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Literature Review On Crowd Analysis And Management Using Image Processing And Neural Networks

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Abstract: Crowd analysis and management research has evolved as an important subject for solving public safety issues, urban planning, and event management. In 1895, Gustave Le Bon published The Crowd: A Study of the Popular Mind, which marked the beginning of the study of crowds and their behavior [39], and since then several researches have emerged on this topic. Researching crowd behavior is still one of the most fascinating subjects available today. Overcrowding is one of the most serious issues created by a large crowd. Public area overcrowding frequently results in safety risks, ineffective logistics, and diminished personal experiences. Effective systems that are able to track, evaluate, and forecast crowd behavior in real time are required due to the growing frequency and size of gatherings. In dynamic contexts, conventional techniques like static surveillance and manual monitoring have not worked well. Therefore, utilizing developments in neural networks and image processing presents revolutionary opportunities for automated crowd analysis. The most recent approaches and systems that use deep learning and image processing methods for crowd control are examined in this literature survey.

Keywords - Crowd Analysis, Image Processing, Neural Networks, Overcrowding Detection, Crowd Management.

I. INTRODUCTION

Due to an increase in large-scale events and gatherings throughout the world in recent years, crowd safety has grown in importance. Nowadays, a lot of people from different backgrounds join together to form ever-larger crowds all around the world. Keeping big crowds safe has grown to be a difficult task with many aspects. A group of people in one place is called a crowd. However, how can we identify a crowd? When the congestion becomes an issue for safety, health, or potential effects on human decisions due to herd culture if the population size surpasses standard. Numerous elements influence the notion of congestion, crowd behavior, and concentration.[2] Crowd behavior is often thought to have collective features that may be broadly defined, despite the fact that crowds are composed of separate people, each with distinct objectives and personality traits. For instance, it is acceptable to use terms like "an angry crowd," "a peaceful crowd," etc. At least since Roman times, the usage of phrases like "mob" and "mob rule" has implied that a crowd is more than the sum of its parts and that it may exhibit behavioral patterns that deviate from those anticipated of its members individually.[13]

Given India's constantly expanding population, we need to pay close attention to crowd control and analysis to ensure everyone's safety. The greatest economic resource that may help a nation grow or develop is its people, which calls for careful planning at all starting points. [45] Overcrowding at practically all events in India, including weddings, concerts, and even public transportation, has made overpopulation an issue of the modern period. India's overpopulation has an impact on both big and minor things, including the fact that they

may put a pressure on the services and resources that are available, which might lead to shortages and economic instability. The nation's economy may stagnate if the possibilities presented by demographic shift are not seized. [44] India has a population of 1,457,142,863 as of Tuesday, December 24, 2024, according to Worldometer. India's population accounts for 17.78% of the global population. India is the nation with the largest population (including its dependents). Additionally, the population is expected to grow by around 15.26 percent, reaching 1,679,589,259 by 2050. [42] Even though India only makes up 2.4% of the planet's land area, it is home to 17.78% of the world's population, which causes congestion at practically every event. [41]

Every kind of human gathering has unique characteristics, including the behavior, location, time, and goals of the participants. [2] For instance, religious activities draw enormous crowds of people to celebrate festivals, political rallies draw large crowds to support politicians, and concerts draw large audiences. Here, we observe that even if individuals assemble for legitimate reasons, each time someone chooses to attend, the number of persons attending grows. In 2014, the Indian government's National Disaster Management Authority (NDMA) published an official document titled "Managing Crowd at Events and Venues of Mass Gathering" [46]. In this document, the government outlines a number of rules that must be adhered to in order to prevent accidents caused by large crowds of people. These rules serve as a benchmark for the organizers in addition to aiding in understanding crowd behavior. According to the document, it serves as an official guide for event organizers, administrators, and other stakeholders on how to safely handle crowds at mass gathering locations. State governments, local governments, and event organizers/administrators, as well as venues for mass gatherings, can all benefit from this guide's assistance in planning and setting up the necessary systems for crowd management.

Conventional techniques like manual surveillance and monitoring have been used to manage crowds. Accessing and analyzing a wide range of information sources, forecasting crowd behavior, and selecting from a number of potential, highly context-dependent intervention strategies are all part of crowd management practice.[4] A useful and standardized platform to support different mass events has not yet been developed, despite the fact that key components of crowd management, including measurement, simulation, crowd behavior prediction, visualization, and physical crowd control, have been developed and some of them have been implemented in practice.[2] Numerous research and projects have been conducted to integrate technologies such as deep learning, big data, and neural networks with crowd control and analysis.

This review focuses on specific research, including convolutional neural network-based feature extraction, trajectory prediction models (like Social LSTMs for crowd dynamics analysis), and object identification models (like YOLO and Faster R-CNN for real-time person recognition). Several academics use these diverse methods to incorporate the newest technologies into improved crowd control and comprehension. These studies will provide crucial information for tracking risk management as well as crowd density, proximity to one another, and crowd mobility. Numerous case studies that concentrate on the analysis and education of efficient crowd management techniques for high-density occasions, such religious gatherings like the Hajj pilgrimage or research on the Sabarimala Mandir, are observed in the review. Pedestrian behavior and public transportation, such as metro stations, are also examined in these case studies. Last but not least, it also discusses major athletic events like the Olympic Games and the study of metropolitan systems in places like Singapore and Japan, which are renowned for their methodical approach to crowd management.

The review also emphasizes the essential need of integrating both the technological advancements as well as human favored approaches, this allows a better and dynamic development. Major issues related to the crowd analysis and management are also discussed like the distortions of perspective, errors caused in dense and concentrated scenes, and scalability and reliability of the present systems. Apart from this the future trends and scope is also discussed with respect to the systems which are based on AI technologies like the generative models used for predictions and analysis. This report provides an overview of the state of crowd management and analysis today. It highlights important flaws in the current approaches and makes recommendations for further study, including the requirement for flexible, real-time solutions that can function in a variety of settings. The knowledge gathered from this review would help researchers and practitioners create solutions that, not only solve the contemporary problems but also predict a demand in crowd control within the future.

II. METHODOLOGY

Search Process and Criteria for source inclusion:

The literature evaluation described here is based on a deliberate and methodical analysis of academic publications, conference proceedings, reliable web pieces, and government-provided recommendations. We have reviewed this topic by considering several credible written works. We have used several reliable information sources about the variety of deep learning techniques and image processing. The field of crowd management and crowd analysis is broad and complex, and we have carefully considered recent research in order to examine the technical developments associated with this subject. We have used research from a range of sectors and sources to provide a far more accurate and comprehensive look at the present applications and surroundings. We have selected the advance work on the topic as suggested by several scholars in the area. Resources were selected for inclusion and deletion based on their perceived credibility and relevance to the needed topic. As this field continues to evolve, we have decided to concentrate on more relevant and optimized work. Numerous materials are accessible on the topic, and we have included a comprehensive summary of them in the references section of this review.

We have taken the following steps, which are shrewdly outlined in the formal explanation of how to write a literature review [48]. The inverted triangle in figure 1 illustrates the methodical procedures that must be followed in order to compose a literature review. first taking into account the topic's historical context. The study of crowd control and analysis spans a wide range of disciplines, including technology and psychology. We have taken into account its heterogeneous character and talked about the most beneficial studies conducted to comprehend the subject from a variety of angles. To fully understand the subject, we have taken care to consult the official documents and guidelines as well. We have considered a number of case studies as well, including the crowd management for the Hajj pilgrimage [2] and the Umrah use case [6]. In relation to Indian religious gatherings, we have considered one of the largest meetings and its crowd management study, the Sabarimala management.[7] This study also includes research that address crowd control in sports centers [8], which host varying numbers of groups every day. In addition, we have taken into consideration the study of CNNs (Convolutional Neural Networks) for crowd counting and research on metro platforms that regularly penetrate enormous crowds.[20] We have spoken about the methods and tactics used by large cities, which are renowned for their efficient administration.[34] This study has also included pedestrian crowd management experiments [29].

