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TECHNOLOGY FORECASTING USING THEORY OF INVENTIVE PROBLEM SOLVING: A CASE STUDY OF AUTOMOTIVE HEADLAMP SYSTEM

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ABSTRACT

This paper deals with the drawbacks of the current application of technology forecasting by introducing a new methodology, the Theory of Inventive Problem Solving, or commonly known as TRIZ. After explaining some critical issues and constraints of technology forecasting, a proposed framework that adopted the TRIZ methodology was presented to address the highlighted issues. Then, a case study was presented on the technology forecast of an innovation of automotive component using the proposed framework. This paper helps practitioners to understand the trends, aligned with the industry value, and push forward towards the goal of products design improvement and innovation management.

***Keywords**: TRIZ; Methodology; Technology Forecasting; Innovation; Management; Design; Automotive*

1.0 INTRODUCTION

Technology forecasting is one of the most interesting activities for any type of industry to develop strategic products. It requires critical information and characteristics to forecast the future of a new product that will emerge [1]. By having this special capability, any industry will have strategic competitive ad-vantages among others. The key element in having a strong competency in technology forecasting depends on the methodology used [2].

Recent developments in the field of technology forecasting have led to a renewed interest in the competitive situation of technology change [3]. Traditionally, technology forecasting is positioned as the highest interest in the characteristics of technology that impact the products and processes. This leads to the demand of having a reliable methodology to support the industry's competitive goals. The industry has set their most desirable outcome as the target and has selected the best method for forecasting and for decision-making activities

[4]. Currently, several fundamental methods are used in technology forecasting. They are technology forecasting by rational method, explicit method, and intuitive method [5]. On top of all methods, the methodologies must be systematic, reliable, reproducible, repetitive, taught, and learn [6]. It must not just depend only on imagination.

Despite various methods exist to support technology forecasting, there is an increasing concern on the methods that are lack in-depth, detail, and specific discussion [7]. This brings disadvantages in the application of technology forecasting to achieve the industry goals. There are two most significant issues that frequently emerged in a failed technology forecasting. The first issue is lack of multidisciplinary competency in developing a strong justification of technology forecasting [3]. In common practices, technology forecast normally covers a single technology development area and application. This over-looks other areas of technology disciplines that are critical or may be a part of the key component in the development of technology forecasting. The second issue is the inconsistency of the forecast [8]. In a real application of technology forecasting, there are many variations and uncertainties of the critical factors in forecasting. This is a core reliability issue of developing a justified forecast.

So far, the existing methods face great challenges in developing technology forecasting, and there has been little discussion about the best methodology that can be applied in various industries [5]. This paper focuses on examining the application of 'Theory Inventive Problem Solving' or known as TRIZ methodology in technology forecasting of a product design. This paper begins by reviewing the existing methods of technology forecasting and the introduction of TRIZ methodology in technology forecasting. It will proceed with the case study of TRIZ application in technology forecasting and then continue with the discussion. Finally, it ends with conclusion statements.

1.1 THE DRAWBACKS OF CURRENT TECHNOLOGY FORECASTING METHODOLOGY IN COMPETITIVE MARKET

A serious weakness in the multidisciplinary approach in technology forecasting is to break away from the common area of industry or technology [5]. The industry normally gets stuck in their thinking pattern to generate breakthrough ideas due to psychological inertia. Psychological inertia ignores other technology disciplines. The recommended solution to overcome this issue is to have a combination of system growth, trend growth, and functional growth [8]. Next, the historical data of each item will be used to represent the current status of technology achievement. This will help the forecaster to understand and identify the conclusive pattern about the future growth of the technology focus.

In the existing method used for forecasting such as using an analogy, people normally study the similar or related area of the industry. This method mostly considers data scattered in the system growth that is influenced randomly, which is difficult to control or measure [9].

Trends support industry to forecast better results towards competitive goals. Therefore, the trends referred to must have a strong justification, not just showing the direction of technology evolution, but are able to show the specific concepts of evolution that will happen.

