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Global Traffic Accident Investigation Based on UAV 3D Modeling Technology

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ABSTRACT

In order to solve the problems of traditional traffic accident scene investigation, such as taking a long time, evidence easily lost and difficult to save in case of bad weather, low survey accuracy, and field measurement data, DJI Mavic 3E UAV is used to convert the collected data into digital two-dimensional ortho image and three-dimensional model by using DJI Intelligent map software, such as mid-way point flight, map construction aerial photography and oblique shooting. One-stop help traffic accident investigation comprehensively improve the efficiency of scene investigation, standard forensics, improve the accuracy of accident scene investigation, in order to quickly restore traffic order, ease the demand for police, and improve the identifiability, safety and timeliness of traffic accident scene investigation.

Keywords: UAV aerial survey, Three-dimensional modeling, Oblique photography, Traffic accident investigation

1. Introduction

With the rapid development of economy and society, the number of motorists and automobile ownership is growing rapidly. Due to the increasing mobility of people and the unqualified driving skills or relatively weak safety awareness of some drivers, the total number of road traffic accidents in China continues to rise, and the situation of road traffic safety is still serious [1-3]. After the occurrence of road traffic accidents, it is necessary to quickly dispose of the accident scene, otherwise it is easy to induce secondary accidents, which will lead to more serious economic losses and social impact [4-6]. Therefore, accurate and timely traffic accident scene investigation, fixing and extracting traces and other physical evidence at the scene, analyzing the causes of accidents, and effectively preventing traffic accidents in the future are of great significance [7-8].

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Road traffic accident scene investigation refers to the public security traffic management department in accordance with the law using scientific methods and technical means will be related to the accident time, place, road, person, vehicle, goods for the survey, inspection, as well as the parties involved and the person concerned to investigate the visit, and the results will be objectively, completely and accurately record the activities [9-12]. Among them, the road traffic accident scene diagram based on the principle of positive projection, the use of standardized graphic symbols to draw and record the accident-related traffic environment, traffic management measures, vehicles, human body, traces, physical evidence and other accident elements of the distribution of the situation and location, comprehensively reflecting the actual situation at the scene of the accident, for the analysis of the cause of the accident and the determination of accidental responsibility provides a strong scientific basis [13-16].

At this stage, most of the traffic accident scene investigation, the location of the traces of the relevant scene elements, geometric dimensions, spatial distribution relationships and other physical attributes of the test, the main use of manual survey methods (such as tape measurements, on-site mapping) [17-18]. The manual survey method is simple and fast, however, it is easy to be limited by the external environment, time-consuming, inefficient, heavy workload, and slow. Secondly, the longer the field investigator investigates at the scene of a temporarily closed road, the greater the probability of an accident [19-20]. In addition, the road traffic accident scene investigation work is generally a one-time completion, and then evacuate the scene and restore traffic, which can not be a secondary extraction of accident scene information [21]. Due to human negligence and other accidental factors, in the on-site investigation or in the drawing of the accident scene investigation map, it is easy to produce the phenomenon of omission of drawing, wrong drawing, omission of measurement, wrong measurement, etc., so that the important evidence of the traffic accident scene is lost due to improper extraction. Therefore, manual measurement methods cannot meet the realistic requirements in terms of efficiency, accuracy, and especially in avoiding indirect losses in traffic accidents [22-23].

Outay, F et al. illustrated the application of UAV technology in road transportation, traffic safety, and road infrastructure trailers, focusing on the shortcomings of UAV computer vision based traffic accident assistance investigations and giving relevant optimization suggestions [24]. Perc, M. N et al. compared the differences between UAV 3D construction and police measurement methods in traffic accidents, noting that the difference in measurement accuracy between the two was small, but that traffic accident investigations based on UAV 3D construction techniques were more efficient and easier to analyze [25]. Meng, Z et al. conceived a stochastic optimization model with data-driven core logic to assist UAVs in traffic accident investigation and analysis, and confirmed the feasibility of the proposed approach through evaluation tests on a framesize traffic accident data set [26]. Lee, J et al. corroborated that UAVs are more advantageous than manual traffic accident data information collection and are most suitable for real-time road traffic accident monitoring by conducting an empirical research methodology [27]. Serhani, M. A et al. envisioned a damage estimation method for UAV-assisted detection of accidents with deep learning algorithms as the underlying architecture, which has a good performance in practice with excellent classification accuracy and loss cost estimation accuracy [28].

