

Research on LINGO Problem of Solving Railway Station Safety Marking Based on Bernoulli Effect

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Abstract: In order to study the problem of safety marking setting in railway stations, this paper analyzes the factors directly related to the setting of safety markings, establishes a theoretical model based on Bernoulli effect, carries out the analysis of the interval planning of safety marking setting by debugging the parameter range in the model, and analyzes the sensitivity of the controllable parameter factors of the railway department. Reasonable control of the speed of the train into the station, reasonable setting of the platform hardware environment and other related suggestions.

Keywords: Bernoulli effect; Safety marking; Optimization model; Interval planning

1. Introduction

At a train station or subway platform, about 1 meter from the edge of the platform, there is a yellow (or white line) drawn on this line, which is called the security line, and people must stand outside the security line while waiting for the train. People on the side of the platform will be pushed from the high-pressure area behind them to the low-pressure area in front of their body, which may cause people to get close to the train and cause accidents.

Therefore, it is necessary to establish a mathematical model to determine the size of the "suction" or "thrust" of the person standing on the platform when the high-speed rail or bullet train passes at full speed according to the relevant mechanism, considering the influencing factors such as human weight, volume and distance from the person, so as to explain the basis for setting the safety marking of the platform. Analyze the impact of different factors on the setting of safety markings, and accordingly, provide your advice to the railway authorities on ensuring the safety of railway platforms.

2. Optimization model for safety reticle settings

2.1 Establishment of the model

Therefore, considering the important factors such as human weight, volume, air density in the area where the platform is located, and the speed of the train entering the station, the Bernoulli model is established to calculate the "suction" or thrust at the set speed, and the optimization model is as follows:

$$\begin{aligned} \min \quad & L - x_0 \\ \text{s.t.} \quad & \begin{cases} f = \mu mg \\ F = \int_v dF = \frac{1}{2} \frac{2x_0 - w}{L^2} \rho V v_0^2 \\ F \leq f \end{cases} \end{aligned}$$

The optimization model provides the minimum reference value for a certain group of groups set by the safety marking, so that the factors that are directly related can be listed as shown in Table 1.

Table 1: Factors and descriptions directly related to the setting of safety markings

Symbol	Meaning	Description
ρ	Air density	Uncontrollable, will change, often take the value of 1.293kg/m ³

μ	Friction coefficient	It is related to the platform material, and it will change, and the value is often 0.3
g	Gravitational acceleration	Uncontrollable, unchanged, often 9.81 m/s ²
L	Wind speed attenuation distance	Uncontrollable, will change, often take the value of 3m
m	The weight of the person	Uncontrollable, subject to change, and comprehensive
V	The volume of a person	Uncontrollable, subject to change, and comprehensive
v_0	The speed at which the train enters the platform	Controllable
x_0	The position where the person stands	It can be controlled by the safety marking position

As can be seen from Table 1, except for the controllable speed of the train entering the platform and the position of the human station, other factors are uncontrollable by the railway department.

For parameters ρ , μ , g , L , which are only due to the problem of accuracy, the degree of influence can be determined by modifying the parameter values and observing the effect on the target value. The basic formula for calculating the degree of impact is as follows.

$$\alpha = \frac{\Delta A}{\Delta b}$$

where ΔA represents the amount of change in the target value corresponding to a small change in the parameter Δb .

For the passenger factor parameter m , V that needs to ensure extreme conditions, the extreme value can be set to obtain the optimal solution that can ensure the safety of all passengers. After enumerating the possible values of the parameters, the interval programming model is obtained, and the interval values corresponding to the decision variables and objective functions are obtained.

$[m^-, m^+]$ represents the possible range of passenger weight, $[V^-, V^+]$ represents the possible range of passenger volume, $[w^-, w^+]$ represents the possible range of passenger body width, $[x_0^-, x_0^+]$ represents the range corresponding to the decision variable, and $[opt^-, opt^+]$ represents the variation range corresponding to the objective function.

