Human factors requirements in the design of CCTV systems

Contents

1. Introduction

This document presents requirements aimed at facilitating ergonomic good practice in the specification, design, installation and operation of Closed Circuit Television (CCTV) systems. The purpose of these requirements is to ensure that user needs, and abilities, are considered throughout the specification, design and operation of these systems.

The requirements addressed include those associated with CCTV work organisation, CCTV interface design and CCTV equipment design. The standard includes process charts which may be found helpful in assessing CCTV workloads and arranging the optimal grouping of multiple CCTV images.

2. Scope

This standard presents human factor requirements for the specification, design, installation and operation of CCTV systems. The standard is intended to be used by a wide range of individuals including project managers, CCTV technicians, installers, control centre managers, human factor engineers and operators.

The topics covered by this standard include ergonomic requirements associated with the design of CCTV hardware, human system interface design, workload estimation, task design and organisational issues involved in operating of these systems.

The standard is applicable to all types of CCTV installation including those used in the process industries, security & surveillance, road transportation, rail, aviation and in medical applications.

Normative references

1	ISO 11064	The Ergonomic Design of Control Centres	Part 3: Control room Part 4: Workstation layout and dimensions Part 5: Displays and controls
2	ISO 9241	Ergonomics of human system interaction	
4	ISO 9355-2	Ergonomic requirements for the design of displays and control actuators	Part 2: Displays
5	ISO EN 50132-7	Alarm systems – CCTV surveillance systems for use in security applications.	Part 7: application guidelines

Abbreviations

CCTV	Closed Circuit Television	
DoF	Depth of Field	
FoV	Field of View	
HF	Human Factors	used interchangeably with ‘ergonomics’ in this document
KPI	Key Performance Indicator	
PTZ	Pan Tilt & Zoom	

3. Definitions

Area

Geographical area, structure or both to be observed

Brightness

Attribute of visual sensation according to which an area appears to emit more or less light (ISO 9241-302:2008).

Closed Circuit Television System (CCTV)

A television transmission system in which live, or prerecorded signals, are sent over a closed loop to a finite and predetermined group of receivers.

Codec

The codec describes the encoding and decoding of video data streams.

Control

Device that directly responds to an action of the operator, e.g. by the operator applying pressure (ISO 11064-5).

Control room

Core functional entity, and its associated physical structure, where control room operators are stationed to carry out centralised control, monitoring and administrative responsibilities (ISO 11064-3).

Control room operator

Individual whose primary duties relate to the conduct of monitoring and control functions, either on their own or in conjunction with other personnel both within the control room or outside (ISO 11064-5).

Control workstation

Single or multiple working position, including all equipment such as computers and communication terminals and furniture, at which control and monitoring functions are conducted (ISO 11064).

Critical detail

Detail distinguished by the average (corrected) human eye; equal to 1 minute of arc (i.e. detail of 1 mm, just visible at 3.4 m viewing distance).

ALTERNATIVE DEFINITION

Essential feature(s) which need to be discernable in a target presented by a CCTV system.

> *NOTE 1 – e.g. for checking motorways for debris the critical detail would be defined in relation to the smallest size of debris which should be reliably picked out.*
>
> *NOTE 2 – e.g. for checking the Passenger Train Interface (PTI) the critical detail would be the ability to discern a gap between passengers and the side of the train.*
>
> *NOTE 3 – e. g the minimum requirement for surveillance of a crowd might be a recognizable view of the face.*

Depth of field (Doff)

Range of visual focus of images from the distance at which all images are in focus (ISO 9241-302).

Display

Device for presenting information that can change with the aim of making things visible, audible or discriminable by tactile or proprioceptive perception (ISO 11064-3).

Display, visual

Visual display (in the sense of format) providing visual presentation of data, mappings or videos (NEN-EN-ISO 11064-5).

Field of view (FOV)

- Related to the human operator: angular region subtending the active area of a display as observed from the viewing direction or other eye position (ISO 9241-302).
- Related to cameras: the area of a scene, observed by a camera and lens combination and measured both horizontally and vertically, that can be seen through the camera.

f-number

The lens aperture, indicated by f-number or f/.. determines the amount of light on the sensor. The f-number is given by the focal length f divided by D (diameter of the effective aperture).

Frame

One of the many still images that compose a complete moving picture in film, video production, animation and related fields. (2011, APTA).

Frame rate/ frame frequency / fps

Frame rate, or frame frequency, is the measurement of how quickly a camera produces unique, consecutive images called frames. The term applies equally well to computer graphics, video cameras, film cameras and motion capture systems. Frame rate is expressed in frames per second (fps) or hertz (Hz).

Image

visual information on a monitor, recorded by a camera (also indicated as “picture”).

(NOTE – a single display screen may accommodate multiple images).

Legibility

Ability for unambiguous identification of single characters or symbols that may be presented in a non-contextual format (ISO 9241-302).

Line of sight

Line connecting the point of fixation and the centre of the pupil (ISO 9241-3).

Line of sight, normal

Inclination of the line-of-sight with respect to the horizontal plane, when the muscles assigned for the orientation of the eyes are relaxed. For design purposes, an inclination of 15° below the horizontal plane is usually assumed.