2. Drone overview

2.1. Tilt photogrammetry

Unmanned Aerial Vehicle (UAV) is an unmanned aircraft with autonomous control and navigation capabilities. At present, the rapid development of UAV technology, the continuous innovation and development of various functions, has been widely used in the military field, scientific research field and civilian field, to assist in the completion of various exploration, investigation and cruise work, especially in the field of transportation, UAV can monitor traffic conditions in real time and provide some help for traffic accident handling.

Oblique photogrammetry means that by obtaining the limitation of orthophoto from a vertical Angle, the operating UAV can simultaneously obtain image data in five directions: front, back, left, right and orthophoto. Through the combination of POS system and IMU, the carrier's position, attitude, speed and other navigation information can be recorded in real time. According to the image information, the geometric position relationship and texture features of the terrain are analyzed and three-dimensional reconstruction is carried out, and finally the real scene three-dimensional model is obtained.

2.2. UAV Models

The UAV used in the experiment is DJI Mavic 3E UAV, and its parameters are shown in Table 1.

Table 1. Specific parameters of UAV

Item	Argument
Flight load	1050g
Flight speed	15 m/s
Flight altitude	6000 m (no-load flight)
Flight time	No wind: 45 minut
Hover accuracy	Vertical: ±0.1 m (when visual positioning is working normally) Level: ±0.3 m (when visual positioning is working normally)
Lens	Viewing Angle: 84°; Equivalent focal length: 24 mm; Aperture: f/2.8 to f/11; Focal point: 1 m to infinity
Photo resolution	5280×3956
Video resolution	4K: 3840×2160@30fps; FHD: 1920×1080@30fps
Sensor	4/3 CMOS with 20 million effective pixels
ISO range	100 to 6400
Shutter speed	Electronic shutter: 8 seconds to 1/8000 second; Mechanical shutter: 8 seconds to 1/2000 second

2.3. DJI Terra

Dji Zhitu can control its DJI UAV to carry out autonomous flight according to the planned route adjusted by the system, and reconstruct the 2D model and 3D model by the electronic data collected by the UAV oblique photography, which can be applied to various fields such as urban reconstruction and site reconstruction. The 3D reconstruction generated by DJI Zhitu and the parameters of the 2D reconstruction project are shown in Table 2 and Table 3.

Table 2. 3D reconstruction parameters

Item	Argument
Scale	400 PCS /1GB Free memory (single machine)6000 pieces /1GB Free memory (Cluster)
Efficiency	5000 sheets /2 hours (single) 5000 sheets /80 minutes (cluster)
Precision	centimeter-level

Table 3. Two-dimensional reconstruction parameters

Item	Argument
Scale	400 PCS /1GB Free memory (single machine) 6000 pieces /1GB Free memory (Cluster)
Efficiency	30,000 sheets /3 days (single) 30,000 sheets /21 hours (cluster)
Precision	centimeter-level

3. Experimental design

3.1. General Idea

The steps and parameter Settings of sample generation will be shown, and two 3D models will be generated, which are daytime accident model and night accident model, respectively. By using DJI Mavic 3E UAV and DJI Terra, navigation tasks such as navigation point flight, mapping aerial photography and tilt photography will be performed. Adjust side overlap rate and course overlap rate, flight altitude, flight time, number of photos. According to the above parameters, the optimal flight parameters for spot exploration are obtained.

Through DJI Terra, the data collected by the UAV can be converted into orthographic images and three-dimensional models, the traces of the accident site can be observed through the three-dimensional model, and the coordinate points (that is, the three-dimensional spatial coordinates of the added coordinate points, including latitude /XE, longitude /N, and height Z/U) can be added to the two-dimensional reconstruction plan. The height corresponds to the elevation in the coordinate system where the photo data source is located. The experimental information of the new technology is compared with each standard according to China's road traffic accident scene survey photography and scene map rendering standards, and the accuracy of the experimental information of the new technology equipment is checked.