One of the main reasons of current methods of technology forecasting is that the approach does not use evolution S-curve analysis as the fundamental knowledge [29]. The S-curve analysis is derived from the biological evolution of microbe life cycle that consist of 4 main phases; infant phase, growth phase, maturity phase and declining phase. Those phases have been generalized and adopted by Altshuller into the fundamental knowledge called TRIZ [30]. Instead, most technology forecasting used extrapolation method from statistic, math or science to support their prediction. Meanwhile, TRIZ's S-curve analysis provides meta-trends that can be used in many areas including technology. The S-curve analysis has more advantages compare to normative method, analog method and expert evaluation method because it able to eliminate or reduce mental block in understanding system and functionality [31].

Furthermore, the proposed method of technology forecasting will result in product improvement and innovation. Technology forecasting requires a direction to move the product forward and also needs improvement or innovation tools as the substance for product realization [10]. However, most of the technology forecasting methods exclude specific product improvement and innovation to ensure that the product is ready to be marketed on targeted goals [4]. On the other hand, the forecast will be useless as the industry is unable to materialize the forecast product since the methods to improve the design or manufacture with new resources are missing.

2.0 TRIZ METHODOLOGY: TRENDS OF ENGINEERING SYSTEM EVOLUTION

TRIZ is a powerful methodology used in the invention of problem solving that involves engineering or physical contradictions [11]. The contradiction in this context means developing the solution for the problem; it does not only solve the problem, but also overcomes the disadvantages inherited in the system. TRIZ methodology is different from other problem-solving tools because it does not depend on trade-off or compromise. This resulted in a higher value of a system improvement and innovation. Beyond problem solving, TRIZ is strong and has reliable systematic innovation in forecasting. TRIZ has been used by many leading industries in developing strategic technology forecasting, such as Philips, Samsung, Hyundai, and P&G. Within TRIZ methodology, there are several tools or combinations of tools that really support the industry to forecast more systematic, reliable, reproducibility, taught, and learned technology [10]. Figure 1 shows a proposed framework of technology forecasting using TRIZ methodology.

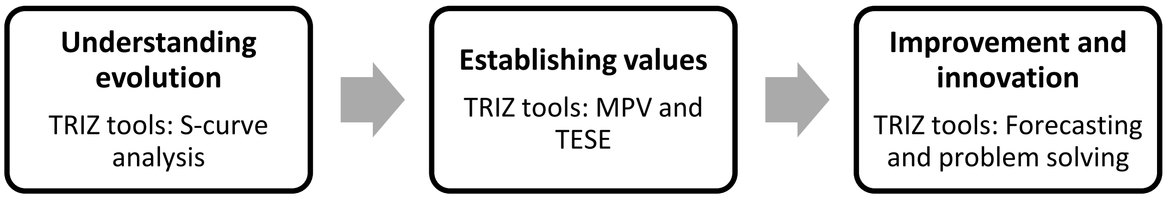

Figure 1: Proposed Framework of Technology Forecasting

The proposed framework starts with understanding the evaluation of the targeted system using 'S' Curve analysis. This helps the industry to identify the pattern of the targeted system evolution and the position of the current system evolution. This will provide the overview and the next action required based on the recommendation given by the analysis. Next, the industry needs to firmly establish their value to drive the targeted system and aligned them accordingly with the Trends of Engineering System Evolution (TESE). Lastly, the existing system needs to be improved and requires an innovation to push towards the forecasted target system. The tools used in this phase consisted of TESE and several other TRIZ tools that are combined into a tool called 'Forecasting' [11].