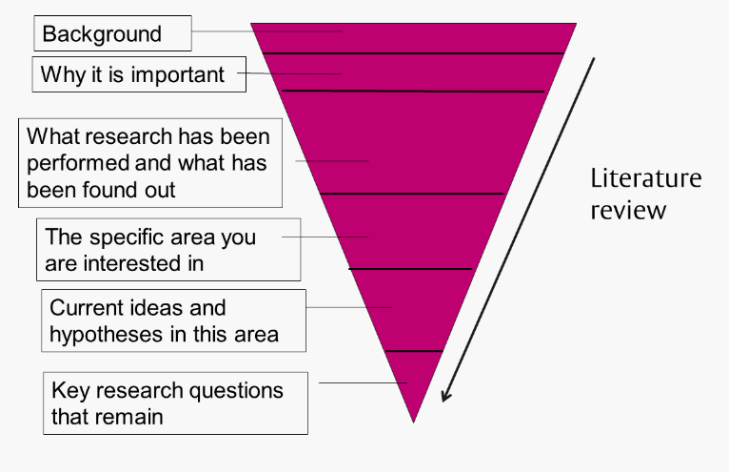


Figure 1: Systematic Steps to write a literature review [48]

Then, as previously said, we have given the reasons why this study is significant and have included a number of studies that clarify the consequences of overcrowding, both immediate and long-term. After that, we went over every relevant study and scientific contribution in this area. In this section, we have added all the works that are significant and pertinent to the research while being quite discreet. For this section in particular, we have taken into account two goals: first, what studies have been conducted on this subject, and second, what are the findings of this investigation? Next, we have provided a thorough guide for studying crowd management and analysis. In this guide, we have compiled data from several sources and presented particular conclusions and information that one should be aware of. After that, we tallied the current systems, comparing

and learning from them. Finally, we spoke about the case studies, their conclusions, and how crucial they are to giving our research a useful edge.

Research Insights:

Over 50 investigations have been conducted for this project, which includes a careful and systematic review of scholarly publications, conference proceedings, trustworthy online articles, and recommendations from the government. According to figure 2, we have mostly employed current research; the bar graphs indicate that more than 65% of our study was completed utilizing research from the last four years. Additionally, we have taken into account certain older studies that are crucial to understanding the development of crowd management technology.

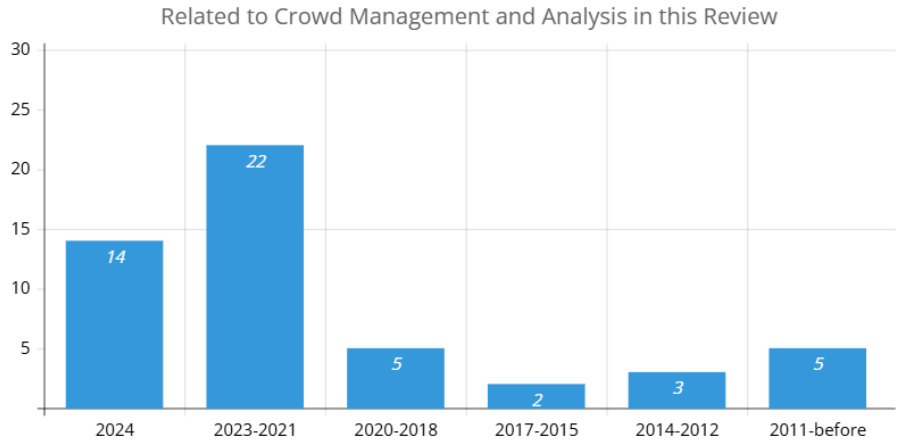


Figure 2: The year wise distribution of studies considered in this literature review.

Objective of the study:

Our goal in conducting this research is to obtain a useful analysis of deep learning models and image processing techniques used to study the crowd management and analysis. We hope to learn more about the most recent developments in this topic. We have included all the recent and major studies, articles and other published material to write this literature review. We have also included the discussions and talks that add new perspectives to the study. Ranging the studies from various fields on this topic we have merged the studies in this review to learn more about the recent findings and works related to this field.

Additionally, it investigates and learn about the upcoming future possibilities of new technologies in this field such as self-regulating surveillance and monitoring systems, generative algorithms that helps understand the nature of crowd, and predictive analytics techniques which used to predict the crowd behavior. It is a comprehensive report which includes various studies that help understand the current state of crowd management and analysis. It highlights significant shortcomings and problems in current methods and systems, and suggests areas for further investigation such as the requirement for adaptable, real-time solutions that can operate across different settings. We have tabulated a comparative study of recent findings for a comparative study. The insights gained from this review will be utilized by researchers, students and practitioners to create cutting-edge solutions as well as state of art algorithms that can address both current and future crowd control challenges.

III. SIGNIFICANCE OF THIS REVIEW

Now, let's address the significance of this literature review. As mentioned in [49], some studies conducted on animals specifically to examine their overpopulation issues reveal that a high density of any species of organisms results in a number of risk factors, the most important of which is unequal access to resources, which could include food, shelter, or even space. Some of the concern about the consequences of high density and crowding in human populations has been stoked by observations of the detrimental impacts of overpopulation in nonhuman animal species. The precise causes of the detrimental impacts of density on crowd health and behavior are difficult to determine, even in animal populations, but generally speaking, a lack of resources is cited as one of the primary causes of a number of issues. According to this study's definition [49], crowding is

a negative psychological state brought on by the perception that there are too many individuals using the available space. The relationship between density and the psychological effects of crowding often varies depending on the person and the social context. For instance, a busy city street, a small apartment, a sporting event, a concert, a supermarket, or a political protest can all expose people to high levels of density. While some of these congested settings are thrilling and welcoming, others are ominous and frightening.

Crowds are common and often don't cause major issues. Injuries and deaths are occasionally caused by inadequate venue conditions and poor crowd control. There are descriptions of significant crowd occurrences. Overcrowding causes psychological and physical issues as well as a loss of personal control. Numerous serious incidents have happened as a result of massive crowds congregating in various locations. Some significant examples [50] include disasters like as

- **Air Raid Shelter**: In 1943, during World War II, a person fell on a lower-level entry stairway in a London Underground air raid shelter, resulting in 173 deaths from compressive asphyxia and 92 injuries.

- **Funeral Procession**: Following Joseph Stalin's death in 1953, a huge procession of three million people gathered in Moscow, Russia, to visit his body, resulting in the deaths of hundreds, if not thousands.

- **Sporting Event Egress**: In 1981, a throng of 45,000 people tried to exit the Athens stadium just before the game ended, killing 24 Greek soccer supporters. The front-row fans discovered that the escape gates were shut, but the back-row fans persisted in their advance. There were reports of 340 fatalities at a game in Moscow's Lenin Stadium in 1982.

An increasing number of situations are reported [50] in which a huge number of individuals had to die simply because an unmanageable mob gathered and concentrated in one area. The causes of crowd accidents are also highlighted in this study, along with the potentially lethal force that crowds may generate when they come together. Crowd forces may become so strong that they are nearly difficult to manage or resist. Almost all crowd deaths are caused by compressed asphyxia instead of the "trampling" that the public eye has been describing. After many deadly crowd occurrences, evidence of bent steel railings indicates that pressures exceeding 4500 N (1,000 lbs.) were applied. Pushing and the cascading effect of humans leaning on one another are the causes of forces. Here, we see that these massive crowd dynamics have the potential to not only produce major calamities but also to take a person's life.

Recently, a large mass tragedy occurred in the Indian state of Uttar Pradesh at a region named Hathras. At a religious gathering, more than 300 people were hurt and more than 120 people, including children, were murdered.[51] This catastrophe is the most recent in India's long history of crowd catastrophes. India has seen several catastrophic disasters, including

- Twelve people were killed and fifteen injured in a calamity that occurred at the Mata Vaishno Devi temple in Jammu and Kashmir on January 1, 2022. An altercation between pilgrims during New Year's festivities set off the violence.

- Eight people were killed on December 28, 2022, when supporters rushed towards the platform during a stampede during a political event in the southern Indian state of Andhra Pradesh.

- A mob disturbance during a university performance in Kerala, in southern India, on November 25, 2023, resulted in four fatalities and several injuries.

- At the Prayag Kumbh Mela in northern India in 1954, millions of people came for a religious pilgrimage, which led to a mass tragedy that killed about 800 people. The worst mob tragedy in Indian history is still this one.

More than 1,477 individuals have died in more than 50 catastrophic mass gatherings in India since 2000, according to a global database of crowd disaster deaths (not including the most recent incidence). Especially in the last 20 years, India continues to rank among the world's leading hotspots for fatal crowd accidents. Other notable hotspots include portions of West Africa and Saudi Arabia, mostly because of occurrences during the yearly Hajj pilgrimage. The majority of recent incidents have happened in West Africa and India. But, with the exception of Antarctica, crowd accidents have happened on every continent. Several crowd occurrences are depicted in Figure 3, and we discover that India is one of the countries where such incidents frequently take place.