3.2. Flight parameter debugging and 3D modeling

3.2.1. Determine the course task and flight altitude. Select the navigation route setting task option on the DJI Mavic 3E UAV interface, select the aerial survey area on the satellite map according to the control area of the accident site, and the area of the survey area will be displayed in the upper left corner of the page. The preliminary selection of the general location of the image control point will be completed according to the existing topographic map of the collected mapping area.

Click the tilt capture option in the control panel, the default GSD is 5cm/pixel (pixel), the default GSD is 7.075cm/pixel, and the default PTZ Angle is 45°. Carry out relative takeoff height adjustment, the default safe takeoff height is the best 20m, change the estimated flight time and estimated storage variables, the time of ordinary accident scene investigation and collection of evidence ranges from 15min to 30min (depending on the specific situation). When the minimum number of photos collected by tilt photography is 500 and the best storage is within the range of 800 to 1500 photos, the optimal flight altitude can be adjusted by this method, and the specific parameters are shown in Table 4.

Table 4. Flight altitude parameters

Flight altitude /m	Estimated time	Estimated storage (number of photos)/ photos
22	1h55m13s	8516
32	1h3m20s	4079
42	48m32s	2381
56.1	18m19s	1347
62	33m13s	1075
72	30m50s	809
82	28m15s	615
92	26m25s	525
102	24m28s	406

Flight height analysis: when the flight altitude is less than 50m, the expected time is more than 30min. The flight time is too long, and it is not suitable for on-site quick survey and evidence collection. When the flight altitude is >60m and <100m, the expected time is 25min to 30min, and the expected storage is 500 to 1000 pieces, which is not applicable because the expected time is too long; When the flight altitude reaches 100m, the expected time is 24min, but the expected storage does not meet the requirements. In conclusion, when the flight altitude is between 50m and 60m, the flight time and expected storage reach the best, so the flight altitude between 50m and 60m is the best flight altitude for accident investigation.

3.2.2. Determine the overlap degree of the image. The higher overlap rate can increase the number of connection points of the photo and avoid the defects of rough connection and weak adjustment structure of the connection points. By setting the side overlap degree and the course overlap degree, the appropriate estimated time and estimated storage variables are adjusted. By using the drone remote control for debugging, the estimated time and estimated storage limit standards are the same as above. The default course overlap rate is 80%, and the course overlap rate is determined according to the interval of the nearest side overlap rate. The flight altitude of 55m is taken as the reference frame for both groups, so as to debug the best combination of side overlap rate and course overlap rate. The data are shown in Table 5 and Table 6.

Table 5. Side overlap rate parameters (course overlap rate default 80%)

Side overlap rate /%	Estimated time /s	Estimated storage (number of photos)/ photos
20	559s	759
30	614s	753
40	815s	788
50	968s	864
60	1144s	917
70	1467s	1006
80	2202s	1215
90	4345s	1125

Table 6. Course overlap rate parameters (default side overlap rate 60%)

Course overlap ratio /%	Estimated time /s	Estimated storage (number of photos)/ photos

20	1144s	339
30	1144s	419
40	1144s	532
50	1144s	657
60	1144s	786
70	1144s	887
80	1144s	1317
90	1144s	1633

Side-overlap rate analysis: the overlap rate increases in direct proportion to the expected time. When the side-overlap rate is less than 50%, the expected time meets the requirements, and the expected storage cannot reach the best range (800 ~1500 pieces); When the side overlap rate is greater than 70%, the estimated time limit is greater than 30 minutes. To sum up, the best side overlap rate range of accident scene investigation is 50%~70%.

Course overlap rate analysis: the overlap rate increases in direct proportion to the expected storage, and the expected time does not change with the course overlap rate. When the course overlap rate is less than 60%, the expected storage cannot reach the best interval (800 ~1500 pieces); When the course overlap rate is >90, the storage is expected to exceed the optimal range (800 to 1500 pieces). It is concluded that the optimal course overlap rate range of accident scene investigation is 60%~80%.

