TRIZ-assisted Stage-Gate Process for Developing New Products

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Abstract This paper describes a method to improve innovation by integrating TRIZ tools into the Stage-Gate process. The problem now is that existing best industry practices for developing new products, in particular the Stage-Gate process, are still relatively inefficient, especially as concerns radical and disruptive innovations. On the other hand, a method such as TRIZ, which is specifically directed at efficient innovation and could dramatically improve these practices, is underused. The proposed TRIZ-Assisted Stage-Gate process engages TRIZ tools throughout the entire development – from generating ideas for new products through developing production prototypes. This approach makes new product development significantly faster and reduces cost, thereby decreasing risks associated with development. In addition, it is easy to implement because it retains the general structure of the Stage-Gate process. The paper also includes a brief case study on the development of a novel Smart Antenna for Wi-Fi systems to illustrate the practical implementation of the proposed method.

Keywords: *new product development, stage-gate process, TRIZ*

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1. Introduction

Modern industry has developed its own best practices such as the Stage-Gate process [1], which is widely used for developing new products and demonstrates superior efficacy relative to ‘undisciplined development’.

However, if a new product is truly innovative and requires solving difficult inventive problems, the Stage-Gate process frequently introduces great delays or even fails, and, so, many promising ideas either have never been developed into products or their development took much more time and money than was initially expected.

On the other hand, the existing arsenal of TRIZ [2] tools and even more advanced arsenal of GEN3 TRIZ [3] tools have been specifically developed to solve difficult inventive problems. Years of practice in TRIZ-consulting has proved these tools to be highly effective, giving reason to believe that TRIZ will be especially valuable in developing truly innovative products that normally possess numerous complex problems.

Unfortunately, most products are still being developed without TRIZ mainly because industry people, who perceive TRIZ as an alternative to Stage-Gate, question whether TRIZ-consulting really is so efficient relative to industry’s best practices and whether it is worth using TRIZ to develop new products. As a result, in many cases TRIZ is underused or not used at all, and, therefore, new product development is often much less rapid and efficient than it could be.

In this paper the author is trying to show that the TRIZ approach and an industry’s best practices are not rivals and can greatly benefit each other, if properly used.

2. Why Neither the Stage-Gate Process Nor TRIZ Alone Are Perfect Methods for Developing New Products

2.1. Strengths and Weaknesses of the Stage-Gate Process

The Stage-Gate process seems to be the most widely adopted best practice for developing new products. Most large corporations use this or a similar process to reduce the time and cost needed for their new developments. As shown in Figure 1, the Stage-Gate process has five stages where rough ideas are consecutively developed into a commercial product, and between the stages are five gates at which strategic decisions are made about whether an idea, concept, or design should be developed further.

Due to a well-developed and detailed step-by-step algorithm for its implementation, the Stage-Gate process significantly reduces development time and cost relative to ‘undisciplined development’ because unpromising ideas, prototypes and designs are rejected at earlier stages and do not consume resources and time after that.

There are special tools used within the Stage-Gate process to efficiently identify unpromising solutions. One of these tools is Failure Mode and Effect Analysis (FMEA) [4], which has actually become an industry standard for

assessing various risks that may occur during the development of the new product. The algorithm for FMEA relies on a team of experts collected from various departments who use their experience and skills to identify potential risks. Normally, big businesses use FMEA or some proprietary equivalent as a part of their Stage-Gate process at the gates in order to identify and reject unpromising (in terms of too high risk) solutions.

Figure 1. Typical Stage-Gate process map

However, despite its recognized efficiency, the Stage-Gate process is still suboptimal in terms of reducing time, cost and risks associated with the development. This is because it relies heavily on specialists with skills and expertise in a particular field; however, even the best expert can overlook a solution or problem, especially outside their field, and make incorrect decisions.