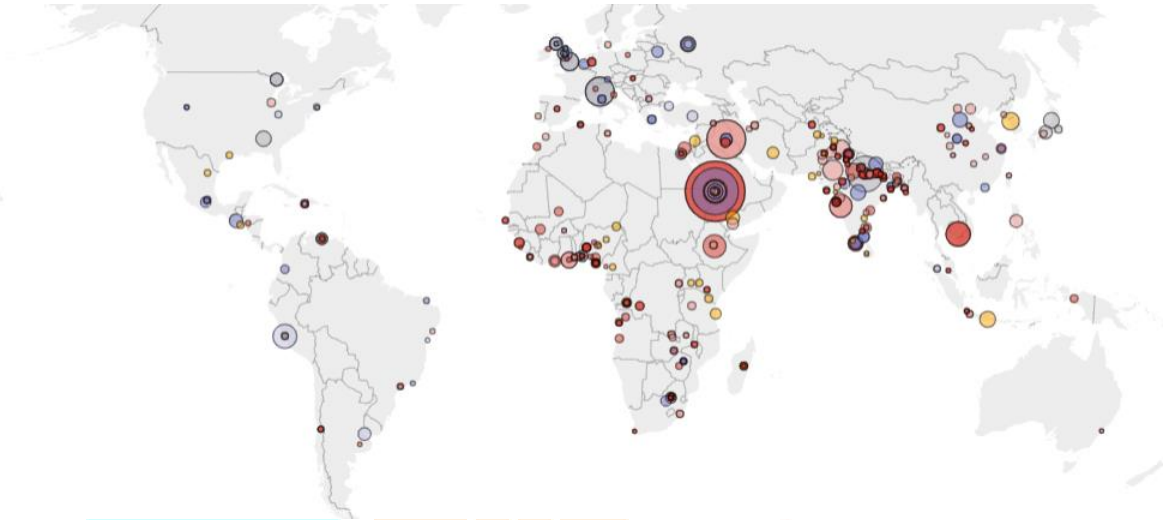


Figure 3: Disasters caused due to crowd accidents [51]

Just to illustrate why learning about crowd control and analysis is so important, the ten worst crowd crushes in history must be covered. [52] Several of the 193 deadly crowd crushes depicted on the map had mortality tolls that are significantly higher than the others. Over 340 persons were killed as a consequence of crowd crushes in each of the blocks in Table 1. Additionally, the article explains the origins of these deadly crowd episodes. Figure 4 presents this data, and it is clear that religious gatherings, sporting events, and festivals or concerts rank as the top three causes.

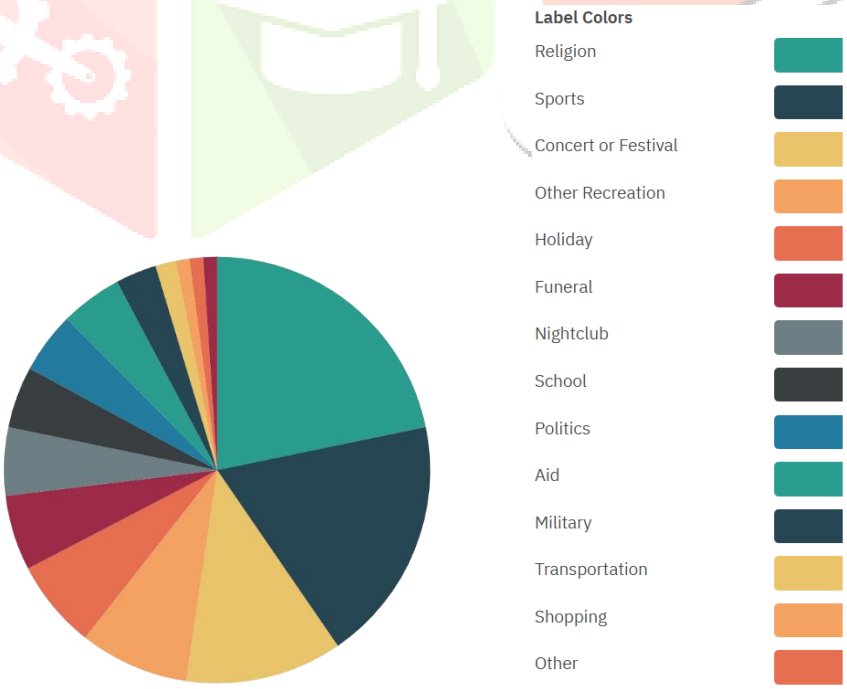


Figure 4: Distribution of origins and causes of crowd disasters [52]

SNo.	Event	Estimated Deaths
1)	2015 Mina stampede	2,400+
2)	1990 Mecca tunnel tragedy	1426
3)	Khodynka Tragedy	1,389
4)	2005 Al-Aimmah Bridge disaster	953
5)	1954 Prayag Kumbh Mela stampede	500-800
6)	Iroquois Theatre fire	602
7)	Chongqing tunnel massacre	461
8)	Unnamed	354
9)	Phnom Penh stampede	347
10)	2006 Hajj stampede	345

Table 1 showcasing the top 10 crowd accidents [52]

IV. Related Works and Research Contributions

We must take into account the current work and research contributions because this sector has seen a number of studies, many of which are too recent. "ML powered crowd management, crime prevention and work monitoring" is a significant study that explores the idea of crowd management and analysis that has been combined with the detection of weapons and crime.[1] Additionally, by monitoring staff presence, workspace use, and non-violent events, the work monitoring module maximizes workplace safety. This study presents a system that combines cutting-edge machine learning methods with pre-existing CCTV networks. The framework uses ResNet50 for face recognition, RetinaFace for face detection, and the state-of-the-art YOLOv8 algorithm for object detection.

With an emphasis on the most often used DL strategies, we have identified 30 major publications that examine the taxonomies, methodologies, and thorough examinations of crowd control both locally and internationally. We discovered that while both supervised and unsupervised DL methods have attained great accuracy, each has unique advantages and disadvantages. Many of these studies cover components of crowd scene analysis that are recorded by cameras that are placed around the area. Numerous studies that concentrate on specific applications are likewise significant scientific contributions [2]. On a number of levels, it has highlighted the dearth of Hajj data analysis themes. Second, this study also found that the advancement of CNN models will determine the future course of data analysis and prediction. Third, research on crowd analysis places greater emphasis on the study of video surveillance than on textual data.

An integrated platform for crowd control was presented by the researchers in the article "Recent developments in crowd management: theory and applications"[3], which they anticipate will emerge as a setting for the establishment of efficient and safe services. For crowd control in the Tokyo Dome, JR station, and other locations, all the fundamental components are prepared and in use; they employ both the LOS and the congestion number, which gauges the degree of flow mixing. They anticipate that by using their platform, crowd accidents would be totally prevented and that venue pedestrians will feel more at ease and productive.

The INCROWD decision-support framework was developed by researchers in another significant paper titled "A landscape of crowd-management support: An integrative approach"[4], which aims to provide better integrated help for operational crowd management. The many components required to facilitate crowd management—crowd interaction (actuating and sensing), mining, prediction, and decision-making—are reflected in and integrated by INCROWD. Stated differently, it is crucial to have (semi-)automated assistance in decision-making during crowd events, if only for security reasons. The framework serves as an architecture to facilitate the creation of auxiliary models and decision-making in crowd management.

A methodology for crowd management is offered in this fascinating study, "Crowd Management Intelligence Framework: Umrah Use Case" [6]. Using anomaly rules, the framework is intended to forecast and identify crowd occurrences as well as gather and analyses crowd intelligence data from several sources. All four of the

main crowd management problems—crowd counting, localization, density estimate, and behavior monitoring—are covered by the framework. If the method is created in a complete system, the intelligence data collected by the framework can additionally offer sophisticated features like reports and trends.

"Carrying capacity assessment for religious crowd management - an application to Sabarimala mass gathering pilgrimage, India"[7] is another significant case study. According to the study, a crowd regulation factor occurred when a managerial or physical subsystem had an impact on how people moved around the venue. The elements that affect crowd control are distinct and change depending on the location. Instead of using a single unit technique, more specialized research is needed in religious venues where crowd movements are significant and there is a chance of crowd crush. In order to determine the acceptable pilgrim density and crowd accommodation threshold limitations, the current study examined Sabarimala's crowd movement and space use patterns. Without taking carrying capacity evaluation into account, crowd management planning will not allow administrators to make risk-informed decisions, which might result in crowd tragedies. The goal of the current study is to emphasize how crucial crowd carrying capacity is to risk-informed crowd management planning for pilgrimages. The study's methodology might be used to modelling and the creation of information systems for crowd control at religious mass events.

