfecting toothbrushes during storage, and other systems.

3. Brief Review of Project Results

1. The main outcome for the client consisted in the following. It was explicitly and convincingly shown (and proved) that as applied to this old and already

"ploughed" field of engineering solutions for non-mechanical toothbrushes, new solutions are to be expected in future, which would be able to

- revitalize the market in existing consumer niches of this product, and, moreover,
- create new consumer niches, and, jointly,
- bring the evolution of non-mechanical toothbrushes from the stage of stagnation to the new stage of evolutionary S-curve.

Certainty of this outcome was ensured by:

- analysis of biological grounds for teeth cleaning and compliance of existing toothbrushes to these biological grounds;
- analysis of explicit and latent expectations of consumers associated with that;
- analysis of evolutionary trends of the "toothbrush" system;
- conceptual design of new systems within the frames of existing directions;
- conceptual design of new directions and corresponding systems;
- prognostic* design of new systems for long-term future; and
- scientific substantiation of operational ability of proposed concepts.

Concurrently, the client has got a brief analysis of relationship between the performance of similar functions by two interacting systems – toothbrushes and toothpastes. A common approach to rational distribution of functions between them was worked out.

2. What did the contractor acquire in addition to payment?

The above-listed actual outcomes, which predominantly ensured the success of the project, in their turn, appeared as a result of a number of methodological and other innovations. Practical and theoretical experience was enriched quite significantly.

Main achievements of the contractor:

a) methodological, for instance:

* Prognostic concepts are understood in the present article as concepts with supposed implementation in the very distant future - i.e. in 20-50 years

- for the first time, statistics of patenting in terms of directions and sub-directions was studied within the frames of particular project. Moreover, the notion of benchmarking appeared in practice of the contractor after the completion of this project because of this analysis of patenting statistics;
- for the first time, cause-effect chains were developed to microlevel processes (subsequently, it became a commonly accepted practice). This achievement served as a basis for new methodological developments, which took the form of a number of published materials;
- multi-criteria approach to working out the ratings for concepts perspectiveness was successfully used.

b) actual achievements in project results: a number of directions and concepts was generated and main goals of the project were attained (see above)

c) organizational achievements: a technology was developed for gradual improvement of synthetic outcomes in course of obtainment of information and analytical results and with contracting still higher number of external experts, and so forth.

d) business goal of the contractor was certainly attained.

3. A lot could be said about success here, but errors are of much higher importance for a researcher. This article is devoted specifically to some errors.

Let us make it clear: the author didn't set a goal for himself to study all possible errors that might be done in forecasting projects. The goal of the present article consists in identifying some particular types of errors and illustrating them with specific examples from a "real" – moreover, successful - project.

Due to obvious and all-round success, at that time the project seemed to approach the ideal in terms of achieved results. However, with accumulation of experience and further development of methodologies not only the achievements became obvious, but certain errors as well. The time that have passed since then also gave an opportunity to see the actual evolution of products offered at the market. Besides, at present it is possible to conduct some kind of "verification" of concepts by analyzing patent information for the period that has passed since then.

So, let's switchover to identified errors.

They could be classified using different approaches, - for example:

- purely methodological errors – ones associated with insufficient development of particular methodological approaches or with faults in applying them;
- errors resulting from "perception stereotypes", "preconceived viewpoint", and insufficient engineering analysis;
- errors resulting from shortage of information;
- errors resulting from underestimation of market potential;
- errors resulting from overestimation of market demands; and
- psychological errors – ones associated with stereotypes as well as with effect of insufficient thoroughness in thinking without apparent reason for that [10].

Depending upon accepted classification of errors, one can systematize reasons for these errors and give recommendations for avoiding them. In the present article they are analyzed from the viewpoint of methodological faults, which are directly associated with "experience and art".

