Usability of Mobile Control Room and CCTV Systems for Crowd Control at Large-Scale Events with the Occurrence of a Large Number of People With Focus on the Czech Republic

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Abstract **– This article deals with the issue of the use of modern instruments for crowd control, in particular the use of a mobile closed-circuit television system connected directly to the control room during large-scale events. The article has two aims: to check the usability of this type of system especially from the perspective of increasing the safety of event visitors, and to identify the optimal technical solution for crowd monitoring and management and possible obstacles for deployment in the field. The article further focuses on the practical usability of the information obtained through the mobile camera system and the control centre for increasing the safety of event visitors from the perspective of security managers. The conducted investigation identified obstacles to the deployment of a mobile camera system as well as described the optimal parameters for the use of a mobile camera system, and it collected feedback from the security team participating in the security management of the event. The results of the contribution enable easier orientation in the selection of suitable hardware and software for crowd control; Key vulnerabilities in deploying mobile CCTV systems were identified, including issues such as data transmission stability over LTE networks and the financial costs of alternative solutions like satellite connections. Based on field testing and feedback from security teams, recommendations were made to improve the system's effectiveness and adaptability, leading to more precise decision-making and proactive risk management at large-scale events.**

Keywords **– Mobile CCTV systems, crowd safety, crowd control, control room, large-scale events.**

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1. Introduction

The number of people attending large-scale events such as concerts and festivals, as well as public gatherings and demonstrations, is constantly increasing. A crowd that forms at such events is vulnerable to external threats as a potential soft target, and with the increasing density of the crowd, it also becomes dangerous to itself. Queuing, crowd movement, weather, and deployed mobile infrastructure all affect crowd safety. One of the basic tools for increasing crowd safety is crowd control. For quality crowd management, the crowd must be monitored in order to manage it properly. Crowd management is an interdisciplinary field that requires the integration of engineering and modern technical tools along with an understanding of crowd behaviour, i.e. psychological and sociological aspects. It is therefore a complex issue which needs to be grasped well in order to avoid tragic accidents.

In Central and Eastern Europe, crowd monitoring is usually not formally anchored at large-scale events with a large number of people. Most festivals and concerts do not have a security study prepared, and a quality security plan is often absent.

Security usually focuses primarily on protecting the property of the organizer and preventing visitors from entering the premises without a valid ticket, or on preventing access to the facilities. With the advancement of time, the pressure to increase the safety of visitors is growing. The direction of development can be observed in the countries to the west of the Czech Republic, where the safety standard for large-scale events is currently higher. The positive trend in the field of modernization of access to security in the Czech Republic thus contributes to both influences from the West and the pressure of large promoters and world bands that perform in the Czech Republic and demand the highest security standards. These standards also include the preparation of a security plan, which also includes working with the crowd, i.e. both the setting of its monitoring and the subsequent management structure.

Until now, security management at smaller events has typically been the responsibility of a security agency, headed by a security manager. At larger events, there is already a security director, possibly also a security/crisis management team including the promoter, the head of the security agency, a meteorologist, PR (public relations) person, medics, and possibly representatives of the emergency service units.

At such events, current information is most often transmitted via radio stations, while summarizing information for the setting of further measures through retrospective reports for the day is presented at security/crisis meetings. Up-to-date information and information from reports are both distorted by the transmission of information between individual participants in the communication chain. The transfer of information and the description of the situation may not only be inaccurate, but their transfer may be time-delayed. This is especially dangerous in emergency situations, which include e.g. evacuation, but also in normal situations such as the so-called ingress and egress. In these situations, the movement of a dangerously large crowd typically occurs.

Timely and accurate information concentrated in one place is the key to realizing a safe event. All this can be supported by the implementation of a mobile camera system supplemented by a control centre. This article describes the pitfalls, optimal settings, advantages, and disadvantages of deploying such a system at large-scale concerts in the Czech Republic, based on a field investigation.

This topic has not been extensively published in the Czech Republic, nor in other countries of Central and Eastern Europe, academically nor practically. Theoretically, it is possible to start from the available resources in the topic of security of indoor spaces, stadiums, and airports.

