sustainability

MDPI

Article

A Dynamic Emergency Plan Generation Method Considering Different Situations and Limited Resources

Zixin Zhang [1,†], Liang Wang [2,†,*], Jiayan Lai [2] and Yingming Wang [1]

1 School of Economics and Management, Yango University, Fuzhou 350015, China
2 Decision Sciences Institute, Fuzhou University, Fuzhou 350116, China
* Correspondence: wangliangg322@hotmail.com; Tel.: +86-591-22866677
† These authors contributed equally to this work.

Abstract: When an emergency event occurs, emergency plans are usually employed to respond the emergency situations in order to prevent or mitigate possible losses of life and property. Therefore, emergency plans play an important and indispensable part in emergency decision-making. With regard to the question of how to generate emergency plans, extant studies have discussed the problem from various perspectives, and fruitful results have been obtained. Dynamic evolution is a typical feature of emergency events, and usually involves the updating of related information regarding an emergency event. Existing studies have considered dynamic evolution during the emergency plan generation process only from a single perspective, neglecting the related need to update information as dynamic evolution occurs. Information related to the emergency event plays a vital role in the emergency plan generation process, and needs to be considered. To overcome these limitations, the present study proposes a novel dynamic emergency plan generation method based on integer linear programming, which considers different emergency situations and limited resources. An illustrative example and descriptive comparisons are provided to demonstrate the novelty, superiority, and validity of the proposed method.

Keywords: emergency plan; emergency management; different situations; limited resources

Citation: Zhang, Z.; Wang, L.; Lai, J.; Wang, Y. A Dynamic Emergency Plan Generation Method Considering Different Situations and Limited Resources. *Sustainability* **2023**, *15*, 5996. https://doi.org/10.3390/su15075996

Academic Editor: Victoria Gitelman

Received: 12 February 2023
Revised: 23 March 2023
Accepted: 26 March 2023
Published: 30 March 2023

1. Introduction

With the rapid development of society, more and more emergency events (EEs) have occurred in recent years, i.e., natural disasters, production accidents, fires, etc. When an EE occurs, emergency decision-making (EDM) plays an important role in mitigating various losses and negative impacts. This has drawn increasing attention and become a very important and active research field in recent years [1–7].

As an important part of EDM, emergency plans are usually selected according to different criteria to handle emergency situations in order to mitigate losses and negative impacts as much possible when an EE occurs. When handling emergency situations, emergency plans are the key measures and elements, and have direct influence on whether emergency situations are successfully handled or not. Therefore, due to the importance and influence of emergency plans, studies related to emergency planning have been conducted from various perspectives, such as evaluation of emergency plans [8–10], mathematical programming-based emergency plan formalization [11–13], case-based reasoning emergency plan generation [14–17], hierarchical task network-based emergency plan generation [18,19], and various features (uncertainty, incomplete information, etc.) involving consideration of EEs within emergency plan generation [18–21].

Although related research on emergency plan generation has obtained fruitful results, previous studies have largely neglected a critical feature of EEs, that is, dynamic evolution, in which relevant information, including changes in timing, emergency situations, available emergency resources, etc., is updated. Information plays a critical role in all different kinds of decision activities, particularly dynamic updating information, and generation of emergency plans is no exception; therefore, all relevant information should be considered during the emergency plan generation process. Additionally, despite emergency plans playing an indispensable role in EDM, and despite fruitful results having been obtained, there are obvious drawbacks in that plans may not flexible enough when most of them are predefined, and may not be able to handle a variety of different emergency situations because of the dynamic evolution of EEs [22,23].

To overcome these drawbacks, the dynamic features of EEs have been discussed in a number of previous studies, which have proposed situation/scenario response models to address the emergency plan generation problem [5,6,24–26]. However, although a few studies [24–26] have considered different situations regarding emergency plan generation, ref. [24] handled the dynamic features from only a single perspective, i.e., if the generated emergency plan cannot deal with the situation successfully, the plan is updated according to feedback. However, the dynamic evolution of EEs involves multiple perspectives in which the relevant information on the EE changes, such as changes in the available information about the emergency situation, available resources, professional equipment, and personnel, etc. Such dynamic information change has largely been ignored in previous studies. It is necessary to consider the updating of such information during the emergency plan generation process.

Motivated by the aforementioned drawbacks in the existing studies, this study proposes a novel dynamic emergency plan generation method that considers different emergency situations and limited available emergency resources, and updates the relevant information accordingly. Such information may include changes in time requirements, the overall emergency situation, and available resources. The proposed method is based on integer linear programming, which is easy to understand, and the computations can be performed easily and quickly. The novelty and superiority of this approach enables the proposed method to overcome and improve on the drawbacks of previous studies, and is closer to the real-world situation, which enriches the method library of emergency plan generation.