3.0 CASE STUDY: TECHNOLOGY FORECASTING ON AUTOMOTIVE HEAD LAMP

3.1 System evolution review using 'S' curve analysis

A variety of methods are used to deploy technology forecasting. Each method has its own advantages and drawbacks. A case study approach was chosen to show the application of TRIZ methodology in forecasting automotive components, in which some studies have been done in the similar area of application [12]. Figure 2 shows the 'S' Curve analysis done on a headlamp system for an automotive application [20]. From the 'S' Curve analysis, the headlamp has reached some development limits, which is limited by the contradiction.

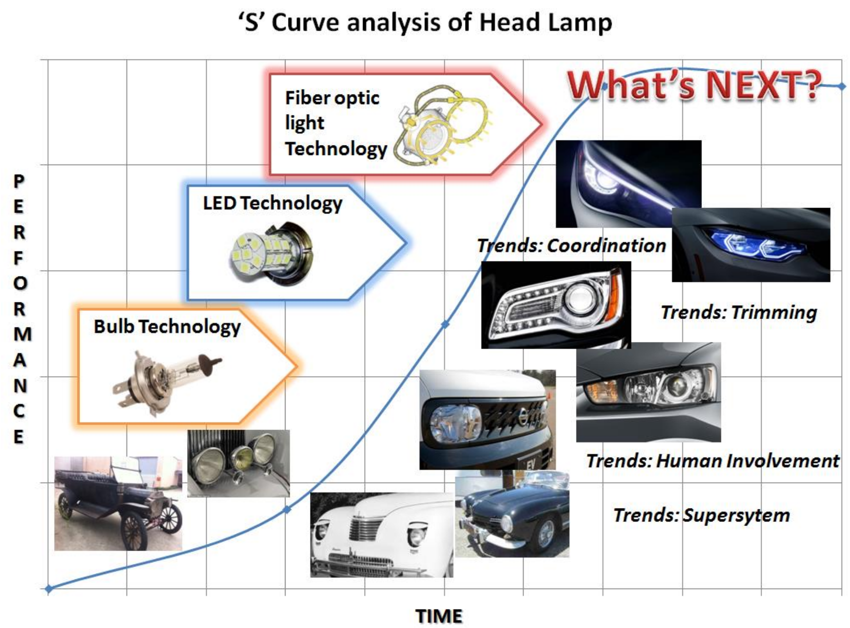

Figure 2: 'S' Curve analysis on automotive headlamps [20]

The main contradiction of the headlamp was "the better illumination is achieved, the clearer the driver is informed but the size of the headlamp is restricted". Another indicator showed that the headlamp combined with an alternative system such as the turning signal lamp. The final indicator that showed the headlamp reached the 3rd stage of the 'S' Curve was that the systems mainly differ by the design and the service function such as the dynamic shape, sporty outlook or attractive color design, but not the technology. Next, the 'S' Curve's recommendations will be studied and reviewed with the support of TESE that is aligned with industry's value [11]. It is apparent from the case study of TRIZ technology forecasting that the industry is able to use semi-structured guidelines in understanding, identifying, and improving their product towards targeted goals. Another important finding was that the forecaster was able to draw a better conclusion by using TRIZ methodology that comprised of 'S' Curve and trends (TESE) analysis.

3.2 Exploring customer product value and product concept development

The evolutions of automotive headlamp were more active at the lighting subsystem technology. The physical shape of the headlamp changed slowly from round symmetry shape to asymmetry shape that follows the contour of the exterior styling. However, TRIZ methodology provides several possibilities for the headlamp to evolve in the near future and beyond through the identified trends shown in Figure 2. There were four identified trends that were based on the historical database of the headlamp design. They were the 'trends of transition to the supersystem', 'trends of increasing degree of trimming', 'trends of decreasing human involvement', and the 'trend of increasing coordination'. Before exploring those identified trends, the 'main parameter value' or MPV need to be cleared. All improvement of the future headlamp must meet the requirements according to the MPV identified for the customer, which is the key attribute of a product that hereto unsatisfied and important in the purchase decision process. Figure 3 shows the identified MPVs for the headlamp [26].

