International Journal of Applied Science and Mathematics
Volume 4, Issue 5, ISSN (Online): 2394-2894

Study of the Desired Vehicle Speed Model on Curved Roads Based on Cooperative Vehicle Infrastructure

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Date of publication (dd/mm/yyyy): 15/10/2017

Abstract **– To ensure the safety of the vehicle traveling on a curve, considering the impact of traffic safety of people, vehicles, roads, and environment, we researched on the expectation safe speed of vehicle on a curve. The desired speed is influenced by many different factors, such as the driver characteristics, the vehicle characteristics, the road condition, and weather. AHP-GRAP method is used to quantify the hierarchy of driver's dynamic decision-making process. The algorithm is feasible through the survey data test, also provide a theoretical basis for the future Safe Vehicle Speed warning on Curved Roads.**

Keywords **– AHP-GRAP, Cooperative Vehicle Infrastructure, Desired speed, Safe speed.**

I. Introduction

Corridor is the highway traffic accident multiple sections. Statistics show that the domestic occurrence of poor line of sight, low technical indicators of the road section of the major traffic accidents at least 70% or more [1]. Vehicles in the passage through the curve, often because of the wrong speed of the wrong way to predict the occurrence of rollover, sliding and other dangerous conditions [2]. In the study of traffic safety evaluation model, the expected speed is an indispensable parameter, and its determination is of great significance to the research of vehicle corridor driving safety model.

The determination of the vehicle speed at the time of passage through the curve is a complex act that is influenced by a variety of factors including driver inclination, weather conditions, road conditions, curvature and ultrasonography [3, 4]. Based on the theory of vehicle road coordination, this paper puts forward the idea of AHP - gray comprehensive evaluation (GRAP) analysis method combined with the model to forecast the expected safety speed of the vehicle through the curve, AHP method and GRAP method, the establishment of safe vehicle speed prediction model, the main idea is: The relative weights of the influencing factors in the criterion layer and the scheme layer are calculated according to the listed judgment matrix, and then the vector and scheme layer composed of the importance of the factors in the criterion layer are given according to the GRAP method. The expected vehicle speed characteristic matrix determined by the relative weight of each factor is calculated by calculating the correlation degree of each factor.

II. Analysis of Influencing Factors of Expected Speed

When you submit your final version, after your paper has been accepted, prepare it in two-column format, including figures and tables.

The expected speed is also referred to as the psychological speed, which refers to the maximum "safe" speed that the driver expects to achieve when the vehicle is traveling, subject to other vehicle constraints, or less constrained. The "safe" speed in this definition means only a safe driving speed for a driver, and does not necessarily mean a truly safe driving speed in a strict sense. There is a deviation between the expected speed and the actual driving speed, but when the actual speed and the expected speed in the process of driving a certain value, the driver will take appropriate measures to adjust the current speed. In simple terms, if the conditions permit, if the heart of the desired speed is higher in the actual driving process in the driving speed will be higher and higher, until close to the expected speed, the actual speed of travel and the expected speed there is a positive correlation between the level. In terms of factors affecting the expected speed of the curve, the size of the curve will vary depending on the driver's characteristics, vehicle characteristics, road conditions, and weather conditions within a certain range.

A. The Driver Factors

Defined in terms of the differences of age, the expectations of the speed of the highest value is often a young driver, it is worth noting that the age, particularly prominent in drivers under the age of 25, followed by middle-aged drivers, determine the expected speed is the youngest of elderly drivers. In terms of gender differences, under the condition of male workers than women drivers also identify the expectations of the high speed, but the difference is not big. Similarly, people of different character set expectations speed is different also, in order to more accurately reflect the difference, in the simulation of road traffic safety, usually divides into the driver tended to outside, in the tendency, in type 3 kinds. Types of drivers on the selection the speed there is a big difference: in the same condition, the model outside tendency driver during driving, tend to expect speed numerical determine relatively high; Type tendency within the driver will tend to expect speed numerical determine relatively low; Driver in the tendency of numerical is expected to speed between type tended to outside and within [5]. According to the driving technology proficiency is different, the driver's actual driving experience can be divided into the following 1 year, 1~3 years, 3 years different types. Overall, driving experience is less than 1 year of the driver, because just take the driver's time is too short, car driving slowly rising stage, so in the process of driving heavy numerical tend to determine the expectations of the speed is low. 1~3 years driving experience driver, because of its basic driving technology is already relatively skilled, psychological exist to further improve the desire of the driving speed and emergency handling capacity, determine the speed of expectation is higher; drivers driving experience in more than three years, due to the driving skills have been relatively mature, determine the expectations in the process of actual driving speed value is normal.

