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Application of TRIZ Method in Developing Vehicle Lane Support System Testing Infrastructure for Raining Condition

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Abstract – *Theory of Inventive Problem Solving (TRIZ) is an inventive problem-solving method developed to find a solution for issues involving contradictions. The TRIZ method was applied to develop a new method of simulating raining weather conditions for vehicle lane support system (LSS) on-road testing infrastructure. The objective of the project was to develop a mechanical solution capable of dispensing a consistent amount of water to a moving vehicle to simulate raining weather conditions, while at the same time it is portable and easy to set up. Based on the requirement, the TRIZ 40 inventive principles were applied as the solution, based on the principles of "the other way around", "segmentation", "dynamicity" and "feedback". The specific solution generated based on the inventive principles identified was to make both the vehicle and the rain simulating machine movable during the on-road test. This is achieved by creating a customized rain machine that can be fitted onto a moving vehicle. This simple setup enabled both vehicle-under-test (VUT) and the rain machine vehicle to move simultaneously during the test, at any test speed and type of test track desired. Furthermore, the rain machine itself is designed with the capability to dispense the water by using a control unit, hence making the testing method safer and less human effort required. Based on the literature review, there is yet no similar solution for simulating raining conditions in LSS on-road test made using the same principle developed in this project. The innovative portable rain machine developed in this project could also be applied for other Advanced Driver Assistance System (ADAS) test protocols requiring similar raining testing conditions especially involving moving VUT.*

Keywords: TRIZ, portable rain machine, lane support system, vehicle on-road test

1.0 INTRODUCTION

The introduction of the Advanced Driver Assistance System (ADAS) in modern vehicles has elevated road safety performance towards reducing road accidents and fatalities. Among the technology introduced under the ADAS umbrella are Autonomous Emergency Braking (AEB), Lane Support System (which includes Lane Departure Warning (LDW) and Lane Keep Assist (LKA)), Adaptive Cruise Control (ACC) and others (Jayan & Muruganantham, 2020). The Lane Support System (LSS) is part of the active safety technology which functions to assist the driver during un-intentional lane change situations, either by alerting the driver through steering vibration signal or/and audio signal (for the case of LDW), or making automatic trajectory correction when the vehicle is deviating away from the correct path while in motion (for the case of LKA) (Mansor et al., 2020).

To test the performance of LSS technologies, the vehicle is subjected to on-road test based on dedicated test method/protocol such as stipulated by Euro NCAP LSS test v.2.0.2 (Euro NCAP, 2018), as well as International Standard Organization (ISO) 17360:2017 LDW test (ISO, 2017). In general, these test methods are developed based on the general vehicle use, which are tested in ambient environmental conditions. For a vehicle with LSS technology sold in the ASEAN market, there is also an important need to test its performance under the influence of the local environmental conditions. Due to the geographic location of ASEAN (nearby the equator), the environmental condition especially the rain is intense in most of the countries which may affect the accuracy of the existing camera sensor used to operate the LSS system and the overall LSS effectiveness (Jawi et al., 2010).

Based on the available literature review, the execution of the LSS test protocol under the effect of rainy conditions is yet uncommon. A market survey was made on searching for the available technological solution in making the simulated rain condition, which is suitable for the on-road testing requirement. Based on the market survey, there are three (3) types of mechanical solution to produce the desired raining condition on the test track, which are based on the fan concept, tower concept, and gun concept as shown in Figure 1.

(a)


(b)


(c)

Figure 1: Example of existing mechanical solution for simulating raining condition on test track (a) fan concept, (b) tower concept, (c) gun concept (all images are gained from the internet)

In general, all three concepts were able to dispense high and low volumes of water over a certain testing range. However, the existing solution could not fully meet the project requirement which has the constraint of a dedicated and secure test track to perform the LSS test. The unavailability of a dedicated and secure test track required the solution to more robust and portable, as well as requiring very minimum equipment setting up process and time. Hence, the main goal of this project was to devise a solution to enable the existing LSS test protocol to be tested under rainy conditions. The objective of the project was to develop a mechanical solution capable of dispensing a consistent amount of water to a moving vehicle to simulate raining weather conditions, while at the same time it is portable and easy to set up. To achieve the objective, the team involved has opted to use the Theory of Inventive Problem Solving (TRIZ) method in devising the solution. Later, a complete drawing of the solution was developed, and the final prototype of the new rain machine is fabricated and tested. Details of the process are described in the following section.