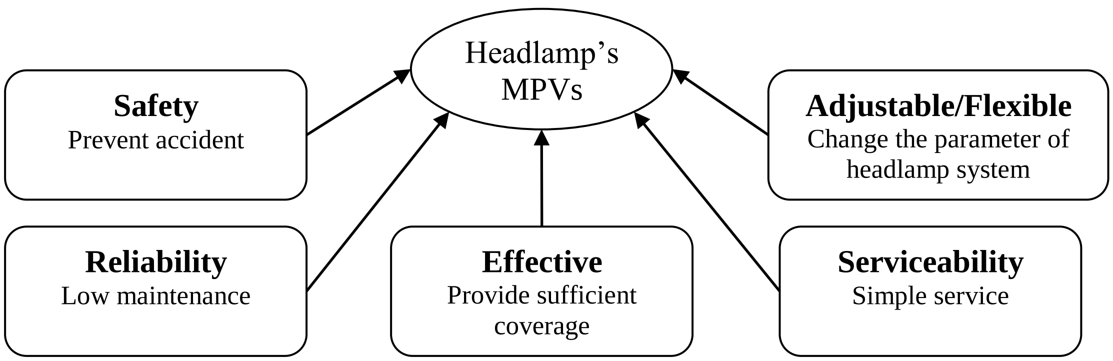

Figure 3: Main parameter value for headlamp system [26]

The MPVs need to select one MPV that was able to contribute high value to the customers and con-tribute more profit to the company. This selected MPV was very important and had unsatisfied performance in current headlamp system. In this study, two MPVs were selected through hypothesis testing. First MPV focused on the brightness of the light. Second MPV focused on the effectiveness of the headlamp on the cover area. Next, the key problems that prevent achieving high performance of MPV were identified. The key problems were as follows:

- Safety problem - If the headlamp light is brighter, then the driver can see more clearly, but the other driver is unable to see due to the excessive brightness.
- Effective problem – If the headlamp scope of light coverage is larger, then the driver can see more clearly, but the space of the headlamp is small.

After the key problems were established, the solutions and generated ideas need to start by using the four trends identified previously. Table 1 shows the solutions generated by the four trends of the analysis of the headlamp. The 'trend of transition to the supersystem' suggested to increases the number of light sources from a single source of light; such as a bulb or led. With many source of lights, 'trend of increasing coordination' suggested to have various directions of lights from the headlamp. However, 'trend of decreasing human involvement' and 'trend of increasing degree of trimming' suggested reducing the subsystem level. These trends demand that, if it is possible, take out the wiring system as transmission, take out the electric from the system as the energy source, take out the control system of the light level from the steering, and lastly take out the operating agent such as the bulb from the headlamp system.

Table 1: Conceptual solutions for key problem using trends

Type of trends	Sub-trends	Type of key problem	Conceptual solution
Trend of transition to the supersystem	Mono-bi-poly	Effectiveness	Evolve from single source of light to double light sources to many light sources
Trend of decreasing human involvement	N/A	Safety and effectiveness	Reducing transmission; then energy source; then control system; then decision making.
Trend of increasing coordination	Coordinate action	Safety and effectiveness	Focus light on one direction to two or more directions
Trend of increasing degree of trimming	Trimming subsystem	Safety and effectiveness	Reducing transmission; then energy source; then control system; then operating agent.

3.3 Enhancing product innovation of headlamp system.

The next process used the conceptual solution extracted from the identified trends and developed a specific solution for the new headlamp system. The trends provide guidance on the part of the system evolution of the headlamp and the direction to enhance system innovation. Both 'trends of transition to the supersystem' and 'trend of increasing coordination' showed converging functions were able to complement each other features. Figure 4 shows both trends that were applied to the headlamp system [27].