The final evaluation of perspectiveness of a direction or concept was carried out in a complex way, taking different factors into account and using several criteria. For example, evaluation of compliance with TESE (Trends of Engineering Systems Evolution) was conducted in such a way that different trends were analyzed concurrently, and the results of previous evolution of the system as well as supposed consumer demands and other circumstances were taken into consideration. Multi-criteria evaluations allowed to minimize errors in final conclusions. Therefore, as a rule, the errors were determined not by one reason, but by several reasons at once. In connection with this, certain examples (given below) concurrently illustrate several reasons for forecasting errors.

Practical work showed that multi-criteria approach for evaluations does not always protect against errors. Therefore, even with such "protective" approach, it is very important to enhance the reliability of estimate in terms of each of the criteria.

4. Analysis of Errors

4.1. Forecasting Errors Associated with Incorrect Use of the S-curve Analysis

Let us first assume the following:

1. By regularities of S-curve evolution the author means the modern view at trends of irregular evolution of systems, which, in addition to [1, 2], was reflected in a number of modern studies, e.g. [4, 5, 6] and others.

2. Nevertheless, the basic notions [1, 2] developed by the time of project performance are used in the analysis presented in this work, - this is done for the sake of simplicity and briefness of reasoning. In the author's opinion, these notions were quite sufficient (and are quite sufficient nowadays) for preventing errors, if the information and analytical work is organized properly.

4.1.1. Wrong Timing of Beginning and Duration of Stage 1 of System Evolution

This is a very interesting and probably infrequent error encountered in forecasting projects.

If one manages to identify a system that stays at Stage 1 of its evolution, forecast for this system depends upon estimate of time required for transition to Stage 2.

When conducting the project, the author proposed a direction for modifying the toothpaste, and this direction implied the use of different effects generated by toothbrush. The goal was to confer such additional properties to toothpaste at the moment of teeth cleaning that were missing during toothpaste storage during its storage due to any reason. The author understood modification in this case as a qualitative change of physical and/or chemical properties of substances that were already available in the toothpaste - not, for example, simple addition of an accessory substance from the toothbrush.

The author was not aware of such ideas at the moment of project performance. Therefore, it was supposed that even Stage 1 had not yet started.

By the time of project performance, the author was not aware of such ideas that anybody has been working on. Therefore, it was supposed that even Stage 1 had not yet started.

Therefore, based on a set of various factors, it was anticipated that active development of this direction would take place in a distant future – in about 20 years. However, when working on this article, the author found out that developments, which refer to this direction, were underway already at the time of project performance. In particular, in 1997 a patent US5658148 with priority date of April 1995 (Fig.1) was published. By 2003 and later, a number of patents referring to this direction were published. Joint analysis of commercial and patent information shows that, for example, such companies as Oroscience Inc. (http://www.oroscience.com/home.html), Biolitec AG (www.biolitec.com) and CeramOptic GmbH (http://www.ceramoptec.de) are already orienting their business for products belonging to this direction. This fact confirms the truthfulness of the forecast on the whole. However, adhering to strictly critical position, the author thinks that incorrect timing for this forecast implementation was an error.

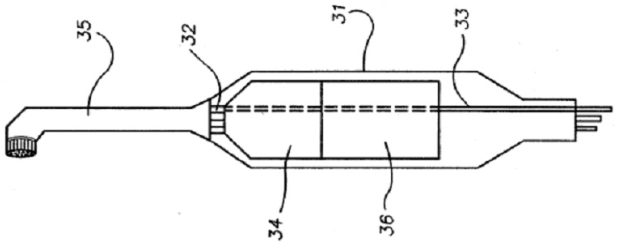

Fig. 1. Toothbrush for use at home with a semiconductor laser (32) for activating a special toothpaste according to patent US5658148 (1997)

The reason for this error in determining forecast implementation period consists in **insufficient investigation into background (prehistory) of some developments**, which, in one or another way, preceded the appearance of the concept under consideration. For example, if we had had an opportunity to conduct an in-depth investigation into patent solutions evolution, we would have discovered that some of them were coming nearer to the anticipated direction. Then the timing for forecast implementation would have been more exact.

Nowadays, such opportunities have appeared owing to commercial patent data bases with their advanced search and analysis service.