B. The Vehicle Factors

Highway grade is determined, if the performance of the vehicle can always keep in a good state, the driver will raise expectations to the heart of the speed value. On the other hand, if the driving performance of poor vehicle, the driver can reduce the idea of the expected speed on its own. For vehicle type, small car performance is often better than general large cars, speed is relatively high, expect speed of itself has a certain requirements, big cars, on the other hand (general border vehicle speed faster, but the bus for dock site and safety aspects of reasons, the speed is slow) [8].

C. The Weather Factors

The road condition is one of the most influential factors of the expected speed [9]. In general, the better road conditions, road adhesion factors, driving horizons, road crossings and design speed are more reasonable, the driver based on the desire for faster, the expected speed will increase the value. Therefore, the road conditions to a large extent reflects the road traffic conditions are good or bad, thus affecting the driver to the desired speed of the establishment. So that the road conditions are different, the expected speed is different. The weather conditions also have a significant effect on the expected speed. In good weather, the driver will generally determine the higher expected speed, otherwise, the lower.

D. Influencing Factor Parameter Acquisition

According to the analysis of the factors affecting the speed of vehicle safety and the results of classification study, this paper presents a vehicle speed parameter acquisition scheme for dynamic vehicle corners based on vehicle routing technology, as shown in figure 1.

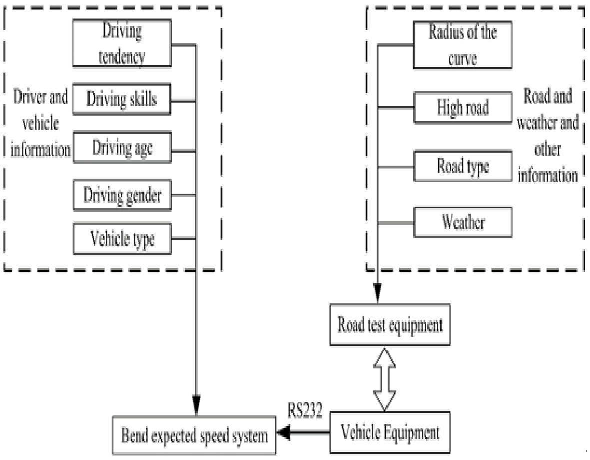

Fig. 1. Vehicle corridor safety speed acquisition program

III. Establishment of Probed Vehicle Speed Model based on AHP-GRAP Method

A. The Basic Principle of AHP-GRAP Method

1) Establishment of Hierarchical Model

In the use of analytic hierarchy process to study the problem, according to the causal relationship between the problems first, the relevant factors are divided into several levels, generally divided into the target layer, the standard layer and the program layer, when a level contains more factors, the level can be further decomposed into several sub-levels.

2) Judgment Matrix is Constructed

Judgment matrix A = $(a_{ij})_{n \times n}$ is a positive and negative matrix, which is used to describe the n factors $X = \{x_1, x_2, \cdots$ to compare the impact of the event after the importance of the introduction of the “1-9” scale [10].

Table 1. Relative importance scale

Scale value	The relationship between indicators	Scale value	The relationship between indicators
1	The factor i is just as important as the factor j	7	The factor i and the j factor are very important
3	The factor i is slightly important to the factor j	9	The factor i and the j factor are extremely important
5	The factor i is more important than the factor j	2, 4, 6, 8	The median of two adjacent judgments
Reciprocal	If the factor i is compared with the j-factor, the judgment value is Aij, then Aji = 1 / Aij		

3) Single Order Sorting and Consistency Test

According to the theory of the current algebra, the eigenvalues of the positive and negative matrix can be used as a measure of the proportion of each factor in the uniform level. The formula of the sum of the largest eigenvalue and the weight vector of is:

$$\lambda_{\max} = \frac{1}{n} \sum_{k=1}^{1} \frac{\sum_{j=1}^{n} a_{kj} \omega_j}{\omega_k} \quad \omega_k = \frac{\sum_{j=1}^{n} a_{kj}}{\sum_{i,j=1}^{n} a_{ij}} \quad k = 1, 2, \dots, n \tag{1}$$

Use ratio $CR = CI/RI$ to determine whether the consistency of the reciprocal matrix is up to the actual requirement. Only when $CR < 0.1$, the reciprocal matrix is considered to be consistent.

