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Information System for Authorities

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Acronyms and Abbreviations

CDI	Crowd Dynamics International Limited
EC	European Commission
EMT	Executive Management team
FZJ	Forschungszentrum Julich Gmbh
GA	Grant Agreement
INRIA	Institut National De Recherche En Informatique Et Automatique
KPIs	Key Performance Indicators
ONH	Onhys
PO	Project Officer
UL	University of Leeds
ULM	Universität Ulm
URJC	Universidad Rey Juan Carlos
UCL	University College London
WP	Work-package

Executive Summary

This report focuses on the proposed design and requirements for an “information system for authorities”. The information referred to is about crowd data, and this can also be used as a crowd management system for the operation of crowded places. The intention is to consider the needs of practitioners in managing crowds and how they could leverage CrowdDNA and other technologies through a dashboard approach.

User and system requirements have been developed to capture the information required for designing a crowd management dashboard. The user requirements examine what information and how it should be accessed and analysed for the users controlling the dashboard; while the system requirements look at what features the system would require for being an operational system.

A mockup design for the information system (“dashboard”) has been built to explore the design space of the operation management of crowds. The dashboard has been designed to exemplify how potential crowd management data can be acted upon through an operational dashboard and provide key information for authorities managing crowds in a variety of scenarios. This will allow practitioners in industry to better imagine the practical application of CrowdDNA technologies, which are in early-stage scientific development and often not accessible to industry.

1. Introduction

1.1. Purpose and scope

The purpose of this deliverable is to describe the design process for a crowd management and information system that could be used by authorities (or privately employed crowd managers). The report also describes a mock up dashboard that has been created to demonstrate the principles. Whilst CrowdDNA is an early stage research project with many exciting new technologies, how these can be used is not easy to grasp by practitioners. This deliverable aims to bridge the gap by considering the practitioner viewpoint, their needs and then how crowd technologies could be leveraged in the future. It is hoped that this will help bring together academic research and industry.

1.2. Goals

The following summarises the key goals of the deliverable:

- Develop set of user and system requirements to help define the scope of the system based on practitioner needs.
- Build a mockup of the system that can be interacted with.
- Identify how to best integrate the work carried out in the whole project into the system design.

2. Crowd Management Processes

2.1. Overview

Crowd Managers rely on multiple phases of planning and execution to safely and efficiently manage crowded places such as events, venues, transport hubs and mass gatherings.

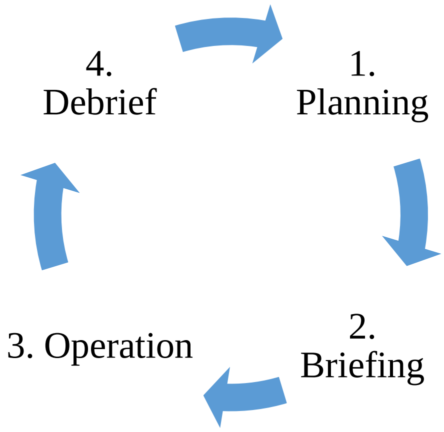


Figure 1 – Crowd Management Phase Diagram.

2.2. Planning/Briefing

The planning phase occurs before crowds arrive and lays out how the crowds should be managed. This generally involves the following elements:

- **Risk Assessment**: Identify potential hazards related to crowd movement, dynamics and behaviour. This includes evaluating the venue, expected crowd size, and specific event activities.
- **Crowd Management Plan**: Develop a comprehensive plan that includes crowd management measures, emergency procedures, and communication strategies.
- **Coordination with Stakeholders**: Work closely with all internal and external stakeholders, including event organizers, security personnel, and emergency services, to ensure everyone is aligned on safety protocols.
- **Training and Briefing**: Provide training for staff and volunteers on crowd control techniques and emergency response procedures. Regular briefings and specific briefing before an operation ensure everyone understands their roles and responsibilities.
- **Emergency Preparedness**: Have a detailed emergency plan that includes evacuation routes, first aid points, and contact information for emergency services. Regular drills and simulations can help prepare for real-life scenarios.

In the context of CrowdDNA, risk assessment, crowd management planning and emergency preparedness all require analysis to be able to put in place the correct measures. This analysis is currently limited to simple hand calculations considering crowd flow, simulation of crowds if an expert crowd consultant has been commissioned, and subjective thought exercises to help work through. In the future, CrowdDNA techniques can assist this analysis through analysing previous historical data/video footage, predicting different situations and optimising evacuation plan intelligently. The proposed system could also be a way to play through simulated drills to help prepare for real life scenarios using real data and prediction. The CrowdDNA synthetic dataset production can be used to bring realism to the drill, allowing for the crowd manager to view synthetic camera feeds and perform analysis on them as if they were real crowds.

2.3. Operation

During operation, crowd managers rely on up to date "intel" – information regarding the current status of the crowds. Currently, this is mainly done through observing CCTV, reports from staff on the ground and where the technology is in place - a count of the number of people entering through turnstiles or ticket gates. The following

- **Monitoring and Supervision**: Continuously monitor the crowd during the event to identify and address any safety issues before they escalate. Use barriers, staff resource to manage crowd flow.
- **Communication**: Effective communication systems are essential for managing the crowd and responding to incidents. Provide information to crowds on entry, exit, and emergency procedures. Advise on routes and actively update crowds with relevant information. This can be done through signage, public address announcements, communication via text or smartphone apps and through staff on the ground instructed to relay messages.
- **Emergency Evacuation:** Enact emergency evacuation plans when required. This involves multi-stakeholder communication to achieve a safe evacuation. Often, the emergency evacuation plan needs to be adapted to the prevailing situation because not every specific scenario can be planned for.

The proposed crowd management system could assist the real-time operation above through intelligent monitoring of crowds – CrowdDNA has used Internet of Things (IoT) sensors to obtain live data on crowds and to display this in an easily understandable way. More advanced analyses of crowds through sensors and video footage can raise alerts of dangerous situations. Predictive methods could be used to identify potential overcrowding before it has occurred and algorithms that enable an optimisation of crowd routing would be able to proposed solutions to crowd managers (such as proposed in D4.2). Crowd managers would therefore be much better informed than they are currently by using such a system and empowered to make better decisions.

Communication with crowds would be based on the decisions taken to help guide crowds and this subject is dealt with in D4.4.

2.4. Debrief

After the event, a debrief should occur to gather lessons learnt and assist in planning for crowd in the future. After the debrief, documentation can be produced as a record of things that occurred. A system for crowd management as developed in this report can assist in this documentation by including any analysis, alerts raised and the historical data that can subsequently be used in planning.

2.5. Modes of the System

The proposed system could work in two modes to facilitate how crowd managers would use a system to achieve the above:

- **Analysis**: offline analysis of historical data sets, looking back on recently gathered data during a live event or making a prediction based on a "what if" scenario.
- **Real-time**: a view of the current situation as happening, including live camera views, live crowd densities, live crowd movements being measured and alerts raised by the technologies.

Separating these modes allows a crowd manager to know whether they are looking at a live view and need to react or a hypothetical or historical scenario. The manager would use analysis mode in planning and debrief and both analysis and live during operation.

3. User and System Requirements

To design the system we went through a process internally to create a list of user and system requirements in line with how we would carry out this process when creating a full piece of software. Through this exercise it allowed us to systematically define and identify the elements that would be needed for creating a management system for authorities.

