Analysis of Stampede Emergency Management Capability in Subway Station Based on Analytic Hierarchy Process

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Abstract

Large crowds cause stampede and casualties with constant development and widely use of the subway, which has been one of the major factors in negative social impact. And thus pose a major challenge to the emergency management. This study intends to improve the ability to respond to emergencies is of practical significance. The current explorative study aims to use Analytic Hierarchy Process (AHP) to have a comprehensive evaluation of stampede emergency management capability in subway station. An indicator system is constructed, including four main criteria such as prevention and preparation, monitoring and early-warning, emergency response and rescue, restoration and reconstruction and 19 sub-factors. The results of the AHP analyses indicate that emergency response and rescue phase and some other sub-factors are the most important criteria which occupy a heavy weight. In addition, recommendations for improving the capability of stampede emergence management are also included in the report as well as suggestions for follow-on analyses.

Keywords

Subway station, stampede emergency management, Analytic Hierarchy Process (AHP).

1. Introduction

As China's economy and technology surge, subway has undergone rapid development unprecedentedly, which representing an increasing important part of both the public's trip and the society function among multitudinous public transports for the convenience, placidity and comfort it provides. Meanwhile, the contradiction between the increasing number of passengers and the limited throughput of the metro is arising gradually, which triggering exceeding of safe capability and the emergence of damaged casualty accidents afterwards [1]. As John J Fruin states, the majority passengers usually generate panic psychology lacking of information when an emergency issue happens [2]. Subsequently, resulting from the high density of the crowd, they will be perplexed with a disorder behavior and unable to respond to the relative actions and forming a vicious ring, then, the stampede accident occurred. For example, according to incomplete statistics, there are 13 stampede accidents and lead to more than 135 individuals injured in railway station, figure 1 shows the elements' proportion which result in stampede from 2008 to 2017 [3].

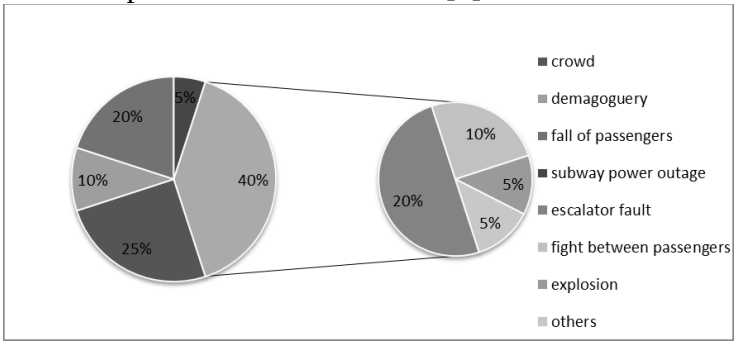

Fig. 1 Proportion of factors attributing to stampede, 2008 -2017

The remainder of the paper is organized as follows: The indicator system constructed to evaluate and calculate the stampede emergency management capability is given in Sect.2 based on AHP. Then, Sect.3 presents the literature references. Finally the evaluation conclusion and some recommendations are provided in Sect.4.

2. Organization of the Text

2.1 Design of the AHP Instrument

2.1.1AHP Introduction

The Analytic Hierarchy Process (AHP) [4], since its invention has been available and found an increasingly wide utilization in all fields among multiple criteria decision-making tools resulting from its practicability, simplicity and systematism. AHP provides a solution for decision makers to create the hierarchical structure of a complex problem, using the relationships of the overall priority, objectives, criteria, and alternatives: the final outcome of the method is a ranking of the decision alternatives [5]. Due to the system of stampede emergence management has the characteristics of hierarchy, diversity and fuzziness, we can utilize the final total ranking of the AHP and present the relative importance of the subsystems of each layer to the total target [6]. Therefore, the analysis of the stampede emergency management system capability can be viewed according to the result based on AHP as following.

2.1.2 Indicator System Descriptions

There are several of factors affecting the management under stampede, which interacting each other and jointly affect the process. According to the phases of emergence management and Present situation in railway station [7], four stampede emergence management capability categories (Prevention and Preparation, Monitoring and Early-warning, Emergency Response and Rescue, Restoration and Reconstruction) are considered as the main criteria in this study and 19 elements has been selected from previous studies of Peng as the index layer. AHP consists of four main steps: (1) the decomposition of the problem into sub-problems; (2) pairwise comparison of the elements; (3) consistency evaluation and (4) synthesis of the results to obtain a final ranking [8]. Figure2 shows the research model and the AHP hierarchy tree design.