In practice, however, the differences between facility security and a festival or concert agenda at outdoor large-scale events are so great that they can hardly be applied in the area of crowd management.

Available literature that can be considered reliable may be divided into academic publications and practical manuals published in various foreign countries.

An important protagonist and expert in the field of crowd management is Prof. Dr. G. K. Still. His work is characterized by a complex and interdisciplinary approach to crowd management. The publication “Introduction to Crowd Science” can be considered as the basis [1] and is further developed to the application level by his next publication “Applied Crowd Science” [2], set mainly in the environment of Great Britain and Western countries in general. The opposite side of the coin is the experience of the largest events, typically of a religious nature, during which tens to hundreds of people die in the crowd every year, as described by e.g. Kanaujiya in his article on crowd management and the use of CCTV systems at similar events [3].

Foreign functional models are well described in the literature [4], [5], [6], [7], [8],which usually have the characteristics of instructions and manuals for event organizers [9], [10], [11]. Unfortunately, we lack such a unifying methodology in the Czech Republic.

2. Methodology Section

The mobile CCTV system was applied in a test mode at several large-scale events with a large number of people in the Czech Republic (Table 1). Most of the concerts (except Arctic Monkeys) took place at PVA EXPO PRAHA which covers approximately 105,000 square metres. It has 8 halls (35,000 square metres) and 6,000 square metres outside. The CCTV system was not used during the concert Beats for Love which took place 1–4 July 2022. The reasons for not testing were the extent of the concert and financial restrictions.

Table 1. Tested events

Concert	Date	No. of people
Rammstein	15.5.2022	55,000
Rammstein	16.5.2022	55,000
Imagine Dragons	5.6.2022	55,000
Imagine Dragons	6.6.2022	65,000
Guns N’ Roses concert	18.6.2022	65,000
Metallica concert	22.6.2022	50,000
Arctic Monkeys	18.8.2022	19,000

The entire process of deploying the system was observed and analysed from the early stages of event preparation, through building the mobile infrastructure, putting the camera system into operation, further into interaction with security management and promoters, up to the evaluation of the events. Therefore, a combination of quantitative and qualitative data collection methods was employed. The research included a review of available information on mobile camera system applications and an extensive field investigation. Interviews were conducted with security managers, representatives from emergency services, promoters (e.g., První pražská mediální produkce s.r.o., 4ALL Production s.r.o., Live Nation Czech Republic s.r.o.), and camera experts (Avalon s.r.o., TSS Group s.r.o., EyeTowers s.r.o.). Crowd safety management experts from BSB Services s.r.o. were also consulted, and security reports were thoroughly evaluated. Technical parameters were consulted with the aforementioned experts: suitable connectivity (5G, LTE, optical link, reticle, Skylink), software and hardware (possible platform, system-control, towers), and strategic disposition of cameras for suitable acquisition of data.

It was important to deal with camera system contractors (namely IPSECURITY, s.r.o., Avalon s.r.o., TSS Group s.r.o., EyeTowers s.r.o.). After consultation with them, the decision was made to test cheap (less quality Chinese models) as well as more expensive models.

Technology testing and subsequent data collection can be divided into several areas. On the one hand, this concerns suitable hardware, specifically selected basic features of the cameras, which had a fundamental influence on the quality of the obtained data. The second area is the strategic-tactical deployment of cameras and the control centre itself. The third area is interface and software solutions.

2.1. Hardware and Selected Camera Features

2.1.1. Pan-Tilt-Zoom (PTZ) Versus Still Cameras

The ideal solution for events is a combination of both types of cameras. Still cameras are much better at handling dramatic changes in their field of view. Compared to the usual use of cameras, it was necessary to cope with very sudden changes such as lighting effects, fire shows, dust, and rain. In the case of still cameras, their price for the given features is also an indisputable advantage. Their use can therefore be recommended at entrances/exits, on perimeters, and for areas with high light requirements, i.e. typically towards the stage.

The data collected from still cameras proved to be important when analysing crowd behaviour for future events, e.g. how to properly place the infrastructure (stands, tribunes, toilets, etc.). On the other hand, PTZ cameras were necessary to solve specific incidents. While still cameras helped to identify the incident, with the help of PTZ cameras it was possible to properly evaluate the incident and arrange follow-up actions, such as navigating paramedics to the scene.