3.1. User Requirements

In developing the user requirements, the starting point was to identify the hypothetical actors and their goals. We chose to focus on the role of the "Operator", who would be managing the control and information system. This is likely to be someone using the system and reporting to the crowd manager who would be making the decisions and instructing what to look at or what analysis to run. The user requirements are guided by conversations with professionals and the experience of the authors as crowd management consultants. In the future to design and build a full version of this system further user requirements would be considered from other roles such as "Stewards" and "Security" who while not directly interacting with the system, would interact with the Operator and the functions of the system.

Without aiming to be an exhaustive collection of the ways in which the system can be deployed, the user requirements depict a set of core goals and the processes the users have to go through towards the completion of the desired goals, by capturing, step-by-step, the users' interactions with the system as well as the system's response.

Each case is comprised of the following categories of information:

- **ID:** A unique code to facilitate cross-referencing.
- **Name:** A clear title that communicates the scope of the user requirement (the user's goal).
- **Management Phase:** Which phase of crowd management is applicable (Planning/Operation/Debrief).
- **Modes:** Which modes does this use case require.
- **Actors:** The user interfacing with the system to achieve the goal.
- **Description:** A brief explanation of the user requirement.
- **Flow:** A description of the steps taken during the use case.

Table 1 – User Requirements Table

ID	UR_01
Name	Crowd Viewing Via Camera
Management Phase	Operation
Modes	Real Time
Actors	Operator
Description	An operator needs to view current level of crowding at different locations around the site
Flow	1. The Operator finds the location on the map they want to view the crowd at. 2. The Operator clicks on the camera icon at the corresponding location. 3. The Operator views the camera footage in the video pop up window.

	4. The Operator decides the appropriate action based on the crowd situation displayed via the camera.

ID	UR_02
Name	System Alert And Response
Management Phase	Operation
Modes	Real Time
Actors	Operator
Description	Operators are alerted when predetermined thresholds or values are detected by systems.
Flow	1. An element in the system detects values have reached a predetermined threshold. 2. The system generates an alert with the information about the values and threshold. 3. The alert is displayed on screen for the operator to read and determine the next course of action based on the information.

ID	UR_03
Name	Alerts History Display
Management Phase	Operation / Debrief
Modes	Real time / Analysis
Actors	Operator
Description	Operator can view history of alerts in a widget
Flow	1. An element in the system detects values have reached a predetermined threshold. 2. The system generates an alert with the information about the values and threshold. 3. The alert along with the time it was generated, and any metadata is stored in the system. 4. The alert history display is updated to include the newly generated alert.

ID	UR_04
Name	Alert History Reported Out Of System

Management Phase	Debrief
Modes	Analysis
Actors	Operator
Description	Operator can generate report from history of alerts
Flow	1. Operator presses the “Generate Report” button. 2. The system outputs the all the alerts from the event and their metadata into the report format. 3. The Operator can now access and share the generated report.

ID	UR_05
Name	Site Navigable Map
Management Phase	Planning / Operation / Debrief
Modes	Real time / Analysis
Actors	Operator
Description	Operator can view entire site map in system.
Flow	1. Operator manoeuvres viewport in different directions. 2. Viewport changes what part of the site map is show.

ID	UR_06
Name	Timeline Navigation
Management Phase	Operation / Debrief
Modes	Analysis
Actors	Operator
Description	Operator can use the timeline to review the data recorded across the event.
Flow	1. The operator move the control on the timeline to a different position. 2. The timeline updates to reflect the new time selected. 3. The data in all visible windows updates to reflect the data from that time.

ID	UR_07
Name	Map Data View
Management Phase	Planning / Operation / Debrief
Modes	Realtime
Actors	Operator
Description	Operator can view the selected results outputted on the map.
Flow	1. Operator selects the desired type of data to be viewed. 2. The view on the main map screen changes to display the desired output type.

ID	UR_08
Name	Crowd Density Predictor
Management Phase	Planning / Operation
Modes	Analysis
Actors	Operator
Description	Operator Receives Alerts About Crowd Density Predictions
Flow	1. Crowd Densities are recorded/processed by a sub system. 2. Crowd densities are used as an input to the crowd density predictor. 3. If a crowd density prediction fulfils pre-determined criteria, raise an alert with this information. 4. The operator receives the alert through the main interface. 5. Operator reviews the information from the crowd density prediction alert and acts accordingly.

ID	UR_09
Name	Individual Velocity Analysis
Management Phase	Planning / Operation
Modes	Realtime/Analysis

Actors	Operator
Description	Operator reviews the individual velocity analysis of areas.
Flow	1. Operator opens the individual velocity analysis page. 2. Operator selects which camera and which time period of video footage they want analysing. 3. Operator looks at the individual velocity analysis and takes appropriate future action.

ID	UR_10
Name	Crowd Movement Diagrams
Management Phase	Planning / Operation
Modes	Realtime
Actors	Operator
Description	Produce graphs of detected crowd movement.
Flow	1. Operator navigates to movement diagram tab. 2. Crowd movement from the most recent defined period is displayed through the graph. 3. While open the graph updates to the most update to crowd movement data.

ID	UR_11
Name	Crowd Movement Visuals
Management Phase	Operation
Modes	Realtime
Actors	Operator
Description	Display crowd movement and build up.
Flow	1. Operator navigates to crowd movement visualiser. 2. Current crowd movement is displayed on top the plans or satellite image. 3. The visualisation of crowd movement updates to the to the most up to date crowd movement data as time progresses.

ID	UR_12
Name	Graph Viewer Select Data Type
Management Phase	Planning / Operation / Debrief
Modes	Realtime, Analysis
Actors	Operator
Description	Operator selects the desired data type to view in the graph.
Flow	1. Operator selects the data type they want from the selector. 2. The selected data type is displayed in the graph.

ID	UR_13
Name	Graph Viewer Time Range Select
Management Phase	Planning / Operation / Debrief
Modes	Analysis
Actors	Operator
Description	Graph data can be refined to a specified time period.
Flow	1. Operator selects the time period they want to view. 2. Graph viewer displays data from only the selected time range.

ID	UR_14
Name	Crowd Count Detection
Management Phase	Operation
Modes	Realtime
Actors	Operator
Description	When viewing camera footage of crowds, view count of people.
Flow	1. Operator opens a CCTV view. 2. Operator views count of people in the cctv view.

ID	UR_15

Name	Area Selection For Analysis
Management Phase	Planning / Operation / Debrief
Modes	Realtime / Analysis
Actors	Operator
Description	When an area is selected, the screen and other elements should focus on it.
Flow	1. Operator selects and area, camera or POI on the map. 2. The screen zooms appropriately to focus on that area. 3. Data elements change to display the selected elements data.

ID	UR_16
Name	Simulate Crowd Scenarios
Management Phase	Planning
Modes	Analysis
Actors	Operator
Description	Use specified parameters to simulate crowd movement scenarios.
Flow	1. Operator enters specified parameters for the crowd simulation. 2. The system produces synthetic crowd data from the entered parameters. 3. The operator views the resulting crowd simulation.

3.2. System Requirements

After defining the user requirements for the system, we then carried out the task of defining the technical elements required by the proposed system in order to fulfil those user requirements.