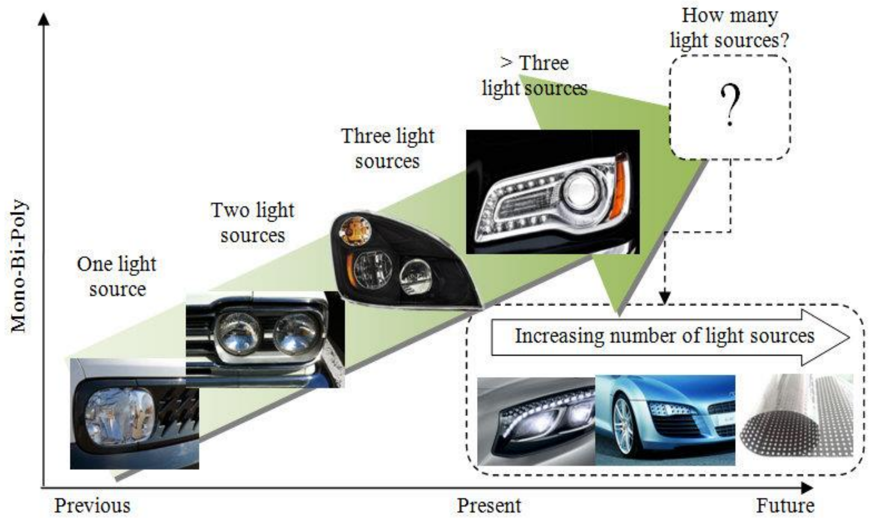

Figure 4: Headlamp evolution using trends [27]

Based on figure 4, the headlamp will eventually increase the numbers of light sources, where the function is currently being carried by the bulb and led lights. Near future, the headlamp system will replace all bulbs with led and create all led headlamp system. Beyond that, the headlamp system will adopt the flexible led technology and change the total physical and function of headlamp system. Currently, some studies have been done on the led technology application to improve the lights coverage area, which is better than bulb as shown in Figure 5 [28]. The predicted system was able to align with the 'trend of increasing coordination' evolution.

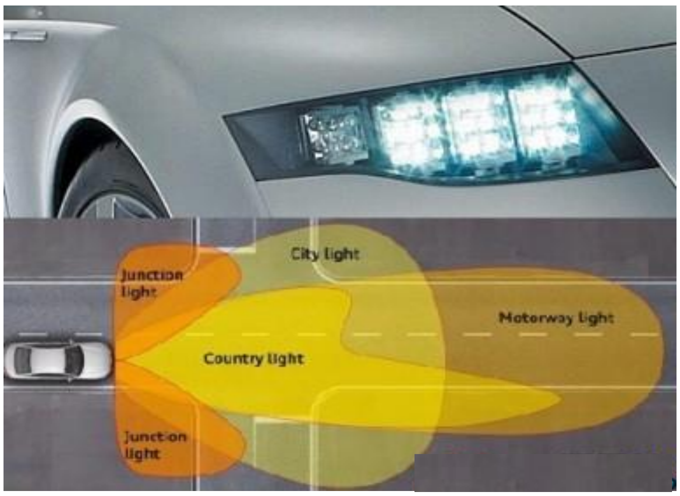

Figure 5: Led light coverage area for headlamp system [28]

Meanwhile, the other two trends, 'trend of increasing degree of trimming' and 'trend of decreasing human involvement' focused to eliminate the subsystem of the current headlamp system. Based on the prediction of all led headlamp system, the wiring system can be simplified to the circuit board, which was considered as the 'transmission' of the subsystem. Eliminating the 'energy source' cause insignificant changes in the subsystem of the predicted headlamp system. However, there was a possibility to adopt the luminescence technologies that have the 'glow-in-the-dark' effect to reduce the dependability of the 'energy source' on the current lighting system. For 'control system' elimination, the headlamp system can be improved to a 'smart' lighting control that automatically adjusted using its sensors. This auto-adjust system was able to address the issue of excessive brightness or glare to other drivers by adjusting the level of light refraction. This will also eliminate the headlamp switches and levers at the steering column area. This showed that the previous prediction of the headlamp system from one trend could be complemented with other trends that were compatible. The concepts predicted from the trends need to be refined and tested by the company to ensure the product is competitive and is able to bring profits after the product enters the market. The predicted headlamp system for the future has several criteria that aligned with the selected trends and able to bring higher satisfaction to the customer with a better profit margin for the manufacturer.