Below are examples of pitfalls, which exist in the Stage-Gate process (see Figure 1):

1. Ideas of the product generated at the Discovery stage and decisions on what ideas to proceed with further are normally based solely on the input provided by marketing people. This input represents 'voice of the customer' as it is perceived at the moment, and, so, there is a risk that either the voice of the customer may change during the development and the product will not be needed anymore, or the idea that passed Gate 1 is unfeasible, and, so, will never be implemented.

2. At Stages 1 and 2 engineering problems associated with developing a totally new ES are normally solved by a team of engineers with expertise in the field related to this particular ES. However, at this point, good solutions may sometimes be found in distant areas of engineering not being considered by the team. This may result in the implementation of imperfect solutions or rejection of a good idea as unfeasible if the development team is not aware of a more perfect solution.

3. At Gates 2 through 4, a concept or prototype design may be rejected because it is thought that it might infringe a 3rd party's intellectual property (IP). Even a small risk of infringement identified by patent attorneys could lead to rejecting a good concept that, perhaps, requires just a minor modification to circumvent the obstructive 3rd party's IP.

4. At Stage 3, 'secondary problems' (or implementation problems) may appear that are so difficult that the development team will be unable to solve them, especially if the solution is beyond the team's area of industry and science. Such implementation problems may appear because, for example, constraints and requirements imposed by marketing or manufacturing people are too rigid. The inability of the engineering team to solve these problems will kill the entire development.

5. Even at the testing and validation stage (Stage 4 in Figure 1), severe problems sometimes arise when the new product requires new testing methodology that does not yet exist. Inability to test the product and convince consumers of its benefits may greatly delay or make it impossible to commercialize the product, which will result in rejecting the product at Gate 5.

It would be fair to say that in most cases the development goes through the Stage-Gate process smoothly, especially if a new product is not very different from the old one, which the development team is thoroughly familiar with. However, even in this case some of the above-listed pitfalls may manifest themselves and delay the development.

These pitfalls become especially critical when the development relates to a highly innovative product that is completely new to the development team. In this instance the Stage-Gate process demonstrates lower efficiency; the development normally experiences delays and frequently ends unsuccessfully.

The reason for this is that the Stage-Gate process doesn't include tools to address efficiently all of the technical problems that arise during the development of a truly innovative product as they may require knowledge and skills outside the developers' area of expertise.

2.2. Strengths and Weaknesses of TRIZ with Regard to New Product Development

As opposed to the Stage-Gate process, modern TRIZ and GEN3 TRIZ have developed a whole arsenal of tools for solving complex technical problems associated with technical contradictions [5] that may arise at any stage in the development of a completely new product.

This arsenal includes tools for generating ideas for a new product, tools for identifying Key Problems [6] that need to be solved in order to manufacture the product, and tools for solving these problems. All these tools rely on objective trends rather than the expertise of specialists,

thus minimizing the possibility of overlooking important flaws in the ES.

The high efficiency of these tools has been proven through the extensive experience gained in TRIZ-consulting. It is important to note that these tools are equally efficient for both new and mature products.

Below are a few examples of TRIZ and GEN3 TRIZ tools that are effective for new product development:

- Main Parameters of Value (MPV) [7] Analysis helps to identify critical product features to be implemented in the new product.
- Trends of ES Evolution (TESE) Analysis [8] reveals how the product should evolve over time, thus helping to avoid unpromising ideas that ignore objective trends of the product's evolution.
- Cause and Effect Chain Analysis of disadvantages (CECA) [9] reveals Key Problems that need to be solved in order to create the new product.
- Contradiction Matrix with the 40 principles [10] of solving technical contradictions associated with the Key Problems.
- ARIZ [11] represents a detailed step-by-step algorithm for solving identified engineering problems specifically designed to identify and solve technical contradictions.
- Function Oriented Search (FOS) [12] identifies Key Problem solutions implemented in engineering areas far from the product's area.

TRIZ instruments, however, are not structured enough to represent a complete tool for developing new products from the idea generation stage to a commercial prototype. Additionally, TRIZ tools do not work well with typical engineering design tools such as various types of CADs, etc. Therefore, they cannot as yet entirely substitute industry best practices like the Stage-Gate process.