The system requirements for the Crowd Management dashboard are presented below in Table 2with their relevant use cases (where applicable).

Each system requirement is comprised of the following categories of information:

- **ID:** A unique code to facilitate cross-referencing.
- **Description:** A description of the what the system does for this requirement.
- **Relevant Use Cases:** References to all user requirements that will need this function of the system to be fulfilled.

Table 2 – System Requirements Table

ID	Description	Relevant Use Cases
SR_01	Camera icons appear on the map at their corresponding physical locations.	UR_01
SR_02	Clicking on a camera icon opens the video pop window for that camera.	UR_01
SR_03	Video pop up window display the associated video feed.	UR_01
SR_04	Systems raise alerts at predefined thresholds.	UR_02
SR_05	Raised alerts display pop ups with the appropriate information.	UR_02
SR_06	Raised alerts are stored in the system.	UR_03, UR_04
SR_07	Raised alerts are timestamped.	UR_02, UR_03, UR_04
SR_08	Raised alerts can be displayed in order.	UR_03
SR_09	Raised alerts can be extracted from the system for reports.	UR_04
SR_10	Entire site map can be viewed in system by moving the viewport.	UR_05
SR_11	Site map is accurate and in enough detail to be clear to operator.	UR_05
SR_12	Timeline can be controlled by user, with time updating.	UR_06
SR_13	Camera view changes to what it recorded at time selected on timeline.	UR_06
SR_14	Area LOS viewer changes to LOS recorded at time selected on timeline.	UR_06
SR_15	Map data display options can be selected.	UR_07
SR_15	Desired map data is displayed when selected.	UR_07

SR_18	Data for map displayed is recorded throughout realtime operation.	UR_07
SR_19	Crowd density can be captured from Data Sources.	UR_07, UR_08
SR_20	Crowd density can be sent to other sub-systems.	UR_08
SR_21	Future crowd density can be predicted from current crowd densities.	UR_08
SR_22	Crowd density can be used by the crowd density predictor.	UR_08
SR_23	Video footage is available to individual velocity analyser.	UR_09
SR_24	Individual velocity analyser can produce results from video footage of crowds.	UR_09
SR_25	Crowd movement is detected through IoT sensors.	UR_10, UR_11
SR_26	IoT sensor data can be translated to crowd movement.	UR_10, UR_11
SR_27	IoT sensor locations are named and defined for crowd movement analysis.	UR_10, UR_11
SR_28	Diagrams can be produced from crowd movement data.	UR_10
SR_29	Visuals of crowd movement are displayed against designated backdrop.	UR_11
SR_30	Selected data type is displayed on the graph viewer.	UR_12
SR_31	Graph viewer data can be narrowed to showing only from a selected time frame.	UR_13
SR_32	Number of people in a camera view can be counted.	UR_14
SR_33	A specified elements data is only shown in the graph viewer.	UR_15
SR_34	A crowd simulation based on specified scenarios can be simulated.	UR_16

SR_35	Synthetic crowd data sets can be generated and stored.	UR_16

4. Crowd Management Information System Operational Design

4.1. Overview

Translating the system requirements into the system design in terms of functionality, look and feel is described below. The screenshots are taken from the mock up system that has been developed based on these requirements to highlight the potential look and feel.

The mock up 3d model is created from plans of Hellfest to represent some of the main datasets gathered at the observatory. In reality, this can be a plan of any building, event or public space.

The overview of this is shown in Figure below.

Figure 2 - System Mock Up Displaying the Hellfest Arena

4.2. System Modes

A control is required to switch between the two modes: Analysis and Realtime. The look and feel of each mode is different to easily differentiate which type of data the operator is looking at. Real-time mode will use a red rectangle surrounding the display to identify the screen as being in real-time mode and live data being shown (see Figure below).

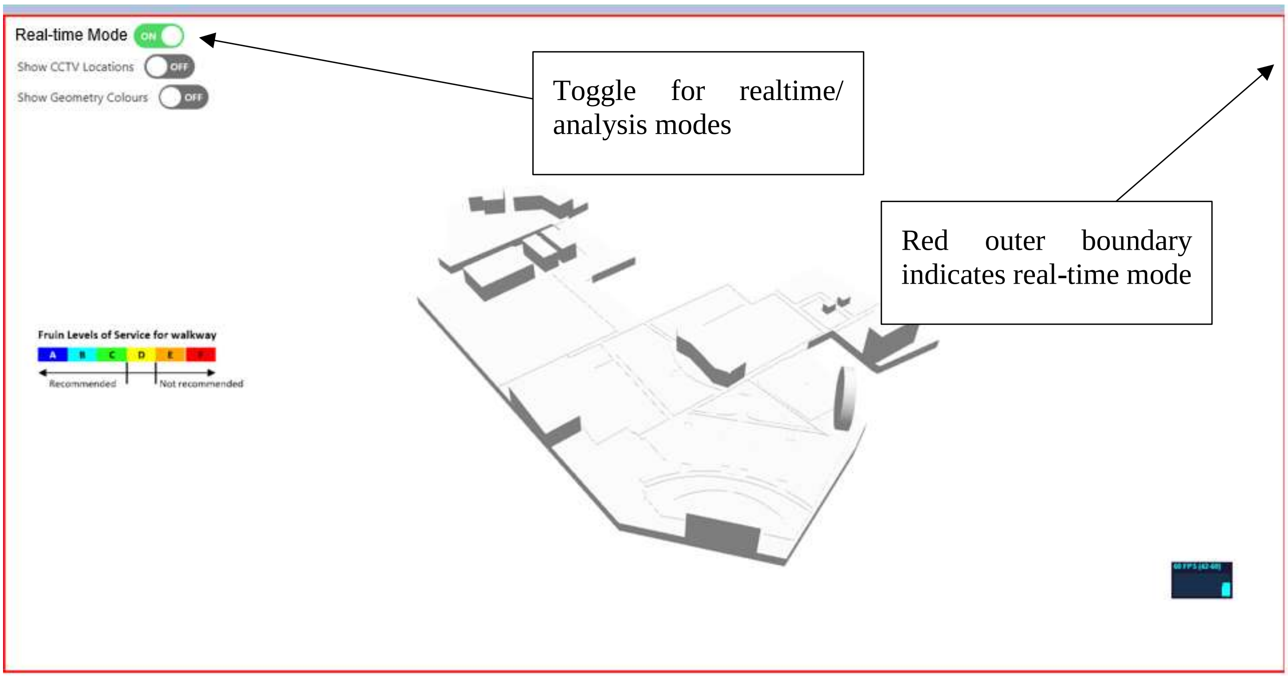


Figure 3 – "Real-time" mode highlighted by red rectangle around window and toggled by switch

4.3. System Features

4.3.1. Map View

The key feature to a system for managing and operating a site is the ability to know where everything is happening across the site. The map system allows the user to access information in the site in a natural way, such as selecting a camera that is displayed at its corresponding location (see Figure below).