4) Gray Correlation Coefficient and Gray Correlation Analysis

The similarity between the two gray systems is measured by the gray correlation. Define the two series $\{X_i(t), X_j(t)\}$, at time $t = k$, the gray correlation formula as (3):

$$rij = \frac{1}{n} \sum_{k=1}^{1} \varepsilon_{ij}(k) \tag{3}$$

Where $\varepsilon_{ij}(k)$ is the gray correlation coefficient, the formula is expressed as (4):

$$\varepsilon_{ij}(k) = \frac{\Delta_{\min} + \rho\Delta_{\max}}{\Delta_{ij}(k) + \rho\Delta_{\max}} \tag{4}$$

$\Delta_{ij}(k)$ Represents the absolute difference between the two sequences at time k, i.e. $\Delta_{ij}(k) = \left|X_i(k) - X_j(k)\right|$.

$\Delta_{\min}$ and $\Delta_{\max}$ are the maximum and minimum values in the absolute difference, usually $\Delta_{\min} = 0$, ρ is the resolution coefficient, between 0 and 1, usually 0.5.

5) Gray System Modeling

There are K security modes, each of which can be composed of several security factors to form a feature vector, the composition of the security model of the characteristic matrix can be expressed as:

$$T_K = \begin{bmatrix} T_{K1} \\ T_{K2} \\ \cdots \\ T_{Km} \end{bmatrix} = \begin{bmatrix} T_{K1}(1) & T_{K1}(2) & \dots & T_{K1}(n) \\ T_{K2}(1) & T_{K2}(2) & \dots & T_{K2}(n) \\ \cdots & \cdots & & \cdots \\ T_{Km}(1) & T_{Km}(2) & \dots & T_{Km}(n) \end{bmatrix}$$

Using AHP method to quantify the weight of influencing factors in the criterion layer, as the importance index. In this way, the weight value of each influencing factor constitutes a set of groups $\{X_\Pi\}$ to be tested.

$$X_\Pi = (X_\Pi(1), X_\Pi(2), \cdots$$

The gray correlation degree between $\{X_\Pi\}$ and the typical feature matrix $\{T_k\}$ is calculated to obtain the correlation degree sequence. The order of relevance from large to small order is the best choice.

B. The Establishment of the Desired Speed Curve Model Based on Collaborative Road Vehicles

As the basis of this article based on the road coordination, road curvature and high information and other information can be learned through the roadside equipment. In the case of known road curvature, high and other information to determine the circumstances, the impact of road driving speed factors are mainly include: driver factors, road factors and other factors. Considering the complexity and uncertainty of the influencing factors, the hierarchical structure is established first, as shown in Fig. 2. Secondly, the safety of the curve is evaluated according to the gray relational degree. Finally, the vehicle is under different influence factors. The driver based on self-judgment to choose high-speed, sub-high-speed, medium and low speed driving speed.