Monitor

The physical surface, on which images are displayed (also indicated as “visual display unit” or "display").

Monitoring

Activity for the purpose of detecting deviations from normal operation (by checking variables, or their course against limits, trends or the values of other variables) to enable timely and appropriate action for response (ISO 11064-5).

Pan and tilt (zoom) unit (PTZ)

A motorized unit permitting the vertical and horizontal positioning of the camera equipment. (sometimes including zoom function) (NEN-EN 50132-7).

Pixel - picture element

A single point in a graphic image.

Pixel area

Area made up by x horizontal and y vertical pixels.

Pixel pitch

Distance between corresponding points on adjacent pixels, both horizontally (*H*pitch) and vertically (*V*pitch) {ISO 9241-302}

NOTE Units: mm or angle of arc in min.

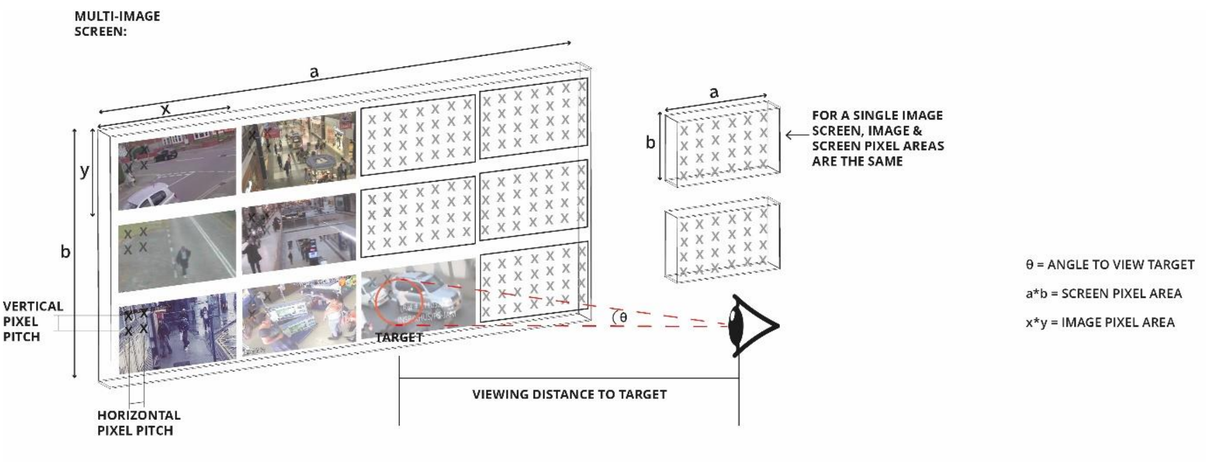


Figure 1: Definitions illustrated

Readability

Characteristics of a text presentation on a display that affect performance when groups of characters are to be easily discriminated, recognized and interpreted (ISO 9241-302).

Scan Pattern

The pattern of eye fixations, which may either be random or based on a previously agreed regime, adopted to check an image.

Scene

A scene is a logical and meaningful set of related and coherent images, and other visual information, to be monitored with a specific aim (see Appendix 1).

Shared visual display device

On-workstation visual display which needs to be used by more than one control room operator while they are at their control workstations (ISO 11064-3).

Situational analysis

Task analysis in an existing situation to analyse all the behavioural aspects of the work system, such as revealing practical experiences, informal communication, expectations and complaints of current users and any other facts that might be useful for redesign purposes (ISO 11064 – 1).

Spot monitor

A monitor, on the workstation, used for detailed search and interrogation of images.

Target

A person, object or event that the operator is required to observe or detect via the CCTV system.

Target Presentation (or Target Features)

Specific features of a target, present on a CCTV image, which would result in those features being visible to 95% of the population when viewed normally.

Target Acquisition performance

The required performance level, measured in percentage of targets successfully seen, of a searched for, and predefined target, by a CCTV operator.

Task

Human activities required to achieve a goal (ISO 11064-5).

Task analysis

Analytical process employed to determine the specific behaviours required of people when operating equipment or doing work (ISO 9241-5; 1998).

Visual angle

Angle measured in minutes of arc subtended at the eye by the viewed object, such as a character or symbol (ISO 11064-4).

> NOTE: it represents an apparent size of an object based on the relationship between an object's distance from the viewer and its size (perpendicular to the viewer's line of sight). If an object of size h is at a distance d from the retina, the visual angle subtended (x) is equal to arctan (h/d).

Visual field, field of vision

Physical space visible to an eye in a given position (ISO 11064-4).

NOTE: separate, distinct stimuli in the visual field will be detected even if they appear simultaneously. While the extent of the visual field is approximately 35° to both sides (left and right, total of 70°), only 1 - 2° of these are for sharp vision.

4. General Principles

Principle 1: Integrate human factors in engineering practice

Human Factors (HF), also termed ergonomics, should be integrated into a project's management guidelines. HF should be accepted by all designers/engineers and to this effect the project owner should issue a statement on the commitment to HF in the project. An interdisciplinary design team, including user representatives, should be formed to oversee and influence all phases of the design project.