As a result, TRIZ is currently used only occasionally for developing new products: companies developing new products do invite TRIZ-consultants from time to time, but as a rule just to solve a specific problem encountered during the development. So, TRIZ-consultants are rarely engaged for more than one stage of the development.

Consequently, even when employed, TRIZ tools often do not fully benefit a development. This is indicated by the fact that relatively few promising solutions generated by TRIZ-consultants are implemented in the final new products.

3. TRIZ-Assisted Stage-Gate Process

As can be ascertained from the previous section, TRIZ and the Stage-Gate process have complimentary features that can benefit each other: the Stage-Gate process has a well-defined structure and involves the best engineering design tools available in industry, while TRIZ provides tools for identifying and solving key technical problems that may contain strong technical contradictions.

Practical experience in TRIZ-consulting has recently led the author to propose integrating TRIZ tools into the Stage-Gate [13] process so as to obtain a faster and more reliable TRIZ-Assisted Stage-Gate process (see Figure 2).

As shown in Figure 2, the TRIZ-Assisted Stage-Gate process retains the general structure of the Stage-Gate process while TRIZ and GEN3 TRIZ tools employed in

this process are 'stage-specific', which means that different tools are used at different stages of the process:

- At the Discovery stage, the most useful tools are TESE and MPV analyses: MPV analysis yields features that need to be implemented in the product; TESE analysis brings 'voice of the product' to the development, which allows for generating more feasible product ideas.
- Introducing TESE analysis for screening generated product ideas at Gate 1 and developed concepts at Gate 2 is an efficient way to identify and reject less promising ideas and concepts that contradict the objective trends of the product's evolution.
- At Stage 1, when the ideas generated for a new product are being developed into concepts, all tools aimed at identifying and solving Key Problems can be employed. The most useful tools at this stage are CECA, FOS, ARIZ, etc.
- At Stage 2, problem solving tools - such as FOS, ARIZ and Contradiction Matrix with the 40 principles - are used to speed up development of the selected concepts into proof-of-principle prototypes and generate concepts for working prototypes.
- At Gate 3, GEN3 TRIZ tools for identifying secondary technical problems [14] are used to enhance the efficiency of screening the concepts for working prototypes.
- At Stage 3, when the product is being further developed into working prototypes and production prototypes, TRIZ and GEN3 TRIZ tools are used less extensively, but, nevertheless, the following tools can greatly contribute to the development:
 1. Comprehensive Analysis [15] aimed at identifying not only technical problems, but other problems as well, such as potential infringement of 3rd party IPs or weak IP protection of the product being developed
 2. Trimming [16], this is a tool for reducing product cost by eliminating some components of the product without changing its overall functionality
 3. Competitive Patent Circumvention [17] that utilizes GEN3 TRIZ to avoid infringing competitive patents.
- At Stage 4, and sometimes even at Stage 5, TRIZ and GEN3 TRIZ tools are used as needed, but normally they are less critical at these stages.

As can be seen from Figure 2, TRIZ tools are particularly useful at the initial stages of the development – from the very beginning through Stage 3 – while at later stages these tools generally become less critical.

For TRIZ-consultants this means that their involvement during the development of a new product will gradually decrease as shown in Figure 3.

Typically, until the time a working prototype is manufactured, TRIZ-consultants and their client are about equally involved in the development, after which the client takes over development. Yet it is crucial that TRIZ-consultants are kept on the development team throughout the entire development so as to be aware of arising problems and make sure TRIZ tools will be used when needed.

Using the TRIZ-Assisted Stage-Gate process as shown in Figure 2 reduces development time and cost over and

above any achieved when using the Stage-Gate process alone. Figure 4 is a qualitative graph illustrating this reduction. “Stages 1-5” in Figure 4 correspond to those in Figure 1 - Figure 2.