The rest of this paper is organized as follows. Related works are presented in Section 2 to highlight the novelty and necessity of this study. The proposed emergency plan generation method is provided in Section 3. To demonstrate the superiority and validity of the proposed method, an illustrative example and descriptive comparisons are presented respectively in Section 4. Section 5 presents the conclusions and future works.

2. Related Works

To illustrate the novelty and necessity of the present study, this section presents a review of previous studies on emergency plan generation. The extant studies on emergency plan generation can be roughly summarized as follows:

(1) *Mathematical programming-based methods*. Bish and Sherali [11] treated the emergency evacuation plan generation problem as a combinatorial optimization problem, and provided a novel framework for modeling evacuation demand that offers demand-based strategies of aggregate-level staging and routing. Pyakurel and Dhamala [12] proposed a mathematical model for a continuous dynamic contraflow approach to emergency evacuation planning. They presented algorithms with a continuous contraflow reconfiguration approach to increase the flow value for a given time horizon and decrease the evacuation time needed to trans-ship the given flow value. Wu et al. [13] proposed a multiobjective risk response model to generate Pareto-optimal risk response plans, opening up the black box of the project process; in addition, they considered the risk correlations among different subprocesses.

(2) *Case-based reasoning methods*. Zheng [14] proposed dynamic case retrieval with subjective preferences and objective information for emergency plan generation, and considered the personal preferences of the decision-makers and attribute changes. Zheng [15] proposed a novel case retrieval emergency plan generation method that combined similarity measurement and a data envelopment analysis model. Zheng [16] proposed dynamic

case-based reasoning group decision-making for emergency plan generation, with the ability to adjust the generated emergency plans based on changing emergency situations. Zhang [17] developed a heterogeneous multi-attribute case retrieval method for emergency plan generation considering five information types: crisp numbers, interval numbers, intuitionistic fuzzy numbers, single-valued neutrosophic numbers, and interval-valued neutrosophic numbers. Yu et al. [27] proposed a new case adaptation algorithm to accelerate the adaptation process, which was able to generate emergency plans more efficiently.

(3) *Hierarchical task network-based methods*. Liu et al. [18] proposed a conditional hierarchical task network-based method, including a temporal reasoning technique suitable for conditional HTN planning to achieve concurrency and a temporal management approach to generate emergency plans. Qi et al. [19] proposed a hierarchical task network method to deal with multi-capacity discrete resources and complex temporal constraints simultaneously during emergency plan generation.

(4) *Process-based related methods*. Le et al. [28] simulated and analyzed different tsunami emergency plans based on a process modelling approach while considering the textual plan in order to represent emergency plans in a more formal way. Zhao et al. [29] applied process mining techniques to improve emergency planning for chemical spills, and considered a fuzzy mining algorithm to reconstruct the drill process for analysing workflows. Guo et al. [30] proposed a novel text similarity measure from the perspective of process description; they considered process-related semantic features, including the extraction of response levels, task statements, departments and roles.

Except for the aforementioned aspects, other related topics have been discussed as well, for example, consideration of different situations [24–26] and different features, including uncertain information, incomplete information, and dynamic evolution [19–21].

Although existing emergency plan generation studies have discussed related topics from different aspects and obtained fruitful results, most neglect an important practical issue, that is, that in real-world situations the available resources are always limited. Additionally, dynamic features should be afforded much attention during the process of emergency plan generation in order to handle EEs in a timely and efficient manner. Taking into account the limitations of previous studies, our study focuses on emergency plan generation while taking into consideration different situations and limited resources. The novelty of our study is that it fills this research gap and enriches the literature on emergency plan generation.

3. Proposed Method

This section presents a dynamic emergency plan generation method that considers different situations and limited resources, in which the dynamic features described include changes in time, information on the emergency situation, and available resources. The general framework of the proposed method is illustrated in Figure 1.

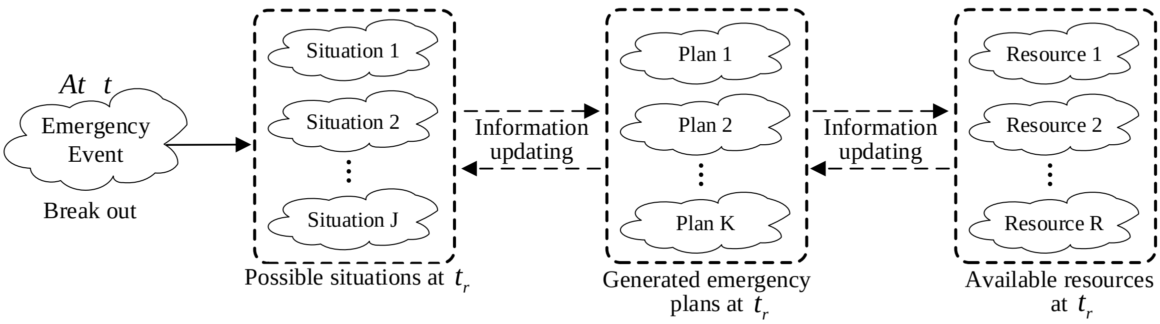

Figure 1. The general framework of the proposed method.