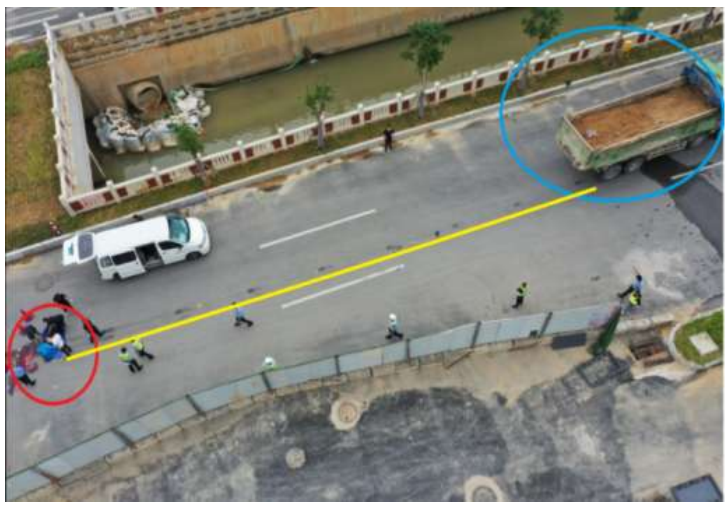
3.2.3. Implementation of pre-flight inspection and aerial photography. According to the above flight altitude and overlap rate planning and debugging, the optimal flight altitude of 55m is selected; Side overlap rate 60%, course overlap rate 80%; Return height set 30m (20-1500m); Height limit set 60m (20-1500m); Joystick mode sets American hand, the rest does not affect the setting.

4. Experimental results

4.1. Comparison and analysis between 3D model and traditional spot prospecting

Comparison and analysis of general picture: In the aspect of full scene restoration, the 3D model completely reflects the full picture of road traffic accident scene, and the completion degree is consistent with the traditional spot survey; In terms of accident elements, the three-dimensional model clearly reflects the vehicle (basket circle), human (body) body (red circle) and brake marks (yellow line) related to road traffic accidents; In terms of shooting direction, the 3D model can automatically slide and debug the appropriate viewing Angle to avoid omissions. To sum up, the general picture photos extracted from the three-dimensional modeling can clearly reflect the overall picture of the accident and the macroscopic position relationship of the on-site elements, and can be adjusted and observed from multiple angles. The completeness is basically similar to the traditional survey, but the clarity is slightly lower than the traditional survey pictures. The effect diagram is shown in Figure 1.

(a) 3D modeling generates screenshot



(b) Traditional on-site photography

Fig. 1. Photo comparison of the general picture of 3D modeling

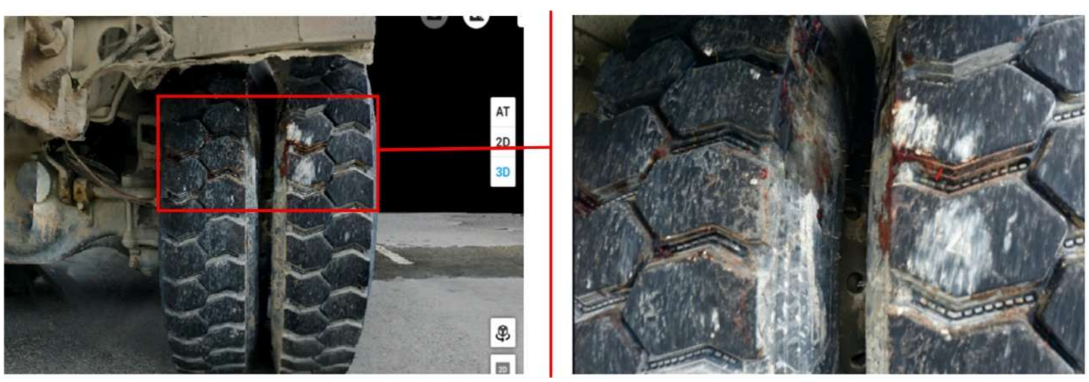
Comparison and analysis of local photos: In terms of the position relationship between the hit vehicle and the human (body) body, the three-dimensional model can clearly reflect the corresponding position relationship, and fully display the start and end point of the trace of the ground vehicle (yellow circle in the figure) and the trace direction (yellow line in the figure). To sum up, the 3D model can choose the appropriate shooting Angle to avoid the line of sight barrier between the shooting objects as much as possible, and the integrity is slightly worse than the traditional spot prospecting. The effect diagram is shown in Figure 2.

(a) 3D modeling generates screenshot

(b) Traditional on-site photography

Fig. 2. Photo comparison of the local picture of 3D modeling

Comparison and analysis of detailed photos: 3D modeling can more clearly reflect the surface characteristics of detailed photos traces and basically reflect trace details, but the specific clarity and integrity gap is obvious compared with the traditional spot survey, as shown in Figure 3.

