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Analysis of the Usability of a Traffic Guide Robot on a Road Work Zone using AHP

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Abstract
This study developed the road traffic safety moderator robot as the traffic safety equipment needed for the road work that blocks traffic and evaluated the applicability of the robot. For the applicability evaluation, it used AHP and placing work orders. As a result of level 2 analysis on the robot, safety and convenience were more favored than the other alternatives, whereas economic viability was less favored. Level 3 analysis showed that Alternative 1 was the most popular posting with 0.497 for visibility, 0.476 for efficiency, 0.485 for operability, and 0.488 for mobility, but the least popular with initial investment at 0.159 and maintenance cost at 0.243.

Keywords: Road Work Zone, Analytic Hierarchy Process, Traffic Guide Robot, Traffic Safety Facility, Safety, Convenience, Economic Viability

Introduction

Existing road maintenance or work with traffic control can make the road conditions different from usual. This means that it can make vehicles using that road more prone to accidents and also place pedestrians, workers and signal men in danger.

Despite such traffic safety issues, the increasing needs to maintain and improve old or existing roads due to changes in the traffic paradigm as well as various underground utilities has called for more road works that would obviously entail traffic control.

The Ministry of Land, Infrastructure and Transport provided 'Road Safety Facilities Installation and Management Guidelines' on traffic control in and around direct road work zones for the use of shoulders and median strips, temporary alternative roads, narrowing road width, lane blockage, and alternative road use to ensure safe work. On the other hand, there is a lack of information or promotion system.

Currently, road work zones mostly put signal men, dummies, road work information boards or a combination of these in place to control traffic flow and inform drivers of the zone but these are nothing but static measures. A signal man on a work zone can make a qualitative judgment on the traffic condition but he can also be hit by a car at night or by a fast moving car.

Therefore, the study developed traffic safety equipment that will help secure safety and manage traffic flows on the road work zone. Information technology (IT) and mechanical engineering technology, such as advanced wireless communication technology and sensor technology, were applied to develop the appropriate safety equipment with various functions.

Based on the convergence of IT and mechanical engineering into traffic, this study developed a road traffic safety moderator robot that can prevent traffic accidents on road work zones and manage smooth traffic flows. This study also evaluated its applicability to an actual work site using the Analytic Hierarchy Process (AHP).

Review on Previous Studies

Ko et al. (2012) analyzed the problems of traffic signs on conventional work sites and their colors to enhance the driver conspicuity. On the other hand, it was conducted only to improve the color of the traffic signs.

Son (1998), Lim et al. (2001), Park et al. (2003), Lee et al. (2003), etc. examined the characteristics of traffic flow, traffic delay and traffic operation, whereas Kim et al. (2003) investigated a systemic perspective to address problems from road work zones.

Most studies of the road work focused on an analysis of the traffic impact on the work zone and the improvement of operation, instead of the development of any equipment for traffic safety. Although Ko et al. (2012) examined traffic signs that can be referred to as road safety equipment, it was quite different from the present study, which collected data of vehicles approaching the road work zone and provided them to the driver and workers.

As mentioned above, the study employed AHP developed by Thomas L. Saaty, which qualifies the knowledge, experience and intuition of the evaluator through a pairwise comparison among the factors comprising the hierarchical structure of decision making. AHP has such a simple and clear theory that it is easy to apply, used widely for decision making and also studied actively.

An application case of AHP to the road work zone was difficult to find. The AHP is used mainly for the priority of road projects and policy making. Jeong (2002) used the AHP to determine the priority of road projects. Cho (2007) and Song et al. (2010) also used the AHP to make a decision on traffic policies while Choi et al. (2011) and Uhm et al. (2012) assessed measures of reducing traffic accidents. Although Cho (2007) applied the most similar methodology to that of this study, they should still be discriminated as the former was about policy making, whereas the latter developed a traffic safety facility and evaluated its applicability.

Development of Road Traffic Safety Moderator Robot

The road traffic safety moderator robot developed in this study is not as simple as the existing dummy that moves the signal stick up and down only. Rather, it can measure the speed of the cars on the road, show it on the display and alarm the drivers. When a car approaches faster than the regulation says, it gives a warning to the road workers with wireless communication to prevent accidents that could otherwise be caused by the car running out of the norm. This suggests that it has adaptive strategies to the traffic condition.

The road traffic safety moderator robot can be controlled manually or with a remote control. The manual mode controls the robot according to the control part input of the motion control board and the remote control mode controls it with the communication board control of the motion control board.

The study designed the road traffic safety moderator robot as a simple and function-oriented one with enhanced practicality so that it could be used as an unmanned security guard at a work zone with a camera and telecommunication technology.

The radar, display panel, antenna, and camera attached to the road traffic safety moderator robot were placed where each of the functions can be maximized and its appearance was kept as simple as possible to better alert the drivers with its display.