4.1.2. Wrong Time Estimate of Duration and Completion of Stage 2 of System Evolution (of ES Location on an S-curve at Stage 2 of ES Evolution)

Diversity of optimization options for a system is one of the major distinctive features of Stage 2 of system evolution, especially after the system has passed the midpoint of this stage.

By the moment of project performance, a great number of engineering solutions has been accumulated in prior art, which were devoted to relatively minor improvements of operating head, bristles, their incline and mutual arrangement of bristles, etc., which slightly enhanced the efficiency of teeth cleaning, but were unable to provide significant gain in efficiency.

This set of solutions could be conventionally joined into a direction of design-related improvement of standard toothbrush. Some similar engineering solutions already existed not only in patents, but were also embodied in products offered at the market.

Our team assigned this direction to the period of system transition to Stage 3 of the S-curve. We decided that, due to insignificant differences in terms of main parameter – namely, teeth cleaning efficiency, – this direction could hardly have serious potentialities for expanding the market in the future. We decided not to waste time and efforts on serious work in this direction, considering it to be of little promise both from the engineering standpoint (in terms of teeth cleaning efficiency enhancement) and from the commercial standpoint.

Fifteen years have passed, and the said diversity of designs increased, is still present at the market and still sells quite successfully. The author's error lied in **underestimation of overall potential of the market and in underestimation of market segmentation.** As the time showed, with appropriate advertising the market appeared to be able to absorb all this diversity of minor improvements and continues absorbing them successfully till nowadays. Transition to Stage 3 turned out to shifted in time.

One of major methodological errors consists in underestimation of market potential. With the high level of the market and its ability to absorb a large number of optimization solutions, the transition of the system to Stage 3 is shifted forward.

However, this error was not of great importance. The Client was primarily interested in the perspectives of non-traditional directions.

4.1.3. Wrong Estimate of Potential (Limit) of Engineering System Evolution

On the outside, this error is expressed in a similar way as the previous one – namely, in a wrong forecast of system transition to Stage 3. However, its essence is different. As it is correctly indicated in [6], correct estimate of evolution limits is rather complex and very often objectively impossible. However, the solution could be sought for in the use of **qualitative estimates and qualitative relationships**.

Example: chewing toothbrushes. It was forecasted that highly effective disposable chewing toothbrushes (with external design that is close to that of chewing gums - Fig. 2) would enter the market quite quickly and widely. Since then similar toothbrushes were mentioned in newspapers and periodicals from time to time. However, this forecast did not come true for the market.

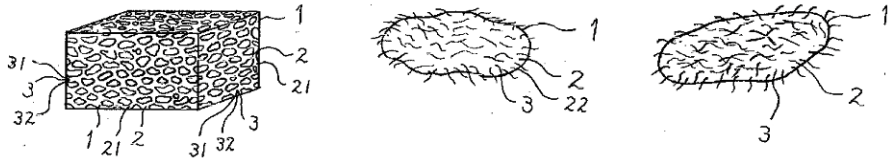

Fig.2. Chewing toothbrushes described in Japanese application JP2000072637 (2000) (2 – water-insoluble fibers or sponge, 3 – cleaning composition)

Besides, chewing gums with cleaning effect appeared and occupied a market segment. We forecasted the appearance of such products too, but they were beyond the scope of project goals and constraints.

What was the reason for this forecasting error? First of all, **evaluation of evolution limit was conducted without taking into account (to a sufficient extent) the biological constraints in combination with safety constraints** (factor

of the supersystem of the next hierarchical level - human body). Excessive degree of optimism played its role here. The efficiency of such devices for solving a complex of problems was overestimated, and the influence of individual differences of people upon teeth cleaning efficiency was underestimated. So, a set of problems inherent to such toothbrushes was underestimated: it is probable that a combination of requirements to safety and hygiene lowered the actual evolution limit of efficiency of such toothbrushes.

Another reason for this error consisted in excessively intensive application of some selected TRIZ tools (See section 4.2.1) to the detriment of other tools.