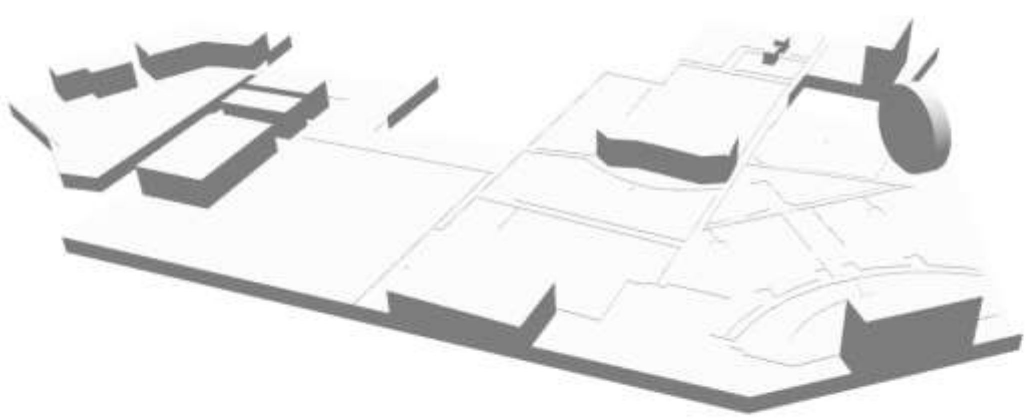


Figure 4 - View of Map of Site

It’s important that the map is accurate to the site and is approved by the relevant stakeholders as part of the tools calibration. As discussed in the previous section on training with data, accuracy and reliability of the models is key to the successful use of a crowd management model.

A key use of the map display is to have data recorded or predicted by the selected tool to be displayed to the operator here. This system should be flexible enough to allow different types of results to be displayed on the map overlay (see Figure below).

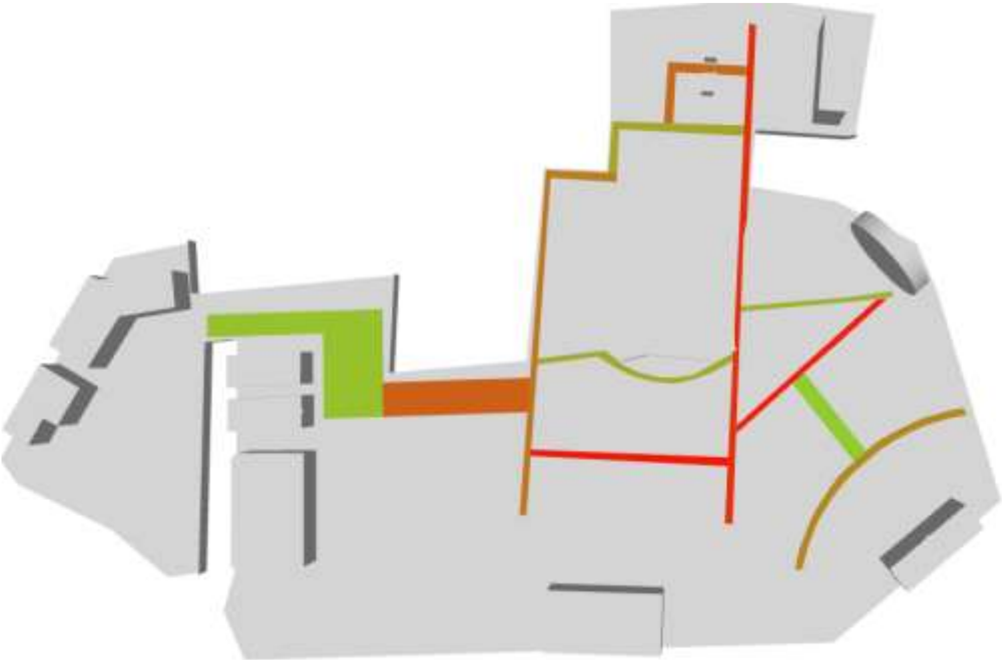


Figure 5 - Route Usage Data Displayed On The Map

One type of result that could be displayed is Level of service. This is a key metric used to identify the quality and safety of crowds. For the level of service to be interpreted by the user, they need to be aware of what the visuals represent on the scale for the level of service (see Figure below).

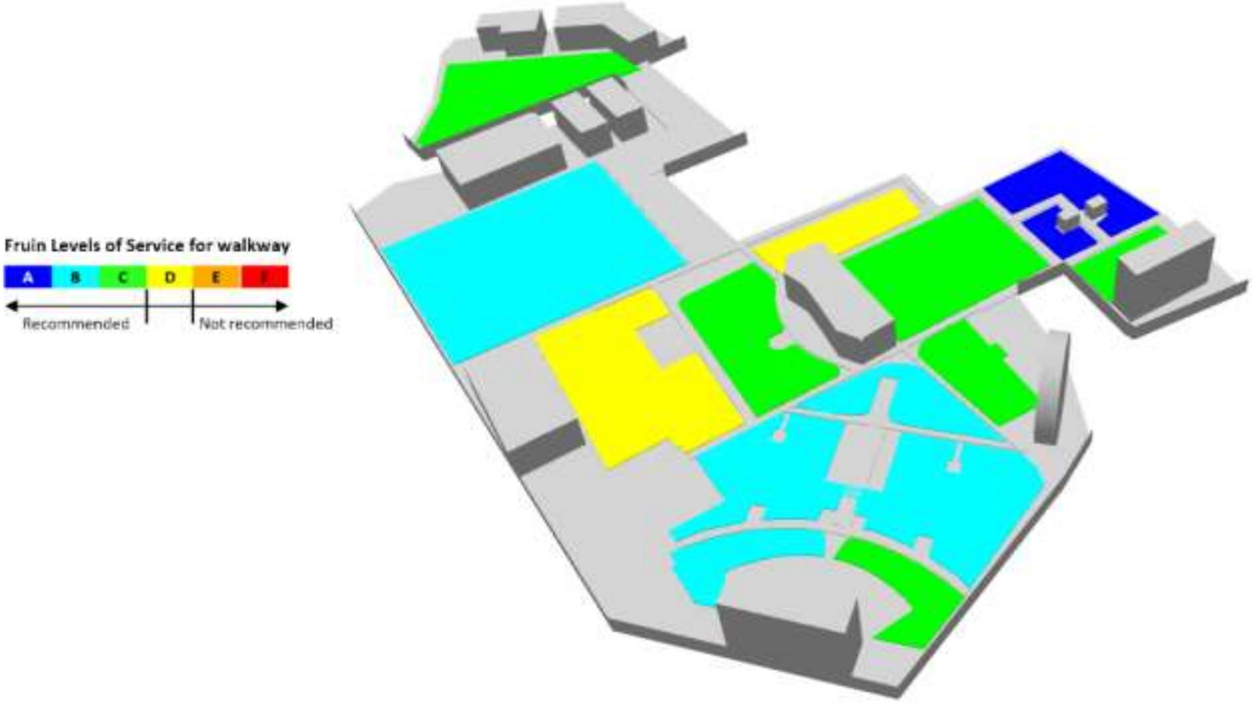


Figure 6 - Level of Service Output and Scale

4.3.2. CCTV / Camera Feeds

Cameras and CCTV are a key tool for crowd managers already. Integrating them and augmenting this video footage with analysis will help a better understanding of crowds (see Figures below).

Using camera views of a site is a great way to provide operational oversight for managing crowds at events. To help give further context to what cameras are displaying about the state of the crowds, a management dashboard would connect the camera feeds to their physical location and apply the ability to connect to that camera from the map.