Principle 2: Improve design through iteration

Design processes are inherently iterative. Iteration shall be repeated until the interactions between operators and designed objects achieve their functional requirements and objectives.

Principle 3: Conduct a situation analysis and a functional analysis

For any ergonomic design activity, an analysis of an existing or similar situation (see section 5.1 & 5.2) is recommended, in order to better understand the operator tasks.

Principle 4: Conduct task analysis

The tasks delegated to individual operators, and to other significant users of the control centre, shall be fully understood (see ISO 6385). The analysis shall consider all modes of system operation including start-up, normal operation, shut-down, anticipated emergency scenarios, periods of partial shut-down for maintenance and the results used in the design process and the development of staffing plans. (see sections 5.3 & 5.4)

Principle 5: Design error-tolerant systems

Human error cannot be totally eliminated. It is therefore necessary to strive for error-tolerant design.

Principle 6: Document ergonomic design basis

The ergonomic design basis for the project should be documented, for example fundamental reasoning or significant task analysis findings.

5. CCTV Task Analysis

5.1 Functional analysis

For a new system estimates of operator workloads, and the likely number of operators, should be carried out including the following tasks:

1. describe the objects to be observed via CCTV by their visual characteristics, see 6.3 .
2. list the number of (field) locations to be observed.
3. list likely key system variables (e.g. regulation of traffic flows, responding to alarms, significant changes during 24 hour operations).
4. list probable CCTV tasks – monitoring, detection, etc - associated with CCTV-based actions.
5. list other available, and relevant, process information (other than CCTV-images).
6. determine operator workload indicators (reference Appendix 5).

For an existing CCTV control room a general overview should be undertaken - this is likely to include the following tasks:

1. room layout, location of workstations.
2. number and size of screens – on and off workstations.
3. Image processing for presentation on displays, such as cropping or resizing.
4. the types of CCTV images being observed and the number of locations.
5. CCTV task(s), such as supervision, surveillance, process control and inspection.
6. non-CCTV related operator tasks such as using radios and answering telephone calls.
7. review of "field tasks" such as conducting site patrols.
8. a description of the objects the operator needs to see (observe/recognize/identify) in terms of their visual characteristics (shape, contrast, colour, specific details).
9. Sources of non-CCTV information, providing redundant an element of redundancy, and actions arising.

5.2 Task Analysis

A formal, documented analysis should be made of all the target objects to be detected via the CCTV system and their associated performance objectives.

An inventory of scenes (reference Appendix 1) shall be made for existing, or proposed, CCTV schemes.

The analysis of workloads should identify whether the CCTV tasks are triggered by an alarm or by general scanning which is interrupted when an actionable event takes place.

Type 1 task - ***No trigger***.
This is where there is no attention-getting signal, the predominant task is **monitoring** images for unusual or pre-specified events. The operator scans images until such an event takes place. This is the typical pattern for surveillance tasks, as indicated in the process: observe - detect - recognize - identify.

Type 2 task - ***Trigger***.
In this situation the operator starts a CCTV task upon receiving a trigger (notification) signal. CCTV tasks start either with detection, recognition or identification, depending on the information of the trigger signal.

Conduct an analysis of the types of trigger and their associated actions (a process for this is presented in Appendix 2).

5.3 Job Design

The job description for a CCTV operator should be fully spelt-out and documented.

To reduce the onset of boredom and fatigue associated with low intensity general surveillance tasks the rotation of staff should be considered.

> NOTE: an extra mental task, providing extra stimulation, has been shown to be a useful means of preventing detection failures in general surveillance tasks, with the proviso that the job is designed to ensure that task conflicts cannot arise.

Measures should be taken to minimise lapses of attention for operators required to perform the same repetitive, monotonous task many times.

The design of CCTV tasks should take care to ensure that any secondary task does not make visual demands on the operator and can be stopped immediately.

Attention grabbing can be maximised when usually blank screens are automatically tripped on by an alarm.

An overall workload of 75% of working time should be aimed for, the remaining time being available for personal care, social contacts, rest, etc.

> NOTE – the level of workload that is planned needs to take account of such factors as:
>
> - Operational predictability – i.e. how much activity is regularly paced and predictable
> - Operational variability (i.e. how / when / for how long does activity peak or trough)
> - Performance criticality (i.e. what are consequences of error)

- Number of potentially competing functions / tasks or input / output channels and interfaces
- Likely levels of task conflict (i.e. number of potentially coincident activities)
- Time required for recovery from workload peaks
- What capacity is required to deal with incidents / emergencies
- Required capacity for personal care / social contact, etc.

A peak load of 100% of working time can be maintained over a certain limited periods of time, such as for handling emergencies.

Low intensity monitoring may be reliably carried out continuously for up to three hours: a cumulative total of six hours per day is the maximum.

High intensity/continuous monitoring can be undertaken for a maximum of 20 - 30 minutes with 5-minute rest breaks in between.

NOTE 1: after this period, operator attention tends to decrease significantly with a consequent increase in errors and loss of performance.