In this context, a framework for crowd and disaster management is provided by the study titled "A roadmap for the future of crowd safety research and practice: Introducing the Swiss Cheese Model of Crowd Safety and the imperative of a Vision Zero target"[9]. This model's visualization, shown in Figure 5, illustrates how crowd safety and security may be accomplished. The researchers claim that improved crowd management may be achieved by the creation, acceptance, and use of a comprehensive multi-layer crowd safety paradigm that includes the many parts and layers shown in the image. They also discovered that the approach facilitates better engagement and communication across the many crowd safety stakeholders. They also came to the conclusion that crowd safety is a science that is still developing and growing, and that its application has been becoming better over time, especially by embracing the role that technology plays in crowd safety. However, the suggested conceptual paradigm also implies that there is no magic bullet for the crowd safety issue. They contend that only by implementing several levels of safety assurance can safety goals be met. They advise that this multi-layer safety protection paradigm be adopted as standard procedure and that practitioners, researchers, government organizations, and other interested parties collaborate closely to improve the efficacy and error-resilience of each layer.

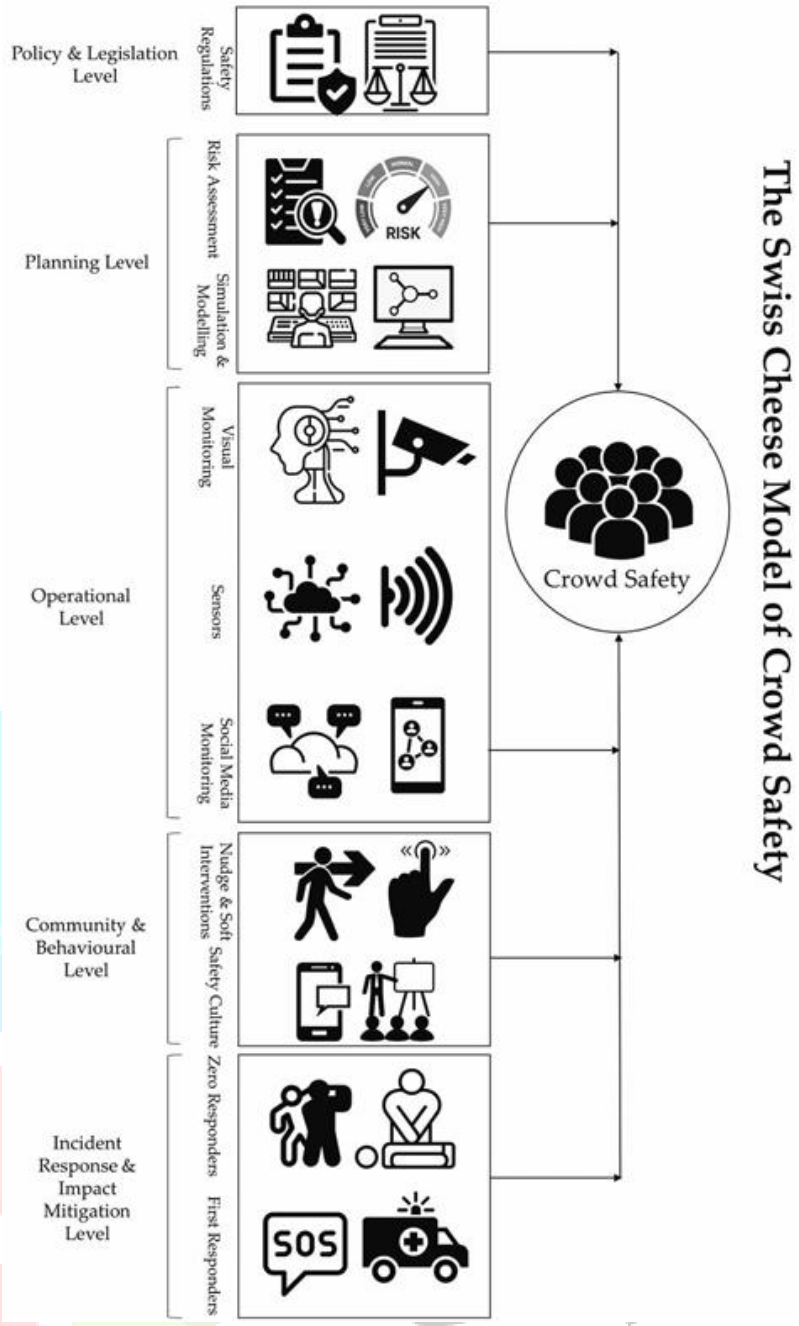


Figure 5: Swiss Cheese Model of Crowd Safety

The "Intelligent Surveillance Framework for Crowd Detection and Alerting"[15], which describes the deployment and testing of a novel AI & ML-based self-alerting system intended for secure, red alert, or sensitive zones, is another significant addition. Using state-of-the-art artificial intelligence and machine learning techniques, the platform provides a dependable way to spot anomalies in crowds and quickly provide notifications. In addition, the deployment is a component of a broader research and development initiative that aims to enhance alerting and anomaly detection capabilities. We acknowledge that additional work has to be done, particularly to strengthen the system's analytical and logical reasoning abilities, even though the current implementation's logical results are promising. Additionally, various earlier studies that are pertinent to crowd management and analysis were covered in this study, including A clever AI-based crowd-controlling system was created by Rajendran et al. in 2021 [53] and is essential for a number of religious festivals, such as Prayagraj's Kumbh-Mela. An automated system is constructed to guarantee that a restricted number of individuals congregate in a restricted location in order to reduce the hazardous effects of uncontrolled gathering. As the baseline models, they have employed deep learning techniques. People's safety can be maintained by their suggested system.

"Deep Learning based Real-time Crowd Monitoring and Management," another ambitious study, discusses the crowd monitoring and management system and shows that it can deliver precise, real-time crowd identification and visualization in a variety of real-world settings. The system effectively strikes a compromise between performance and resource efficiency by utilizing effective machine learning models such as MobileNet SSD,

which enables it to be deployed on a range of hardware configurations. Better crowd control in cities, event locations, and other crucial places is ensured by the combination of interactive visualization and real-time data transfer, which enables efficient monitoring and decision-making. Even while the system has worked well, it may still be improved, especially in terms of maximizing performance in difficult situations like dim illumination or crowded areas. To provide a more complete and reliable solution, future work will concentrate on improving scalability, integrating more sensors, and honing the detection models. All things considered, this technology has a lot of potential to help control crowds in a safer and more effective manner and provides a strong basis for future advancements in real-time crowd monitoring.

The usefulness of technology for crowd control and analysis is covered in another study titled "Development of a real-time crowd flow prediction and visualization platform for crowd management." In this work, the researchers created a real-time crowd flow prediction system that uses agent-based crowd simulation to forecast impending congestion scenarios based on current pedestrian flow data. A scenario that followed a major event near the Tokyo Dome was used to evaluate the system's effectiveness. The main conclusions are succinctly summed up. The number of pedestrians on a pedestrian bridge may be successfully anticipated up to 10 minutes in advance, according to a case study on real-time congestion prediction near the Tokyo Dome that compared simulation projections with observed data.

V. COMPREHENSIVE EVALUATION OF THE CROWD

Let's start by answering the fundamental query: What is crowd management? The methodical organization and oversight of sizable crowds in enclosed or open areas is known as crowd management. To maintain efficiency and safety, crowds must be planned, led, and managed. This idea is useful in a variety of locations, such as retail centers, airports, transit hubs, and emergency evacuations; it is not just for big events. Every component is intended to preserve people's safety and wellbeing, even though certain crowd control techniques could not be apparent to the typical participant.[32]

An integrated approach to crowd management and analysis is provided by the managing crowd guidelines [46]. Figure 6 shows a number of parts pertaining to crowd analysis and management. In contrast, the stakeholders and the course of events in crowd safety are described in Figure 7 [9]. Although this model is mostly based on the Swiss Cheese Model of Crowd Safety, it is crucial to comprehend the stakeholders in charge of the crowd safety events' progression.