Following Figure 1, and in order to demonstrate the proposed method clearly and logically, the problem definition is presented below.

3.1. Problem Definition

First, we define the notation used to describe the proposed method.

- $T = \{t_1, t_2, \ldots, t_r, \ldots\}$: the set of discrete different moments (possibly infinite), where t_r indicates the *r-th* moment and r is an integer, i.e., $r = 1, 2, 3, \ldots$.
- $S = \{s_1^r, s_2^r, \ldots, s_J^r\}$: the set of possible situations at moment t_r, where s_j^r indicates the *j-th* possible situation at moment t_r and $j = 1, 2, \ldots, J$.
- $A = \{A_{j1}^r, A_{j2}^r, \ldots, A_{jK}^r\}$: the set of generated emergency plans, where A_{jk}^r indicates the k-th generated emergency plan regarding the j-th possible situation at moment t_r, $j = 1, 2, \ldots, J$, and $k = 1, 2, \ldots, K$.
- $R = \{R_1^r, R_2^r, \ldots, R_I^r\}$: the set of available resources at moment t_r, where R_i^r indicates the i-th available amount of resources and $i = 1, 2, \ldots, I$.
- $d = \{d_{k1}^r, d_{k2}^r, \ldots, d_{kI}^r\}$: the set of estimated resources required, where d_{ki}^r indicates the estimated minimum amount of the i-th resource required by emergency plan A_{jk}^r regarding the j-th possible situation at moment t_r; here, $d \in R$ and $i = 1, 2, \ldots, I$.
- $x = \{x_{k1}^r, x_{k2}^r, \ldots, x_{kI}^r\}$: the set of resources allocated to emergency plan A_{jk}^r, where x_{ki}^r indicates the amount of the i-th resource allocated to emergency plan A_{jk}^r, $x \in R$, $i = 1, 2, \ldots, I$, and $k = 1, 2, \ldots, K$.

3.2. Emergency Plan Generation Method

The proposed method conducts emergency plan generation from multiple novel perspectives, considering a real-world situation in which the available emergency resources are limited and the relevant information regarding the emergency situation changes over time. The principle of the proposed emergency plan generation method is illustrated in Figure 2.

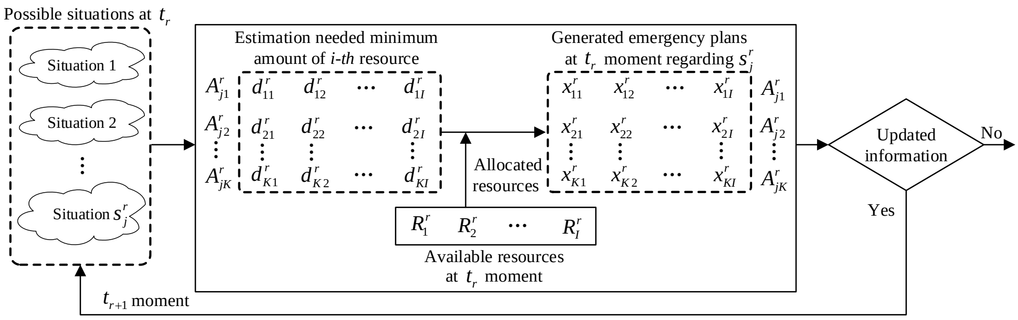

Figure 2. Principle of the proposed emergency plan generation method.

According to Figure 2, suppose that an emergency event breaks out at moment t_r, there are J possible emergency situations, and there are I kinds of available emergency resources R_I^r at moment t_r. Regarding the j-th possible emergency situation s_j^r at moment t_r, corresponding emergency plans A_{jk}^r are generated based on the integer linear programming method.

In a real-world situation, the generated emergency plans A_{jk}^r regarding emergency situation s_j^r at moment t_r is composed of several kinds of emergency resources, as shown in Table 1.