1) Establishment of Hierarchical Model

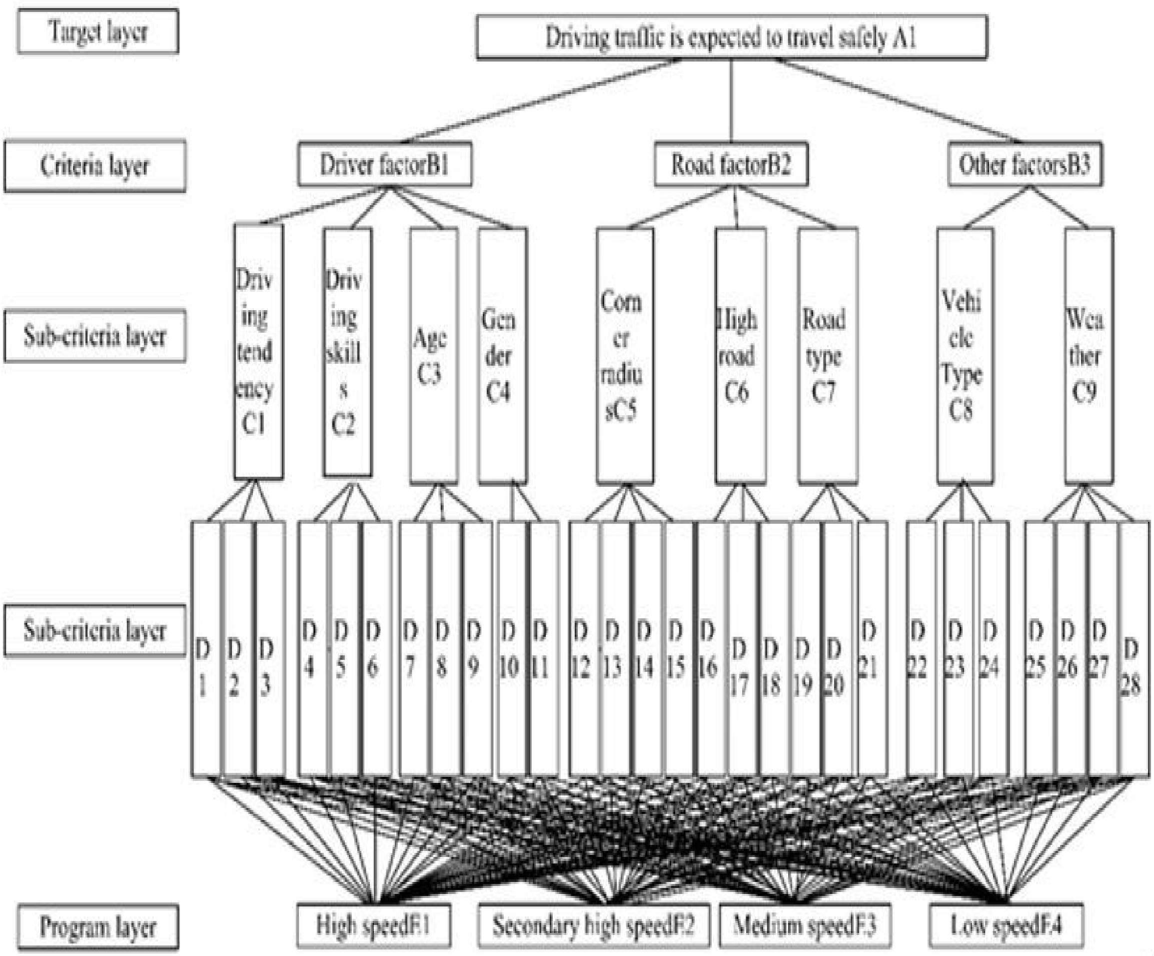

Fig. 2. Hierarchy chart

As the vehicle corners of the road, the curve of the safety of the speed calculation is a very complex project, while the corner of the safe speed to determine and many factors are closely related, is a vague process, respectively, in the study of this paper, according to the study of [11], (0-30 km/h), (80-100 km/h), (60-80 km/h), (30-60 km/h), (30-80 km/h).

2) Determine the Weighting Factors of the Target Layer in the Criterion Layer

Taking the method of expert evaluation to compare the speed of the criterion layer B to the speed of the vehicle in the target layer A and determine the score value to form the judgment matrix. According to the calculation formula described above, we can get the influence factors of the target layer the importance of weight and consistency test parameters, the same structure to construct the standard layer B and sub-criteria layer C.

According to the 1-9 scale criterion, the judgment matrix of the criterion layer B to the target layer A is constructed and the relative weight.

Table 2. Criteria Matrix B to the target layer A judgment matrix

A	B1	B2	B3
B1	1	2	1/2
B2	1/2	1	1/3
B3	2	3	1

It is reasonable to conclude that the above judgment matrix is obtained by the above consistency test formula, and the relative weight values are: driver factor (0.297), road factor (0.539), and other factors (0.164). That is, the factors influencing the speed of the curve are the factors of road factors, driver factors, and other factors.

Similarly, the constructor criterion layer C compares the judgment matrix of the criterion layer B and calculates the relative weights.