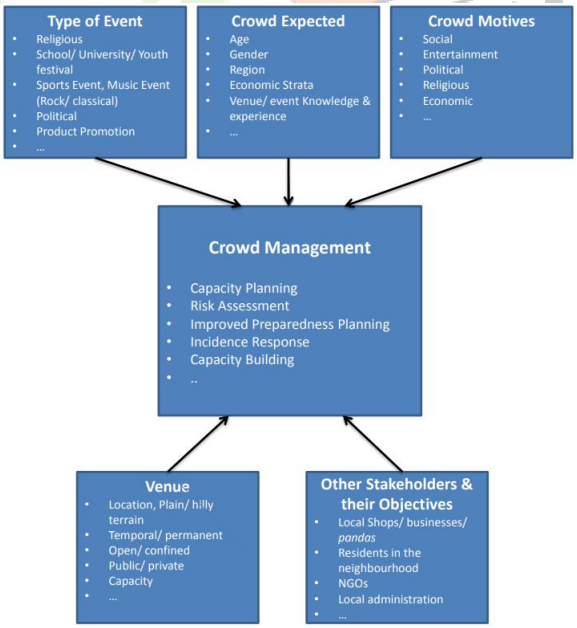


Figure 6: Different aspects of crowd control [46]

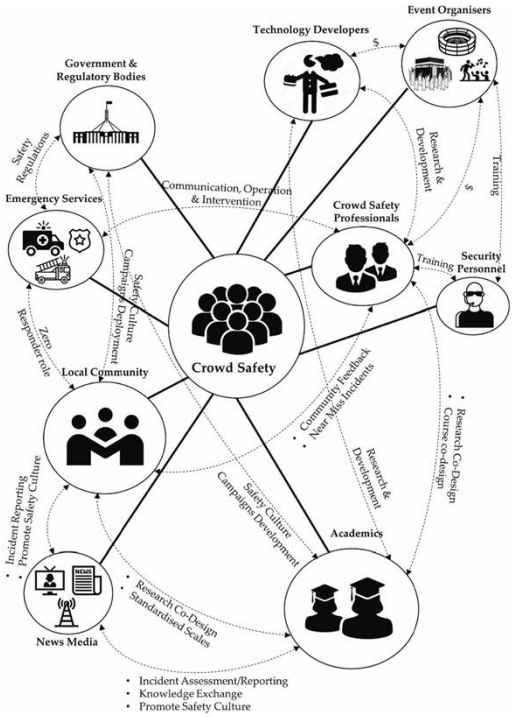
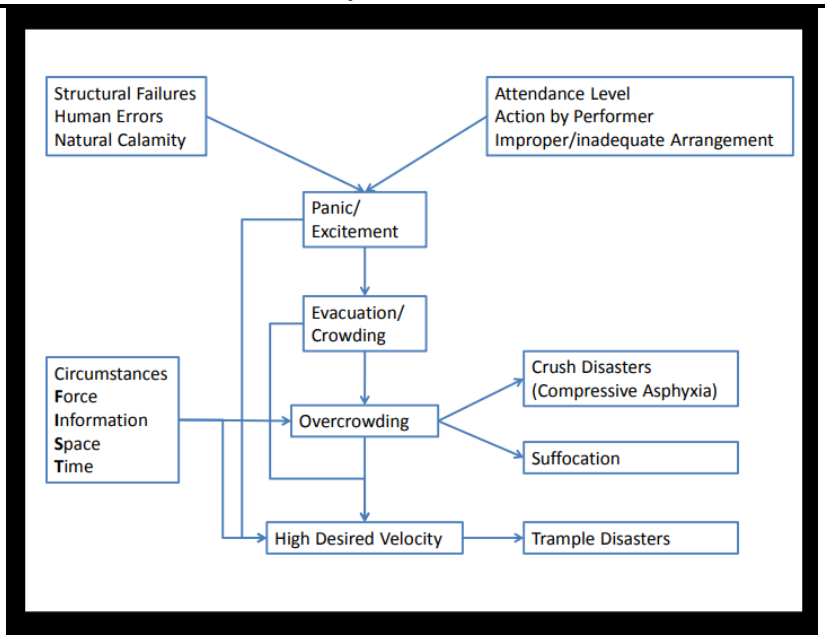


Figure 7: The sequence of activities involving crowd safety stakeholders [9]

With the use of strong crowd management technologies made possible by modern technology, event planners can keep an eye on crowd density and flow in real time. This makes it possible to respond to possible issues more quickly before they become more serious. Among the technological remedies are: Drones and surveillance cameras: Set up cameras to keep an eye on the entire space and provide security personnel a panoramic perspective of the attendees. This makes it possible to quickly identify regions where crowding is starting to cause issues. Software for crowd management: Some events make use of software that monitors the movement of the crowd and notifies organizers of possible congestion. This aids in the immediate prevention of problems like congestion or bottlenecks. Digital check-in systems: RFID wristbands or electronic ticket scanning can be used to track the number of persons in various venue zones and manage the flow of guests.[32]

Figure 8 illustrates how a series of interconnected events can result in crowd tragedies.[46] The Indian government also distributes local population data to determine whether places are strongly inhabited in order to comprehend local areas by persons.[43] Medical research revealed that expert opinion-based medical advice was less accurate than guidance based on the accumulation of data from scientific studies, which led to the development of evidence-based research and practice. Numerous fields, including criminology, social policy, economics, nursing, and others, have since embraced this methodology. [47] For this reason, it is crucial that we talk about this thorough investigation of crowd management in order to gather data that demonstrates the significance of crowd research.



The crowd catastrophe process is explained in Figure 8. [46]

Numerous studies also draw attention to the issue with traditional approaches.[33] According to the conventional method, crowd management has always been mostly a reactive field. In order to measure crowd densities and movements, organizers would erect physical boundaries, send out security guards, and use manual observations. This strategy has a number of drawbacks:

- **Restricted Visibility**: It was difficult to have a thorough overview of the whole event space without the use of technology, which might have resulted in blind spots.
- **Prolonged reply**: Because manual observations were used, there may be a considerable lag in recognizing and addressing new problems.
- **Highly resource-intensive**: The old-fashioned method frequently needed a lot of staff to keep an eye on and control crowds, which raised expenses.

Technology-assisted crowd control and analysis, according to some scholars, also holds promise for the future.[31] Market segmentation for crowd management systems takes into account a number of factors, such as competitors, type, application, and geography. The market is separated into a number of types, each of which caters to certain requirements and features. Applications for Crowd Management System goods are found in a variety of sectors, indicating their adaptability and broad range of use. With distinct market dynamics and growth prospects, the market is geographically divided into important regions including North America, Europe, Asia Pacific, the Middle East & Africa, and Latin America. [40] Data scientists with experience in crowd counting techniques will be sought after by a number of sectors. Finally, given the global environment in which we live, it is crucial. For law enforcement organizations across the world, managing crowds to maintain public safety in the modern period has proven difficult.[35]

By swiftly analyzing vast volumes of data and providing real-time insights that aid in averting possible hazards, artificial intelligence (AI) and machine learning are revolutionizing crowd surveillance. For instance, Createc's AI-powered crowd monitoring system uses LiDAR sensors and AI to measure crowd density and movement patterns. It has been tested in crowded areas like Waterloo Station. Real-time notifications are provided by this technology to improve public safety and assist avoid crowds. These technologies demonstrate how artificial intelligence (AI) can analyze intricate settings and identify minute changes in crowd behavior, eventually enhancing crowd safety and management.[36] AI can help you design live events more successfully and efficiently, boost engagement, improve event safety and security, and collect guest data and feedback in previously unheard-of ways.[37] The use of artificial intelligence (AI) to crowd control and security at events is not only a fad; it is a force for change. [38]

In the Sabarimala Mandir case study [7], the researcher described the approach they took to investigate a sizable crowd and develop a management system. These segments, which constitute a crucial component of

the crowd analysis, are shown in Figure 9. As stated in the research [7], Area includes the whole study space as well as the space needed for crowd flow. The research area's physical features and infrastructure, such as building layout, pilgrim services, geography, climate, and amenities that were mapped, are referred to as zones. The standing, moving, and resting crowd densities for each zone have been computed. To determine the effective carrying capacity, the pilgrimage is viewed as a system with an input, a process, and an output.