2.1.2. Resolution Quality

It might seem that the higher the resolution of the camera, the better. But the research shows that the situation is more complicated. Even if the fact that the price increases exponentially with the resolution of the camera is ignored, the situation is still not clear-cut. High-resolution cameras need to ensure high-quality and stable transmission of a large amount of data in order to function properly. Otherwise, they either chop, the framerate drops, or they reduce the image quality themselves. The optimal camera resolution for PTZ is 16 Mpx, while 5–8 Mpx is sufficient for perimeter cameras. The data streams can be set in software. However, this does not change the complexity of data transmission, which proved to be crucial at large-scale events.

2.1.3. Data Transmission

One of the most important aspects for deploying a mobile CCTV system at an event with a large number of people is the quality, or the directly related method of ensuring data transmission. There are three options, each of which typically has advantages and disadvantages. All three types of connections were tested. Connection via the Long-Term Evolution (LTE) network has the great advantage of being completely undemanding in terms of additional technical security; no cabling is required, so installation is very simple. The cost is very low. However, a large, if not insurmountable, disadvantage is the stability of the connection and the related ability to transfer a large amount of data. Although signal boosters were also installed at some of the tested locations, the volume of transmitted data is simply not enough. The star connection of Subscriber Identity Module (SIM) cards was also tested when several SIM cards are connected together. However, tens of thousands of visitors with mobile phones create an incredible burden on a given telecommunications point, which further escalates in the event of an incident, especially when it is necessary to rely on data transmission. The safest way to connect the camera system is through a cable connection.

The options are either metallic cabling or optical fibres. As part of the testing, both variants were implemented. Metallic cabling is cheaper and more durable, but the quality of the transmission decreases rapidly with over tens of meters of cabling. An alternative is distribution through optical fibres, but these are significantly more expensive and many times more sensitive to damage. The combination of underground fibre optic distribution (where there is no fear of mechanical damage) and subsequent connection at the outputs is ideal, but it is necessary to have a network infrastructure, which not every large-scale event venue has. The most modern option is connection via satellite. The connection was tested through the Starlink system. This was a technically ideal but economically currently unsustainable model. A connection, i.e. a separate flat rate, is necessary for each camera separately. In the case of legal entities, the rate increases multiple times. The implementation of the connection of the entire CCTV system for a one-time event via Starlink would thus be calculated in the order of tens or even hundreds of thousands of Czech crowns, which now excludes the deployment of this technology on a practical scale.

2.1.4. Night Versus Full-Colour Mode

Various imaging properties of the cameras which enable vision in low-light conditions were also tested. The possibility of using Light-Emitting Diode (LED) backlight is very unsuitable for the given use, as it dazzles the visitors and disrupts the light show during the performance. Ideal, but more expensive, are cameras equipped with an infrared illuminator, ideally with two lenses. These cameras provided the best imaging features needed for crowd monitoring and control.

2.2. Camera Location and Control Room

2.2.1. Planning

A significant obstacle in planning the placement of cameras is the planning of the event itself. Large-scale concert-type events are often just one-day events. The organizers of such events plan several events at the same time, and the transmission of information can thus create obstacles. It is important to have an up-to-date map of the area and to obtain accurate information about both the planned built infrastructure and natural obstacles. a field inspection and obtaining the maximum possible amount of information is thus an essential part of planning. Camera coverage is extremely dependent on the complexity of the area.

However, the research clearly showed that the most watched areas were the entrance/exit, the so-called pit area (the closest rows directly in front of the podium), and the escape exits. Therefore, during planning, these places should be occupied as a priority.

2.2.2. Control Centre

The control room should include monitors that allow multiple viewers to simultaneously observe the displayed information. The research showed that 3–6 people are most often present in the control centre (crowd safety manager, camera operator, member of the medical team, then, the event safety manager, promoter, representative of police and local transportation, and other appointed persons). This should be a room where these people can fit, where they can write on the board, and where is quiet enough for radio communication. At the same time, all information about the event should be concentrated here (maps, contact sheet, security studies, security plans, management structure, etc.) to visit it without wasting time. Most of the people moving in the control centre (except for the crowd safety manager, camera operator, and medical representatives) were not present in it for the entire duration of the event.