4.0 DISCUSSIONS

From the case study, the proposed framework for technology forecasting supports the product designer to develop innovative future product that creates higher value for customer and better competitive advantages for the company [12, 13]. The first phase of the framework provides an overview of the evolution of the headlamp system using 'S' curve analysis. As the headlamp system evolves, the designer needs to understand the trends show from the 'S' curve. This is an important skill for the designer to specifically map out the historical evaluation of the headlamp system in order to predict the future system accordingly [14]. The focus on the analysis must also cover the introduction of various technologies into the headlamp system. The main reason for this analysis is to understand the impact of introducing a new technology that changes the headlamp system as a product [15]. For example, the introduction of led technology changes the size of the headlamp system. From phase one, the outcome of the analysis is the identification of four critical trends that aligned with the advancement of headlamp technology.

In comparison with other technology forecasting methods such as trend extrapolation and Delphi methods, there exists a multitude of other technology forecasting methods, which can be categorized as quantitative versus qualitative, and as normative versus exploratory or known as extrapolation of current technological capabilities [32]. TRIZ technology forecasting it is based on the observations of metrics, such as the number of patents. Although TRIZ trends are certainly among the more formalized and quantitative methods, it must be noted that the gathering of the underlying metrics relies on TRIZ expert skills [33]. This brings compound advantages of various technology forecasting methods in systematic innovation approach.

The review of the existing methods for forecasting shows that single method is never used for practical technology forecast [34]. The important of combining methods is when formulating generic conflicting requirements for any method of technology forecasting. From the TRIZ viewpoint, it is very critical how a combination of methods influences the technology forecast errors [34]. Normally, methods are combined in order to reinforce the weakness of one method by the strength of another. However, when several methods are combined, new forecast errors can appear as a result of the compound effects [31]. At present, the question of measurability of forecast errors arising as a result of an integration of several methods remains unanswered. In order to review the existing technology, forecast methods in a holistic and systemic way we propose to classify all forecasting methods from the point of view of a problem solving approach by indicating which problem or a set of problems a given method addresses and aims to resolve [34].

In the second phase of the proposed framework, MPV is defined to bring the strategic perspective in developing the new innovation of headlamp system for competitive advancement [16]. It is very critical to understand the correct MPV that is critical to bring better profit to the company and satisfy the customer needs [17]. The MPV helps the designer to focus on the key of disadvantages of the current system and improve them effectively. The problem of identification process shows how the MPV is affected by un-satisfied level on the current headlamp system. By solving this issue, customers become interested to buy even with high cost because it gives high value to the customer in terms of cost, safety and effectiveness [16; 18]. The trends identified provide conceptual solution and ideas to change and improve the current headlamp system to various levels of predictions [19, 20]. The designer was able to forecast the 'near future' system for the headlamps and predict the introduction of the new technology to change the innovation level of the future headlamp system [21].

The last phase of the framework is to establish and finalize the conceptual future system of the headlamp. The identified trends provide a wider scope of the concept generation with specific directions [22]. These provide the designer to have the flexibility in creating ideas and solutions within the trends scopes [23]. The designer will propose solutions not only within their scope of knowledge or experience, but also beyond their domain of existing expertise [24]. From the case study, the 'mono-bi-poly' sub-trends are able to complement other trends that are logically unmatched with the direction from the 'trend of increasing degree of trimming' that focus on reducing or simplifying the current system. Therefore, it is really important to combine several trends to finalize the future system. The designers are able to redesign the current headlamp system by following the trends and increase the functionality of the system to solve unsatisfied issues of MPV. The designer also predicted that a flexible led technology may change the total design of the future headlamp system and functionality [25]. This case study showed that the proposed framework was practical in developing the future system and improved the competitive advantage for the company.