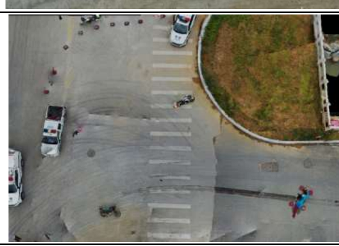
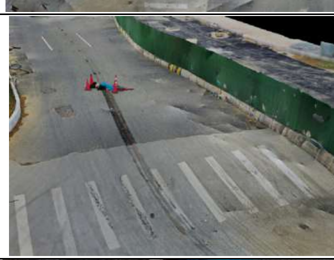
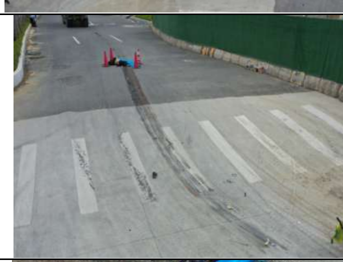


(a) 3D modeling generates screenshot (b) Traditional on-site photography

Fig. 3. Photo comparison of the detailed picture of 3D modeling

Comparison and analysis of element photos: First, the three-dimensional model can clearly reflect the orientation of the human (body) body at the scene, and reflect the damage and blood traces on the surface of the body. Second, the three-dimensional modeling clearly reflects the appearance of the vehicle, the shape of the vehicle body, and the number plate (blue circle in the picture); Clearly reflect the external collision damage of the vehicle and the situation of falling objects. Third, three-dimensional modeling clearly reflects the site traffic marking. Fourth, the three-dimensional modeling clearly reflects the trace starting point, trace ending point and trace direction of the ground trace. Fifth, the three-dimensional modeling reflects the location, shape and distribution characteristics of the scattered objects, which is basically similar to the traditional spot prospecting. The comparison results are shown in Table 7.

Table 7. Comparison of element photos with traditional spot prospecting

Element photo item	3D modeling	Traditional shooting
Vehicle involved 1		
Vehicle involved 2		
Traffic sign		
Ground mark		
Bloodstain		

4.2. Measurement comparison and analysis

Through the annotation and measurement function of DJI Terra in the reconstruction project modeling, the lane size and vehicle length and width in the three-dimensional model are completed, assisting in the completion of the road traffic accident scene diagram, greatly reducing the time and police force required for on-site measurement, and providing efficiency and accuracy guarantee for on-site certification. The comparison of 3D model auxiliary measurement accuracy is shown in Table 8.

Table 8. Comparison of auxiliary measurement accuracy of 3D model

Vehicle involved 1	3D modeling measurement /m	Manual measurement /m
Car leader	10.95	11.2
Vehicle width	2.92	3.0
Distance from the front to the fence	3.63	3.7
Distance between rear and fence	4.01	4.0
Distance from the front to the lane	0.77	0.8
Distance between rear end and roadway	1.36	1.4

4.3. Experimental summary

4.3.1. Comparison conclusion between 3D model and traditional in-situ exploration. By using drones to set the target route for autonomous and automatic oblique photography acquisition and one-stop generation of 3D models, this technology can reduce the pressure of the police investigating the scene of large-scale accidents, reduce the police force required for on-site measurement and photography, and set an estimated time to complete the aerial modeling, reducing the time required for traffic accident scene investigation. The risk of secondary accidents caused by too long survey time is avoided as much as possible in the central road section with relatively heavy traffic and in the morning and evening peak hours.

In addition, through the comparison and analysis of the 3D model and the on-site photos of the general picture, local photo and element photo of the traditional survey, as well as the auxiliary measurement and debugging of the road traffic accident scene map, the 3D modeling can basically achieve the required integrity and clarity of the on-site photos, and increase the function of perspective debugging. After the on-site accident is handled, the three-dimensional on-site reconstruction can be carried out twice, and the accuracy of the road surface data measurement has exceeded the manual measurement level.

To sum up, the use of this technology can solve problems such as lack of evidence in the early stage caused by escalation of the situation, easy loss of evidence caused by bad weather and peak traffic, difficult to save, quick arrival at the scene of special roads such as overpasses and expressways to complete the spot survey, and provide safety and efficiency guarantee for the practical operation of traffic accident spot survey in public security work.