NOTE 2: CCTV tasks should typically be broken down into many relatively short blocks separated by short rest breaks. Tasks requiring focused attention (such as critical surveillance duties) should be of particularly brief duration if operators are to maintain a high level of reliability.

NOTE 3: CCTV tasks requiring high levels of concentration (detailed search, safety critical tasks), will be performed most reliably as dedicated activities without any distractions from secondary tasks.

Where constant monitoring is required (e.g. incident management) this should be managed with contingency staffing or by careful control room and workstation layout.

Short rest breaks should be taken away from the CCTV monitors and should not involve other monitor based activities (email, gaming).

Non-display based tasks (telephone, paper work, verbal communication etc.), at the workstation, may provide and effective respite from CCTV monitoring

The nature and safety criticality of the task should inform both the frequency and duration of rest breaks.

Tasks design should afford operators sufficient time to be able look away from their monitors for short periods during operation, in addition to the longer 5 minute rest breaks, without affecting performance.

NOTE 1: for viewing x-ray images in baggage screening, it is suggested that perhaps every 5-10 minutes the eyes should be momentarily rested by looking away from the screen to greater distance.

NOTE 2: undertaking any non-VDU based tasks or activities (telephone or radio operation, filling in paper logs, verbal communication etc.) at the workstation or simply moving to a different job or workstation not involving VDU based activity can be considered to provide effective rest.

Operators should be trained to recognise the onset and effects of fatigue in order that they can take steps to alleviate it.

NOTE 1: for rest breaks to be effective they must be taken before the onset of fatigue.

NOTE 2: fatigue is characterised by slow thinking, reduced alertness and task performance, forgetfulness, lethargy, poor decision making and communications and increased reaction times. It can be mitigated by:

- Task design that considers avoidance of extreme mental and physical exertion
- Work that combines stimulation and enjoyment, balancing effort and rest
- Control and responsibility over task performance and clarity in task specification
- Matching individuals to tasks and job through careful training and selection
- Ensuring adequate staffing levels
- Careful design of shift patterns
- Providing performance reviews and feedback

Fatigue should be managed by allowing staff to walk about freely when needed.

The use of intelligent detection systems - in association with CCTV systems - to replace continuous human monitoring should be carefully considered in the context of the other jobs which the operator is required to undertake.

NOTE 1: Making certain processes automatic can help to reduce the burden on operators but it is important that operators can override these to deal with more unusual operating conditions.

NOTE 2: the workload of operators may not be reduced by automated detection systems if systems are unreliable or generate an unacceptable level of false positive, or false negative, alarms.

NOTE 3: the appropriate responses required by operators, when dealing with activities arising from automated responses, will require to be included in any job descriptions.

Goals and targets for control room employees, and the introduction of key performance indicators (KPI's), should be in line with the organisational goals and also form part of the appraisal system.

NOTE 1 – individual employees will have less control over goal attainment when performance targets are group-based.

NOTE 2 - Individually-based KPIs have the potential to raise individual performance to the detriment of team performance, especially if linked to remuneration.

6. CCTV Interface design

The following requirements address the setting up of images on screens, navigation, target sizes, picture stability and on-screen information.

6.1 Number of images in a pixel area

The appropriate numbers of images, that a single operator can be asked to observe, should be based on a task analysis which will include an assessment of performance requirements and workloads.

NOTE 1: human factor limitations are a major consideration in determining image numbers with constraints imposed by foveal and peripheral vision.

NOTE 2: in an image searching task, such as following a suspect person around a public space, an operator can only effectively concentrate on one image at a time.

NOTE 3: the more images that are presented on a given pixel area size, the smaller targets become and the less resolution they have.

NOTE: research shows a significant reduction in detection rates when increased numbers of CCTV monitors are viewed, fig 2. This result is deemed indicative for the pixel area approach (instead of monitors), though research is not yet available.

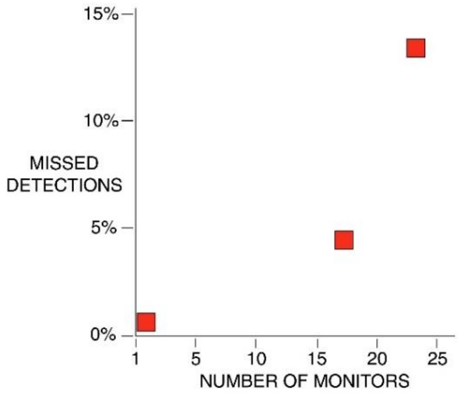


Figure 2: missed detections v monitor numbers

Where pictures display *considerable movement*, and the task primarily involves general surveillance, no more than 12 simultaneously displayed pictures should be observed by an individual (e.g. busy airport departure lounge).

Where pictures display *little movement*, and the task consists essentially of general surveillance, no more than 16 simultaneously displayed pictures should be observed by an individual (e.g. general observation of building interiors or premises out of working hours).

> NOTE: These recommendations are very general in nature; careful consideration of task and operational performance requirements and workloads will be necessary in order to determine the maximum number of monitors that operators can reliably handle for specific applications (Appendix 5).