That's why, a forecasted intensive penetration of these directions to the market did not come true during the time that has passed and possibly it won't come true at all.

General recommendations regarding a group of errors associated with wrong use of S-curves are as follows:

- to study materials on using S-curves of system evolution in innovative designing [1, 2, 4, 5, 6], and others.
- to give greater attention to completeness and depth of information and analytical studies.
- to use modern information and analytical set of tools – namely, data bases, especially commercial patent ones.
- to overcome own stereotypes.

4.2. Errors from Local Application of Individual Methodological Approaches

4.2.1. Non-Critical Tendency for Employment of Resources

Example 1. The chewing brushes (Section 4.1.3) serve as a good illustration for this very reason superimposed upon TRIZ stereotypes. Probably, underestimation of their fundamental disadvantages served as a consequence of non-critical analysis of attractive idea of employing the supersystem resource – chewing movements of human jaws.

Actually, there are no grounds yet to speak about the erroneous forecast of the direction on the whole. However, in any case an error was made regarding timing -

15 years have passed, and such toothbrushes are still not widely used. Besides, a conclusion was not drawn that commercially successful implementation of this direction requires break-through solutions for forecasting contradictions (See section 4.2.5).

Example 2. Intensive evolution of toothbrushes employing another resource of the supersystem – pressure head of water in the faucet - was also forecasted. This forecast also demonstrates excessive enthusiasm about available resources. This forecast is discussed in greater detail in Section 4.4.2.

Recommendations: to study deeper the essence of TRIZ methods; to overcome the so-called TRIZ stereotypes; and to study deeper the prehistory of the direction.

4.2.2. Excessive Tendency to Idealization of Results (Striving for to Find the "Best" Solution)

Let us see, how one can fail to notice a good comfortable path in a forest, while looking for a wide road. The author forecasted the appearance of direction of "Smart toothbrushes", which would control not only simple things - such as teeth cleaning time. In particular, there was proposed a concept of toothbrush capable of correct identifying of cleaning time expiration via estimation of overall mechanical action upon the teeth. A solution of this kind was published only in 2007 (Japanese application JP2007325806 Oral cavity sanitary unit).

However, the project team failed to notice simpler solutions, which were demanded for by the market. For instance, signaling about exceeding the threshold of mechanical action upon the teeth.

As information studies (carried out recently by the author) showed, such developments were already in progress when we were working on the project. During the time passed, a number of applications were filed and a number of patents issued for inventions of this kind. Let's indicate only the recent ones: JP2008012232A2 Toothbrush pressure measuring holder (2008), JP2008006282 (2008, Johnson & Johnson Consumer Co Inc), US20070136964 Multimedia toothbrush (2007), JP2006000361 Toothbrush for learning, and toothbrushing

learning device (2006), US7383603 Flexible neck toothbrush (2006), and US6412137 Pressure sensitive brush (2002). This list could be continued. The main goal is one and the same: prevention of excessive abrasive wear of teeth and toothbrush bristles in the course of teeth cleaning. This intensive patenting activity has already found practical implementation in a great number of products. For example, one can easily find in the Internet 34 brand names of toothbrushes with strain gauge sensors (http://www.twenga.co.uk/dir-Health-Beauty,Facial-hygiene,Electric-toothbrushes-0186671, Pressure Sensor Electric toothbrushes)

Thus, proposing a more advanced concept, a solution was overlooked, which was of great commercial potentiality, though it was far from being "the best".

In the process of improving the solution with the aim to obtain "the best" one, **there is an optimum point**, which should not be surpassed due to the reasons that are usually associated with the cost, side effects or consumer constraints (safety, ecology, etc.). From the methodological standpoint, one can use a criterion of system ideality. However, this criterion is difficult to formalize and to use it in practice. Instead, it is possible to intensify the engineering analysis of the system.

Recommendations: While trying to obtain "the best" future solution, economically optimal options should not be overlooked.

4.2.3. Excessive Deployment – Overloading with Subsystems

A device for teeth cleaning with a jet of water containing air bubbles was mentioned as a promising direction in the project. The reason for that lies in the attractiveness of aerated water as a "working medium" and compliance with the trends of engineering system evolution.