Attributes of each criterion will be explained thoroughly during the following sectors:

Prevention and Preparation: This phase is prepared for preventing, control, reduce and eliminating the potential safety hazard of stampede and enhancing the emergence management capability once it occurs. Thus, some tasks supposed to be complemented in this phase, such as formatting emergency plan, preparing emergency materials, carrying out emergency rehearsal, unfolding publicity and education.

Monitoring and Early-warning: Aiming at provide seasonable hazard identification and evaluations, this phase can take a safety monitoring and a limitation timely on visitor flowrate in the subway station. In addition, it is of benefit to the information release and site instruction to avoid stampede happens.

Emergency Response and Rescue: When an emergency accident happened, it is pivotal for the relative departments to start the emergency linkage and rescue mechanism as soon as possible so that the loss can be decreased at an acceptant level. There are five factors should be involved, information report, emergency plan activation, command and dispatch, real-time rescue and emergency linkage.

Restoration and Reconstruction: Post-disaster reconstruction and reconstruction is a very important link of stampede emergency management. It is necessary to prevent the secondary disasters and draw a conclusion after controlling or eliminating the safety hazard. Therefore, it is considered as one of the main criteria in this evaluation system.

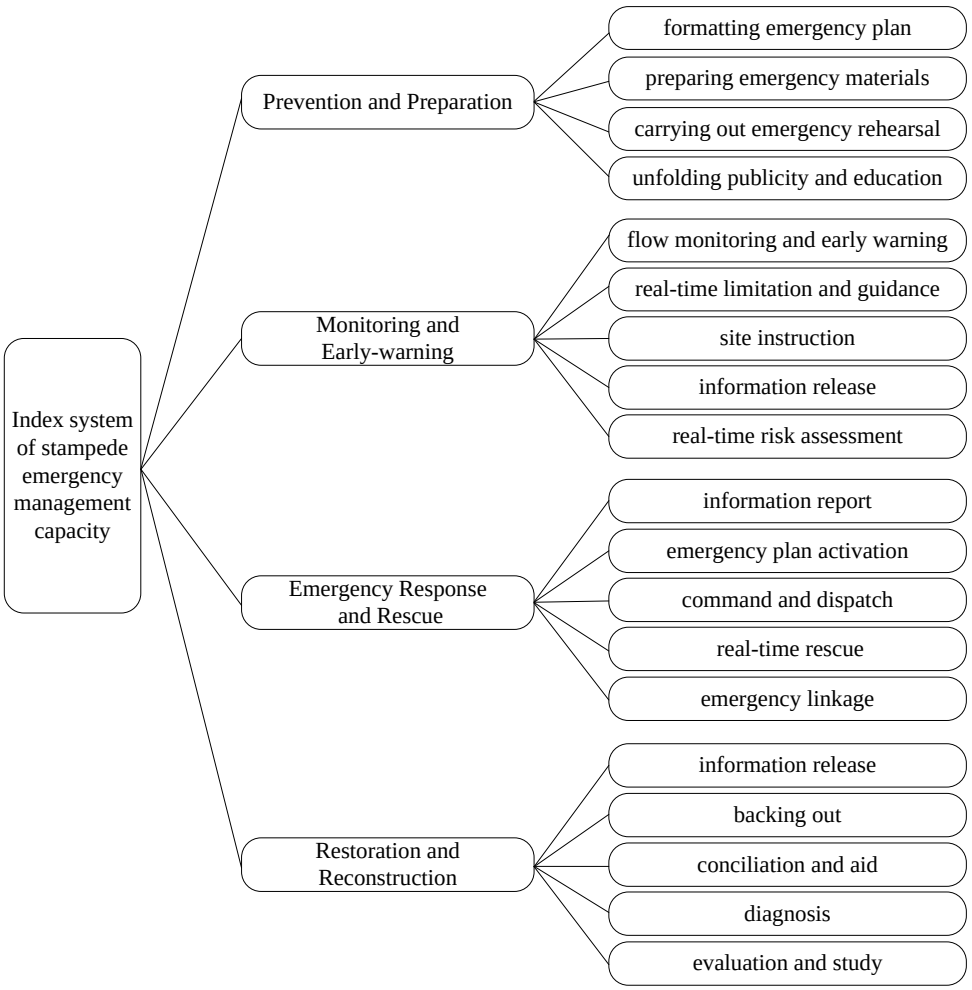

Fig. 2 Index system of capability stampede emergency management

2.2 The Scale and Description

When comparing a pair of elements, a ratio of relative importance expressed on a verbal scale is generally used (see Table 1), The scale ranges from1/9 for 'least valued than' to 1 for 'equal', and to 9 for 'absolutely more important than' covering the entire spectrum of the comparison [9].

Table1. The linguistic description of the numerical scale in AHP

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities considered equally important.
3	Moderate importance of one over another	One activity is marginally favoured over another
5	Essential or strong importance	One activity is strongly favoured over another