2.2.3. Height of the Cameras

The height at which the cameras are placed is extremely important. For perimeter monitoring, a range of 3–6 metres seems optimal, depending on the chosen type of camera. However, for crowd monitoring and control, the ideal location is much higher, in the range of 9–18 metres. It is ideal to place the cameras already during the construction of the mobile infrastructure of the given event, e.g. on the top of the stage, lighting tower, or tribune. In places where it is not possible from a strategic-tactical point of view to place the camera on the existing infrastructure, it is advisable to use stand-alone retractable tripods or towers. They can also be equipped with battery or aggregate power, and when using a wireless connection for data transmission they become fully independent.

2.3. Interface and Software Solution

2.3.1. Control of Rotating Cameras

The cameras can be controlled both with a professional console with a joystick and with the help of a mouse and keyboard. In the first stages, using a mouse seems more intuitive and easier, however, after properly setting up the control panel, a professional control panel equipped with a joystick is the best choice.

Research has shown that proper and thoroughly tested settings of all cameras are necessary for the correct and effective functionality and usability of the desk (their correct naming, division and indexing in the system, date and time settings, as well as key positions necessary for automatic and fast rewinding). This setup requires a considerable amount of time for both the camera operator and especially the security manager. Setting up requires both technical and, above all, local and practical experience. This is not an obstacle for stable camera settings, for example in buildings. For solutions as mobile CCTV systems, which are also placed for one off events, this is already a considerable obstacle.

2.3.2. Transferring Outputs From the CCTVs to Competent People

Managing a large-scale event with a large number of people is a complex discipline itself. An important factor for proper management is accurate and, above all, up-to-date information. The data from the deployed tested camera system thus became an important basis for management and decision-making. The research showed that in the first phase there was not much interest among the staff in the deployed camera system. An important factor for the effective deployment of a mobile camera system is the presentation of all the advantages.

2.3.3. Imaging Software

In order to effectively analyse data in real time, the footage from individual cameras must be properly controlled. The basis for this is the switching of individual shots, their collective display, and shifts in recording time. Furthermore, it is necessary that the software is compatible with the deployed cameras for the system to properly function. Research has shown that the described basic features are handled by most imaging software, and the choice of software is therefore not crucial.

2.3.4. Advanced Software Features

The correct choice of software is essential for advanced features such as automatic data analysis. These functions typically include license plate recognition, but also person recognition. Other functions include automatic behaviour recognition or various types of alarms warning of fire, area disturbance, etc. Research has shown that the most practical application for the use of a mobile CCTV system at large-scale events appears to be the use of license plate recognition. The recognition of people does not encounter technical, but legislative obstacles.

Setting up cameras for more advanced features requires complex setup and testing, which was beyond the scope of this research.

2.3.5. Software Settings

Correct camera settings are extremely important both for the quality of the data and for subsequent work with them. Research has shown that poorly set (sometimes factory set) cameras can in extreme cases completely disable the system, for example by overloading the server. Among the important features for manual settings is the setting of codecs, typically Advanced Video Coding (H.264), which have lower requirements for imaging, while maintaining the considerable functionality of the so-called software magnifier. A software limitation of the maximum transfer rate is also necessary. The ideal time of key frames is 1.2 seconds, and the volume of saved frames is 25 per second.

2.3.6. Other System Options

Along with the deployment of the data infrastructure (either cable or wireless), it is possible to connect other supporting data sources, such as the weather station located on top of the podium. The security management in the control centre thus has immediate and accurate information, especially about the temperature, which is important for the condition of the crowd, but also about the instantaneous wind speed, which is extremely important for the statics of the podium and is also a frequent cause of partial evacuation. a deployed camera system when it is not used for crowd control (i.e. before visitors are admitted and after they leave) can be effectively used as a property security system.