Table 1 provides several explanations: s_j^r denotes the j-th possible situation at moment t_r, A_{jk}^r indicates the k-th generated emergency plan regarding the j-th possible situation at moment t_r, R_i^r indicates the amount of the i-th available resource at moment t_r, and x_{ki}^r indicates the amount of the i-th resource allocated to emergency plan A_{jk}^r that can be obtained based on Equation (1):

$$Min \ \sum(d_{ki}^r - x_{ki}^r)$$
$$s.t.\begin{cases}\sum_{k=1}^{K} x_{ki}^r \le R_i^r, i = 1,2,\ldots,I \\ x_{ki}^r \le d_{ki}^r,\ k = 1,2,\ldots,K \\ x_{ki}^r \ge 0, x_{ki}^r \in \mathbb{Z}^+\end{cases} \quad (1)$$

where $\mathbb{Z}^+$ is the set of positive integers and x_{ki}^r are the variables that indicate the number of emergency resources allocated to the generated emergency plan A_{jk}^r. On this basis, emergency plans are generated to handle to the emergency situation at moment t_r.

Table 1. Possible emergency situations, available resources, and related generated emergency plans at t_r moment.

Situations	Plans	Resources			
		R_1^r	R_2^r	$\cdots$	R_I^r
s_j^r	A_{j1}^r	x_{11}^r	x_{12}^r	$\cdots$	x_{1I}^r
	A_{j2}^r	x_{21}^r	x_{22}^r	$\cdots$	x_{2I}^r
	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
	A_{jK}^r	x_{K1}^r	x_{K2}^r	$\cdots$	x_{KI}^r

The principle of the emergency plan generation method is as follows:

Step 1: Possible emergency situations s_j^r at moment t_r are predicted based on the breakout of an emergency event at moment t_r.

Step 2: Based on the potential possible emergency situation s_j^r, the required minimum amounts of different resources d_{ki}^r for the corresponding emergency plans A_{jk}^r are estimated.

Step 3: The different available resources R_i^r are collected at moment t_r, and are updating according to the dynamic evolution of the EE. For greater simplicity, the proposed method does not consider the process of collecting the available resources or the proximity of each rescue point.

Step 4: According to the required minimum amount of different resources d_{ki}^r for each emergency plan and the available resources, R_i^r at moment t_r, the amounts of different resources allocated to each emergency plan can be obtained based on Equation (1) and then the corresponding emergency plans at moment t_r can be generated.

The emergency plans are generated according to the corresponding changes in the situation and updates to the available resources, ensuring that the generated emergency plans are suitable for real-world emergency situations while being reasonable and effective. If the emergency situation is undergoing dynamic evolution at moment t_r, then the related information and available emergency resources are being updated at the same time; therefore, new emergency plans need to be generated based on the updated information at moment t_{r+1}.

4. Illustrative Example and Descriptive Comparisons

In this section, an illustrative example and descriptive comparisons are presented to demonstrate the novelty, superiority, and advantages of the proposed method.

4.1. Illustrative Example

In this example, a major explosion [4] in a container storage station at the Port of Tianjin (http://www.safehoo.com/Case/Case/Blow/201602/428723.shtml (accessed on 11 February 2023)) containing hazardous and flammable chemicals, including sodium nitrate, calcium carbide, and ammonium nitrate, among others, is employed to demonstrate the feasibility and validity of the proposed method.

Chemical explosions have many remarkable features, with dynamic evolution being a typical one. During the evolution of the explosion, different situations might occur that should be handled scientifically and properly by corresponding emergency plans.

According to this background, two moments (t_1, t_2) are employed to demonstrate the application of the proposed emergency plan generation method. An example of the proposed emergency plan generation method for these two moments is shown in Figure 3 and presented below.