Table 3. Criteria for the criterion C of the subclass C on the criterion layer B

B1	C1	C2	C3	C4
C1	1	1/2	2	4
C2	2	1	3	5
C3	1/2	1/3	1	3
C4	1/4	1/5	1/3	1

Driving skills (0.473), age (0.169), and gender (0.072), respectively. The results show that the judgment matrix is reasonable. That is, the importance of the drivers in the order of driving skills, driving habits, age and gender.

Similarly, C can be compared to B2, B3 weight. The weighting of the listed criteria layer relative to the target layer is as follows and the weight of the sub-criterion layer.

Table 4. Sub-criteria layer C The judgment matrix for target layer A

C	B			ω_k
	B1	B2	B3	
	0.297	0.539	0.164	
C1	0.285			0.085
C2	0.473			0.140
C3	0.169			0.050
C4	0.072			0.021
C5		0.539		0.291
C6		0.297		0.160
C7		0.164		0.088
C8			0.200	0.033
C9			0.800	0.131

3) Determine the Weighting Factor of Scheme Layer E under Sub-Criterion Layer D Influencing Factors

The calculation principle of this step is the same as above, mainly to determine the weight of each factor in the sub-criterion layer D on the program layer, the weight coefficient values listed by the judgment matrix are as follows, and the judgment matrix is not listed here.

4) Gray Correlation Coefficient and Gray Correlation Analysis of the Calculation in the Next Section of the Model Validation in the Calculation Analysis introduced.

IV. Model Validation

1) In the different cases, the expected speed of the driver's choice is obtained through the questionnaire. The gray level analysis method is used to identify the expected speed of the driver to be identified. After identification, the expected vehicle speed and the actual expected speed and the validity of the model is verified according to the accuracy of the recognition.

Table 5 Identify the driver's desired speed

NO.	Expect safe speed	Driving tendency	Driving skills	Age	Gender	Radius of the curve	High road	Road type	Vehicle Type	Weather
1	Secondary high speed	Inside tendency	Over 3 years	Youth	Male	260	5%	One levels	Large car	Sunny
2	High speed	Outside tendency	Over 3 years	Elderly	Male	450	6%	Two levels	Car	Sunny
3	Medium speed	Medium tendency	0.5-3 years	Youth	Female	330	2%	Two levels	Car	Sunny
4	Low speed	Inside tendency	Six months or less	Elderly	Male	150	4%	Three levels	Medium car	Cloudy
5	Low speed	Medium tendency	Six months or less	Middle aged	Female	220	8%	Two levels	Medium car	Foggy

2) The typical risk feature matrix and the model to be tested are given

According to the above questionnaire, there are nine factors that affect the speed of traffic in the road, and there are four speed options. According to the weight value calculated in the previous section, the typical risk characteristic matrix is obtained according to the first case of questionnaire survey.

$$TK = \begin{bmatrix} T_{K1} \\ T_{K2} \\ T_{K3} \\ T_{K4} \end{bmatrix} = \begin{bmatrix} 0.1 & 0.125 & 0.48 & 0.45 & 0.11 & 0.16 & 0.47 & 0.06 & 0.49 \\ 0.16 & 0.375 & 0.28 & 0.27 & 0.48 & 0.48 & 0.28 & 0.12 & 0.28 \\ 0.28 & 0.375 & 0.15 & 0.16 & 0.30 & 0.29 & 0.16 & 0.30 & 0.15 \\ 0.46 & 0.125 & 0.09 & 0.11 & 0.11 & 0.07 & 0.09 & 0.52 & 0.08 \end{bmatrix}$$

Similarly, the model of the model to be tested is composed of the weight of the influencing factors:

$$X_\Pi = \{e_1, e_2, e_3, e_4, e_5, e_6, e_7, Ee_8, Ee_9\}$$

$$= \{0.085, 0.14, 0.05, 0.021, 0.291, 0.160, 0.088, 0.033, 0.131\}$$

3) Calculate the degree of correlation

$X_\Pi = \{0.085,\ 0.14,\ 0.05,\ 0.021,\ 0.291,\ 0.160,\ 0.088,\ 0.033,\ 0.131\}$ is the parent factor, and $T_{Ki}\ (i = 1, 2, 3, 4)$ is the sub-factor.