7	Very strong importance	One activity is very strongly favoured and its dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order
2/4/6/8		Intermediate values between two adjacent judgments

2.3 Construct Judgement Matrixes

Judgment matrix is the basic information of the analytic hierarchy process, and it is also an important basis for weight calculation. According to the structural model, the two factors in the figure are judged and compared, and the judgment matrix is constructed:

Table2. Judgement matrixes of index layers

P	B1	B2	…	Bn
B1	b11	b21	…	bn1
B2	b12	b22	…	bn2
…	…	…	…	
Bn	b1n	b_{2n}	…	bnn

2.4 Determine the Weight of Indicators

In the evaluation of the stampede emergency management capability in the railway station, the accuracy of the index weight directly determines the precision level of the evaluation results. In general, there are two ways to determine the weights of index, which are supervisor assignment method and the objective assignment method. According to the specific evaluation object, the appropriate evaluation criteria are formulated and the weights of each evaluation index are determined by experts in this study.

2.5 The Calculation Results Based on AHP

In the following computational diagrams, W is used to descript the weight of factors compared with the other factors in the evaluate system. The maximal eigenvalue is descripted shortly as λ. The reliability of this estimation can be measured by the Consistency Ratio (CR). Perfectly consistent judgments result in a consistency ratio of 0; CR=1 indicates that judgments were made randomly. Generally, a consistency ratio which does not exceed (0.10) is considered acceptable [5]. The following data are formulated and calculated according to the judgements of some experts.

Table 3 Judgement matrix and weight of main factors set

Capability	Prevention and Preparation	Monitoring and Early-warning	Emergency Response and Rescue	Restoration and Reconstruction	Wi	Priority ranking
Prevention and Preparation	1	1/2	1/5	3	0.141	3
Monitoring and Early-warning	2	1	1/3	3	0.226	2
Emergency Response and Rescue	5	3	1	5	0.560	1
Restoration and Reconstruction	1/3	1/3	1/5	1	0.073	4
$\lambda = 4.13 \quad CR = 0.08$						