6.2 Interface navigation aids

Mapping the CCTV image arrangement to the actual geographic layout of cameras (where relevant or possible) will support spatial understanding and aid navigation and performance.

> NOTE: for example, a set of images covering a sequence, or line of cameras (such as a length or platform or sequence of cameras on a motorway safety lane) may best be presented to the operator as a horizontal series of images on a single screen or series of screens (appendix 3).

For arrays of multiple pictures, a consistent, stable arrangement of images should be sought.

> NOTE. This aids operator identification and saves time under emergency conditions.

It should be possible to select cameras directly, for example by touching icons using a pointing device, on a schematic CCTV layout map.

Images from cameras that have restricted or limited fields of view should include an indication of these to the operator on the actual CCTV display.

Where spot monitors are used, the system interface should include a simple, single action control that allows any image to be passed quickly and reliably to the spot monitor.

6.3 Target Presentation

The appropriate presentation of targets should consider the necessary number of pixels on target, the size of target, displacement from normal line of sight, target acquisition requirements and viewing distances.

For non-transient targets, without supplementary cueing, the following steps are recommended.

Step 1 – general description of the tasks to be undertaken via the CCTV system.

> NOTE – for example 'identify an occupied wheelchair on a level crossing', 'detect debris on carriageway', 'recognize passengers trapped in train doors', 'monitor traffic flows'.

Step 2 – for each CCTV task, specify the critical visual elements associated with the task.

> NOTE – examples of levels of detail are presented in the table below:

	LEVELS OF DETAIL		
TARGET	**general**	**'specific'**	**detail**
car	overall shape	make of car	distinguishing marks such as damage
bus passenger	occupancy of seats	male or female	recognition level
prisoner	presence of individual	features of clothing	recognition level
number plate	existence of number plate	indication of the number of characters	all information legible

	LEVELS OF DETAIL		
TARGET	**general**	**‘specific’**	**detail**
traffic flows	normal versus abnormal flows – no detail	-	-
debris	-	-	all debris greater than X x Y

Step 3 – determine the minimum number of pixels over the target area to reliably achieve target acquisition at the reference viewing distance.

(NOTE – the following examples are typical pixel count numbers).

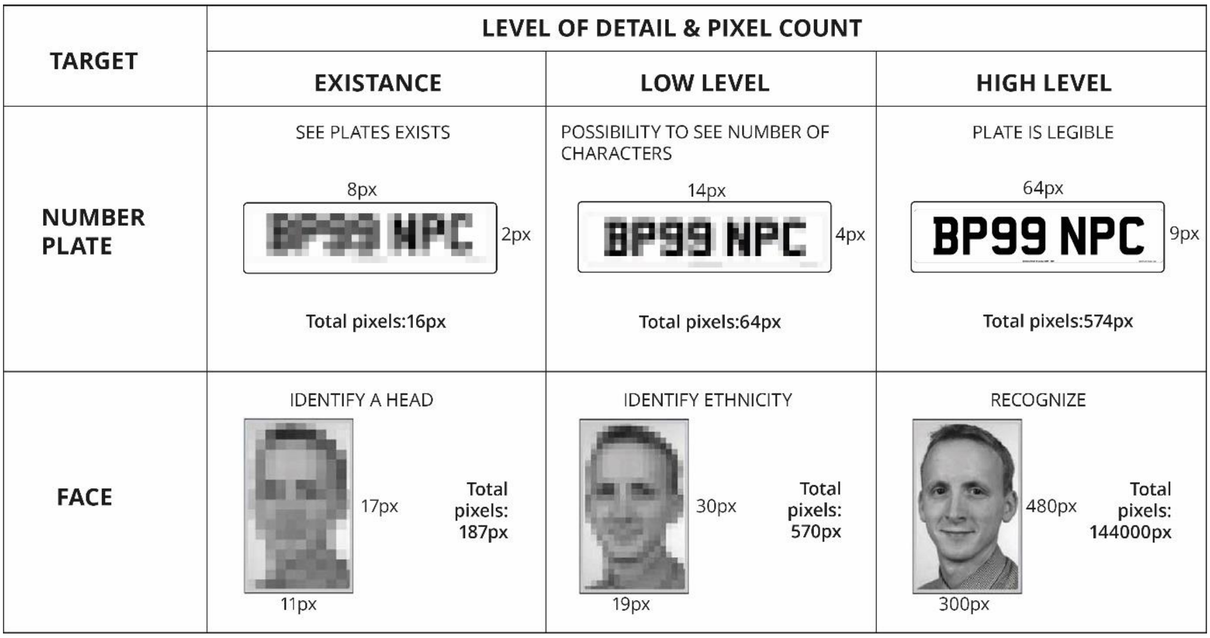


Figure 3: Pixel counts and image resolution

Step 4 –Adjust image presentation to take account for the following factors:

- Image resolution

- Viewing distance
- Contrast
- Transience of target[2]

Figure 4: CCTV performance nomogram (from LUL passenger train interface nomogram)

6.4 Picture stability

Images should not show instability when seen in peripheral vision.

NOTE: peripheral vision is more sensitive to movement and change.

Autocycling should be avoided, e.g. only be used where it has been shown, through a task analysis, to be helpful to the operator.