4.3.2. Conclusion of flight parameter debugging and aerial photography modeling. By debugging the flight parameters of DJI Magic 3E, it can adapt to the scene investigation of road traffic accidents in most cases. Make good use of the efficiency and accuracy of UAV aerial photography, and provide better observation angles and exploration ideas for better field investigation.

5. Summarize

5.1. Advantages of new technology and equipment

Through a series of operations on the new technology equipment in the simulation experiment, it is found that the equipment can, on the one hand, complete the integration of oblique photography image acquisition, real-time modeling and data leak repair through the design of various route tasks, and realize efficient and rapid prospecting and forensics; on the other hand, it can fly autonomously, return by itself, and automatically complete coordinate positioning without manual operation of the aircraft in the whole process, saving a lot of police. In addition, the weight of the equipment is relatively light, and the traffic police can quickly arrive at the scene of the accident. Combined, it can significantly improve the safety and timeliness of traffic accident scene investigation.

5.2. Disadvantages of new technology equipment

Through the simulation experiment, it is found that the equipment still has some shortcomings: in terms of cost, the cost of the equipment is high, and it is necessary to purchase the privilege of DJI wisdom map; In terms of details, because UAV aerial photography has a certain flight height demand, it is difficult to achieve accurate focus when shooting trace details, and it is difficult to ensure the clarity and Angle of a single photo. In terms of unexpected factors, there are environmental requirements for controlling UAV aerial photography flight, such as being unable to set sail under the influence of outdoor typhoon and other bad weather.

5.3. Making Suggestions

Based on the analysis and focused thinking of the shortcomings found in the simulation experiment, the following suggestions and solutions are put forward: To solve the problem of capital cost, we can strengthen cooperation with technology source enterprises to co-create and reduce the use cost; To solve the problem of unclear detail shooting, the camera parameters of the aircraft can be adjusted according to the actual needs, and the second aerial shooting can be implemented. When there are special requirements for a single photo, the UAV can be used separately for shooting without flying; In response to emergencies, grasp the weather and wind direction of the day in advance to avoid the UAV falling to the ground affected by the weather.

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Reference

[1] Retallack, A. E., & Ostendorf, B. (2019). Current understanding of the effects of congestion on traffic accidents. International journal of environmental research and public health, 16(18), 3400.

[2] Casado-Sanz, N., Guirao, B., & Attard, M. (2020). Analysis of the risk factors affecting the severity of traffic accidents on Spanish crosstown roads: The driver's perspective. Sustainability, 12(6), 2237.

[3] Mohammed, A. A., Ambak, K., Mosa, A. M., & Syamsunur, D. (2019). A review of traffic accidents and related practices worldwide. The Open Transportation Journal, 13(1).

[4] Stanton, N. A., Salmon, P. M., Walker, G. H., & Stanton, M. (2019). Models and methods for collision analysis: A comparison study based on the Uber collision with a pedestrian. Safety Science, 120, 117-128.

[5] Bokaba, T., Doorsamy, W., & Paul, B. S. (2022). Comparative study of machine learning classifiers for modelling road traffic accidents. Applied Sciences, 12(2), 828.

[6] Li, L., Shrestha, S., & Hu, G. (2017, June). Analysis of road traffic fatal accidents using data mining techniques. In 2017 IEEE 15th International Conference on Software Engineering Research, Management and Applications (SERA) (pp. 363-370). IEEE.

[7] Deme, D. (2019). Review on factors causes road traffic accident in Africa. Journal of architecture and construction, 2(3), 41-49.

[8] Kitamura, Y., Hayashi, M., & Yagi, E. (2018). Traffic problems in Southeast Asia featuring the case of Cambodia's traffic accidents involving motorcycles. IATSS research, 42(4), 163-170.

[9] Theofilatos, A. (2017). Incorporating real-time traffic and weather data to explore road accident likelihood and severity in urban arterials. Journal of safety research, 61, 9-21.

[10] Conklin, T. (2019). Pre-accident investigations: An introduction to organizational safety. CRC Press.

[11] Dawson, D., Reynolds, A. C., Van Dongen, H. P., & Thomas, M. J. (2018). Determining the likelihood that fatigue was present in a road accident: a theoretical review and suggested accident taxonomy. Sleep medicine reviews, 42, 202-210.