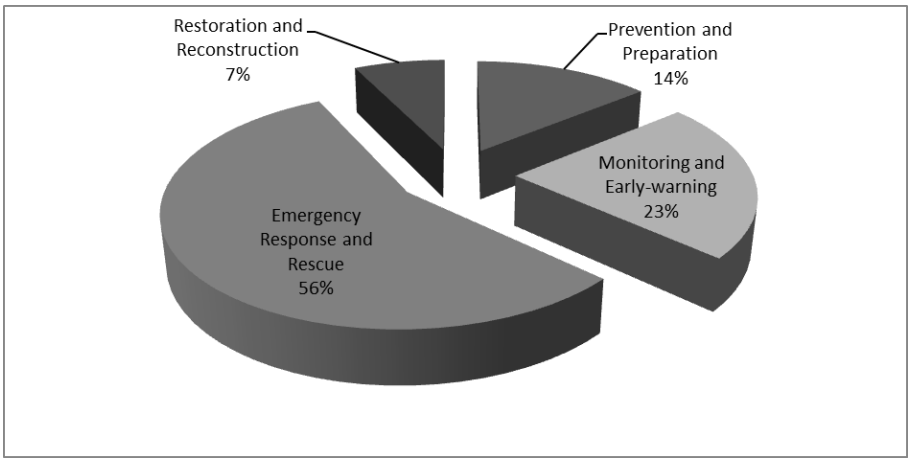

Fig. 3 Proportion of main criteria in the evaluation system

What we can conclude from table3 and figure3 is that when it comes to the capability of stampede emergency management, the emergency response and rescue ranks the first among these four main factors in that having some emergency responses is essential to rescue individuals' life and reduce the loss at a minimal level. Monitoring and early-warning system is secondly important for its function of real-monitor and pre-warning. Prevention and preparation of the stampede emergency is behind. Even though the restoration and reconstruction is an important part after the stampede accidents happened, it is at a low weight of 0.073 when it compared to the other three factors in a stampede emergency management.

Table 4 Judgement matrix and weight of prevention and preparation factors set

Prevention and Preparation	formatting emergency plan	unfolding publicity and education	carrying out emergency rehearsal	preparing emergency materials	Wi	Priority ranking
formatting emergency plan	1	6	2	2	0.444	1
unfolding publicity and education	1/6	1	1/2	1/5	0.072	4
carrying out emergency rehearsal	1/2	2	1	1/3	0.152	3
preparing emergency materials	1/2	5	3	1	0.332	2

$$\lambda = 4.11 \quad CR = 0.06$$

Table 4 provides details on the weight of four main sub-factors in the prevention and preparation system ranked as formatting emergency plan > preparing emergency materials > carrying out emergency rehearsal > unfolding publicity and education. As we know, formatting an emergency plan -a guiding principle, is indispensable to have a comprehensive consideration about what and how we supposed to do when a stampede emergency happened in a railway station. Besides, it is of significance to prepare emergency materials in the daily routine in the preparatory phase. In addition, carrying out emergency rehearsal at a regular time does good to save more time of rescuing for a rapid and ordered response it provides. Despite the weight of unfolding publicity and education is relatively small, but it can't be emphasized too much.

Table 5 Judgement matrix and weight of monitoring and early-warning factors set

Monitoring and Early-warning	flow monitoring and early warning	real-time limitation and guidance	site instruction	information release	real-time risk assessment	Wi	Priority ranking
flow monitoring and early warning	1	3	3	1/3	3	0.282	1
real-time limitation and guidance	1/3	1	3	1/3	3	0.182	4
site instruction	1/3	1/3	1	1/2	1/5	0.074	5
information release	3	3	2	1	1.3	0.260	2
real-time risk assessment	1/3	1/3	5	3	1	0.202	3

$\lambda = 5.01 \quad CR = 0.002$

The result indicates that flow monitoring and early warning is the most important part of Monitoring and Early-warning, which is part of real-time risk assessment as well. Information release ranked as the 2nd most important in this sub-system, which is a key phrase to guide passengers to flow into a corrective direction as well as site instruction. In addition, it is necessary to have a real-time limitation and guidance of passengers, avoiding concentration in confined areas such as elevators or aisles so that a stampede accident occurs.

Table 6 Judgement matrix and weight of emergency response and rescue factors set

Emergency Response and Rescue	information report	emergency plan activation	command and dispatch	real-time rescue	emergency linkage	Wi	Priority ranking
information report	1	1/3	3	1/3	3	0.182	4
emergency plan activation	3	1	5	1/3	1/3	0.202	3
command and dispatch	1/3	1/5	1	1/2	1/3	0.074	5
real-time rescue	3	3	2	1	1/3	0.260	2
emergency linkage	1/3	3	3	3	1	0.282	1

$\lambda = 5.11 \quad CR = 0.048$

Figure 3 presents that real-time rescue and emergency linkage are almost at the same weight in Emergency Response and Rescue phase in that it is vital to have a comprehensive rescue under the cooperation of different departments and professors such as doctors and firemen as soon as possible. When the stampede occurs, the emergency plan should be activated at the first time so that the whole rescue task can be completed steadily and fast. Also, how the emergency rescue carried out is

important information in the site that should be shared with all individuals who concerned about. Although command and dispatch plays a least important part, it is an independent part of the emergency linkage phase to decrease the rate of casualty.

