Research on Spatio-Temporal Publishing Strategy of Traffic Guidance Information

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Abstract Scientific and reasonable induced traffic information release strategy can effectively reduce traffic congestion, this paper first research and put forward the general structure of information service system, and then further study generalized information service oriented induced traffic information release strategy of time and space, based on traffic wave theory, put forward the total traffic incident duration and accident influence scope and traffic event queue length prediction model, Through the induced traffic information release area, put forward many terminal induced traffic information release strategy, and finally analyzed the relevant verification, analysis results show that the information release strategy can effectively guide the induced traffic information release is scientific and certainty, further enhance the highway public travel information service level.

1 Introduction

With the high-speed development of the highway informatization, the domestic highway development trend of information release way also is diverse, such as car terminal, VMS (Variable Message Sign), mobile phone APP (Application) and website, etc. Although diversified ways to disseminate information to a certain extent, improve the highway public travel information service level, but the information release system are independent. Moreover, China's expressway guidance information release system needs to be improved. Traffic incident information decision and release are mostly rely on managers' experience for manual operation. It is difficult to provide active, personalized and refined traffic information services to travel users because a complete publishing strategy of road guidance information has not been formed yet [1].

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L. C. Jain et al. (eds.), *Advances in Wireless Communications and Applications*,
Smart Innovation, Systems and Technologies 299,
https://doi.org/10.1007/978-981-19-2255-8_17

2 Structure of Generalized Information Service System

Based on the existing travel information service publishing modes, the highway guidance information publishing strategy oriented to generalized information service is studied. Establish effective traffic guidance information release strategies for different information release systems such as VMS, vehicle-mounted terminals, and mobile phone apps through scientific methods, and provide travelers with real-time, active, and personalized traffic information services [2]. The system architecture is shown in the Fig. 1 below:

The system includes information acquisition layer, information processing layer and information release layer. The information acquisition layer mainly obtains traffic related information such as traffic flow, congestion state, event type and weather condition through information acquisition equipment. Followed by information processing layer, because of the collected data format and standard not unified problems, needs the data cleaning, after processing the data in the database of the standby, in addition, the collected data needs to be further data filtering, data fusion, data mining and data retrieval process. Then through the related algorithm and calculation model, the prediction model of the spatio-temporal range of traffic events and the information release area were obtained. Combined with the traffic related information such as the event type and road network operation state, the spatio-temporal

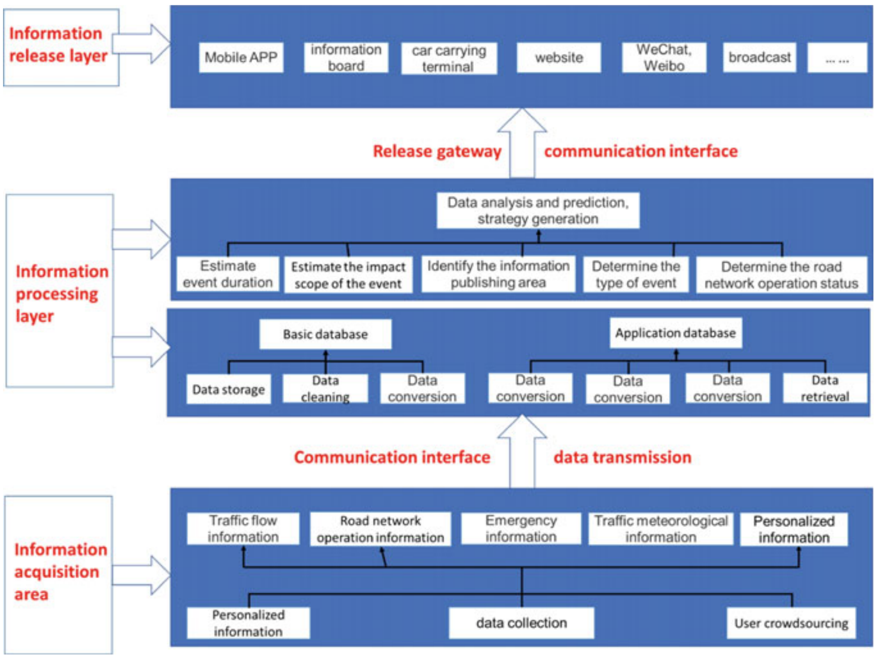

Fig. 1 Generalized information service system architecture

release strategy of induced information was formed [3]. The information release layer will release the processed data through mobile phone APP, VMS, vehicle-mounted terminals, websites, WeChat public accounts, broadcasting, and other publishing methods [4].