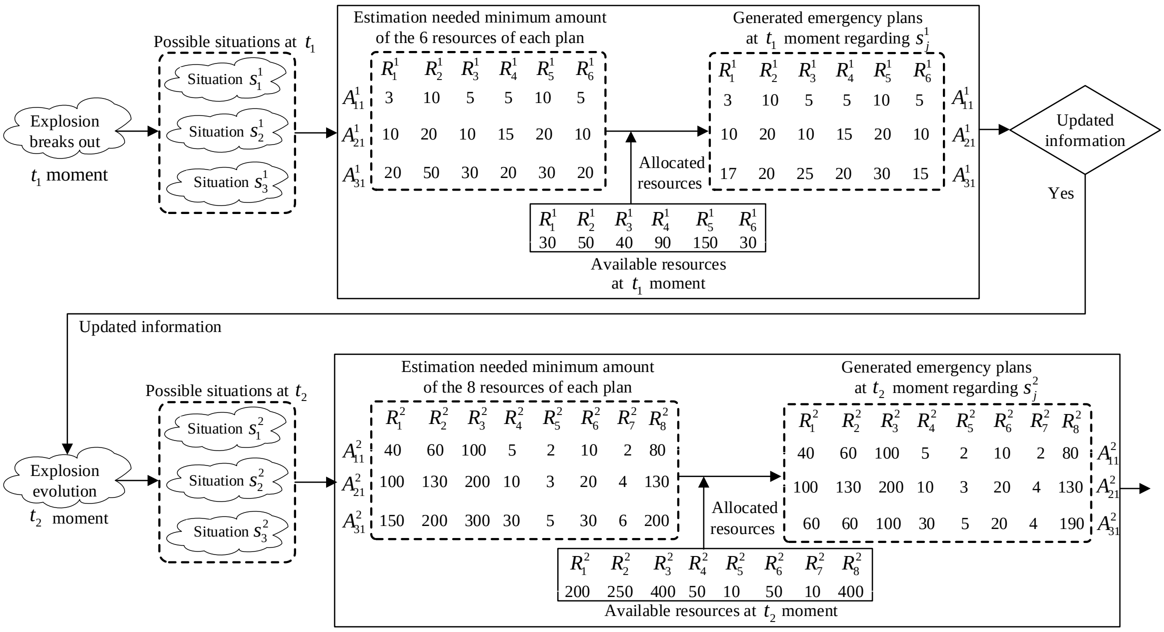

Figure 3. Example of the proposed emergency plan generation method.

4.1.1. Moment t_1

Step 1: Suppose that the explosion breaks out at moment t_1, the local government immediately receives the alarm informing it of the explosion, and the relevant government departments (i.e., fire department, traffic management department, hygiene department, etc.) organize to collaborate and handle the emergency situation.

Regarding the explosion at moment t_1, we assume that three possible emergency situations $S = \{s_1^r, s_2^r, s_3^r\}$ might occur according to experts' estimation, as shown in Table 2.

Table 2. Possible emergency situations at moment t_1.

Situations	Description
s_1^1	The local area of the independent container storage station catches fire
s_2^1	Half the area of the independent container storage station catches fire
s_3^1	The entire area of the independent container storage station catches fire

Step 2: According to the possible emergency situations presented in Table 2, the minimum amounts of needed resources regarding the different emergency plans are generated as presented in Table 3.

Table 3 shows the corresponding emergency plans (A_{11}^1, A_{21}^1, A_{31}^1) generated regarding the three possible situations (s_1^1, s_2^1, s_3^1) along with the estimated minimum amount of resources d_{ki}^1 needed for each plan.

Table 3. Estimation of needed minimum amount of resources for emergency plans at moment t_1.

Situations	Plans	Needed Minimum Amount of Resources					
		d^1_{k1}	d^1_{k2}	d^1_{k3}	d^1_{k4}	d^1_{k5}	d^1_{k6}
s^1_1	A^1_{11}	3	10	5	5	10	5
s^1_2	A^1_{21}	10	20	10	15	20	10
s^1_3	A^1_{31}	20	50	30	20	30	20

Step 3: Considering the features of chemical explosions, namely, inflammability, explosibility, diffusivity, and chain reaction, the available emergency resources at moment t_1 are: carbon dioxide fire trucks (R^1_1), foam fire trucks (R^1_2), high-expansion foam fire trucks (R^1_3), high-pressure water tank fire trucks (R^1_4), low-pressure water tank fire trucks (R^1_5), and ambulances (R^1_6). The amounts of these resources are shown in Table 4.

Table 4. Amounts of available emergency resources at moment t_1.

Moment	Amounts of Available Resources					
	R^1_1	R^1_2	R^1_3	R^1_4	R^1_5	R^1_6
t_1	30	50	40	90	150	30

Step 4: Based on Tables 3 and 4, the resources allocated to each emergency plan can be obtained based on Equation (1); the generated emergency plans with the allocated resources are presented in Table 5.

Table 5. Generated emergency plans at moment t_1.

Situations	Plans	Allocated Amounts of Resources to Each Plan					
		x^1_{k1}	x^1_{k2}	x^1_{k3}	x^1_{k4}	x^1_{k5}	x^1_{k6}
s^1_1	A^1_{11}	3	10	5	5	10	5
s^1_2	A^1_{21}	10	20	10	15	20	10
s^1_3	A^1_{31}	17	20	25	20	30	15

Based on Table 5, it can be seen that the emergency plans have been generated to handle the emergency situations at moment t_1. The decision-maker selects a specific plan in order to deal with the corresponding situation; this study does not consider how the decision-maker selects the most reasonable plan for handling a given situation.

4.1.2. Moment t_2

As the emergency situation evolves, the situation changes from that at moment t_1; at the same time, the availability of emergency resources is updated. Consequently, the generated emergency plans need to be updated according to the changes in the situation and availability of resources.

Step 1: Suppose that a possible emergency situations at moment t_2 occurs, as shown in Table 6.

Step 2: Based on Table 6, the minimum amounts of the needed resources for the different generated emergency plans are presented in Table 7.

Step 3: Based on Table 6, the available emergency resources at moment t_2 are as follows: foam fire trucks (R^2_1), high-expansion foam fire trucks (R^2_2), high-pressure water tank fire trucks (R^2_3), fire tanks (R^2_4), fire helicopters (R^2_5), professional chemical defense vehicles and equipment (R^2_6), drones (R^2_7), and ambulances (R^2_8). The required amounts of these resources are presented in Table 8.