2.0 METHODOLOGY

TRIZ (Russian acronym for "Theory of Inventive Problem Solving") is a systematic problem-solving method developed by Genrich Altshuller in the 1940s. The principle of the method is to solve the problem with contradictions. Problem with contradictions is defined as a problem in which when a solution is obtained, it will create another resulting problem. Often in the traditional problem-solving process, the problem with contradiction is faced and ending up having to satisfy with the solution having trade-off results (Mansor et al., 2015). There are many successful pieces of evidence on the implementation of the TRIZ method in solving problems especially related to product development such as the development of chemical filtration devices and fish skin peeling devices (Wu et al., 2020), the development of cross-arm transmission towers (Sharaf et al., 2020), and development of biocomposites side door impact beam (Shaharuzaman et al., 2020). Figure 2 shows the overall TRIZ problem-solving process implemented in this project.

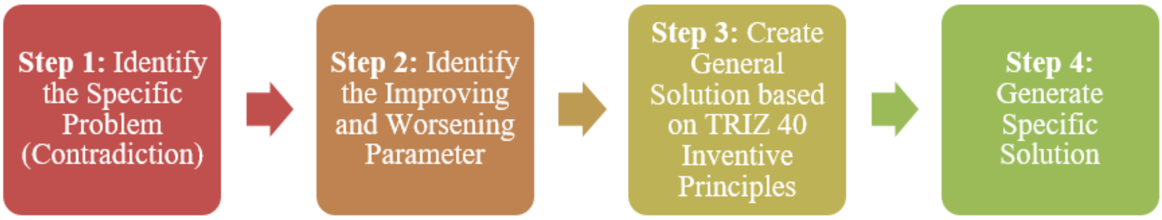

Figure 2: TRIZ problem-solving process implemented

2.1 Step 1: Identify Specific Problem and Contradiction to Solve

As mentioned in the previous section, the objective of this project is to develop a rain machine solution capable of dispensing a consistent amount of water to a moving vehicle to simulate raining weather conditions during LSS on-road test, while at the same time it is portable and easy to set up to meet the challenging test-track limitation. There are already existing mechanical solutions in the market that can be adapted to create the rain condition during the on-road test but are concluded not suitable to be implemented in this project due to the test track condition. The test track used will be a State road, which already has its own road design features and is completely disconnected from a steady water source, and no connection available to be tapped to the existing electricity source. To prepare the LSS test section at safe driving and stipulated vehicle maneuver distance, would require very long water piping infrastructure and many rain machine towers/guns/fans to be used. Furthermore, to road condition itself does not have adequate road edge space to safely place all the rain machines. The State road condition itself requires the solution to be portable and short device setting uptime. All three identified existing rain machines worked in the principle whereby they are placed stationary along with the test section distance, and the Vehicle-Under-Test (VUT) is driven towards the test section to perform the lane departure scenario.

Hence, the specific problem can be summarized as below:

The rain machine must be portable and can cover long testing range with consistent water dispensing volume, BUT in the same time only require minimum number of rain machine.

The existing rain machine solution in the market can comply with the portability requirement as mentioned above, however, none could comply requirement of long testing range capability, as it requires many individual rain machine units (either fan type, tower type, or gun type) to use and arrange in series along the test section.

2.2 Step 2: Identify the Improving and Worsening Parameter

The next step in the problem-solving process is to identify the contradiction. This can be clearly showed by mapping the key points in the problem statement into improving the parameter (a feature that we want in the solution) and the worsening parameter (the undesired feature which arises due to the implementation of the improving feature).

Based on the identified problem statement, we can divide the statement into the improving and worsening parameters as below:

Improving parameter (a feature that we want for the rain machine):
A portable machine with long-range and consistent water dispensing capability;

Worsening parameter (undesired feature for the rain machine):
Required many units of individual rain machines to be used.

The statement above clearly shows the contradiction faced in the problem. Hence, the ideal solution for this problem would be a single unit of rain machine which is portable but able to dispense a wide range and consistent volume of water simultaneously through the LSS test duration.