3 Spatio-Temporal Publishing Strategy of Traffic Guidance Information for Generalized Information Service

3.1 Prediction Model of Total Duration of Traffic Events

T1 prediction model of traffic accident duration. This study defines the duration of the traffic accidents as dependent variable, the factors that will affect the traffic incident duration is defined as the independent variable, the duration of traffic accident is defined as the dependent variable, assuming a linear relationship between the dependent variable and each variable, get type (1):

$$T_1 = \beta_0 + \beta_1 X + \beta_2 X_2 + \beta_P X_P + \varepsilon \tag{1}$$

where, $\varepsilon \sim N(0, \sigma^2)$, $\beta_0, \beta_1, \beta_2 \ldots, \beta_P, \sigma^2$ is unknown, and matrix is used to obtain the formula (2):

$$T_1 = \begin{cases} y_1 \\ y_2 \\ \cdots \\ y_n \end{cases}, \beta = \begin{cases} \beta_1 \\ \beta_2 \\ \cdots \\ \beta_n \end{cases}, \mathrm{X} = \begin{bmatrix} 1 & x_{11} & x_{12} & \ldots & x_{1p} \\ 1 & x_{21} & x_{12} & \ldots & x_{2p} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & x_{n1} & x_{n2} & \ldots & x_{np} \end{bmatrix}, \varepsilon = \begin{cases} \varepsilon_1 \\ \varepsilon_2 \\ \cdots \\ \varepsilon_n \end{cases} \tag{2}$$

The regression model is expressed as (3).

$$T_1 = X\beta + \varepsilon, \varepsilon \sim N\left(0, \sigma^2 l_n\right) \tag{3}$$

where 0 is the n-dimensional 0 vector, the identity matrix of order n.

T2 prediction model of traffic accident duration. Under the condition of traffic accident, the deterministic queuing model can accurately express the accumulative arrival and departure states of vehicles at each stage. Based on the deterministic queuing model theory and the predicted value of T_1 established earlier can be used to calculate the recovery time T_2 of traffic events. Where, represents the time when a traffic incident occurs; $t_0 t_a$ Represents the end time of traffic incident duration; t_b Represents the end of traffic recovery time;T_1 Represents the duration of the event;T_2 Represents the traffic recovery time;C_0 Represents the lane capacity after the event is handled;C_1 Represents the capacity of the remaining lanes after the incident; Q

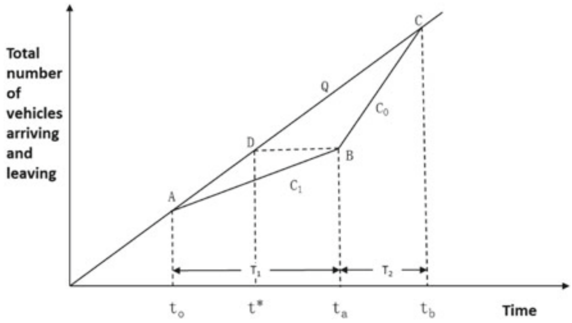

Fig. 2 Cumulative arrival and departure curves of vehicles

represents the upstream arrival rate and the slope of the cumulative arrival vehicle curve (Fig. 2).

Suppose Q and C_0, C_1 is constant. The value of C_0 can be determined according to the traffic flow parameters detected by the traffic detector, and then combined with the effective capacity coefficient table· We can determine the value of C_1.

The calculation formula of traffic recovery time t_b is as follows:

$$t_b = \frac{(C_0 - C_1)T_1}{C_0 - Q} + t_0 \tag{4}$$

The calculation formula of traffic recovery time T_2 is as follows:

$$T_2 = t_b - t_0 - T_1 = \frac{(C_0 - C_1)T_1}{C_0 - Q} \tag{5}$$

The formula for calculating the total duration of traffic incidents is:

$$T_A = T_1 + T_2 = \frac{(C_0 - C_1)T_1}{C_0 - Q} \tag{6}$$

3.2 Traffic Event Queue Length Prediction

When a traffic accident occurs on an expressway, its capacity will be affected. At this time, a gathering wave with uniform velocity propagating upstream will be generated at the event section, and its velocity is W_{01}; After a period, the traffic police will close part of the lane to deal with the accident site. At this moment, a new gathering wave will be generated with a speed of W_{12} And when the assembled wave W_{01} And dissipation wave W_{12} When meeting, the maximum queue length L_m will be generated at this moment. When the traffic accident is handled, the main line will restore the maximum capacity, and at this moment, the dissipating wave W_{23}