The user can click on the camera icons on the map to open the video feed of that camera. Situating the controls of the camera within the context of the map and the other data being shown to the user allows them to have more information about what is happening in the camera view, and vice versa with the live footage being able to confirm what has been shown by other data.

Camera footage can then also be processed by the CrowdDNA technologies to produce new data and insights about what the crowd is doing. With data and analysis that can not be produced in real time it can be later viewed alongside / on top off the video footage that has been captured. Utilising a timeline to look at the different times of the event and what occurred then and there the camera footage and associated analyses can give a view of what occurred.

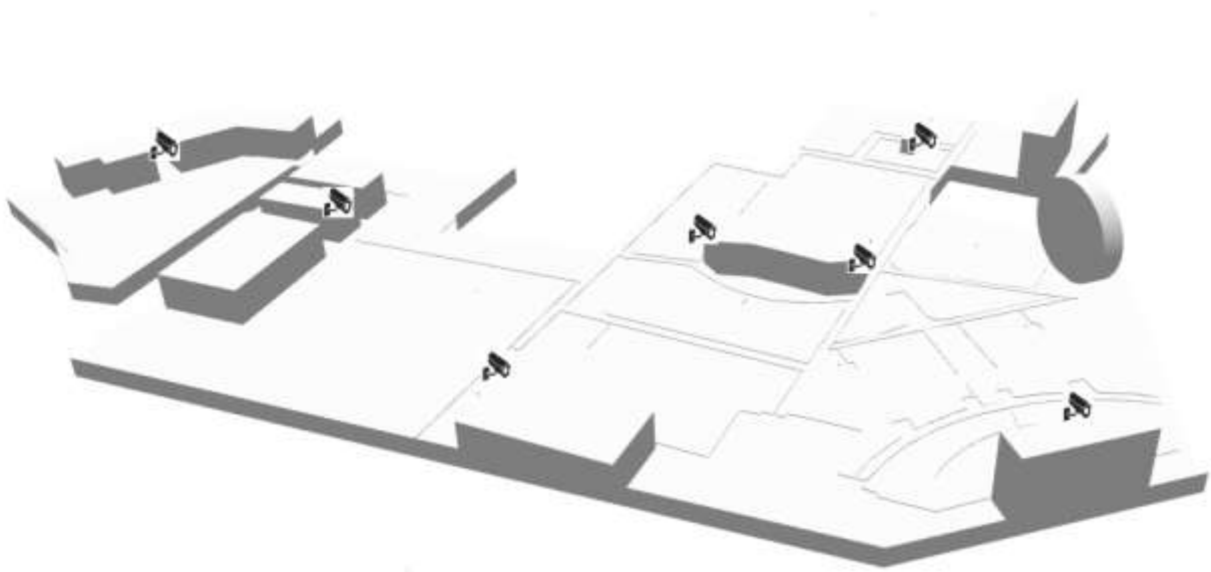


Figure 7 - Camera Icons Shown On Map

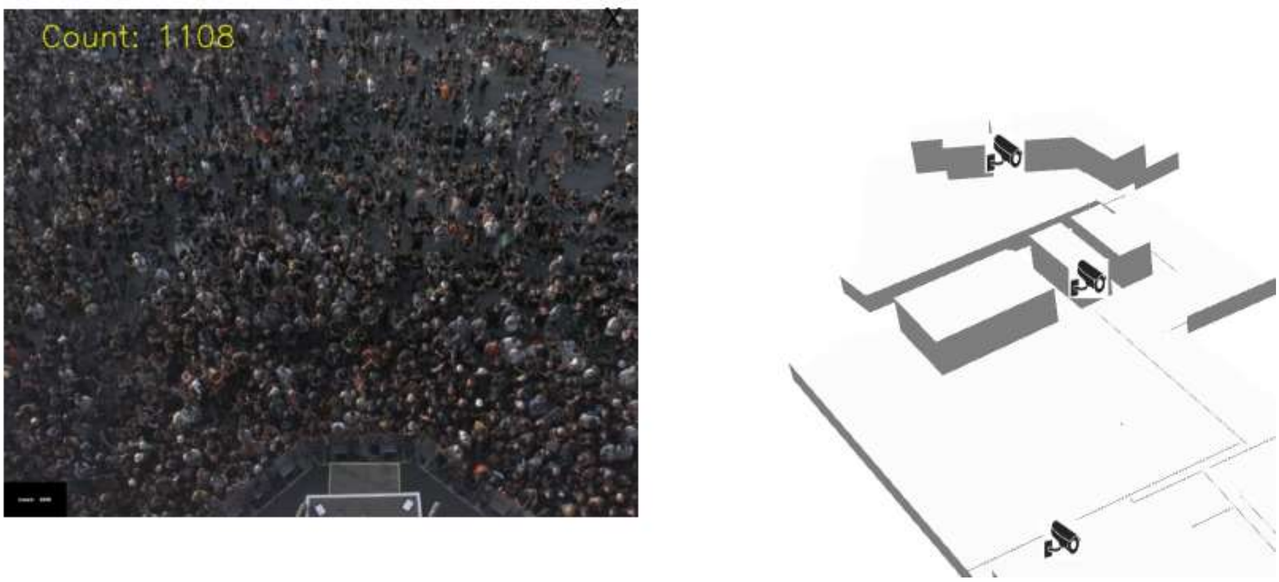


Figure 8 - Camera Feed After Selecting To Open, using the People Counting Tool

As well as showing the video footage from the cameras, any analysis tools that can process in real times should be able to be applied on top of the cctv footage. With this the operator can visualise additional information such as counts of people within the camera frame, or information about abnormal people velocities at the same time as viewing the live footage.

4.3.3. Alerts

Subsystems that run autonomously should have thresholds where they will record, report and prompt a response to analysis / data being recorded. While subsystems can be accessed and monitored at any time by an operator, they can not be watching everything at once. This especially true for something like viewing all camera feeds. This means that when systems such as the crowd movement predictor reaches a pre-determined value that would imply crowd movement that could be dangerous or is on its way to being, the user should be warned of this (see Figures below).

Figure 9 - Alerts indicated on the map

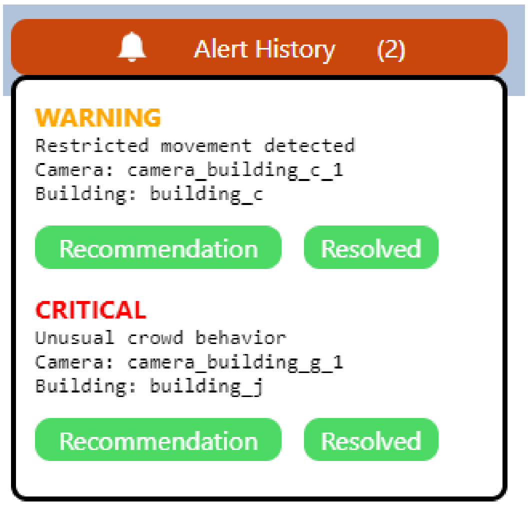


Figure 10 - List of Alerts

For this a robust and flexible alert system has been designed. When a sub-system has detected or calculated a result that needs examining it will raise an alert to the system. While all alerts will be different dependent on what sub-system they are part of, they will all have the following key pieces of data:

- **Brief Description:** This should describe the type of alert and some information about the specifics. This should be kept to as a short as possible so that it can be displayed in alert windows and clearly describe the occurrence.
- **Detailed Description:** This should describe everything about what has been detected, calculated, or recorded. This will be viewed and read when the alert is selected or read in a

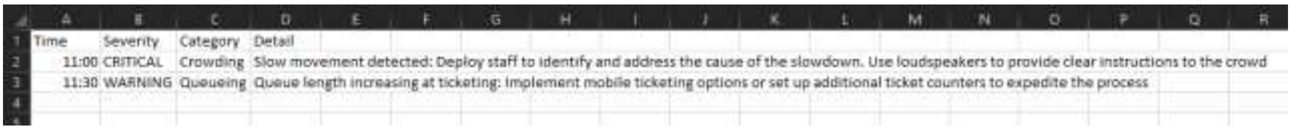
report later so this can be shown in detail. This should also include all appropriate data that is human readable.