Figure 2. The TRIZ-assisted Stage-Gate process map

Figure 3. Relative involvement of TRIZ-consultants and their clients in the new product development

Based on the author's knowledge and experience in consulting projects, investments at the latest stages of new product development are normally from 100 to 1000 times more than investments required at early stages. Therefore, employing TRIZ-Assisted Stage-Gate process from the

very beginning of the development process could save tens of millions of dollars (see Figure 4).

Figure 4. Expenses associated with new product development

4. Example of Practical Implementation of the TRIZ-Assisted Stage-Gate Process

4.1. Background

The TRIZ-Assisted Stage-Gate process was successfully implemented in a series of TRIZ-consulting projects performed by GEN3 team for California-based startup company Airgain, Ltd. in 2000-2010. During this period Airgain and GEN3 had an FTE contractual agreement in place that allowed a GEN3 team lead by the author to contribute to the development of several products for Airgain.

All these products were Smart Antennas (SA) for various Wi-Fi systems, such as Wi-Fi routers, embedded and external Wi-Fi cards, Wi-Fi-enabled set-top boxes, etc. (a Smart antenna is an antenna system that automatically focuses its beam in the direction that provides the best signal quality and, so, dramatically improves communication range and speed.)

At the Discovery Stage of the first project in 2000, the idea of incorporating an SA into a Wi-Fi system was generated by the GEN3 team based on the results of an MPV analysis. This analysis revealed that the most valuable MPV of a telecommunication system is the signal-to-noise ratio (SNR), which, as it increases, can be translated into larger communication range/coverage area or higher communication speed. The team also identified the most promising way to improve the SNR is to increase the antenna gain, which requires using a steering-beam Smart Antenna.

Implementing an SA in a Wi-Fi system was quite a new idea and represented a challenging task as it required solving several engineering contradictions. Previously, SAs had only been used in big and expensive systems, such as military radars and cellular towers.

Using TRIZ tools, the GEN3 team solved all of the technical problems and by 2003 prototypes of inexpensive SA-enabled Wi-Fi devices in the form of a desktop 'tower' module were built, tested and patented [18]. Soon after, Airgain became an antenna company, which produces and sells various SAs to Wi-Fi equipment manufacturers.

Described below is an example of the practical implementation of the TRIZ-Assisted Stage-Gate process for developing one of these SAs, namely - Airgain MaxBeam75, which progressed through the complete development cycle from idea to commercial product.

4.2. Using TRIZ-Assisted Stage-Gate Process in Developing Airgain MaxBeam75 Smart Antenna

Figure 5. Airgain MaxBeam75 smart antenna development map

In 2003 Airgain's marketing people identified Wi-Fi market needs for an SA which fits inside a flat box. At that time most manufacturers of Wi-Fi equipment produced their modules in such a box and were unwilling to buy any more Tower SAs. The overall dimensions of the antenna were specified at 15x100x100 mm (HxWxL).

The biggest problem was that the antenna's profile had to be very low (15 mm), far lower than the height of the half-wave vibrator (basic antenna element), which at Wi-Fi frequency is about 60 mm. Using 15-mm vibrators would decrease the SA performance, which was

unacceptable as the performance had to exceed that of the half-wave vibrator.

Airgain engaged the GEN3 team to solve this technical contradiction and develop the required antenna from scratch. Figure 5 highlights the development process and indicates what TRIZ and GEN3 TRIZ tools actually contributed to the development.

As shown in Figure 5, TRIZ and GEN3 TRIZ were used through Stage 4 (testing) of the antenna:

- At stages 1 through 3, these tools (ARIZ, Trimming, Contradiction matrix and the 40 principles of solving technical contradictions, etc.), were aimed at solving technical problems so as to meet the tough spec for the antenna dimensions and performance.
- At Stage 4, the GEN3 team used the Cause-Effect Chain Analysis to identify why the results of an SA testing were inconsistent in different environments.

It must be mentioned that at two critical moments during this project both the development and Airgain itself were under threat. If the GEN3 team had not found solutions for the problems encountered, the development would have been cancelled and the company could have gone bankrupt.