5.0 CONCLUSIONS

This paper has given an account and the reasons for the widespread applications of TRIZ methodology as a secret in technology forecasting. The present study was designed to demonstrate the effect of adopting TRIZ methodology in product forecasting and used automotive headlamp as case study. One of the most significant findings emerged from this study is that the effective technology forecasting can be achieved by understanding the trends, aligned with customer's MPV and the industry goals in competitive product innovation. The results of this study indicate that the industry was able to enhance their competitive strategy using the proposed framework. The proposed technology forecasting framework used TRIZ methodology through engineering trends and problem-solving approach that are not yet available in other technology forecasting methods as combination of several methods such as normative, extrapolation, analogy or expert validation. The current study has only examined new technology forecasting in product development. Further research could be performed by investigating the application of the proposed technology forecasting framework in the process and service applications.

REFERENCES

[1] Modis, T. (2003). A Scientific Approach to Managing Competition. *The Industrial Physicist*, 9(1), 24-27.

[2] Porter, A.L. and Cunningham, S.W. (2005), *Tech mining: exploiting new technologies for competitive advantage*. Hoboken, N. J.: John Willey & Sons Inc.

[3] Modis, T. (2007). Strengths and weaknesses of S-curves. *Technological Forecasting and Social Change*, 74(6), 866-872.

[4] Petrov, V. and Seredinski A. (2005). Progress and Ideality, *TRIZ Future Conference 2005, ETRIA World conference*,2005 (11), 1-8.

[5] Schnaars, S.P. and Chia S.L., (1993). Five Modern Lessons from 55-Year-Old Technological Forecast. *Journal of Product Innovation Management*, 10, 66-74.

[6] Armstrong, J.S. (2002). *Principles of Forecasting: A Handbook for Researchers and Practitioner*. (1st ed.), Boston, USA: Kluwer Academic Publishers.

[7] Schnaars, S.P. (1989). *Megamistakes: Forecasting and the Myth of Rapid Technological Change*. New York, USA: The Free Press.
[8] Kucharavy, D. and Guio R. D. (2005). Problems of Forecast, *ETRIA TRIZ Future*, 2005 (11), 1-14.
[9] Debecker, A. and Modis T. (1994). Determination of the uncertainties in S-curve logistic fits *Technological Forecasting and Social Ch*ange, 46, 153-173.
[10] Kucharavy, D. and Guio R. D. (2007). Problem Mapping for the Assessment of Technological Barriers in the Framework of Innovative Design. *International Conference On Engineering Design, ICED'07*, 2007, 385-386.
[11] Altshuller, G. S. (1975). *About forecasting of technical systems development*. Baku, Azerbaijan: Sovietskoe radio Publishing House.
[12] Gao, C., Sun, J., Zhai, P., and Chi, X. (2015). Research on Product Technical Maturity Forecasting and R & D strategy based on TRIZ. *International Conference on Information Sciences, Machinery, Materials and Energy*, 2015, 319-324.
[13] Zulhasni, A. R., Nooh, A. B., Sarimah, M., and Yeoh, T. S. (2015). TRIZ Business Improvement and Innovation Framework for Malaysian Small and Medium Enterprise. *Applied Mechanics and Materials*, 735, 349-353.
[14] Kim, S. J., and Kara, S. (2014). Predicting the total environmental impact of product technologies. *CIRP Annals-Manufacturing Technology*, 63(1), 25-28.
[15] Ping, E., Tan, R., Zhang, J., and Han, B. (2014). Research on generation ideas process for product radical innovation based on technology evolution theory. *Management of Innovation and Technology (ICMIT): 2014 IEEE International Conference*, 10-14 June. Sydney, Australia, 256-261.
[16] Litvin, S. (2011). Main Parameters of Value: TRIZ-based Tool Connecting Business Challenges to Technical Problems in Product/Process Innovation. *7th Japan TRIZ Symposium*. 9th September. Tokyo, Japan, 1-25.
[17] Liu, T. L., and Kuo, S. T. (2011). A study of applying TRIZ to technological patenting deployment. *International Journal of Systematic Innovation*, 1(3), 2-12.
[18] Rahim, Z. A., and Bakar, N. A, (2013). Implementation Framework for Design-To-Cost Using TRIZ: Product Concept Design in Automotive Stamping Process. *American Journal of Economics*, 3(5C), 100-107.
[19] Yihong, L., Yunfei, S., and Ting, C. (2012) ,Study of new wall materials design based on TRIZ integrated innovation method. *Management Science and Engineering*, 6(4), 15-29.
[20] Rahim, Z. A., and Abu Bakar, N. (2014). Complexity Planning for Product Design Using TRIZ. *Advanced Materials Research*, 903, 396-401.
[21] Sheng, I., Namasivayam, S., and Thong, K. (2012). Analyzing the Trends of Engineering Education Using TRIZ. *International Proceedings of Economics Development & Research*, 2012 (30), 183-188.
[22] Li, H., Tan, R. H., Jiang, P., and Zhang, H. G. (2013). Research on the strategy of patents layout basing on TRIZ. *Industrial Engineering and Engineering Management (IEEM): 2013 IEEE International Conference*, (2013), 13-17.