Table 7 Judgement matrix and weight of restoration and reconstruction factors set

Restoration and Reconstruction	information release	backing out	conciliation and aid	diagnosis	evaluation and study	Wi	Priority ranking
information release	1	1/3	1/3	1/5	1/3	0.067	4
backing out	3	1	3	1/3	3	0.278	1
conciliation and aid	3	1/3	1	3	3	0.278	1
diagnosis	5	3	1/3	1	1/3	0.198	2
evaluation and study	3	1/3	1/3	3	1	0.179	3

$\lambda = 5.13 \quad CR = 0.055$

In the Restoration and Reconstruction factors on criterion layer, backing out and conciliation and aid dominates the other elements accounting for the 50% of the total weights, and the results showed there is no significant difference between them and clearing of site and making the railway station running again is of great importance to the stampede emergency management. At the same time, the organizations also need to release the site information as soon as possible and spend much time to placate those who injured or lost their relatives. After the complement of the relief effort, it is of significance to have a comprehensive analysis, summary and study timely to prevent similar accidents happens again.

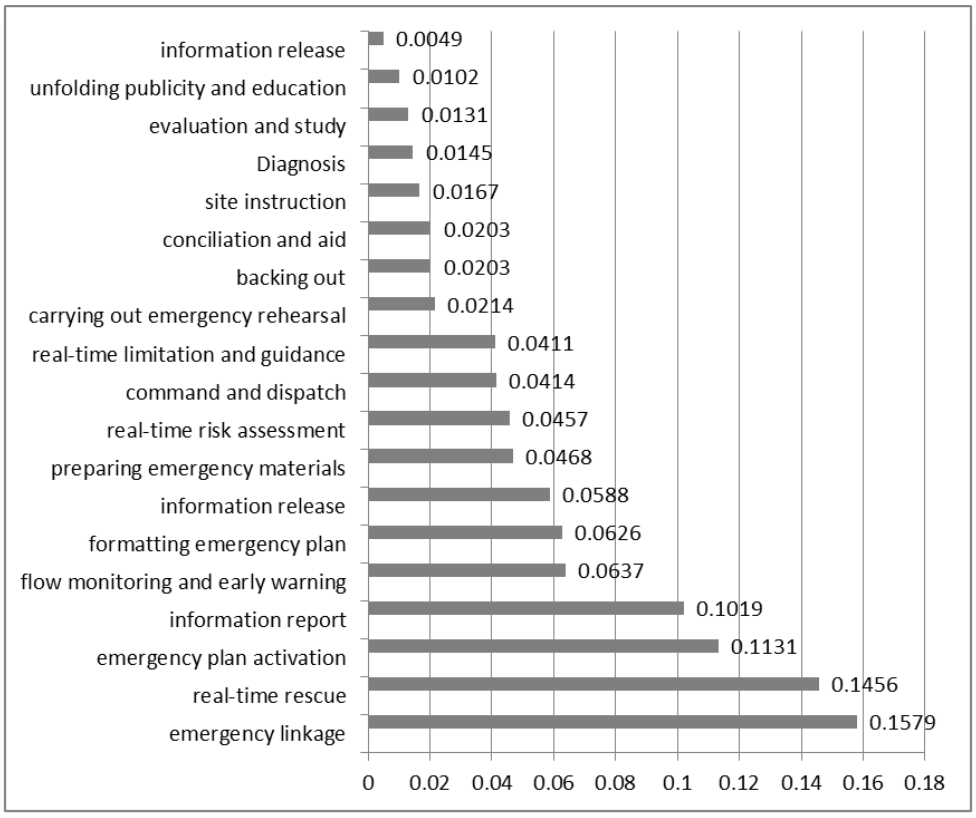

Fig. 4 Priority ranking and weight of attributes

After performing the analysis of the scoring sheet, the priority rankings and weights in figure2 were obtained for the main factors and the second-level (attributes). The four main capability indicators (emergency linkage, real-time rescue, emergency plan activation and information report), accounting for over 10% of the total weights, are of great significance to the stampede emergency management.

3. Literature References

Wang shows that once the stampede occurs, it will have greatly effect on the social stability and people's lives and property, and specifically, it has difficulty in evacuation and rescue for its underground space with complex structure and personnel intensive [10]. In many cases, there will be more than one specific hazard within this. For this reason, the high stampede emergency management capability is a key for the success of rescuing people in need and should play its dual role in carrying on some seasonable measures. Therefore, it is of great significance to study the emergency management capability at rail transit stations to improve the evacuation efficiency and ensure the safety of personnel, and to provide scientific references for stampede prevention.