2.3 Step 3: Create General Solution based on TRIZ 40 Inventive Principles

Based on the identified improving and worsening parameters, and the ideal solution to be achieved, the next problem-solving step in the TRIZ method is to search for potential general solutions listed in the TRIZ 40 Inventive Principles. The 40 inventive principles are a list of forty (40) solution keywords that can be used to spur solution ideas for any technical problem. The list was created based on the study of existing patents solution principles used (Liu et al, 2020). Among the general solution principles included are segmentation, taking out, local quality, and merging. Afterward, the general solution is analyzed to come out with a specific solution that relates to the actual problem.

3.0 RESULTS AND DISCUSSION

After examining all the potential inventive principles listed, the project team has identified solution principle number #13 which is highly applicable to solve the problem contradiction. The inventive principle is "the other way around" which is described as below (triz-journal.com, 2020):

- Invert the action(s) used to solve the problem (e.g. instead of cooling an object, heat it).
- Make movable parts (or the external environment) fixed, and fixed parts movable).
- Turn the object (or process) "upside-down".

Using the principle of the "other way around", we have come out with a solution whereby instead of placing the rain machine statically along the test section, the rain machine will move alongside the moving VUT. By having the rain machine move along with VUT, the critical issue of having long water dispensing range and consistent water dispensing volume is solved by using just a single unit of the machine. Then we applied another inventive principle which is "segmentation" (define as dividing an object into independent parts) to enhance the initial solution. The rain machine is designed as an individual unit and placed on another moving vehicle (carrying vehicle). By making the rain machine and VUT into two different parts (not combining them) but still able to move relatively together, no modifications on the VUT are required and this eliminated the complexity of the solution. This simple setup enabled both vehicle-under-test (VUT) and the rain machine vehicle to move simultaneously during the test, which can cater the test be done at any desired test speed and type of test-track (Figure 3).

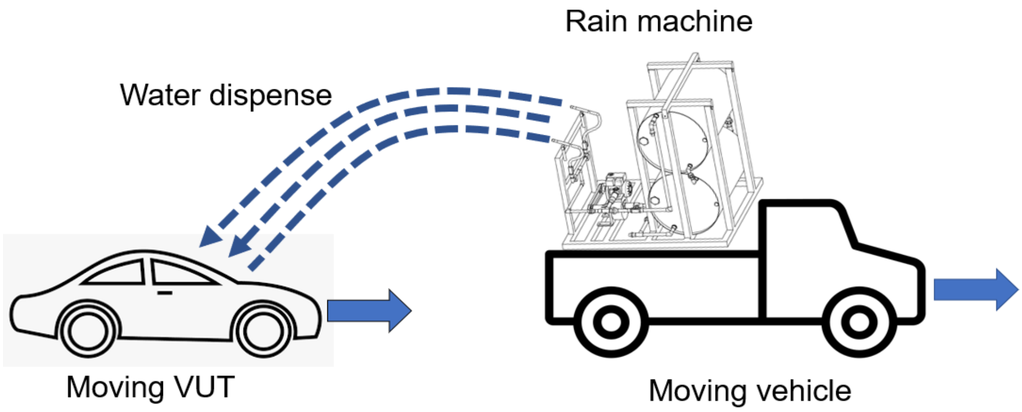

Figure 3: New concept of simulating rain condition for LSS on-road test

To further increase the functionality of the rain machine solution, other inventive principles which are "dynamicity" and "feedback" are also incorporated. The principle of "dynamicity" (define as allowing (or designing) the characteristics of an object, external environment, or process to change to be optimal or to find an optimal operating condition) was applied to the rain machine water in the form of adjustable water nozzle size, which enables a varying range of water volume to be dispensed to reflect varying rain intensity condition. The principle of "feedback" (define as introducing feedback (referring back, cross-checking) to improve a process or action) was applied to the rain machine waste dispense control system, whereby it now has the capability to dispense the water by using a control unit, hence making the testing method safer and less human effort required. Figure 4 shows the completed prototype of the rain machine solution developed in this project.

Figure 4: Customized rain machine developed for LSS on-road test

4.0 CONCLUSION

Several conclusions from this project are listed as below:

- An innovative method to create raining conditions during LSS on-road test was developed in this project using TRIZ problem-solving method.
- The TRIZ inventive principle of "the other way around" and "segmentation" were applied in formulating the solution, whereas inventive principles "dynamicity" and "feedback" were applied to improve the functionality of the new customized rain machine in this project.
- The TRIZ method applied was shown able to generate innovative ideas in solving the contradiction faced in this project, through a simple, quick, and systematic problem-solving process.

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