Table 1 Calculation model of traffic incident influence length

Number	Maximum influence length of mainline	Maximum influence length of connecting road
1	$L_m = \mathrm{W}_{02}\mathrm{T}_{02} + \mathrm{W}_{12}\mathrm{T}_{12}$	–
2	$L_m = L + W'_{23}T'_{23}$	$l_m = w_{02}t_{02} - l$
3	$L_m = L + W'_{23}T'_{23}$	$l_m = w_{12}t_{12} + w_{02}t_{02} - l$ or $l_m = w_{23}t_{23} + w_{13}t_{13} - l$
4	$L_m = \mathrm{W}_{23}\mathrm{T}_{23} + \mathrm{W}_{13}\mathrm{T}_{13}$	–
5	$L_m = L + W'_{13}T'_{13}$	$l_m = w_{13}t_{13} - l$
6	$L_m = L + W'_{23}T'_{23} + W'_{13}T'_{13}$	$l_m = w_{12}t_{12} + w_{02}t_{02} - lor$ $l_m = w_{23}t_{23} + w_{13}t_{13} - l$

spreading uniformly to the upstream section of the accident will be generated; In addition, the impact of ramps and connecting roads on traffic capacity should also be considered in the whole highway network environment. Due to the change of ramps or connecting roads into vehicles, a new aggregation wave W_{ij} will be generated.

The traffic wave theory is widely used in the analysis of the characteristics and influence of traffic flow fluctuation on expressways. The basic model is $W = \frac{\Delta q}{\Delta k}$, wherein Δ Q and Δ K represent the changes of traffic volume and traffic density before and after traffic accidents respectively, and W is the wave speed of traffic wave. Greenhill model is a speed-density linear model. Its basic model is $Q = KV_f\left(1 - \frac{K}{K_J}\right)$, where K represents density, V_f represents free flow velocity, and Q represents traffic volume. Based on the traffic wave theory and Greenhill model, this paper constructs the traffic event model of ramps and connecting roads to predict the queue length. The queue length of traffic events can be divided into the following six situations (Table 1):

3.3 Division of Inducing Information Release Area and Determination of Traffic Information Priority

In this study, the inducing information releasing area is divided into strong information releasing area and weak information releasing area. Travelers in the releasing area can decide whether to detour according to the congestion time and scope of traffic events. In reference [5], the release principles of strong prompt information and weak prompt information are further divided according to the distance from the traffic incident point. Strong prompt information has a higher priority than weak prompt information [5].

Among them, the area of strong prompt information release is determined based on the prediction model of the influence area of the traffic accident mentioned above, and the strong prompt information such as notice the accident ahead, reduce the speed, pay attention to avoid traffic and drive carefully is issued to the vehicles within this area. The weak warning information release area is determined according to the information effectiveness attenuation theory. Information validity can be specified by $\emptyset_{rs} = e^{kl}$, where $\emptyset_{\text{rs}}$ represents the validity of the information, k represents the correlation coefficient, which should be based on the results of the driver's questionnaire, and l represents the distance from the vehicle to the specified section. The farther away the operator and passenger is from the event point, the less effective the information is. The weak warning information release area is to remind vehicles within this area that they are about to enter the accident affected area and drive carefully.

3.4 Induced Information Advertising Policy

Through the establishment of the prediction model of the total duration of the accident and the model of the influence range of the traffic event, this paper further divides the release area of the traffic guidance information and determines the release range of the strong prompt information and the weak prompt information based on the priority of the information release. Then combined with the meteorological information, traffic event information, traffic network operation state and other information collected by the traffic detector, data analysis and further strategy generation are carried out. The adjusted spatio-temporal guidance information is published through VMS, mobile phone APP, vehicle-mounted terminal, roadside base station, traffic broadcast, Internet, and other terminals [6].

4 Experimental Verification

In this paper, a traffic accident in a highway in Shandong Province is selected. The traffic information release strategy is based on the premise that traffic congestion will occur when the traffic event occurs, and the case verification and analysis of the traffic guidance information release strategy are carried out. The data information can be retrieved from the database. The relevant information is shown in the following Table 2.