In recent years, how to eliminate or control the hazards and enhance the capability of stampede emergence management has been studied on several occasions. For example, an improved DEA model was built for risk assessment of crushing and trampling accidents in subway stations and applied in 13 subway stations in Beijing which agree with the actual conditions fairly well [11].Yasser A. Alaska et al. used the crowd simulation models and gave assessment of the best ways of grouping and crowd management and control engineering technologies, luggage management, video monitoring, and changes in the construction of the transport system [12]. Based on the analysis and comparison of 3 main trampling accidents happened at home and abroad, such as 2014 Shanghai stampede, 2015 Mina stampede and the cross year activities of New York Times Square, Lu and Tian found the transformation mechanism of stampede and proposed the relative improvement measures of emergency disposal and stampede prevention [13]. Using the Management Oversight Risk Tree (MORT) technique and the FIST (Force, Information, Space, Time) model, Jaime and Samuel has highlighted a number of causal factors leading to the ‘News Divine’ stampede disaster and identified some potential recommendations, which hoped to be beneficial for crowd management [14]. A extended floor-field (FF) model combined with risk factors presented for emergency evacuation is provided by Wang and Wang who designed a novel dynamic rerouting mechanism to elucidate the exit choice behavior of evacuees, and the recommended dynamic risk-field model is fully explored to deal with dynamical features of disaster which is validated through numerical simulations with specific room structures [15]. In order to solve subway stampede accidents cannot control effectively in relying heavily on experiences, a subway stampede accidents emergency linkage system was designed on the basis of the STAMP model [16].

Together, the results of previous studies suggested that many hazard installations attribute to potential safety hazard which leading to the stampede afterwards, and it is significant to carry out some effective measures for emergency evacuation. However, to our knowledge, there is lacking of studies in analyzing the capability of stampede emergency management and it is hoped to provide some better recommendations to enhance this kind of capability. Building on these findings above, a study that takes another perspective on the analysis of stampede emergency management capability in subway station and assessing the faults of this emergency management system. This study also contributes to provide scientific and efficient methods for improving the capability.

4. Conclusion

The present study confirms that an analytic Hierarchy Process (AHP) approach in the evaluation system is an applicable method to enhance the capability of stampede emergency management in subway station. Based on the Analytic Hierarchy Process, it establishes the evaluation system of the capability of multi-level to carry on synthetically analysis, making scientific and reasonable quantitative evaluation of the qualitative indicators. From the analysis above, we can conclude as the following.

The index of measure level should be improved and improved for the criterion layer with high weight. Especially, the results that Emergency Response and Rescue accounting more over 50% of the total weights indicate that it is the most important factors attributing to the whole evaluation of stampede emergency management capability in subway station. Therefore, it is of significance to emphasize and enhance this kind of capability.

The indicators of relatively poor performance at the level of measures should be reviewed and improved, such as flow monitoring and early warning, formatting emergency plan, information release and preparing emergency materials, which emphasize the preparation and early-warning phase. Moreover, in the routines, to draw up the emergency responsible progress good enough and establish the early-warning system is effective to eliminate the potential safety hazard and decrease the rate of casualty dramatically.

The index with relatively low weight doesn't necessarily mean that it is not important in the emergency management system. The lack of attention to any one index will affect the whole system and bring about potential safety hazard. Besides, even the element of unfolding publicity and education occupy a low weight among the other factors, but it is still important to enhance the realization of passengers to carry out emergency evacuation, which attribute to cut down their unsafe acts and depress casualty accidents happens.

Furthermore, the limitation of this research is the fact that the findings cannot be generalized and claims that they are valid for the entire stampede emergency management system. The findings of this paper just represent the opinions of the experts who participated in this study. And, this paper merely evaluate the capability of stampede emergency management in subway station objectively, it contributes to provide one result of qualitative and quantitative analysis for managers to make a decision better off in modern safety management system. All the factors analyzed in this paper will have an influence on the whole stampede emergency management in railway station more or less, accordingly, manage ought to consider them selectively. Therefore, for a better evaluation of the stampede emergency management, it is hopeful that future researches should make a comprehensive and authoritative analysis about this theme.

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