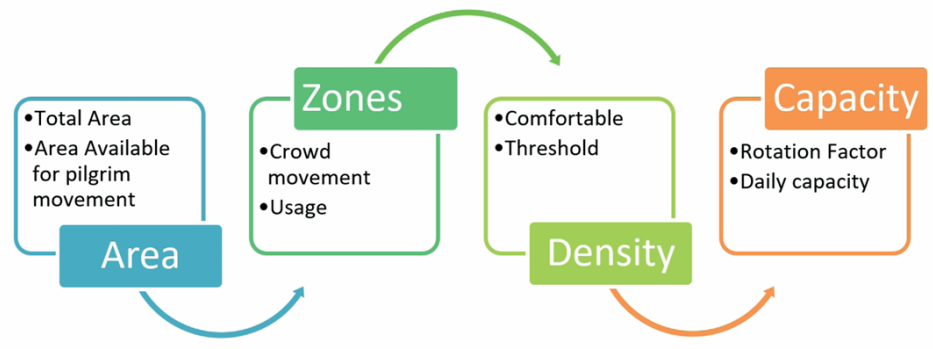


Figure 9: Elements of crowd capacity [7]

The taxonomy of crowd control was given by the researchers in the thorough assessment of crowd management [2], and figure 10 makes it evident how crucial crowd studying is. While traditional techniques cannot manage efficient solutions in a time-bounded way, new approaches must offer effective solutions for crowd video analysis in real-time. Because crowds are so large and dynamic in real-world situations, traditional methods are inadequate for crowd analysis.

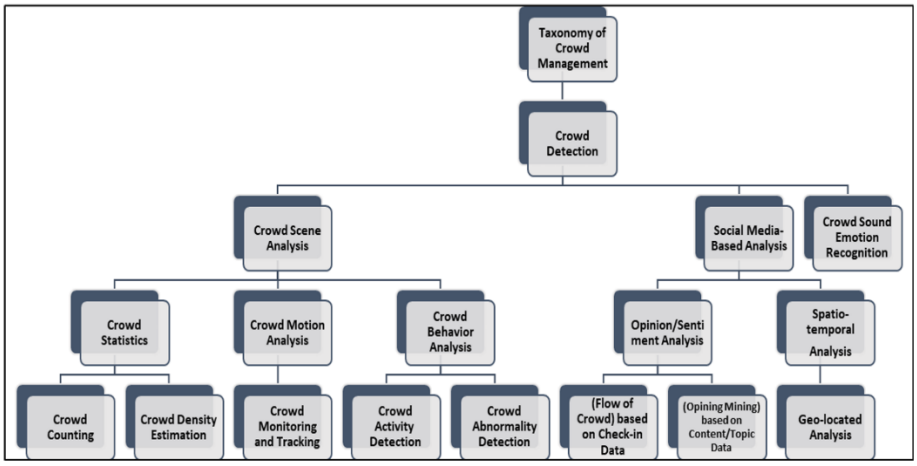


Figure 10: Crowd management research [2]

VI. COMPARATIVE STUDY OF RELATED WORKS

Table 2 presents a comparative analysis of similar works. The required references are listed in the table and may be mapped using the reference and scholar numbers. In addition, we have taken into account the research paper's name, the year it was published, the publication name, the study's objectives, a synopsis of the techniques, a description of the main conclusions, and the study's advantages and disadvantages for comparative analysis. We just analyze the work to gain a deeper grasp of the subject; we do not make fun or mock any of the work that is given.

Table 2 - Comparative Study of Related Work

S. No	Name of the Research Paper	Year	Published In	Aims of Study	Brief Summary of Methods	Summary of Key Findings	Strengths / Weaknesses
1	"ML Powered Crowd Management, Crime Prevention and Work Monitoring"	2024	IJRCT Volume 12, Issue 4	To develop AI-based crowd monitoring solutions, and focuses on crime prevention.	Utilizes machine learning algorithms to detect, predict, and manage crowd behaviours.	Demonstrated improved crowd safety through predictive models.	**Strength:** Focused on real-world implementations. **Weakness:** Limited scalability for diverse environments.
2	"Recent trends in crowd management using deep learning techniques: a systematic literature review"	2024	J. Umm Al-Qura Univ. Eng. Archit.	To review advancements in deep learning for crowd management.	Analyses recent deep learning techniques and their applications to improve crowd detection and risk management.	Identifies key trends and challenges in AI-driven crowd management systems.	**Strength:** Comprehensive review of trends. **Weakness:** Lacks practical implementation examples.
3	"Recent Developments in Crowd Management: Theory and Applications"	2024	Journal of Disaster Research Vol.19 No.2	To integrate theoretical frameworks with practical crowd management.	Discusses models like social force and game theory to simulate and manage crowd behaviours.	Highlights the importance of theory-based applications for disaster management.	**Strength:** Strong theoretical foundation. **Weakness:** Limited real-world testing.
4	"A landscape of crowd-management support: An integrative approach"	2016	Elsevier - Safety Science	To provide an integrative overview of crowd management tools and strategies.	Combines simulation models, surveillance technologies, and data analysis for a holistic approach to crowd safety.	Identifies gaps in integrative tools for modern crowd management.	**Strength:** Broad scope. **Weakness:** Outdated for recent AI advancements.
5	"Crowd Management System Using Deep Learning"	2022	International Journal of Research in Engineering and Science	To create a crowd management system based on deep learning.	Implements CNNs for detecting crowd density and predicting movements.	Demonstrates effective real-time crowd density analysis.	**Strength:** Focus on real-time performance. **Weakness:** Limited dataset diversity.
6	"Crowd management intelligence framework Umrah use case"	2024	IEEE Access	To develop an intelligent framework for Umrah crowd management.	Integrates AI tools with physical infrastructure for enhanced crowd flow management.	Successful application of AI for religious pilgrimage events.	**Strength:** Practical application. **Weakness:** Focused on a specific use case.
7	"Crowd Management - An Application to Sabarimala Mass Gathering Pilgrimage, India"	2021	Research Gate - International Journal of Religious Tourism	To evaluate crowd management in religious gatherings.	Assesses existing systems and proposes enhancements for managing mass gatherings.	Effective analysis of religious gathering management.	**Strength:** Context-specific insights. **Weakness:** Limited generalizability.
8	"Understanding Crowd Control in Sports Facilities: Through Current Design Strategies in Existing Sports Centers"	2022	Global Scientific Journals - Volume 10, Issue 5	To analyse crowd control in sports facilities.	Examines design strategies and tools for managing crowd flow in sports events.	Highlights effective architectural strategies for crowd control.	**Strength:** Practical focus on design. **Weakness:** Limited technological integration.
9	"A roadmap for the future of crowd safety research and practice: Introducing the Swiss Cheese Model of Crowd Safety"	2023	Elsevier - Safety Science	To propose a comprehensive model for crowd safety research.	Introduces the Swiss Cheese Model for addressing safety gaps in crowd systems.	Offers a roadmap for crowd safety research and its practical applications.	**Strength:** Visionary and forward-looking. **Weakness:** Lacks implementation details.