The first critical moment occurred at Stage 1 when an important client of Airgain wanted to see a concept of the SA that met both dimension and performance requirements simultaneously. The client set a tough deadline for delivering the concept, but Airgain engineers did not have a good solution. In this situation the GEN3 team, using TRIZ tools, were able to quickly come up with a good concept.

The second critical moment happened at Stage 4: tests of the developed MaxBeam75 SA at the client's facility did not reveal any benefit of this antenna when compared to a regular dipole antenna, while at the Airgain lab an impressive benefit was measured in all of the tests. Airgain engineers spent a few months trying to identify the reason for this discrepancy. Finally, the client set a deadline for solving the problem and Airgain engaged the GEN3 team again.

The GEN3 team found that the measured benefit was inconsistent because the testing methodology employed had not been designed for use in a multipath environment. The GEN3 team came up with a new methodology for over-the-air field testing of Wi-Fi systems [19], which was eventually adopted by Airgain and submitted to an IEEE802.11t task group. Later this methodology became an important part of Airgain antenna technology.

With the exception of these two critical moments, the development went smoothly through the TRIZ-Assisted Stage-Gate process and yielded a commercial NaxBeam75 SA that was patented [20] and successfully commercialized.

In January 2007 this antenna won an award from the government of California as the most innovative product of 2006 in the communications category [21].

5. Discussion of the Results

Practical implementation of the TRIZ-Assisted Stage-Gate process has confirmed its high efficiency in terms of reducing a development's time and cost.

Moreover, the development of Airgain MaxBeam75 smart antenna, described in the previous section, would have been stopped and this product would not have appeared if TRIZ tools had not been used at the right time. This, in fact, seems to be a fairly common situation: the author has witnessed quite a number of cases when the Stage-Gate process failed and promising developments were stopped just because TRIZ tools were not used.

It would be fair to mention, though, that the TRIZ-Assisted Stage-Gate process does not yet represent a fully optimized methodology as its practical, full-scale implementation is limited to just one project, as highlighted in the previous section. However, all parts of this process were separately tested and refined by the author in a number of projects at various stages of new product development.

Optimization of the TRIZ-Assisted Stage-Gate process to further enhance its efficiency may include:

- Customization of all TRIZ and GEN3 TRIZ tools used in this process. The fact is that any new product represents an ES at its early stages of evolution, which means that not all of the known Trends of Engineering System Evolution need to be taken into account with regard to new products. So, some tools can be greatly simplified.
- The process map (see Figure 2) can be further refined so that sets of TRIZ tools can be optimized for specific stages. Only tools that are most efficient at a particular stage should be used at that stage.

6. Conclusions

The TRIZ-Assisted Stage-Gate process does demonstrate a significant reduction in new product development time and cost relative to that provided by the Stage-Gate process alone.

Furthermore, the TRIZ-Assisted Stage-Gate process may be able to save the development and yield a successful product in a situation where the Stage-Gate process would otherwise fail.

Using the TRIZ-Assisted Stage-Gate process is especially efficient for developing truly innovative products that

1. Require solving severe technical contradictions starting from the early stages of the development, and/or
2. Involve solutions from distant areas of engineering.

Less innovative products in many cases can be successfully developed using the Stage-Gate process without involving TRIZ tools.

Implementation of the TRIZ-Assisted Stage-Gate process assumes including TRIZ-experts in the engineering development team at all stages of the development, although the role of these experts is different at different stages:

- The role of TRIZ experts is especially important at the initial stages of the development and remains critical until the working prototype is built;
- At final stages of the development it remains important to keep TRIZ-experts on the team (maybe just part-time) to make sure TRIZ tools will be timely used to help the engineering team.
- The TRIZ-Assisted Stage-Gate process is simple to implement wherever the Stage-Gate process is

already being used because the general structure and formal procedures employed in the Stage-Gate process remain intact.

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