(1) Initialize processing for $\{X_\Pi\}$.

$$X_\Pi = \left(\frac{0.085}{0.14}, \frac{0.14}{0.14}, \frac{0.05}{0.14}, \frac{0.021}{0.14}, \frac{0.291}{0.14}, \frac{0.16}{0.14}, \frac{0.088}{0.14}, \frac{0.033}{0.14}, \frac{0.131}{0.14}\right)$$
$$\cdots ,1,0.36,0.15,2.1,1.14,0.63,0.24,0.94) \quad (2)$$

Solve the difference sequence

$\Delta_{\Pi Ki}(K) = \left|X_\Pi - T_{Ki}\right| \qquad i = 1, 2, 3, 4$

$\Delta_{\Pi K1} = (0.51,\ 0.875,\ 0.12,\ 0.30,\ 1.99,\ 0.98,\ 0.16,\ 0.18,\ 0.45)$

$\Delta_{\Pi K2} = (0.45,\ 0.625,\ 0.08,\ 0.12,\ 1.62,\ 0.66,\ 0.35,\ 0.12,\ 0.66)$

$\Delta_{\Pi K3} = (0.33,\ 0.625,\ 0.21,\ 0.01,\ 1.8,\ 0.85,\ 0.47,\ 0.06,\ 0.79)$

$\Delta_{\Pi K4} = (0.15,\ 0.875,\ 0.27,\ 0.06,\ 1.99,\ 1.03,\ 0.54,\ 0.28,\ 0.86)$

According to the above formula, the maximum and minimum values are obtained.

$$\max\left|X_\Pi - T_{K1}\right| = 1.99$$
$$\max\left|X_\Pi - T_{K2}\right| = 1.62$$
$$\max\left|X_\Pi - T_{K3}\right| = 1.8$$
$$\max\left|X_\Pi - T_{K4}\right| = 1.99$$

The maximum value is 1.99 and the minimum value is 0.01.

(2) Calculate the correlation coefficient $\varepsilon_{\Pi ki}\ (k)$ Take $\rho = 0.5$, find the following table 6.

Table 6 Correlation coefficient

	k = 1	k = 2	k = 3	k = 4	k = 5	k = 6	k = 7	k = 8	k = 9
i = 1	0.66	0.53	0.89	0.77	0.33	0.51	0.86	0.85	0.69
i = 2	0.69	0.62	0.93	0.89	0.38	0.60	0.74	0.89	0.60
i = 3	0.75	0.62	0.83	0.99	0.36	0.54	0.68	0.94	0.56
i = 4	0.87	0.53	0.79	0.94	0.33	0.49	0.65	0.78	0.54

(4) Calculate the degree of correlation

From the formula table 7 as follows:

Table 7 Correlation

$r_{\Pi k1}$	$r_{\Pi k2}$	$r_{\Pi k3}$	$r_{\Pi k4}$
0.677	0.704	0.697	0.658

From table 7 we can see that the degree of correlation is, we can draw the following conclusions: Can be drawn as follows: In the introverted, more than three years, youth, male, curved radius of 260m, high 5%, a highway, cart, sunny and other factors under the influence of the driver selected sub-high speed as the best expectations Safe speed, which coincides with the questionnaire. The result of this recognition is consistent with the results obtained from the questionnaire. It can be seen that the gray level analysis method is used to determine the expected accuracy of the vehicle with high accuracy, medium speed, low speed and low speed. , And can also be embedded in the vehicle monitoring and early warning system, to achieve vehicle traffic in the process of real-time dynamic analysis and evaluation of the vehicle speed for the vehicle to provide a new way of warning.

V. Conclusion

(1) In summary, the driver in different traffic conditions, different weather conditions to choose the best expected safety speed is an incomplete information, inaccurate system. The evaluation of gray system theory can expand the information source and improve the credibility of evaluation and analysis under the condition of incomplete and inaccurate information.

(2) The driver chooses the desired safety speed when driving in the corners is a very complicated system engineering. The safety speed is related to many factors. In order to make the safety speed more scientific and effective, this paper constructs the AHP-GRAM evaluation Model, according to the importance of the safety factors to determine the importance of speed to determine the level of the speed, resulting in the best driving speed when the road speed.

(3) Through the questionnaire survey data to verify the model, the model can accurately predict the expected speed under different conditions, the vehicle corridor driving safety has a high theoretical value.

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