However, if the analysis of this direction were performed fairly critically, it would have been possible to draw a conclusion about inevitable overloading of such system with subsystems. Here one would find water supply, gas supply, elaborate design of operating head and/or bristles... Improvements in this direction appear until nowadays - for example, WO2007118373A1 A bubble toothbrush (2007), - but actual commercial proposal would be quite limited. A

forecasting error associated with **non-critical attitude to excessive deployment** of a system is observed in this case.

Recommendation. One should study the essence of TRIZ methods in greater depth and, what is more important, the practice of building actual systems should be also studied deeper. In such cases, a forecasting problem aimed at design simplification via trimming of subsystems should be set first of all. If it turns out that it is impossible to solve such problem, it is recommended to think about rejection of such forecasting concept.

4.2.4. Not Deep Enough Work with Effects: Overlooking/Loss of Concepts or Their Engineering Merits

The author forecasted the appearance of a direction aimed at indication of teeth cleaning quality by means of toothbrushes and proposed at least two versions for implementing concepts belonging to this direction. However, at least one concept was still overlooked - namely, indication of dental plaque simply by means of optical sensors. During the time elapsed, some developers did not miss this idea: for example, see patent US5894620, Electric toothbrush with means for locating dental plaque (1999). This fairly obvious concept was overlooked under the direction, which was successfully forecasted.

The author believes that this error is also a methodological one.

Recommendation. Careful work with physical, chemical and other effects should not be forgotten; it is necessary to pay attention to work on systematic use of patent information [7, 8, 9].

A publication should be also mentioned here [11], which is not intentionally directed at patent information, but in terms of problem statement is similar to [7,8,9].

4.2.5. Inattentiveness to Key Forecasting Contradictions (Excessive Optimism)

In some concepts, serious problems associated with forecasting contradictions were seen. However, there was little time for search for solutions. Therefore, we sometimes made use of the right to leave these contradictions for the future as secondary problems. It is impossible to solve all problems within the frames of a

forecasting project. It is obvious that, on the one hand, excessive optimism is fraught with errors. However, it is also clear that there is still a possibility to estimate the degree of substantiation of this optimism.

For example, for chewing toothbrushes, contradictions should have been formulated that are associated with the fact that the combination of requirements to safety and hygiene should lower the actual limit of their efficiency growth (See section 4.1.3). Probability of finding solutions for generated secondary problems was estimated too optimistically. Were there justified grounds for such optimism? These contradictions and secondary problems (corresponding to them) were of high significance. However, our team did not see more or less simple solutions for them.

Despite this, these problems were left "for the future", based on a supposition that they are quite solvable. The analysis of patent documents published for the passed time, conducted by the author, shows that solving of "secondary" problems in this case leads to making the design much more complex, while in simple designs the problem of efficiency is still left unsolved. It is not by chance that, despite long patent history of chewing toothbrushes, almost only product related to this direction and offered at the market is the chewing "toothbrush" for children (e.g., Biodegradable 'Chewing' Toothbrush http://www.gogreen.cellande.co.uk /shop/products/toothbrush/toothbrush.htm, Fig.3).

Fig.3. "Chewing toothbrush" for children

Thus, the forecast has not come true yet and will hardly come true at all.

Recommendations:

- to overcome own "optimistic" stereotypes;

- if a secondary problem is significant enough, and there is no sureness in the existence of solution, it is better not to classify a certain concept with the group of promising ones, or it is better to label it with an appropriate comment.

4.3. Insufficiently Deep Investigation into Tendencies and Prior Art

When performing forecasting projects, one should study prior art and existing tendencies as applied to:

- a field of direct interest (in our case this is teeth cleaning at home);
- related and alternative industries (for example, other kinds of oral care, dentistry, teeth whitening, chewing gums, toothpastes);
- close supersystem fields/industries (for example, medicine, food industry); and
- fields that are similar in terms of characteristic features, in which parallel lines of evolution could be observed [12] (cleaning devices of different purpose, massagers).