- **Time:** The time at which the alert was created should be recorded so that it is correctly recorded in the history of the event. When view lists of alerts throughout an event, or in after the fact reports the time of each alert is very important for understand when events occurred and being able to find correlations between other recorded events and the time when the alerts occurred.
- **Severity Level:** To help manage what alerts to view and prioritise levels should be assigned to the alerts. Using universal scales (Green: Low/Normal, Amber: Medium, Red: Danger/Important) if multiple alerts are on screen this can help the operator decide how to respond. These levels are also useful when looking at the recorded alerts after the event to see how often the different levels of alerts for different systems have occurred. It is very important that each sub-system is correctly calibrated for the different levels appropriate to that sub-system.

All alerts raised throughout the course of an event need to be accessible at the end of the event for reviewing. The alerts as well as all the data from the event will need to be saved to database system design in the future. All alerts need to be outputted to a report format, so that team members other than the system operator have access to the information from the alerts (see Figure below).

Figure 11 - Generate alerts button

The report needs to contain all the information generated by the alerts, including the timestamps of when they occurred. The alert format as well can be tailored for different events, based on what sort of alerts are being raised and the essential information required for the operator and other team members (see Figure below).



Time	Severity	Category	Detail
11:00	CRITICAL	Crowding	Slow movement detected: Deploy staff to identify and address the cause of the slowdown. Use loudspeakers to provide clear instructions to the crowd
11:30	WARNING	Queueing	Queue length increasing at ticketing: Implement mobile ticketing options or set up additional ticket counters to expedite the process

Figure 12 - Example alerts report

4.3.4. Graph Data Viewer

In order to provide a way to view the data that has been accumulated over the course of a day or event, line graphs are straightforward and well understand way to display and analyse data (see Figure below). The application of a line graph view in this manner is important as it can be multipurpose: there are lots of possible types of data being recorded across an event that can be displayed on this graph feature.

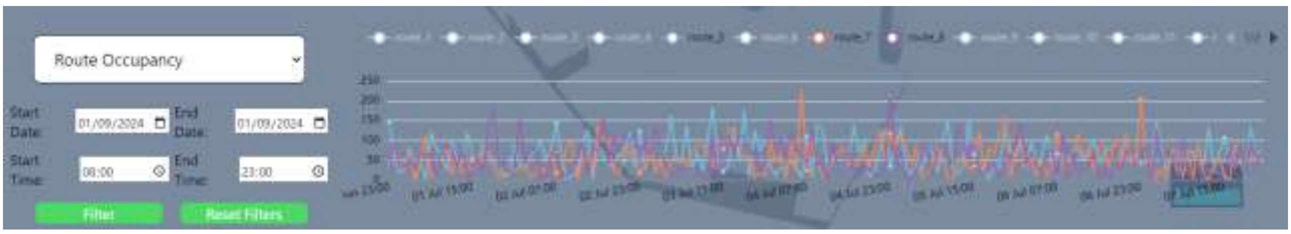


Figure 13 - Graph Results Filtered to specified routes

When review historical data, it is important to be able to narrow the timeframe, whether it is to a specific day, or to a period of hours. The graph view feature should have a straight forward date and time selector that can be used. It is also important that the date and time are clearly displayed on one the graph axis to see that the data is reflecting the required time (see Figure below).

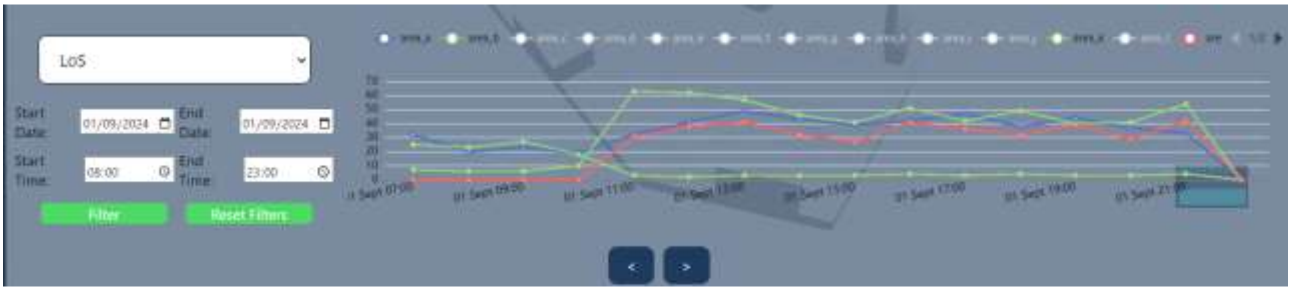


Figure 14 - Graph Results filtered by time

4.3.5. Timeline

In order to perform an analysis of an event, or a period of time at a location, the temporality of information is vital to determine what has been happening. In order to manage all of this correctly the information within the system needs to be recorded with the time of it. This needs to then be accessible through the system so that when a desired time is selected from the timeline, the data from point of time is displayed (see Figures below).

Figure 15 - Timeline before watching it through analysis has started.

Figure 16 - Timeline showing the date & time it is currently at during playing

4.3.6. Origin-Midpoint-Destination Graphs

Sankey diagrams are a type of data visualisation that describes the flow or change between states, and from that state to another, and another, etc (see Figure below). This diagram is very useful for describing the movement of people between areas of an event. It’s especially useful for looking at a very busy area and trying to determine where people are coming from into that point and then where they go after that.

Figure 17 - Sankey Diagram

A movement graph like this could be generated by IoT data. Looking at when devices are picked up by sensors in different areas movement can be inferred, and a diagram like above can be generated from it. This sort of data is useful in both real time and analysis modes of the system. In real time mode, a period would need be defined (5 minutes for example) in which the most recent data from that period would be used to show the general movement occurring currently on site. In analysis mode the periods could be larger to look at more general trends in the movement. Specific key periods could also be created in graph form to look at if the movements match what were expected from what was planned.

There are also other similar formats that could be used for displaying this type of data, including circular Sankey diagrams (see Figure below). The system should have all of these options available to ensure that the best options for the type of event are available for the operator to analyse the data..