Table 6. Possible emergency situations at t_2 moment.

Situations	Description
s_1^2	The neighboring areas of the independent container storage station catch fire
s_2^2	Half the area of the whole container storage station catches fire
s_3^2	Two-thirds of the area of the whole container storage station catches fire

Table 7. Estimated minimum resources required for emergency plans at moment t_2.

Situations	Plans	Needed Minimum Amount of Resources							
		d_{k1}^2	d_{k2}^2	d_{k3}^2	d_{k4}^2	d_{k5}^2	d_{k6}^2	d_{k7}^2	d_{k8}^2
s_1^2	A_{11}^2	40	60	100	5	2	10	2	80
s_2^2	A_{21}^2	100	130	200	10	3	20	4	130
s_3^2	A_{31}^2	150	200	300	30	5	30	6	200

Table 8. Available emergency resources at moment t_2.

Moment	Amounts of Available Resources							
	R_1^2	R_2^2	R_3^2	R_4^2	R_5^2	R_6^2	R_7^2	R_8^2
t_2	200	250	400	50	10	50	10	400

Step 4: According to Tables 7 and 8, the resources allocated to each emergency plan can be calculated based on Equation (1). The generated emergency plans with their allocated resources at moment t_2 are presented in Table 9.

Table 9. Generated emergency plans at moment t_2.

Situations	Plans	Allocated Amounts of Resources to Each Plan							
		x_{k1}^2	x_{k2}^2	x_{k3}^2	x_{k4}^2	x_{k5}^2	x_{k6}^2	x_{k7}^2	x_{k8}^2
s_1^2	A_{11}^2	40	60	100	5	2	10	2	80
s_2^2	A_{21}^2	100	130	200	10	3	20	4	130
s_3^2	A_{31}^2	60	60	100	30	5	20	4	190

Note that various resources are employed to handle emergency situations in the real world, such as manpower, sandy soil, protective suits, protective respiratory equipment, the proximity of each rescue point, and more. For greater simplicity, only two moments (t_1, t_2) and a limited number of different resources are considered in the illustrative example to demonstrate the application of the proposed method.

To simplify and illustrate the feasibility of the proposed method, this example supposes that all available resources are ready to be scheduled and allocated. In a practical scenario, the problem of emergency plan generation is complex, and many aspects need to be considered, i.e., collaboration among different government departments, the execution of resource scheduling, etc. Therefore, the application of the proposed method in real-world situations should be conducted according to the specific problems.

4.2. Descriptive Comparisons and Contributions

Motivated by the drawbacks in the extant literature, the present study proposes a novel dynamic emergency plan generation method based on integer linear programming. The proposed method simultaneously considers different situations and resources limitations during the emergency plan generation process, thereby filling a research gap and enriching the previous studies on emergency plan generation. To the best of our knowledge, the proposed method is the first to consider both different situations and limited resources; thus, it would be unfair to conduct computational comparisons with prior studies. Although a descriptive comparison cannot reflect the differences directly, as the computation process can, it can obtain results through comprehensive analysis [31]. Therefore, a descriptive comparison is provided to highlight the features of the proposed method, and is presented in Table 10.

Table 10 clearly shows the differences between the existing studies and our proposed method. Several previous studies have discussed emergency plan generation in terms of several different aspects, i.e., different situations [16,24–26] and limited resources [19], while others have considered neither [11–13]. The proposed method simultaneously considers both different situations and limited resources, highlighting the novelty, superiority, and advantages of the proposed method in emergency plan generation.

Table 10. Descriptive comparison with existing studies.

Literature	Method/Model	Different Situations Considered	Limited Resources Considered
literature [11–13]	Mathematical programming-based method	No	No
literature [16]	Case-based reasoning method	Yes	No
literature [19]	Hierarchical task network-based method	No	Yes
literature [24–26]	Scenario-based method	Yes	No
Our proposal	Integer linear programming	Yes	Yes

Based on the aforementioned analysis regarding emergency plan generation, the contributions of the proposed method can be summarized as follows:

(1) The proposed method provides a novel perspective by considering both different situations and limited emergency resources during the emergency plan generation process, thereby overcoming the limitations of existing studies and bringing the proposed method closer to real-world situations. This is the most prominent contribution of the proposed method.

(2) The proposed method uses integer linear programming to allocate resources when generating emergency plans, which is both easy to understand and simple and fast to compute. This approach allows complex practical problems to be solved easily and efficiently. The proposed method provides a reference for following related studies, and enriches the method library of emergency plan generation.