NOTE 1 – where not required, autocycling can present a serious distraction due to the eye's sensitivity to peripheral movement.

NOTE 2 – autocycling, for example, may be helpful to motorway operators where large numbers of cameras are need to be checked for general flows of traffic.

6.5 On-screen information

Characters superimposed on a screen should be sharply focussed and stable.

The location of specific types of information on the screen (such as camera identification, geographic location or date and time stamp) should be standardised to help to reduce search time and error, fig XX.

NOTE: this may shorten the time taken to learn locations and reduce confusion and errors associated with mistaken camera identity.

[2] with human abilities to focus fully on only one area of the visual field at a time, the probabilities of detection will be degraded with increasing numbers of screens as well as with a reduction in presentation time.

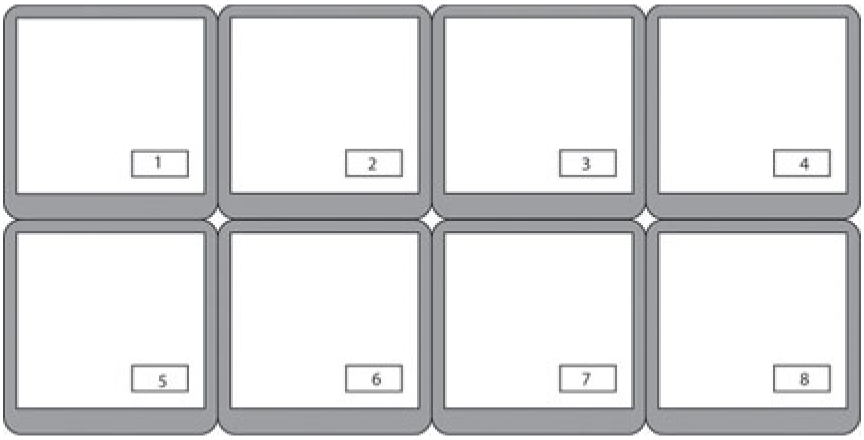


Figure 5: Consistent location for on-screen information

Overlaid information should not obscure any important task-related features of the underlying CCTV image.

The brightness contrast between the text and the background should be at least 3:1.

> NOTE: the most appropriate direction of contrast, i.e. positive (dark characters on a light background) or negative (light characters on a dark background) should be considered in relation to the content of the CCTV images forming the background.

6.6 Image viewing distances

Off-workstation, overview displays can be used to provide an additional pixel area for the presentation of images which need to be simultaneously monitored.

Target sizes should be adjusted to subtend the same visual angle at the operator's eye.

6.7 Grouping of Images

Where multiple CCTV images are viewed, either in parallel or sequentially, they should be organised in accordance with the task being undertaken.

> NOTE: this will help operators to scan and evaluate images more effectively and will also help cue an operator to view images systematically rather than promoting random monitoring which is de-motivating and less effective.

The arrangement of multiple images, either in parallel or sequentially, on pixel areas should be consistent.

NOTE 1: Consistency in the location of images on a pixel area can be used as a means of inducing a systematic approach to sampling.

NOTE 2: “cueing” appropriate operator responses can also be assisted by the use of a stable layout of pictures on a pixel area with multiple images.

The physical arrangement of simultaneously presented images should reflect any underlying relationships between the camera views.

NOTE – these underlying relationships may relate to the geographic location of cameras or the plan layout of a complex building.

Where images present moving objects (process control or traffic management), images should be arranged to emphasize any natural flow over consecutive images

NOTE 1: Figure 6 shows an example of a pixel area, without a logical structuring of 3 groups (a, b, and c) of images.

NOTE 2: figure 7 shows two alternative for structuring of images that may assist in an easy identification of clustered information.

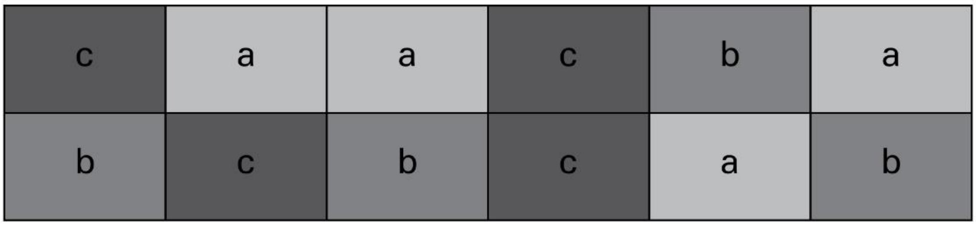


Figure 6: Three groups (a, b, and c) of related images without a logical presentation structure

Figure 7: Examples of logical image clustering

6.8 Input devices

The following requirements relate to input devices associated with the operation of CCTV systems.

CCTV control panels should accommodate both right and left-handed users.

CCTV system controls should be positioned within easy reach and designed so that any requirement for operators to divert their gaze away from the CCTV images is minimised.

Control buttons should be large, and adequately separated, to avoid inadvertent operation.

All labelling on input devices should be clear and unambiguous and be of sufficient size and contrast to suit the full range of anticipated ambient light levels.