4.1 Prediction of Total Duration of Traffic Incidents

A total of 6,264 complete traffic event data were selected from a highway in Shandong province from 2019 to 2021, 56 traffic events with incorrect data were removed, and a total of 6,208 traffic accidents with valid data were removed. The duration of traffic accidents was defined as a dependent variable, and each factor affecting the duration of traffic incidents was defined as an independent variable. This paper

Table 2 Basic information

Attribute	Value	Attribute	Value
In the date	2021/2/8	The event type	Traffic accident (rear-end collision)
Time of occurrence	6:31 AM	Take up the driveway	2
Processing end time	8:46 AM	Number of vehicles involved	3
Processing duration	135 min	Length of congestion	30 km
Recovery time	10:42 AM	Number of goods vehicles involved	3
Event description	Three freight cars rear-ended each other	Number of truck rollovers	0

conducts variance analysis and regression analysis based on SPSS (Statistical Product and Service Solutions) simulation software. The significant factors influencing the duration of traffic events are determined by an ANOVA (Analysis of Variance) as shown in the following Table 3:

Based on the results of analysis of variance, independent variables with significance less than or equal to 0.04 are screened, including traffic accident type, discovery period, number of trucks involved, number of buses involved and number of congested lanes. Further regression analysis is carried out based on the screened significant factors, and non-standardized coefficients β (Mentioned in 3.1) are obtained as shown in the Table 4.

According to the non-standardized coefficients β of the respective variables, the optimal linear regression equation of the traffic accident duration in Eq. (2) is:

$$T_1 = 16.461 + 4.935X_1 + 12.116X_2 + 22.270X_3 + 7.84X_4 + 8.95X_5$$

Table 3 Intersubjective effect test

Source	Significance
Modified model	0.000
Intercept	0.000
Type of traffic accident	0.000
Find time	0.000
Number of trucks	0.000
The tanker number	0.053
Bus number	0.036
Number of vehicles involved	0.042
Number of blocked lanes	0.000

Table 4 Non-standardized coefficients β

Model	non-standardized coefficients β
Constant	16.461
Type of traffic accident	4.935
Find time	12.116
Number of trucks	22.270
Number of vehicles involved	7.840
Number of blocked lanes	8.952

Further, substitute the traffic accident case data selected in this paper, and get $T_1 = 2.098$ h.

Similarly, the traffic accident case data selected in this paper are substituted into Eqs. (5) and (6): $T_2 = 115.42$ min, $T_A = 4.02$ h.

Thus, the predicted value of the total duration of the traffic event is, where the predicted value of the traffic event duration is, and the predicted value of the traffic recovery time is. The accident is expected to end at 8:37am and recover at 10:32am.

4.2 Prediction of Traffic Accident Influence Area and Determination of Inducing Information Release Area

Based on the Greenshield model, the traffic volume Q and traffic density K values at each stage are shown in the following Table 5.

Based on the classical traffic wave theory, there is.

$W_{01} = \frac{Q_0 - Q_1}{K_1 - K_2} = 13.65$;$W_{12} = \frac{Q_1 - Q_2}{K_1 - K_2} = 147.47$; $W_{23} = \frac{Q_2 - Q_0}{K_2 - K_0} = 18.45$;

The traffic wave speed calculation data of traffic accident duration prediction above from Table 1 are substituted respectively to obtain $L_m = 31.55$ km.

4.3 Comparative Analysis of Results

The verification results are compared with the real data of a highway rear-end collision in Shandong selected in this paper, and the results are as follows (Table 6):

Table 5 Traffic volume and traffic density calculation

i	$Q_i(pcu/h)$	A formula to calculate	$K_i(pcu/km)$
1	$Q_0 = 3000$	$K = Q/v = 3000/100$	$K_0 = 30$
2	$Q_1 = C_1 = 1716$	$Q_1 = 100K\left(1 - \frac{K}{144}\right)$	$K_1 = 124.1$
3	$Q_2 = 4400$	$Q_2 = 100K\left(1 - \frac{K}{144}\right)$	$K_2 = 105.9$

Table 6 Data comparison

Compare the parameters	Actual accident data	Accident prediction data
Traffic accident handling time	135 min	125.85 min
Traffic accident recovery time	116 min	115.42 min
Maximum queue length of traffic accident	28 km	31.55 km

By comparing and analyzing the actual and predicted data of the traffic accident, it is found that the actual processing time, recovery time and the maximum queue length of the traffic accident are basically consistent with the predicted data, which can effectively predict the spatio-temporal range of the traffic accident.

5 Conclusions

Based on summarizing the inducing information publishing strategies at home and abroad, this paper firstly proposes a generalized information service system architecture which can be published in time through coordinated and efficient multi-channels, and further studies the inducing information spatio-temporal publishing strategies for generalized information services based on the traffic wave theory. The duration of traffic events and the influence range prediction model of traffic events are studied and established to determine the release time and space of highway traffic guidance information under traffic events, and then determine the time and space release strategy of highway traffic guidance information under traffic events. Finally, an example is analyzed and verified. Based on the analysis results can be found that this strategy can be to traffic managers to formulate scientific and reasonable traffic induced information release strategy of time and space to provide technical support, for users provide more scientific and accurate travel induced traffic information service, and further enhance the highway public travel information service level.

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