[12] Ali, F., Ali, A., Imran, M., Naqvi, R. A., Siddiqi, M. H., & Kwak, K. S. (2021). Traffic accident detection and condition analysis based on social networking data. Accident Analysis & Prevention, 151, 105973.

[13] George, Y., Athanasios, T., & George, P. (2017). Investigation of road accident severity per vehicle type. Transportation research procedia, 25, 2076-2083.

[14] Lobanova, Y., & Evtiukov, S. (2020). Role and methods of accident ability diagnosis in ensuring traffic safety. Transportation Research Procedia, 50, 363-372.

[15] Chand, A., Jayesh, S., & Bhasi, A. B. (2021). Road traffic accidents: An overview of data sources, analysis techniques and contributing factors. Materials Today: Proceedings, 47, 5135-5141.

[16] Dong, B., Ma, X., Chen, F., & Chen, S. (2018). Investigating the Differences of Single‐Vehicle and Multivehicle Accident Probability Using Mixed Logit Model. Journal of Advanced Transportation, 2018(1), 2702360.

[17] Wang, D., Liu, Q., Ma, L., Zhang, Y., & Cong, H. (2019). Road traffic accident severity analysis: A census-based study in China. Journal of safety research, 70, 135-147.

[18] Gohari, A., Ahmad, A. B., Rahim, R. B. A., Elamin, N. I. M., Gismalla, M. S. M., Oluwatosin, O. O., ... & Lawal, A. (2023). Drones for road accident management: A systematic review. IEEE Access, 11, 109247-109256.

[19] Podoprigora, N., Dobromirov, V., Pushkarev, A., & Lozhkin, V. (2017). Methods of assessing the influence of operational factors on brake system efficiency in investigating traffic accidents. Transportation Research Procedia, 20, 516-522.

[20] Madana, A. L., & Shukla, V. K. (2020, June). Conformity of accident detection using drones and vibration sensor. In 2020 8th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions)(ICRITO) (pp. 192-197). IEEE.

[21] Zhang, L., Wang, H., Meng, Q., & Xie, H. (2019). Ship accident consequences and contributing factors analyses using ship accident investigation reports. Proceedings of the Institution of Mechanical Engineers, Part O: Journal of risk and reliability, 233(1), 35-47.

[22] Park, Y. W., Kim, Y. J., & Park, S. H. (2023). A Study on the Methodology for Analyzing the Effectiveness of Traffic Safety Facilities Using Drone Images. The Journal of The Korea Institute of Intelligent Transport Systems, 22(5), 74-91.

[23] Bucsuházy, K., Matuchová, E., Zůvala, R., Moravcová, P., Kostíková, M., & Mikulec, R. (2020). Human factors contributing to the road traffic accident occurrence. Transportation research procedia, 45, 555-561.

[24] Outay, F., Mengash, H. A., & Adnan, M. (2020). Applications of unmanned aerial vehicle (UAV) in road safety, traffic and highway infrastructure management: Recent advances and challenges. Transportation research part A: policy and practice, 141, 116-129.

[25] Perc, M. N., & Topolšek, D. (2020). Using the scanners and drone for comparison of point cloud accuracy at traffic accident analysis. Accident Analysis & Prevention, 135, 105391.

[26] Meng, Z., Zhu, N., Zhang, G., Yang, Y., Liu, Z., & Kec, G. Y. (2024). Data-driven drone pre-positioning for traffic accident rapid assessment. Transportation research part E: logistics and transportation review,

183, 103452.

[27] Lee, J., Zhong, Z., Kim, K., Dimitrijevic, B., Du, B., & Gutesa, S. (2015, January). Examining the applicability of small quadcopter drone for traffic surveillance and roadway incident monitoring. In Transportation Research Board 94th Annual Meeting (No. 15-4184, p. 15).

[28] Serhani, M. A., Ng, T. T., Al Falasi, A., Al Saedi, M., Al Nuaimi, F., & Al Shamsi, H. (2019, July). Drone-assisted inspection for automated accident damage estimation: A deep learning approach. In 2019 Eleventh International Conference on Ubiquitous and Future Networks (ICUFN) (pp. 682-687). IEEE.