As each coin has two sides, in addition to the summarized contributions, the proposed method has limitations in its current version. For one, it does not consider responsibility and collaboration among different government departments during the emergency plan generation process. This issue is very important to the emergency plan generation process in real-world situations, particularly when resources must be drawn from different sources. Although this is a major limitation of the present study, it provides an important possible direction for future studies.

5. Conclusions and Future Works

Emergency plans play an indispensable and important role in emergency management; they are used to prevent or mitigate the losses and negative impacts caused by EEs. In light of the importance of emergency plans, this field has drawn considerable attention and become a very active research topic in recent years. Previous studies have discussed emergency plan generation from various perspectives and obtained fruitful results. However, even though the dynamic evolution of EEs and updating of relevant information are critical elements in the emergency plan generation process and should be carefully considered, the existing emergency plan generation literature has neglected them. In order to overcome this drawback, the present study proposes an emergency plan generation method that considers the dynamic evolution of EEs and related information during the emergency plan generation process, including changes in time, the emergency situation, resource limitations, and more. The proposed method is based on integer linear programming, which is easy to understand and can be computed simply and quickly. We have provided an illustrative example and related descriptive comparison to demonstrate the novelty, superiority, and advantages of the proposed method. It is hoped that the proposed emergency plan generation method will have potential applications in practical emergency management.

In future work, interesting and promising research directions include the following: (1) development of an emergency plan generation support system, in which possible emergency situations and related information, including available resources, needed available resources, etc., at different moments t_r are input into the system to allow corresponding emergency plans to be generated automatically and quickly, and (2) consideration of responsibility and collaboration among different government departments, which is an important and inevitable issue in real-world situations and yet to be fully addressed.

Author Contributions: Conceptualization, Z.Z. and L.W.; methodology, Z.Z., L.W. and J.L.; writing—original draft preparation, Z.Z. and L.W.; writing—review and editing, Z.Z., L.W. and Y.W.; information collection, J.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China (Project No. 71901071), the National Social Science Foundation of China (Project No. 21CTJ004), the Young Project of Social Science Planning of Fujian Province (Project No. FJ2020C017), the Natural Science Foundation of Fujian Province (Project No. 2021J01569), and the University Philosophy and Social Science Research Project of Fujian Province (Project No. JAS20462). The APC was funded by start-up research funding from Yango University.

Data Availability Statement: Not applicable.

Acknowledgments: The authors thank the editors and anonymous reviewers for their valued time in reviewing our work.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Wang, L.; Zhang, Z.X.; Wang, Y.M. A prospect theory-based interval dynamic reference point method for emergency decision making. *Expert Syst. Appl.* **2015**, *42*, 9379–9388. [CrossRef]
2. Wang, L.; Wang, Y.M.; Martinez, L. A group decision method based on prospect theory for emergency situations. *Inf. Sci.* **2017**, *418*, 119–135. [CrossRef]
3. Wang, L.; Labella, Á.; Rodríguez, R.M.; Wang, Y.M.; Martínez, L. Managing non-homogeneous information and experts' psychological behavior in group emergency decision making. *Symmetry* **2017**, *9*, 234. [CrossRef]
4. Wang, L.; Rodriguez, R.M.; Wang, Y.M. A dynamic multi-attribute group emergency decision making method considering experts' hesitation. *Int. J. Comput. Intell. Syst.* **2018**, *11*, 163–182. [CrossRef]
5. Zhang, Z.X.; Wang, L.; Wang, Y.M. An emergency decision making method based on prospect theory for different emergency situations. *Int. J. Disaster Risk Sci.* **2018**, *9*, 407–420. [CrossRef]
6. Zhang, Z.X.; Wang, L.; Wang, Y.M. An emergency decision making method for different situation response based on game theory and prospect theory. *Symmetry* **2018**, *10*, 476. [CrossRef]
7. Zheng, J.; Wang, Y.M.; Zhang, K.; Gao, J.Q.; Yang, L.H. A heterogeneous multi-attribute case retrieval method for emergency decision making based on bidirectional projection and TODIM. *Expert Syst. Appl.* **2022**, *203*, 117382. [CrossRef]
8. Qin, J.D.; Ma, X.Y. An IT2FS-PT3 based emergency response plan evaluation with MULTIMOORA method in group decision making. *Appl. Soft Comput.* **2022**, *122*, 108812. [CrossRef]
9. Ni, W.J.; Shen, Q.; Liu, T.; Zeng, Q.T.; Xu, L.Z. Generating textual emergency plans for unconventional emergencies—A natural language processing approach. *Saf. Sci.* **2023**, *160*, 106047. [CrossRef]
10. Zhou, J.F.; Reniers, G. Petri-net based evaluation of emergency response actions for preventing domino effects triggered by fire. *J. Loss Prev. Process. Ind.* **2018**, *51*, 94–101. [CrossRef]