Due to the above indicated, information and analytical studies acquire large volume [3].

4.3.1. Errors in Studying Prior Art and Tendencies in a Given Field/Industry (Underestimation of Prior Art)

It is obvious that attained Prior Art (the term, which is well known to patent specialists) and already formed tendencies in a given field or industry represent a foundation for any forecast.

Therefore, it is necessary to analyze the possibility of multidirectional evolution of systems. Usually, subsystems and supersystem also should be subjected to analysis. Therefore, Prior Art has to be identified for many directions at once. This is one of numerous specific complications of forecasting projects. The volume of information and analytical work is rather high.

In his project our team first analyzed all available information, identified the tendencies and determined their character. In doing so we made one searching error - namely, patents for devices intended for cleaning teeth with a water jet containing air bubbles (aerated water) was overlooked. Additional study carried out by author while he was working on this article showed that at that time such

solutions had already appeared. This is, for example, patent US4903688 Tooth cleaning toothbrush and system (published in 1990). We proposed this direction without knowing that it actually already existed. Moreover, we classified this direction with the ones that had high potential and promise (thus making another mistake analyzed in Section 4.2.3).

Such errors of omission are associated with problems of search for and processing of a huge body of information in the absence of time for double-checking. From the current author's standpoint, it reflected the absence of available set of tools for information and analytical work.

Recommendations. First of all, it is always necessary, if possible, **to double-check the completeness of basic information about prior art** – i.e. a foundation, on which the entire "building" of the project stands.

Secondly, it is necessary to take care of instrumental support of such an opportunity. This is provided by the same means, which we recommended earlier. Even if there is an access to high-quality commercial reports, one should conduct own studies involving the use of commercial databases of patent information. They provide an efficient set of search and analytical options and allow an analyst to obtain results that are not found and cannot be found in reviews and marketing reports. These are, for example, the bases Questel [13], Delphion [14], STN [15], and others. Service of patent data given by **Questel** company **(www.questel.com)** is distinguished among them from the standpoint of the author in terms of offered opportunities. It supports all methodological abilities to conduct information and analytical studies necessary for performance of forecasting projects with high degree of completeness, quality and efficiency.

Thirdly: it is necessary to pay attention to published materials on system-based use of patent information [7, 8, 9] and to learn how to use it professionally.

4.3.2. Insufficiently Deep Study of Tendencies in Related, Similar and Alternative Fields/Industries or Insufficient Use of These Tendencies

There is a fine line between insufficient-degree investigation into tendencies, on the one hand, and non-application of acquired knowledge for generating

forecast directions and concepts, on the other hand. However, in this article the author is not going to make distinctions between these two types of errors. The importance of completeness of such studies will be illustrated with an example.

In the course of project performance the industry of systems for teeth whitening at home was already developing. We should have identified this direction in the course of information and analytical studies, but failed to do so. And the fact that it remained beyond the scope of attention has to be assumed as a serious methodological error.

Therefore, the author believes that the absence of concepts that place an emphasis on the whitening action was a serious error in the project. History shows that other researchers did not miss this issue, though, in author's opinion, no significant achievements have been demonstrated here as yet. Nevertheless, if our team had known about home teeth whitening at that time, we would have forecasted at least the appearance of whitening toothbrushes.

Lack of knowledge in this particular case could have been compensated by system-based study of the super system – industry of oral care. At that time our team did not manage to conduct such a study with sufficient degree of completeness.

Recommendation: to pay appropriate attention to information and analytical studies, especially those aimed at studying the supersystem; to pay attention to materials on system-based use of patent information [7, 8, 9] and to learn to use it professionally.

4.3.3. Insufficiently Deep Study of Directions and Tendencies in More Remote Fields/Industries, including Areas with Parallel Evolution of Systems.

Different approaches were used when doing the project. Among the issues subjected to analysis were perspectives as seen from the standpoint of directions and tendencies identified in different fields and industries.