The radar speed measuring device was produced to measure the car speed under 200km/h from 100m ahead and give an alarming signal to both the drivers and road workers, promoting worker safety. The robot communication module is connected to external networks to control the robot and transmit images. The robot communication module can communicate with the robot control part and receive the robot control command from outside servers before sending this to the robot control part, connect to external networks using Wi-Fi and/or 4G LTE as well as USN (Ubiquitous Sensor Network), andsend images saved on the camera.

The robot installed a camera with a HD image processing function and infrared camera that produces a good quality image, even when it is dark. The control part that controls the entire robot was designed to enable remote control and video image transmission with a connection to the motion part, motor control and communication part. In addition, manual control and remote control via Bluetooth is also available.

Evaluating Applicability of Road Traffic Safety Moderator Robot

The study employed AHP to evaluate the applicability of the road traffic safety moderator robot. The use of road and traffic safety installation is greatly affected by the public employees that manage the budget and order construction works. Therefore, this study surveyed the public employees responsible for road works on the applicability of the road traffic safety moderator robot. The survey was a man-to-man interview.

The level 2 hierarchical structure for survey was categorized into safety, convenience and economic viability. The safety was then subdivided into visibility and efficiency, convenience into operability and mobility, and economic viability into initial investment and maintenance cost.

Safety is about how safe it is and guaranteeing it. Convenience refers to how good the status or condition for use is. Finally, economic viability shows whether it provides more with less finance, resources and time.

Visibility is the degree of attracting a person's attention or seeing something. Efficiency is defined as the degree of securing safety. Operability is how easy it is to move or handle, and mobility is how fast it can be moved from one place to another. The initial investment is the amount of money spent from the planning stage to commercialization, and the maintenance cost is the replacement cost and the labor cost required to maintain and manage the facility function.

As the alternative to the applicability evaluation, this study chose a traffic safety installation that functions like the developed road traffic safety moderator robot. The robot was established as Alternative 1, the lane changing sign board for cars as Alternative 2 and the speeding sign board as Alternative 3.

The study used AHP for the applicability evaluation and Expert Choice for the analysis software. The survey of the public employees responsible for road works on the road traffic safety moderator robot revealed safety to be the most important at 0.651 for traffic safety installations at a road work zone followed in order by economic viability (0.180) and convenience (0.169). Table 1 lists the applicability evaluation result, and Figure 1 to 3 present the AHP analysis result of the evaluation criteria for each alternative.

Table.1: Result of usability evaluation of public official

Classify		Alternative 1	Alternative 2	Alternative 3
Valuation basis	Detail valuation basis			
Safety (0.651)	Visibility (0.500)	0.497	0.290	0.213
	Efficiency (0.500)	0.476	0.219	0.305
Convenience (0.169)	Operability (0.717)	0.485	0.251	0.263
	Mobility (0.283)	0.488	0.326	0.186
Economic viability (0.180)	Into initialinvestment (0.272)	0.159	0.596	0.245
	Maintenancecost (0.728)	0.243	0.461	0.296

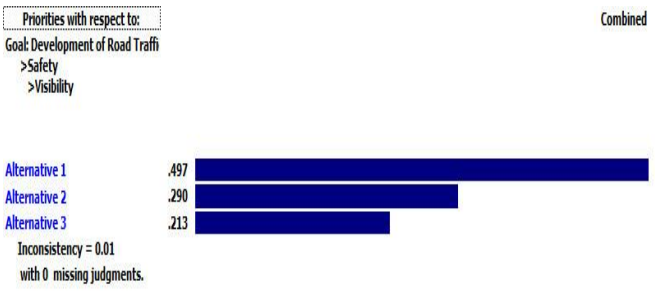

Figure 1:Result of AHP for visibility

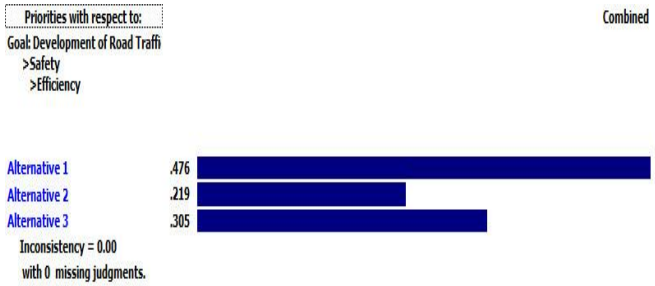

Figure 2:Result of AHP for efficiency

The AHP result on safety stated that Alternative 1 is the most favored with visibility at 0.497 and efficiency at 0.476, showing excellent safety, which is the most important factor of traffic safety equipment for a road work zone.