11. Bish, D.R.; Sherali, H.D. Aggregate-level demand management in evacuation planning. *Eur. J. Oper. Res.* **2013**, *224*, 79–92. [CrossRef]
12. Pyakurel, U.; Dhamala, T.N. Continuous dynamic contraflow approach for evacuation planning. *Ann. Oper. Res.* **2017**, *253*, 573–598. [CrossRef]
13. Wu, D.S.; Li, J.P.; Xia, T.S.; Bao, C.B.; Zhao, Y.; Dai, Q.Z. A multiobjective optimization method considering process risk correlation for project risk response planning. *Inf. Sci.* **2018**, *467*, 282–295. [CrossRef]
14. Zheng, J.; Wang, Y.M.; Chen, S.Q. Dynamic case retrieval method with subjective preferences and objective information for emergency decision making. *IEEE/CAA J. Autom. Sin.* **2016**, *5*, 749–757. [CrossRef]
15. Zheng, J.; Wang, Y.M.; Zhang, K. A case retrieval method combined with similarity measurement and DEA model for alternative generation. *Int. J. Comput. Intell. Syst.* **2018**, *11*, 1123–1141. [CrossRef]
16. Zheng, J.; Wang, Y.M.; Zhang, K.; Liang, J. A dynamic emergency decision-making method based on group decision making with uncertainty information. *Int. J. Disaster Risk Sci.* **2020**, *11*, 667–679. [CrossRef]
17. Zhang, K.; Zheng, J.; Wang, Y.M. A heterogeneous multi-attribute case retrieval method based on neutrosophic sets and TODIM for emergency situations. *Appl. Intell.* **2022**, 52, 15177–15192. [CrossRef]
18. Liu, D.; Wang, H.W.; Qi, C.; Zhao, P.; Wang, J. Hierarchical task network-based emergency task planning with incomplete information, concurrency and uncertain duration. *Knowl.-Based Syst.* **2016**, *112*, 67–79. [CrossRef]
19. Qi, C.; Wang, D.; Munoz-Avila, H.; Zhao, P.; Wang, H.W. Hierarchical task network planning with resources and temporal constraints. *Knowl.-Based Syst.* **2017**, *133*, 17–32. [CrossRef]
20. Tang, P.; Shen, G.Q. Decision-making model to generate novel emergency response plans for improving coordination during large-scale emergencies. *Knowl.-Based Syst.* **2015**, *90*, 111–128. [CrossRef]
21. Jenkins, L. Selecting scenarios for environmental disaster planning. *Eur. J. Oper. Res.* **2000**, *121*, 275–286. [CrossRef]
22. Dynes, R.R. Problems in emergency planning. *Energy* **1983**, *8*, 653–660. [CrossRef]
23. Alexander, D.E. *Disaster and Emergency Planning for Preparedness, Response, and Recovery*; Oxford University Press: Oxford, UK, 2015.
24. Shu, Q.L. Study on scenario evolvement and alternative generation of scenario-response decision-making in unconventional emergencies. *J. Univ. Sci. Technol. China* **2012**, *42*, 936–941.
25. Qie, Z.J.; Rong, L.L. A scenario modelling method for regional cascading disaster risk to support emergency decision making. *Int. J. Disaster Risk Reduct.* **2022**, *77*, 103102. [CrossRef]
26. Jiang, Y.Z.; Zhang, R.; Wang, B.D. Scenario-based approach for emergency operational response: Implications for reservoir management decisions. *Int. J. Disaster Risk Reduct.* **2022**, *80*, 103192. [CrossRef]
27. Yu, X.B.; Li, C.L.; Zhao, W.X.; Chen, H. A novel case adaptation method based on differential evolution algorithm for disaster emergency. *Appl. Soft Comput.* **2020**, *92*, 106306. [CrossRef]
28. Le, N.; Hanachi, C.; Stinckwich, S.; Vinh, H.T. Representing, simulating and analysing Ho Chi Minh City tsunami plan by means of process models. *arXiv* **2013**. arXiv:1312.4851.
29. Zhao, J.J.; Wang, Y.; Yu, L.A. Applying process mining techniques to improve emergency response planning for chemical spills. *Int. J. Disaster Risk Reduct.* **2019**, *34*, 184–195. [CrossRef]
30. Guo, W.Y.; Zeng, Q.T.; Duan, H.; Ni, W.J.; Liu, C. Process-extraction-based text similarity measure for emergency response plans. *Expert Syst. Appl.* **2021**, *183*, 115301. [CrossRef]
31. Wang, L.; Zhang, Z.X.; Ishizaka, A.; Wang, Y.M.; Martínez, L. TODIMSort: A TODIM based method for sorting problems. *Omega* **2023**, *115*, 102771. [CrossRef]