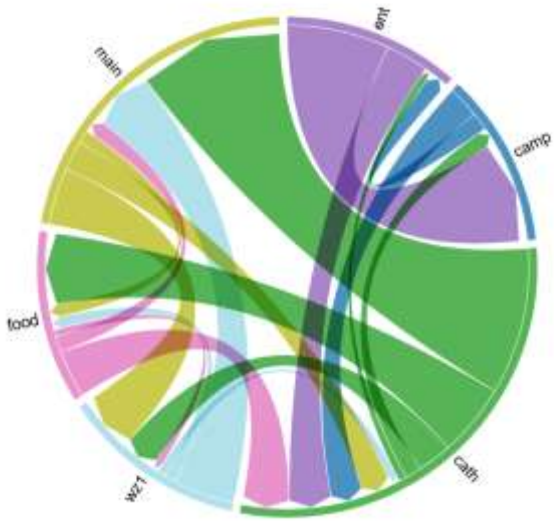


Figure 18 – Circular Sankey Diagram

4.3.7. Crowd Movement Viewer

As with the movement diagrams in the previous section; IoT data describing the movement of crowds can also be plotted in more visual manners as well. Applying these movements to plans of a building or satellite images of an event the crowd movements is an effective way of illustrating the current crowd movements (see Figure below).

Figure 19 – Display of crowd movement from IoT data

In order for this data to be useful for the operator, same as with the movement graphs; the key locations for movement need to be defined. With well-defined and useful locations for analysing movement the operator can make determinations about what the crowd is doing between the locations.

With this type of visualisation levels of crowd at the specified areas can also be show. The changes in the capacity at these points will change in concert with the detected movement values and show the changes and levels of crowding.

4.3.8. Density Prediction Software

A future integration should use the density prediction discussed and developed in D4.2. For the system obtaining crowd density values, these can be fed into a prediction system to provide suggestions to operators for what areas could end up with densities greater than what is wanted or what is safe. In that deliverable examples of auto-regressive simulations were done to perform crowd simulations. Below is a visualisation of the current state of research on this (see Figure below).

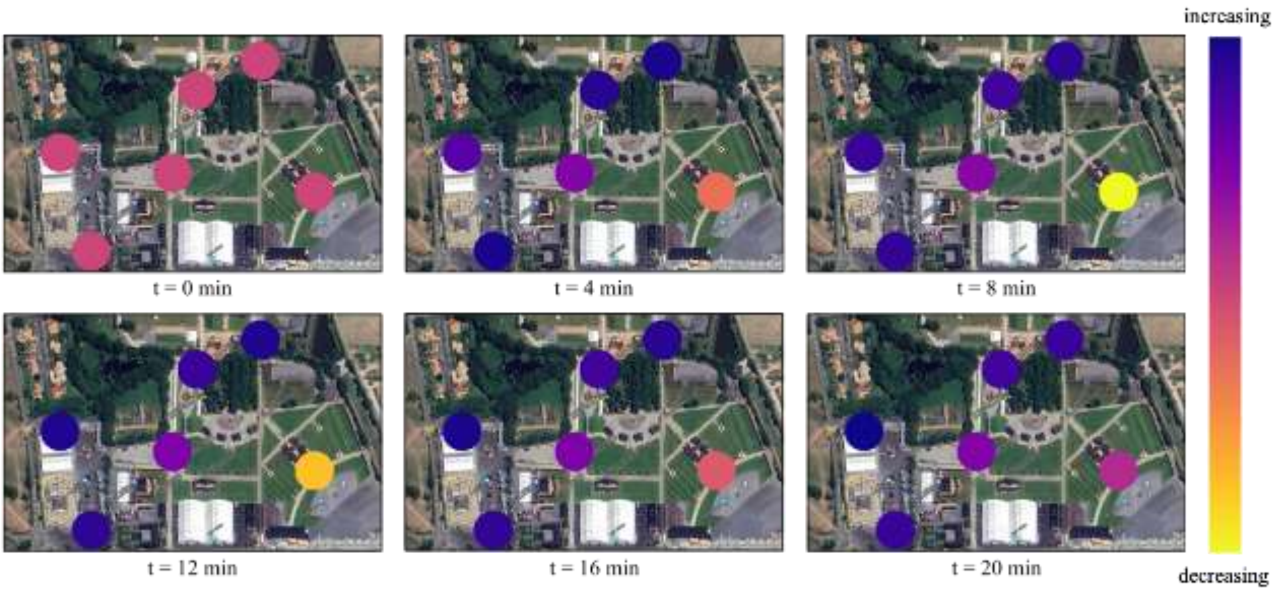


Figure 20 - Output of Crowd Simulation Auto-Regressive Simulation Research

This data can be translated into the visualisation tools to show the transfer of people between the areas based on the simulated density changes. This can be displayed using the radius of circles in each area and the width of arrows connecting these areas to show the density changes, similar to the live display of IoT data (see Figure below).

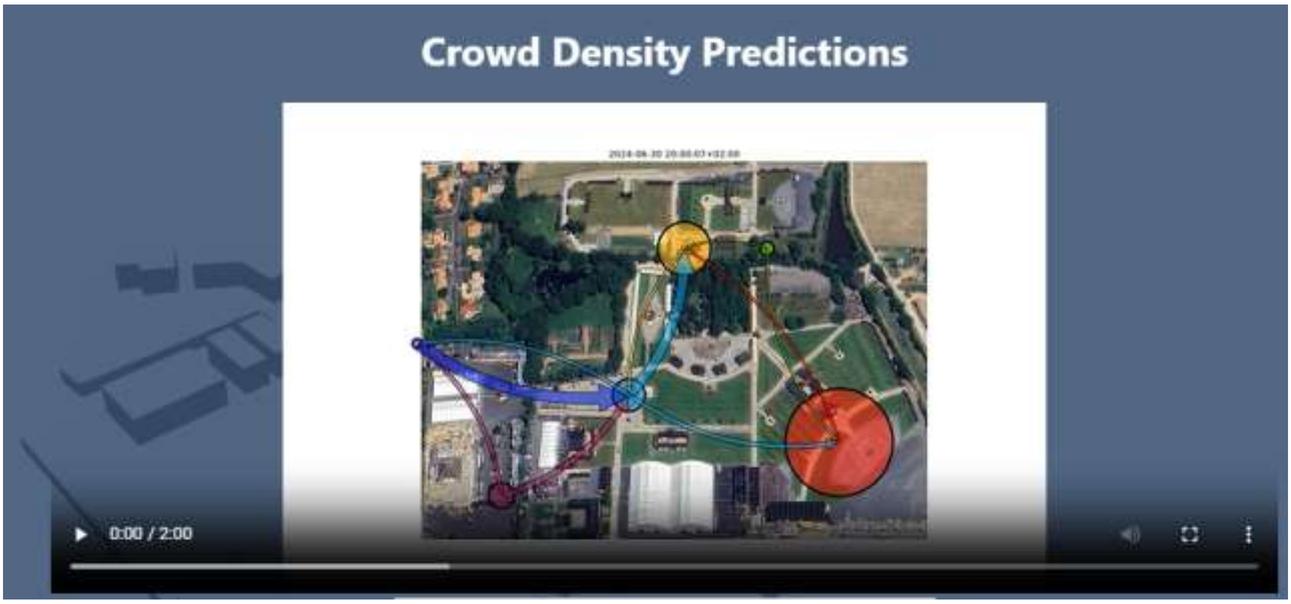


Figure 21 - A route visualisation that could be used to display density prediction and route prediction/generation

4.3.9. Individual Velocity Analysis

The work from D3.1 on analysing crowd motions can be used to show how crowds are moving. The processing of individual velocities can be used to analyse deviations to the average velocity of people in the footage (see Figure below).