In particular, conceptual directions were proposed that were aimed at synthesis of toothbrushes with devices for diagnostics of cleaning quality, control of correctness of movements during the teeth cleaning process (See Section 4.2.2),

curative action both upon mouth cavity and upon other subsystems of human body, etc. All these directions during the time passed appeared to be reflected in new developments in this or that way (see, for example, applications and patents US20070111166, JP09192148, EP1174055, EP1700611, JP2005241335, US7328706, JP2006061486, US20060183071).

Nowadays, from the standpoint of accumulated experience, it seems confusing that there was not proposed a direction aimed at creating toothbrushes with functions of ***medical*** diagnostics of body organs state (not only of mouth cavity). During the last years this direction started developing (WO06071332, US20040049123 and other patents).

What is the reason for errors described in sections 4.3.2 and 4.3.3? Sufficiently systematic analysis of **scientific and technological supersystem** was not conducted. It is possible that someone will consider the last of the described errors to be trivial, to be such a error, which he would never do... Unfortunately, even such "evident" errors appear.

How such errors could be prevented? One should search for resources for conducting research about tendencies in different fields and industries. A strong resource for this, for instance, is a methodology of problem-oriented search in terms of actions (APOS - Action-Problem Oriented search) [7, 8, 9] and a similar methodology of Function-Oriented Search (FOS) [11] combined with the use of powerful search and analytical set of tools offered by commercial databases.

4.4. Underestimation (Insufficiently Deep Study) of Market Aspects of Proposed Concepts

4.4.1. Neglect of Market Advantages Including Entering the Segments of Other Markets

As a rule, these errors are of secondary nature. These are cases of neglect of market advantages associated with one of the engineering aspects of the concept. Inattention to the secondary engineering opportunity could lead (when analyzing the perspectives) to potential loss of an additional market niche.

For example, a concept was proposed involving a system made of elastic polymer, which embraces entirely one row of teeth (or both rows of teeth), the said system being able to move, due to which fact the cleaning process takes place. In fact, the efficiency of teeth cleaning by means of such a system is not high; that's why we did not assign high rank to this concept when evaluating its potential. However, an opportunity of a separate application of such a system for medication delivery was missed, and a conclusion that such a device has its own market niche was not drawn. Patents that were granted later, - for example, US5993413 Intraoral administration device and system (1999), Fig.4, and US7328706 Therapeutic and protective dental device useful as an intra-oral delivery system (2008) -confirm this error.

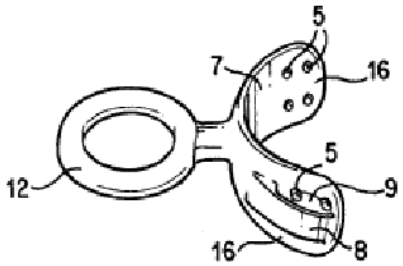

Fig.4. US5993413 Intraoral administration device and system; (9) – area of medication placement.

This is an example of how a seemingly minor technical omission in the analysis of proposed forecasting concept dramatically impairs the estimate of its market potential. In this case, a system for delivery of medications into the mouth cavity should have been forecasted, rather than a device for teeth cleaning.

Was it possible to notice this opportunity in due time? The answer is "yes". The methods are still the same: systematic study of close and remote, alternative and similar fields and industries.

The approaches recommended by the author are APOS and FOS methodologies with the use of patent bases; method of parallel evolutions.

4.4.2. Underestimation of Consumer Disadvantages

Several kinds of devices for teeth cleaning employing the pressure head of water in faucets and mentioned in Section 4.2.1 are currently offered at the market. For example, devices for teeth cleaning by jet of water (Fig.5, http://www.teethjet.co.nz/2452.html) are currently sold for consumers. Therefore, it would be incorrect to say that a positive forecast for such systems was a 100% mistake. However, the supposed serious market success is not observed for such devices. This is an interesting example of a situation, when obvious market advantages of a direction could not outweigh certain market disadvantages.