10	"Leveraging blockchain-based decentralized apps for the Tokyo Olympics amid the COVID-19 pandemic"	2020	First Monday - Peer-Reviewed Journal of Internet	To explore blockchain's role in crowd management during the pandemic.	Utilizes decentralized apps for contact tracing and crowd management in mega-events.	Demonstrates effectiveness in addressing pandemic-specific challenges.	**Strength:** Innovative use of blockchain. **Weakness:** Limited applicability beyond pandemic scenarios.
11	"Bigdata enabled real-time crowd surveillance using artificial intelligence and deep learning"	2021	IEEE BigComp Conference	To enhance real-time crowd monitoring using big data and AI.	Combines AI models and big data analytics to predict and manage crowd dynamics.	Improved real-time responsiveness and data-driven decision-making.	**Strength:** Scalable for large datasets. **Weakness:** Computationally intensive for real-time deployment.
12	"Crowd-11: A Dataset for Fine Grained Crowd Behaviour Analysis"	2021	Fluid Tracks Research Project	To create a dataset for crowd behaviour analysis.	Develops a fine-grained dataset tailored for evaluating crowd behaviours.	Introduced a unique dataset for crowd behaviour studies.	**Strength:** Provides a high-quality dataset. **Weakness:** Focused on dataset creation rather than applications.
13	"Crowd Monitoring Using Image Processing"	1995	IEE Electronic and Communications Engineering Journal	To utilize image processing for crowd monitoring.	Implements early-stage image processing techniques for crowd density estimation.	Pioneering work in crowd monitoring via image analysis.	**Strength:** Foundational study. **Weakness:** Outdated methodologies.
14	"Recent Development of Crowd Monitoring Technology Solution for Covid-19 Prevention at Airport Terminal"	2021	International Journal of Nanoelectronics and Materials	To address Covid-19 prevention through crowd monitoring solutions.	Proposes monitoring tools tailored for pandemic safety in airport terminals.	Successfully mitigates crowd risks at critical locations.	**Strength:** Pandemic-specific insights. **Weakness:** Narrow application scope.
15	"Intelligent Surveillance Framework for Crowd Detection and Alerting"	2024	SNSFAIT Symposium	To create an alerting system for high-density crowds.	Uses deep learning to analyse crowd density and generate automated alerts.	Achieved accurate alerts for high-density crowd scenarios.	**Strength:** Real-time alerting system. **Weakness:** Limited diversity in test environments.
16	"CrowdSurge: A Crowd Density Monitoring Solution Using Smart Video Surveillance"	2022	Journal of Advances in Information Technology	To monitor crowd density using video surveillance.	Combines video analytics and security assessment tools for crowd monitoring.	Improved density monitoring for security-focused applications.	**Strength:** Integration with security features. **Weakness:** High implementation cost.
17	"Deep Learning based Real-time Crowd Monitoring and Management"	2024	Research Gate	To manage crowds in real-time using deep learning techniques.	Implements CNNs to detect density and crowd movement patterns.	Real-time insights into crowd dynamics.	**Strength:** Effective real-time management. **Weakness:** Limited scalability for heterogeneous settings.
18	"Image processing techniques for crowd density estimation using a reference image."	1995	ACCV95 Conference	To estimate crowd density through image processing techniques.	Introduces reference-based density estimation methods for images.	Enhanced accuracy in density measurement for specific conditions.	**Strength:** Early image-based techniques. **Weakness:** Lacks robustness for modern scenarios.
19	"Crowd counting using end-to-end semantic image segmentation"	2021	MDPI Journal Electronics	To develop semantic segmentation techniques for crowd counting.	Employs segmentation models to count individuals in high-density scenarios.	Demonstrates high accuracy for dense crowd settings.	**Strength:** High accuracy. **Weakness:** Computationally expensive for large-scale operations.

20	"Convolutional Neural Network for Crowd Counting on Metro Platforms"	2021	MDPI Journal Electronics	To apply CNNs for crowd counting in metro platforms.	Utilizes convolutional models to analyse crowd densities in transit hubs.	Improved crowd density analysis in metro systems.	**Strength:** Effective for transit hubs. **Weakness:** Application limited to metro environments.
21	"Motion-shape-based deep learning approach for divergence behaviour detection in high-density crowd"	2021	Springer	To detect divergence behaviour in high-density crowds.	Combines motion-shape features with deep learning for analysing crowd divergence.	Accurate detection of divergence in dense scenarios.	**Strength:** Precise divergence analysis. **Weakness:** High computational cost.
22	"Deep neural network model for group activity recognition using contextual relationship"	2018	Elsevier - Engineering Science and Technology Journal	To identify group activities in crowds using DNNs.	Utilizes contextual data and neural networks to recognize group interactions.	Improved recognition accuracy for group activities.	**Strength:** High group-level accuracy. **Weakness:** Limited to specific scenarios.
23	"Counting people in the crowd using social media images for crowd management in city events"	2021	Springer - Transportation	To estimate crowd sizes using social media images.	Employs image analysis from social media for crowd counting and density estimation.	Effective use of social media data for urban crowd management.	**Strength:** Innovative data source. **Weakness:** Reliant on image quality and metadata.
24	"Crowd Detection in Mass Gatherings Based on Social Media Data"	2020	International Journal of Environmental Research and Public Health	To detect crowds in mass gatherings using social media data.	Utilizes social media analytics and geotagged images for real-time crowd monitoring.	Improved response time for detecting and managing crowds at large events.	**Strength:** Real-time monitoring. **Weakness:** Dependence on user-generated content.
25	"Redesigning Multi-Scale Neural Network for Crowd Counting"	2023	arXiv:2208.02894v2	To improve crowd counting accuracy using multi-scale neural networks.	Enhances existing neural network architecture for better handling of diverse crowd densities.	Achieved state-of-the-art accuracy in crowd counting benchmarks.	**Strength:** High accuracy. **Weakness:** Computationally intensive for large-scale deployments.
26	"Stampede Events and Strategies for Crowd Management"	2019	Journal of Disaster Research Vol. 14 No.7	To explore causes of stampedes and propose management strategies.	Analyses past stampede events and proposes strategic frameworks for prevention and management.	Identified key factors contributing to stampedes and effective countermeasures.	**Strength:** Practical insights into stampede prevention. **Weakness:** Limited to case study analysis.
27	"Development of a Real-Time Crowd Flow Prediction and Visualization Platform for Crowd Management"	2023	Journal of Disaster Research Vol.19 No.2	To develop a real-time platform for predicting and visualizing crowd flow.	Combines real-time data acquisition with predictive algorithms for crowd flow visualization.	Improved decision-making for managing real-time crowd dynamics.	**Strength:** Real-time predictive capabilities. **Weakness**: High resource dependency.
28	"Measurement of congestion and intrinsic risk in pedestrian crowds"	2018	Elsevier - Transportation Research Part C	To measure congestion and risks in pedestrian crowds.	Develops risk assessment models to quantify congestion levels and potential hazards in crowds.	Enhanced understanding of pedestrian dynamics and congestion risk factors.	**Strength:** Quantitative insights. **Weakness:** Limited scalability for large-scale crowds.
29	"Pedestrian Crowd Management Experiments: A Data Guidance Paper"	2023	Collective Dynamics	To provide data guidelines for pedestrian crowd management experiments.	Outlines methodologies for conducting and analysing crowd experiments, focusing on pedestrian behaviours.	Offers a comprehensive framework for crowd behaviour research.	**Strength:** Detailed data guidelines. **Weakness:** Focused on pedestrian-specific scenarios.
30	"Crowd Management – Navigating Challenges and Implementing Best Practices in Crowd Management"	2023	8th International Conference on Economic Growth and Sustainable Development: Emerging Trends	To address challenges and best practices in crowd management.	Proposes practical strategies and policy recommendations for effective crowd management.	Identified key practices for improving crowd safety and efficiency.	**Strength:** Actionable recommendations. **Weakness:** Limited focus on technological solutions.

VII. CASE STUDIES

Crowd Control and Management at the Sabarimala Mandir:

On January 14, 2011, Makara Jyothi Day, the 2011 Sabarimala crowd crush—often mislabeled a human stampede—took occurred in Pullumedu, close to Sabarimala, in Kerala, India. It was deemed a "National disaster" when it killed 106 pilgrims and injured over 100 more during an annual trip.[1] On the final day of an annual celebration that draws millions of followers, the pilgrims were making their way back from a Hindu shrine. It started when a Jeep flipped over. [54]

As was previously said, religious gatherings are the primary cause of crowd accidents [52], and as India is the most populous country [42], large religious gatherings frequently occur there. One of the largest temples in India, Sabarimala Mandir has been credited for having large audiences every day of the year. The high volume of pilgrims that visit the temple is seen in Figure 11[7].

This is the very reason why a thorough examination of crowd control is required in this case. In an effort to emphasize the significance of crowd carrying capacity in risk-informed crowd management planning for religious pilgrimages, the current study [7] was conducted. The study's methodology might be used to modelling and the creation of information systems for crowd control at religious mass events. The crowd carrying capacity evaluation in this study was conducted using the Physical Carrying Capacity (PCC) model. The maximum number of guests that a given space can accommodate in a given amount of time is known as PCC:

PCC = A× D× Rf
Where:
A = available area for use (m2);
D = tourist density (tourists/m2);
Rf = Rotation factor (number of the visits per day).

Certain characteristics of the place under consideration have a significant role in determining its worth. The space needed for a visitor to be able to comfortably engage in activities is known as the tourist density, or "D." The number of allowed visits over a certain period of time (often determined by daily open hours) is known as the rotation factor, and it is represented as follows:

Rf= Open period / the average time of visit

This technique can assist organizers in determining and assessing the most people that a location can handle at a given moment. There are 60 acres of land accessible for the pilgrimage in Sabarimala Sannidanam. The pilgrim has access to 19600 m2 of open space. Ten zones have been established for the active crowd movement area based on space utilization mapping. Four pilgrims per square meter is the average density seen inside the barriers at restricted queue locations. In locations with controlled queuing, the density can rise to 7 people per square meter during peak hours. Because crowd density varies within a zone, it is impossible to determine the physical carrying capacity for the entire region as a single unit.