The grouping of controls and displays should be both functional and logical to support ease of operation.

Suitable and sufficient support should be provided for the hand, wrist and / or arm appropriate to the workplace and the frequency of usage of the controls.

The selection of the most appropriate input device should be based on a task analysis of the most likely control activities associated with the CCTV system.

> NOTE 1: Users typically prefer joysticks for controlling camera movement
>
> NOTE 2: A mouse tends to be preferred for selecting cameras from a screen based map or GUI)
>
> NOTE 3: Tracker balls tend to be more effective than either a joystick or mouse when system interfaces, and PTZ camera control functions, need to be combined into one device.

As a general rule, reduce the number of input devices on the desk to the use of one keyboard and one pointing device for a single pixel area.

7. Equipment layout

The following sections identify requirements for the design of workstations and the layout of equipment on them. Detailed guidance relating to the layout of workstations in control rooms, are presented in the control room, office and furniture standards (reference 1, 2 & 3)

The user population of the workplace shall be determined and the relevant, associated anthropometric data applied.

> NOTE 1: the anthropometric data of all potential users during the entire lifetime of the workplace needs to be considered.

The layout of the workstations should take full account of the requirements associated with the following critical ergonomic features:

- vertical, horizontal and lateral clearance for the legs, knees and feet under the work surface.
- work surfaces at or slightly below elbow height
- instruments and displays located in appropriate visual zones - see following sections.

Adjustability of desktop heights for sitting and standing postures is preferred with the following factors taken into account:

– the variety of tasks undertaken (e.g. screen viewing, writing, keyboard use)
– that any adjustments shall be easy to use.
– the range of adjustment should be based on the 5^{th}-95^{th} percentile of the user population.

Controls should be located within normal reach of the seated operator and the following considerations applied:

– input devices should be freely moveable over the work surface in front of the displays.

– emergency stop buttons may require separate consideration related to their rapid access and operation

7.1 Visual zones

This section addresses requirements relating to visual zones and the location of primary and secondary displays. It is assumed that the operator is in a 'reclined' seating posture (ref: 11064 - 4), with a normal line-of-sight SN, in the vertical plane of approx. 15 degrees below the horizontal and that the position of eyes is approx. 150 mm behind the edge of desktop.

NOTE: for standing postures the geometric considerations will remain similar.

The following sections refer to figure 8 where:

I. zone A does not require eye movement (recommended, to be used whenever possible)
II. zone B requires eye movement (acceptable, may be used if area A cannot be used)
III. zone C requires head and/or body movement (should not be used for primary equipment)
IV. S: Line of sight, direction is imposed by external task requirements
V. SN: Normal line of sight, 15° below the horizontal

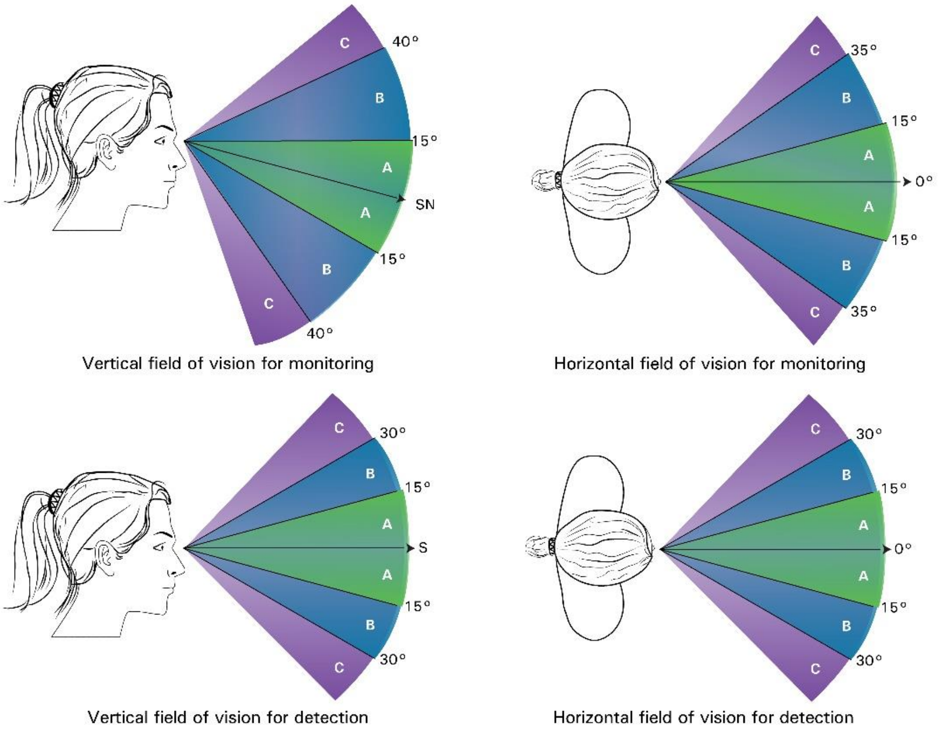


Figure 8: Field of vision (reference: ISO 9355-2)

Sources of primary information (frequent use) shall be located

- within the area A+B
- in the vertical plane vertical plane= between 40̂ above and below SN
- in the horizontal plane approximately 35̂ left and right of 0̂ line.