3. Results

The use of a mobile CCTV system together with a control room is a very effective and modern way of increasing crowd safety. However, in the Czech environment, but also in the countries of Central and Eastern Europe in general, it is a rarely used tool.

Research has shown that it is technically and practically possible to deploy a mobile camera system in the Czech environment. However, the deployment of the system for widespread use is hindered by a number of obstacles that have been identified.

The main obstacles to deploying the system are the lack of knowledge and the financial burden. Most of the relevant literature is not available in the Czech language while at the same time it is set in a foreign environment. The literature and handbooks do not reflect the legislation in force in the Czech Republic.

The obstacle is therefore not only theoretical background, but also practical experience from deploying the system. Each event requires special settings that are difficult to transfer to other events. The economic complexity is related both to the acquisition of technical equipment (cameras, servers) and to the construction of infrastructure (cabling distribution, mobile towers, clamping systems), as well as to the personnel costs associated with the technology and the implementation of the control centre.

From the interviews conducted with interested persons, which included promoters, security managers, and representatives of the emergency services, however, the benefits and a positive outlook on the future usability of the mobile camera system with the control centre clearly emerged. The advantages are mainly immediate access to accurate information about what is happening in the area. Another indisputable advantage is the centralization of information for the safety management of the event in one place, which subsequently enables a detailed ex-post analysis based on accurate data.

4. Discussion

In order to effectively deploy the system and thereby clearly increase the safety of visitors to large-scale events with a large number of people, it is therefore necessary to address three basic areas. The first is the correct choice of the technology that will be used. An important input in this area is the economic dimension of procurement costs. This can be compensated by the right combination of features of the acquired system, where more expensive and more equipped crowd control technology does not necessarily mean a better choice. The economic burden can also be compensated by a partial saving of physical security costs for property security before and after the event itself. The second area consists of the correct placement of cameras and the control room with an aim towards maximum efficiency. In this area, one can largely rely on theoretical foreign publications. These are not subject to international differences in legislation, but are, on the contrary, identical worldwide. The third area is the correct setting of the system and control centre. The research revealed some specific parameters that must be set manually on CCTV systems. At the same time, correctly placing, setting up, equipping, and occupying the control room all play an important role. Only then it is possible to fully utilize the offered potential to increase safety.

Beyond the intended results, it was found that the usability of advanced analytical software functions is currently difficult to use in practice for mobile camera systems, considering the difficulty of setting up and testing the system for its correct functionality. The situation is further complicated by the typically high number of visitors at large-scale events, with which commonly available systems are still poorly able to cope.

5. Conclusion

The aim of the research was to verify the practical usability of crowd control at large-scale events with the support of modern technical means, such as a control centre and a mobile CCTV system, and their contribution to ensuring and increasing the safety of event visitors. Research has shown that the deployment of a mobile CCTV system has a huge benefit for the management itself and thus also for increasing the safety of the event. At the same time, however, the research has shown that there are a few obstacles and limitations that complicate the deployment of a mobile camera system and thus in reality prevent mass deployment.

Both, technical obstacles to practical use, such as signal transmission via an LTE network versus signal transmission via a satellite network versus cabling connections, as well as operational aspects of the use of technology, such as the financial burden for organizers or the added value of increasing the safety of visitors, were investigated. It was possible to prove the added value for security, the interventions of the security forces were faster, more accurate, and more effective, while at the same time it was possible to prevent several incidents by taking measures on time. These incidents could be predicted due to the transmission of quality and real information in real time.

It was also possible to determine which camera features are important for mobile CCTV systems and which, on the contrary, are less so. Thus, the optimal technical solution was identified.

The use of a control centre and a mobile camera system for monitoring and managing the crowd at large-scale events with a large number of people is likely the future of security in this field. There is no need to discuss the safety benefit. The main obstacle, however, is the financial requirement, which can be effectively compensated. The cost of technology also decreases rapidly over time. On the contrary, the characteristics of camera systems, both technical parameters and mainly the development of advanced software analysis functions, predict a promising future for this direction. However, they can hardly replace the human role in security; mobile CCTV systems, together with the control room for large-scale events with a large number of people, form an extremely effective tool for supporting the correct decision-making of security managers.

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