When applied to local conditions, carrying capacity assessment can assist in determining the venue's capacity to accommodate a crowd. In order to prevent crowd tragedies, it can help venue managers and administrators plan and control the crowd's flow. By evaluating the physical carrying capacity and effective carrying capacity, the current study evaluated the pilgrimage to Sabarimala's crowd carrying capability. When applied to local conditions, carrying capacity assessment can assist in determining the venue's capacity to accommodate a crowd. By helping venue managers and administrators plan and control crowd flow, it can help prevent crowd tragedies. By evaluating the physical carrying capacity and effective carrying capacity, the current study evaluated the pilgrimage to Sabarimala's crowd carrying capability.

Figure 11: Lines of pilgrims queuing at Sabarimala Mandir. [7]

Handling Crowds During the Hajj and Umrah:

The biggest Hajj tragedy in history occurred on September 24, 2015, when a deadly crowd crush in Mina, Mecca, Saudi Arabia, killed over 2,000 people, many of them crushed or smothered, during the yearly Hajj trip. [52] The number of fatalities has been estimated to reach at least 2,431; the Associated Press reported 2,411 deaths, while Agence France-Presse reported 2,236. Two days after the incident, the Saudi authorities formally announced that 769 people had died and 934 had been wounded. Iran was the country with the greatest number of casualties, followed by Mali and Nigeria.

Hundreds of thousands of pilgrims congregate in the same building on the same day at the Al-Masjid al-Haram in Makkah, Saudi Arabia, making crowd management a significant concern. During this ceremony, known as Umrah, pilgrims walk seven circles between Safa and Marwa in Al-Ka'ba Al-Musharrafa before continuing on to another location in the same structure (Masjid al-Haram).[6]

The Saudi government is working hard and using a number of methods and strategies. CCTVs, numerous police officers and volunteers, hundreds of clinics and ambulances, several systems and smart applications, crowd schedules (Tafweej), etc. However, throughout the years, the Saudi government has been attempting to enhance crowd control by building new facilities, creating new methods, and enlisting the help of academic institutions and scientific experts to help investigate and support this event.

Up to three million pilgrims from all over the world gathered in one holy location for the Hajj. The holy places where the Hajj is performed are located within a radius of no more than 33 km^2. In order to address the congestion of the Hajj during a particular time and location, the Hajj authorities must first address the security and safety of pilgrims, which presents a significant problem. Our work's goal is to identify effective crowd control techniques for the Hajj rite, which is the most revered event in Saudi Arabia [2]. This study examines the Hajj crowd analysis in detail and provides profound insights on various crowd control techniques.

This study [2] discovered that the flow of data, whether it be audio, text, or visual, during a Hajj event is enormous in terms of crowd control. The Hajj authorities need to make the most of this digital richness in order to lessen the horrible consequences that might arise from a lack of proactive crowd management measures. Similar to earlier research, CNN with LSTM has been successfully utilized to extract visual features in order to categorize abnormal or abnormal crowd behaviour; this has shown outstanding accuracy results.

Other:

Controlling Crowds in Different Countries - The full overview of the worldwide crowd management system industry is explained in the crowd management system market research [55]. For the United States, Canada, Mexico, Germany, France, the United Kingdom, Russia, Italy, China, Japan, Korea, India, Southeast Asia, Australia, Brazil, and Saudi Arabia, among other countries, it includes Top Country data and analysis. Additionally, it provides insight on the development of important regional markets for crowd management systems, including those in North America, Europe, Asia-Pacific, South America, the Middle East, and Africa. Additionally, the market potential for Crowd Management Systems is described and analyzed by kind, Deep Dive, disruption, application capacity, and end-use industry. Among these nations, China, Singapore, and

Japan are leading the way in crowd control. Their ability to control crowds has earned them international recognition.

Metro Station Crowd Control - Due to the growing popularity of urban rail transportation, there is a tendency for the number of people using metro platforms to rise significantly during peak hours. For security-related reasons, it is crucial to keep an eye on the movement of passengers in certain regions. In this study, we present a CNN (convolutional neural network)-based network named the MP (metro platform)-CNN to reliably count people on metro platforms in order to tackle the problem of passenger flow detection. [20] The proposed method consists of three main components: a group of convolutional neural networks on the front end is used to extract image features, a multiscale feature extraction module is used to improve multiscale features, and transposed convolution is used for up-sampling to generate a high-quality density map. Currently, accessible crowd-counting datasets do not adequately cover all of the challenging circumstances considered in this investigation. Many studies have been conducted on the use of CCTV footage to analyze passenger movement at metro stations.[20]

Crowd Control in Sports Facilities - The study [8] explores the significance of user safety in athletic facilities, which calls for careful thought. Attending athletic events draws large crowds, which increases the likelihood of crowd disaster and unrest. The increase in mishaps and injuries among attendees of public events, especially athletic events, is one of the main worries of researchers and experts. Because crowded places can be harmful, masses of people who attend athletic events need to be kept safe. Therefore, this study's objective [8] is to assess the crowd control design features and strategies employed in the building of athletic complexes or facilities, particularly in Nigeria and other countries. Enhancing sports venues' architecture to better accommodate sizable crowds during intense events is intended to boost security and safety. In addition to secondary sources like websites, documents and journals, surveys, and other sources, primary sources like field investigations, case studies, and evaluations of specific current crowd management design solutions in existing sporting facilities or complexes were used to collect data. In order to enhance crowd management regulations for this kind of public facility, this research looks at various crowd control design solutions and how flexible they are in current sports complexes or facilities. In order to prevent crowding or constipation, it also recommends that careful consideration be given to the right ratio of inhabitants to a given space.

Pedestrian Crowd Control - The article "Pedestrian crowd management experiments: A data guidance paper" [29] talks about how designing pedestrian facilities that are both safe and comfortable requires a knowledge of pedestrian dynamics and how pedestrians interact with their surroundings. It is possible to investigate the impact of specific components using experiments. Experiments with over 1000 participants were carried out as part of the CroMa (Crowd Management in Transport Infrastructures) project to test a number of physical and social psychology hypotheses focused on how people behave at train stations and crowd control techniques. The document details all experiments with parameters, geometries, applicable sensor technologies, and pre- and post-processing stages, as well as the fundamental planning and execution steps.

An agent-based crowd simulation and an advanced crowd management system known as crowd management platform as a service were incorporated into a real-time crowd flow prediction and visualization platform created by another study titled "Development of a real-time crowd flow prediction and visualization platform for crowd management" [27]. We showed that recording pedestrian traffic enables precise forecasts of congestion at the closest train station up to ten minutes in advance in a case study centered on the neighborhood surrounding the Tokyo Dome. Furthermore, it took 1 minute and 35 seconds for 3,000 agents to forecast the scenario 20 minutes in advance, demonstrating the viability of real-time processing. In order to improve the precision and dependability of the simulation findings, a sensitivity analysis that took pedestrian flow measurement errors into account showed that basic linear models are insufficiently able to represent the complexity of crowd dynamics.

VIII. CONCLUSION

The rules that a systematic literature review has to adhere to in order to be an effective study have been followed in this one. We have taken into account the careful and systematic examination of scholarly works, conference proceedings, trustworthy online articles, and suggestions from the government. We have examined this subject by taking into account a number of reliable written works. Regarding the range of deep learning

methods and image processing, we have consulted a number of trustworthy information sources. We have considered the latest research.

We draw the conclusion that research on crowd analysis and management has developed into a crucial field for resolving problems related to event management, urban planning, and public safety. One of the most intriguing topics accessible today is the study of crowd behavior. One of the most dangerous problems caused by a big crowd is overcrowding. Overcrowding in public spaces typically leads to decreased personal experiences, unsafe conditions, and inefficient logistics. As gatherings become more frequent and larger, efficient systems that can monitor, assess, and predict crowd behavior in real time are needed.

Traditional methods such as manual monitoring and static surveillance have not been effective in dynamic environments. Thus, automated crowd analysis offers revolutionary prospects by leveraging advances in neural networks and image processing. This literature review looks at the latest methodologies and systems that employ deep learning and image processing techniques for crowd management. This review's strength is the variety of resources we took into consideration.

Recent studies that are very beneficial to our research have been taken into consideration. In order to properly analyze various studies and research projects, we have also conducted a comparison analysis. The review's flaw is that we were unable to compare a wider range of studies because of resource limitations. Even Nevertheless, we believe that the subject of crowd safety and security is crucial to explore, and recent studies in this field indicate that crowd management and analysis will have a promising future.

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