[23] Zulhasni, A. R., and Nooh, A. B. (2015). Innovative Cases of TRIZ Application in the Automotive Industry. *Applied Mechanics and Materials*, 735, 326-330.

[24] Mansoor, M., Mariun, N., Ismail, N., and Abdul, W. N. I. (2012). Towards knowledge engineering based guidance for electrical engineers. *Przeglad Elektrotechniczny (Electrical Review)*, 88, 363-365.

[25] Park, H., Ree, J. J., and Kim, K. (2013). Identification of promising patents for technology transfers using TRIZ evolution trends. *Expert Systems with Applications*, 40(2), 736-743.

[26] Lukasik, M., Kaźmierczak, P., and Mocko, W. (2006). Study of the motor vehicle headlamp model with electronically shaped lighting beam and its practical verification. *Zeszyty Naukowe Instytutu Pojazdów/Politechnika Warszawska*, 4 (63), 111-118.

[27] Hsieh, C. C., Li, Y. H., and Hung, C. C. (2013). Modular design of the LED vehicle projector headlamp system. *Applied optics*, 52(21), 5221-5229.

[28] Chemel, B. J., Piepgras, C., Kondo, S. T., and Johnston, S. D. (2012). *U.S. Patent No. 8,138,690*. Washington, DC: U.S. Patent and Trademark Office.

[29] Higgins, A., Syme, M., McGregor, J., Marquez, L., and Seo, S. (2014). Forecasting uptake of retrofit packages in office building stock under government incentives. *Energy Policy*, 65, 501-511.

[30] Zlotin, B., and Zusman, A. (2013). *Patterns of technological evolution*. Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship. Springer, New York.

[31] Rahim, Z. A., Sheng, I. L. S., and Nooh, A. B. (2015). TRIZ methodology for applied chemical engineering: A case study of new product development. *Chemical Engineering Research and Design*, 103, 11-24.

[32] Verhaegen, P. A., D'hondt, J., Vertommen, J., Dewulf, S., and Duflou, J. R. (2009). Relating properties and functions from patents to TRIZ trends. *CIRP Journal of Manufacturing Science and Technology*, 1(3), 126-130.

[33] Schuh, G., and Grawatsch, M. (2004). TRIZ-based technology intelligence. The *TRIZ Journal*, 2004 (4), 1-11.

[34] Kucharavy, D., and De Guio, R. (2005). Problems of forecast. *ETRIA TRIZ Future*, 2005 (11), 219-235.