INVESTIGATING THE IMPACT OF THE SNOW REMOVAL PROCESS BY INTRODUCING IMAGE PROCESSING INTO INTERRUPTED TIME SERIES ANALYSIS

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ABSTRACT - In countries with winter seasons, the danger of driving on expressways is significant. Thereby, these countries pour resources into snow removal infrastructure and methods to ensure reliable transportation even when snowfall accumulates. In particular, monitoring the effectiveness of snow removal on expressways is crucial for keeping traffic moving unimpeded. By introducing image analysis into interrupted time series analysis, we provide a novel approach to quantify the impact of snow removal. Experiments on real data in Japan were conducted. The results show that snow removal decreased the visibility level defined by the average luminance values by 70.98%.

Keywords: Snow Removal Process; Image Processing; Interrupted Time Series Analysis

1. INTRODUCTION

Heavy snowfall during Japan's winter months is a significant cause for concern due to the increased risk of accidents on the expressways. Vehicle collisions and lengthy traffic delays are only two of the high-profile catastrophes that have occurred on the expressways in recent years due to snow and ice [1], [2].
Japan and regional countries have significantly invested in snow removal technology and processes to maintain clear expressways [3]. Among these measures are the installation of snow storage facilities and the deployment of high-tech snowplows and de-icing chemicals to keep roads passable. But still, researchers are unable to determine the impact of the snow removal process quantitatively.

Expressway snow removal is a complicated procedure that demands meticulous planning and execution to reduce adverse effects. Studying the aftermath of snow removal can teach us important lessons about how to make the process more effective and secure [4], [5]. A possible strategy is to track traffic patterns, road conditions, and meteorological conditions before, during, and after snow removal [6]. Statistical tools, such as interrupted time series analysis (ITSA), are useful to ascertain how snow removal affects traffic flow and safety [4], [7].

In this study, we provide a novel approach based on ITSA to quantify the impact of snow removal. Note that we cannot directly apply ITSA to our task. This is because the available camera images on expressways are unstructured. To overcome this difficulty, we newly introducing image processing into ITSA.

2. MATERIALS AND METHODS

The snow removal process is considered the intervention for ITSA, which is performed to compare the pattern of the outcome variable before and after the intervention in the study. In this study, we

used real expressway images from the CCTV camera in Niigata Prefecture, Japan. We defined drivers' risk level in the expressway as directly proportional to the visibility level calculated via image processing.

2.1. Image Processing

(a) (b) (c) (d)

Figure 1. (a) Snow (b) Snow with Mask (c) Snow Removal (d) Snow Removal with Mask

We used 60 images before the snow removal process and 60 appearances after the snow removal process with a one-minute time interval. Before extracting the features of images, manual masking was done to reduce the interruption from external factors shown in Figure 1. Then visibility level is calculated by taking the average of the luminance values of the masked images.

2.2. ITSA

After 60 minutes in the timeline, the interruption (snow removal) begins. The formula is written as follows:

$$Y = b_0 + b_1 T + b_2 D + b_3 P + \epsilon \qquad \textbf{Equation 1.}$$

Here,

Y: Outcome variable (visibility level)

T: Variable that indicates time passed from the start of the observational period

D: dummy variable indicating observation collected before (D = 0) or after (D = 1) the intervention

P: Variable indicating time passed since the intervention has occurred (before intervention has occurred P = 0)

ϵ: Error.

Knowing the counterfactual is crucial in ITSA. What would have happened to Y if the intervention never took place is what is meant by the term "counterfactual." Therefore, the snow removal process's impact can easily be determined with the above measurements and ordinary least squares regression.

3. RESULTS

The regression in Equation 1 yielded Figure 2. This figure depicts how the model fits before and after intervention (snow removal) while forecasting a counterfactual in the given conditions.

Specifically, visibility levels were predicted to drop by 70.98%. This result is statistically significant, where the p-value is approximately 0 by the model. Additionally, after the snow removal process has been completed, the model predicts a minute-by-minute decrease in visibility level of 0.7508%.

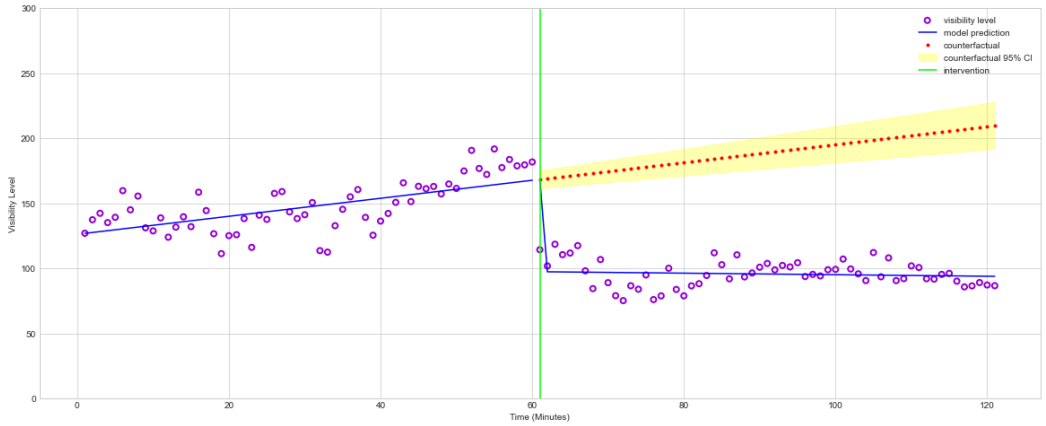

Figure 2. Model Fit Before and After Intervention

4. CONCLUSION

In a country that gets a lot of snow, accidents on the expressway are expected during the winter months. Thus, snow removal is essential for reducing this danger. However, research into the effects of snow removal is lacking. Our methodology sheds insight on how to scientifically assess the process and its effects by introducing image processing into ITSA. We hope to build on this method in the future by utilizing sophisticated machine learning to integrate traffic engineering concepts with image analysis to provide a novel approach to reducing the likelihood of accidents.

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