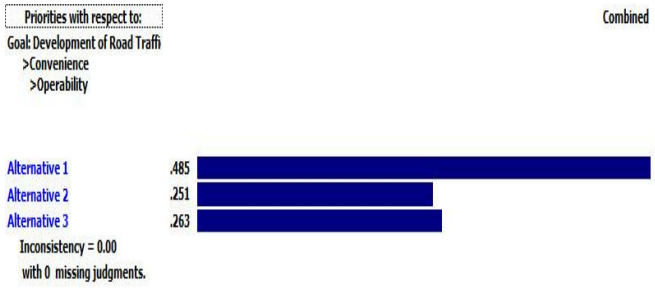

Figure 3: The result of AHP for operability

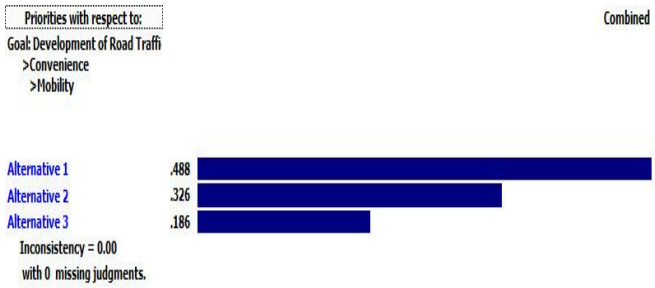

Figure 4: The result of AHP for mobility

The AHP result on convenience also showed that the Alternative 1 was more popular with an operability at 0.485 and a mobility at 0.488 than the other alternatives, bringing the best evaluation, such as safety.

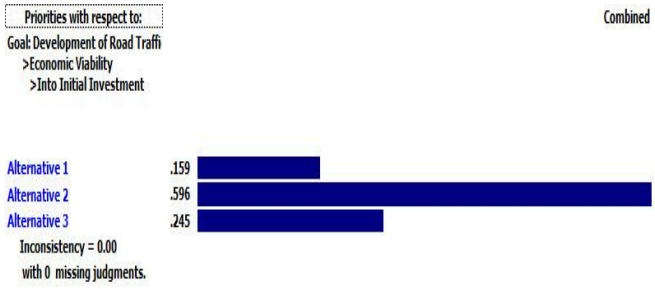

Figure 5: The result of AHP for into initial investment

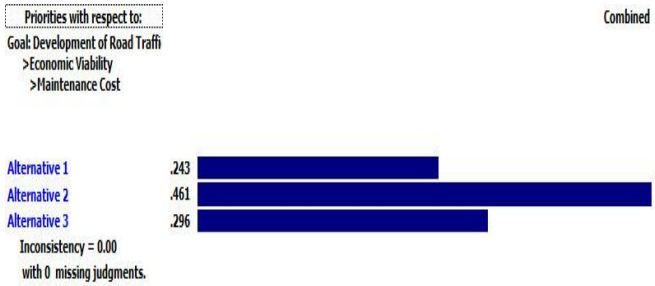

Figure 6: The result of AHP for maintenance cost

According to the AHP result, however, Alternative 1 received lower scores on economic viability with an initial investment at 0.159 and maintenance cost at 0.243 than the other options. Nevertheless, the survey result explained that society increasingly calls for a safety system and safety is always the first among all factors required for traffic safety installations on a road work zone. In this context, it is believed that the road traffic safety moderator robot, which is highly appreciated for its safety and convenience compared to the others, needs to be applied actively, even though this may result in additional cost.

For AHP analysis, the consistency of the survey result should be maintained. Consistency aims to measure the transitive contradiction caused by the evaluator's judgment to remove or review it. According to the consistency index, the closer to 'n' the pairwise comparison matrix of an evaluator is, the more consistent the judgment. The hypothesis was tested by defining the null hypothesis and alternative hypothesis with CR used as the test statistic. If the critical value of CR is < 0.1, the null hypothesis is rejected and the evaluator can be said to have made a consistent judgment. This study analyzed the CR value of each item and found that all were 0.00, rejecting the null hypothesis to demonstrate consistency.

Conclusions

The study developed the road traffic safety moderator robot as the traffic safety equipment needed for the road work that blocks traffic and evaluated the applicability of the robot. For the applicability evaluation, it used AHP and surveyed the public employees responsible for securing the road work budget and placing work orders.

The survey result showed that safety was the most significant factor among all the factors for traffic safety installations on a road work zone followed in order by economic viability and convenience.

As a result of level 2 analysis on the robot, safety and convenience were more favored than the other alternatives, whereas economic viability was less favored.

Level 3 analysis showed that Alternative 1 was the most popular posting with 0.497 for visibility, 0.476 for efficiency, 0.485 for operability, and 0.488 for mobility, but the least popular with initial investment at 0.159 and maintenance cost at 0.243.

Although the road traffic safety moderator robot had lower economic viability than the other options, safety is always the first among all factors required for traffic safety installations

on a road work zone and there are increasing calls for safety systems in society. Given this, it is believed that the road traffic safety moderator robot needs to be applied actively.

Of course, further technological development should follow in the future to build a morecost-effective traffic safety system. This will enable the robot to be used more both widely and economically.

In addition, as the public employees responsible for budget and work ordering were surveyed, the economic aspect could have been reflected more. Therefore, more study will be needed to target more stakeholders in the field of road work including workers and designers.

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