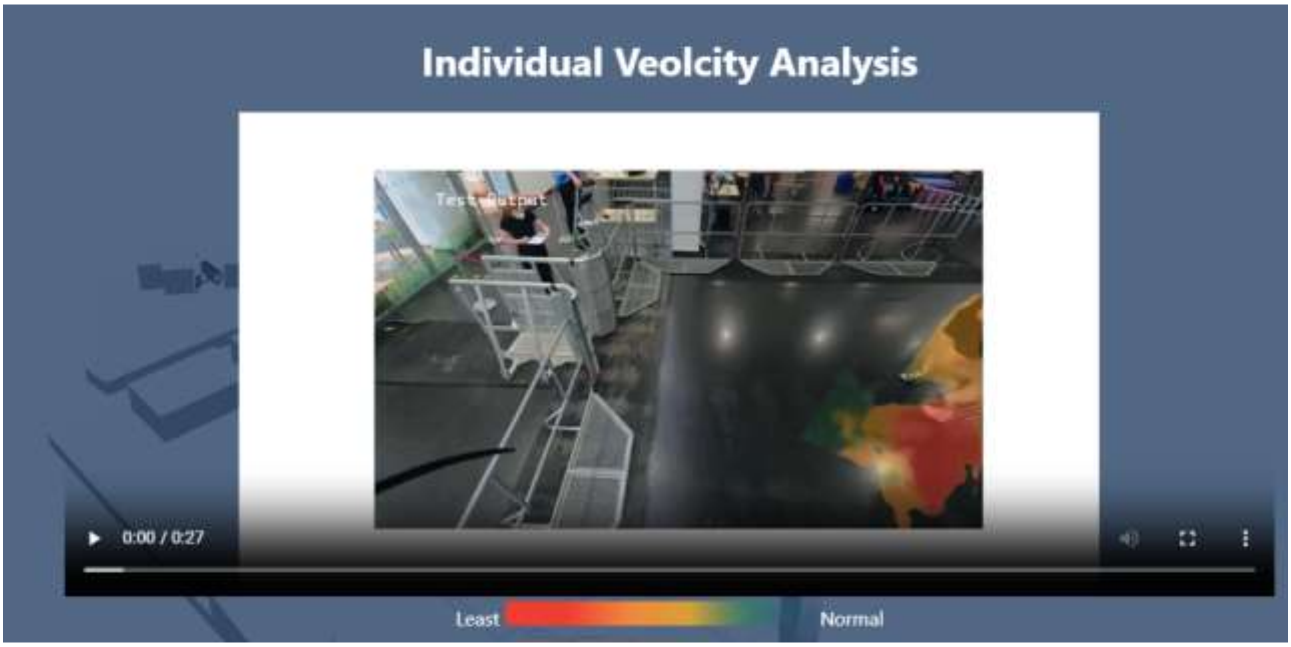


Figure 22 - Individual Velocity Analysis Display

We assume that people's speeds are normally distributed. This means that most individuals will move at a speed near the mean speed, with fewer people moving significantly faster or slower. We estimate the mean and variation in these speeds by running a crowd simulation in an open space without obstacles and measuring the speeds of the individuals.

The Probability Density Function (PDF) gives us a measure of how densely packed the probability is around each speed value. It does not give us the exact probability of observing a specific speed (since the probability of a single value in a continuous distribution is technically zero), but it allows us to compare how likely or typical one speed is relative to others.

We can normalize the PDF values so that they range from 0 to 1, where 1 corresponds to the highest density (i.e., the speed most likely to be observed), and values close to 0 correspond to speeds that are very unlikely or atypical compared to other speeds in the distribution (see Figure below).

Figure 23 - Scale of Individual Velocity Analysis

Looking at these velocities irregularities on areas such a gates and pinch points operators can review and look at if the way people are entering these areas is acceptable and what changes could be made before the next day or next time the event is run.

This analysis can also be applied to the live camera footage, allowing the operator to look for changes to individuals velocities occurring at specific camera (see Figure below).

Figure 24 - Individual Velocity Analysis applied to live footage.

4.4. Training & Synthetic Data

One of the goals of WP1, WP2 and WP3 of this project were to create data from real world experiments on crowds, or to create synthetic data for the training of crowd models. This type of data is very important for the crowd management system in order to perform crowd simulations.

Crowd simulations can be conducted either based on available data or creating "what if" scenarios. The operator can input different parameters such as crowd demands, movements around the event and to test what happens with different routing patterns. Existing crowd simulations can be used for this purpose. This has not been implemented in the mock up as it is a complicated user interface that would need integrating into the system and leveraging the existing technology.

The crowd simulation data could also be used to generate synthetic crowd data visuals as per the CrowdDNA research in WP2. This synthetic data would allow the camera footage to be replaced with virtual crowds and allow for drills and simulations to be run in planning an event. The simulated footage could also train the other analysis for specific camera angles on site leading to better calibration of results if no existing footage is available (see Figure below).

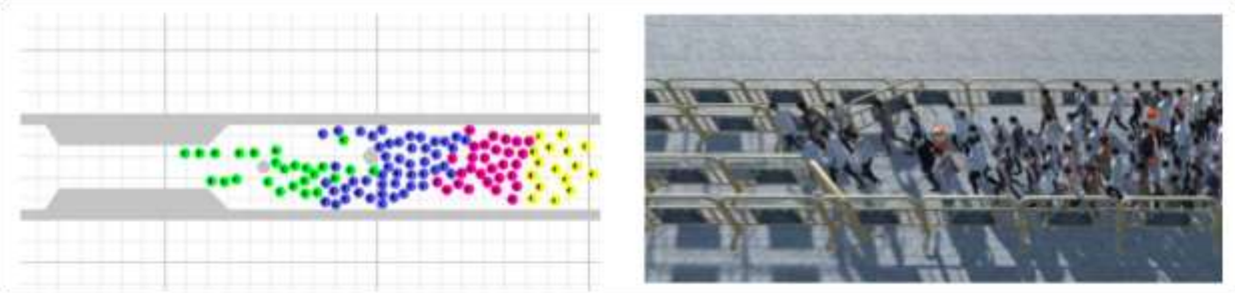


Figure 25 - Example of Synthetic Data From WP2

5. Concluding Remarks

This document has provided a system specification and design from a practitioner point of view – that of a crowd manager who would benefit from the future advancement of CrowdDNA technologies.

The specification focuses only on more innovative aspects from the crowd management point of view. The specification could be easily expanded to identify more standard functionality that would enable a system to be fully developed. Aspects such as user login, database management, hosting, etc. are standard implementations that would need to be developed alongside the more advanced functionality proposed in this report.

Some technologies such as IoT sensing for crowds is currently being put into practice, the more advanced research that has been conducted in CrowdDNA is difficult for practitioners to understand and appreciate the potential use in their everyday lives. To bridge this gap, a mock-up of the system design has been developed from this specification which it is hoped will bring academic research and industry closer with a better understanding of how to further develop the tools into a practical system for crowd management.