Fig.5. Example of commercial product for teeth cleaning by a jet of water

Main Results and Recommendations

1. A large forecasting project (accepted by the Client as quite successful and accomplishing all stated goals) was analyzed in this article in terms of omissions and errors from the viewpoint of long period of time that has passed.

2. A number of particular methodological and other errors were identified. Their reasons were determined. Recommendations are given regarding prevention of such errors.

3. Sometimes the concepts, which were initially supposed to be implemented in the distant future, appear to be implemented already after several years. The introduction of new technologies proceeds rather quickly. However, it could also be predicted.

4. The main generalized recommendations are as follows.

4.1. Methodological recommendations:

- Overcome the so-called TRIZ stereotypes and study the essence of TRIZ methods in greater depth;

- Upgrade self-criticism, even if the forecasting character of the project formally allows to make requirements to the degree of concept development less stringent. Conduct more careful engineering analysis of concepts;

- Thorough work with physical, chemical and other effects;

- If a system subjected to forecasting is significantly more complex than the source system, a forecasting problem should be stated with the aim to simplify this system via trimming of subsystems. If no opportunity to solve the problem is seen by researcher, the idea of rejecting such a concept should be thought over;

- If a secondary problem is quite significant and still there is no certainty in ability to solve it, the idea of rejecting such a concept should be thought over or it should be accompanied by an appropriate comment;

- In case of striving for to obtain "the best" future solution – economically optimum options should not be missed;

- Apply the methodology of parallel lines of evolution;

- Apply the FOS and APOS methods; and

- In actual work – modify the methodology with regard to peculiarities of a particular project.

4.2. Psychological recommendations

- Overcome own stereotypes, both "pessimistic" and "optimistic". Study scientific and technological news; and

- Use discussions and other methods for this purpose.

4.3. Recommendations on information and analytical support:

- Study the background (prehistory) of developments in greater depth;

- Double-check the completeness of basic information concerning prior art;

- Take market potential into account and study it more thoroughly;

- Use modern information and analytical set of tools – databases, especially - commercial patent ones;

- Learn to work effectively and efficiently with these tools; and

- Pay attention to materials on system-based use of patent information.

Conclusion

The frames of the present article did not allow the author to include all observations and give all the examples, which the author derived from project analysis. Besides, an analysis of evidently successful forecasts could probably be of serious interest. However, in this case the volume of the article would be many times larger.

Here is a minor addition to the last item of the previous section.

As it was shown in [9], system-based work with patent information is itself able to ensure solving of practically all problems encountered in innovation projects of any type. With forecasting projects, it is especially important due to a number of reasons.

1. The most serious problem of forecasting projects consists in necessity of multi-directional information and analytical studies:

- of analyzed system;

- of its subsystems; and

- of its supersystems.

2. Another serious problem consists in the necessity to study prior art and tendencies of evolution in a number of fields/industries:

- in the area of direct interest (in our case this is teeth cleaning at home)

- in similar and alternative fields (for example, other kinds of mouth cavity care, dentistry, teeth whitening, chewing gums, and toothpastes)

- in close supersystem areas (for example, in medicine and food industry); and

- in fileds/industries, which are similar in terms of characteristic features, in which parallel lines of evolution could be observed.

All the above, taken together, could be named a 3D-fan of research, or even a multi-dimensional fan. In this case the system-based analysis of patent information

represents an effective and efficient methodological approach to be used. Questel service [13] is the most effective and efficient one for conducting such study among all patent services known to the author.

In particular, when working on this article, the author had to conduct an entire cycle of express studies of patent information. Questel service [13] demonstrated high efficiency in this work.

And the last issue to be covered. Probably there would be a reader, who will ask: how could a project with such a number of shortcomings be successful? The answer is as follows: first of all, the analyzed omissions were identified after thorough analysis only many years later. With a less thorough approach, these omissions could be omitted even nowadays. However, in this case it would be more difficult to learn. Secondly, there would have been many more instances of conceptual success in this project, and the significance of them would be immeasurably higher than that of disadvantages, which were shown here. "Thirdly" and "fourthly" could also be given here...

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