The upper limit of the interval model is as follows

$$\begin{aligned} \min \quad & L - x_0^+ \\ \text{s.t.} \quad & \begin{cases} f^- = \mu m^- g \\ F^+ = \int_V dF = \frac{1}{2} \frac{2x_0^+ - w^-}{L^2} \rho V^+ v_0^2 \\ F^+ \leq f^- \end{cases} \end{aligned}$$

The lower bound model of the interval is as follows

$$\begin{aligned} \min \quad & L - x_0^- \\ \text{s.t.} \quad & \begin{cases} f^+ = \mu m^+ g \\ F^- = \int_V dF = \frac{1}{2} \frac{2x_0^- - w^+}{L^2} \rho V^- v_0^2 \\ F^- \leq f^+ \end{cases} \end{aligned}$$

For the parameters v_0, x_0 , which are controllable in the railway sector, the sensitivity analysis can be carried out to observe the allowable range of the parameters when the feasible solution remains constant under the extreme value of the passenger.

Select the data in Table 2 as the baseline data.

Table 2 Special parameter settings

Symbol	Value
ρ	1.293kg/m ³
v_0	55m/s
μ	0.3
g	9.81 m/s ²
L	3m
m	70kg/m ³
V	0.25 m ³
w	0.2m

The value of parameter ρ, μ, g, L are slightly changed, and the corresponding objective function value is solved with the help of LINGO software, as shown in Table 3.

Table 3: The degree of influence of the slight change parameters

Sym bol	Benchm ark value	Target value	-0.1% param eter value	-0.1% functio n value	Rati o	+0.1% parame ter value	+0.1% functi on value	Ratio
ρ	1.293kg/ m ³	2.719417	1.2917 07	2.71923 6	6.66 %	1.29429 3	2.7195 97	6.62%
μ	0.3	2.719417	0.2997	2.71959 7	-6.62 %	0.3003	2.7192 36	-6.66 %
g	9.81 m/s ²	2.719417	9.8001 9	2.71959 7	-6.62 %	9.81981	2.7194 17	0.00%
L	3m	2.719417	2.997	2.71941 6	-0.11 %	3.003	2.7294 16	0.11%

As can be seen from Table 3, air density and friction coefficient have a stronger effect on the objective function value than gravitational acceleration and increasing distance. Therefore, when making decisions, we should focus on climate factors and anti-slip material factors of the platform.

2.2 Interval planning analysis of passengers' own parameters

Select the data in Table 4 as the baseline data.

Table 4 Special parameter settings

Symbol	Value or range
ρ	1.293kg/m ³
v_0	55m/s
μ	0.3
g	9.81 m/s ²
L	3m
m	[40kg/m ³ , 80kg/m ³]
V	[0.15 m ³ , 0.35 m ³]
w	[0.15m, 0.25m]

The results of the decision variables obtained by using the interval upper bound model were used to write the LINGO solver and the results of the decision variables are shown in Table 5.

Table 5: Interval results of decision variables

Symbol	Value or range
x_0	[0.1719841m, 0.8025925m]
opt	[2.197408m, 2.828016m]

According to Table 5, it can be seen that in order to ensure the size of extreme passengers, it can be seen that at the speed of 200km/h, the minimum safety distance markings can be set to a distance of about 3 meters from the center of the railway, that is, a distance of about 2 meters from the edge of the platform, which is consistent with the marking distance specified in the "Railway Technical Management Regulations".

2.3 Sensitivity analysis of controllable parameters in the railway sector

Select the data in Data Table 6 as the baseline data.

Table 6 Special parameter settings

Symbol	Value or range
ρ	1.293kg/m ³
v_0	55m/s
μ	0.3
g	9.81 m/s ²
L	3m
m	60kg/m ³
V	0.25 m ³
w	0.25m

Using LINGO to write the corresponding solution program, it can be obtained that under the condition that the current optimal solution remains unchanged, the allowable increase and decrease range of the right end term of the equation constraint of friction is $(-\infty, 4.432083]$, the allowable increase and decrease range of the right end term of the equation constraint of thrust is $(-\infty, 78.79688]$, and the allowable increase and decrease range of the right end term of the thrust and friction constraint is $[176.58, +\infty)$, which shows that the heavier the person, the greater the friction. The more you can keep it from being pushed by thrust.

2.4 Conclusion

The models involved in this paper are all based on Bernoulli's principle mechanism model, the model source is reliable, the models involved are based on the train speed, human weight, human body shape, the distance between the train centerline and the person as the main parameters, the model structure is simple and easy to solve. The model has practical application value, and the model can be generalized to other types of trains and different station environments. It can also be extended to safe driving side by side on highways, safe distance for ship navigation, etc.

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