Sources of secondary information may be located:

- in the horizontal plane - up to 80̂ to the left and right of SN
- in the vertical plane: an angle of up to 30° above the horizontal can be used for secondary information display.

NOTE - the zones for ‘detection’ are smaller than those for ‘monitoring’.

The location, position and range of adjustability of monitors should take account of the constraints imposed by corrective lenses, which may have an impact on visual fields, focusing distances and requirements for head movement.

NOTE: operators using multi-focal glasses may suffer from focussing problems unless their needs are accounted for by design of monitor position and adjustability.

7.2 Viewing distances, pixels and shared displays

The operator should not be able to see individual pixels on a monitor.

The minimum viewing distance should never be less than 500 mm.

Displays at the workplace shall be specified as the total pixel area needed with the maximum size of a pixel area being determined by the maximum angle of view.

NOTE: the method of calculation of the maximum size of the pixel area is presented in appendix 5.

Shared, large off-workstation pixel areas should only be used:

- Where a group of users frequently refers to information of common interest and are required to interact as a team.
- Where team members move about but still need to refer to information
- When it is desirable to have general information available for visitors
- If alternate use of a shared pixel area and workplace monitors has a frequency less than 30 x / minute.

Where images include a considerable amount of movement the pixel area should be located at a viewing distance > 2 m.

8. Field equipment

The performance of field equipment may have ergonomic consequences. The following requirements, relating to camera lenses and degraded images, enables these negative effects to be understood, removed or mitigated.

8.1 CCTV system features

System goals should be identified, whether for an existing or proposed new system, and correlated with operator tasks which can then be optimized from a human factors perspective.

The physical area covered by CCTV shall be specified including a consideration of the following -

– objects to be observed.

- the number of cameras in use, including camera locations;
- information on camera location, such as height and camera-object distances.
- camera lens specification (angle, focal length, pan-tilt-zoom capability).

An inventory of CCTV camera characteristics should be made, including:

- camera output resolution (horizontal and vertical number of pixels);
- coding/format of stream of images; data compression (CODEC)
- data transmission including frame rate (number of images/second);
- estimate any reduction of image detail due to data compression.
- identify specific environmental conditions, such as day/night or the influence of (bad) weather conditions.

8.2 Camera lenses

Wide angle, or long focus lenses should not be used where the operator’s task(s) require good estimates of object distances. (see figure 9).

NOTE: the ability to judge distances may be severely compromised by non-standard lenses.

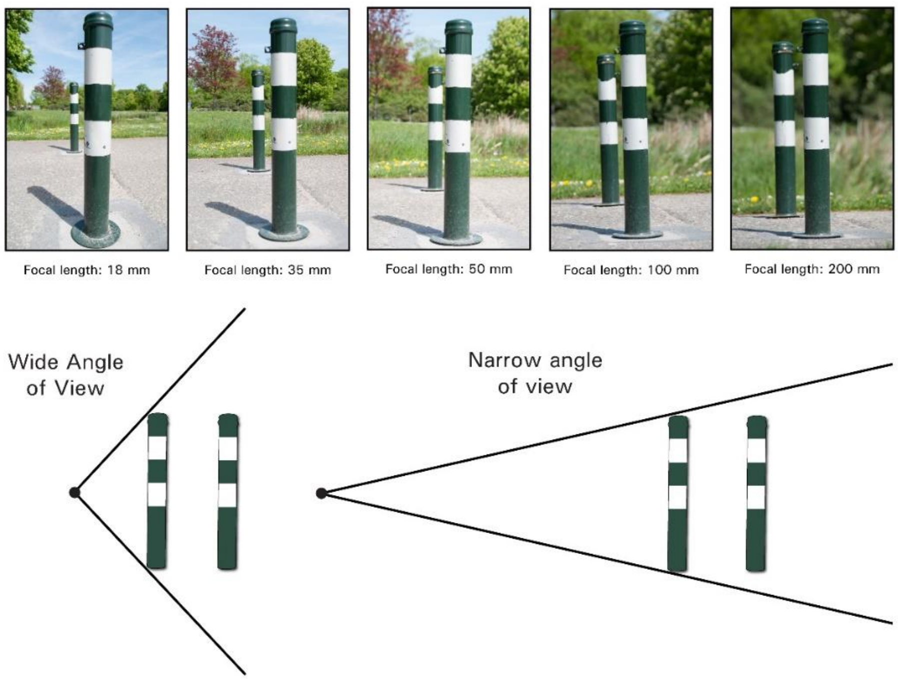


Figure 9: influence of angle of view on distance perception

8.3 Distortions

Clearly visible image distortions to CCTV images should be avoided (Fig 10).

NOTE 1: As a rule, distorted images require more mental effort.

NOTE 2: Less detail is visible near the edges of the image (see figure 11)

NOTE 3: An object moving across a wide-angle image will be subject to a continuous changes of the shape and should be avoided.

- NOTE 4: The following distortions can be seen in figure 10 due to wide angle views of a canal.

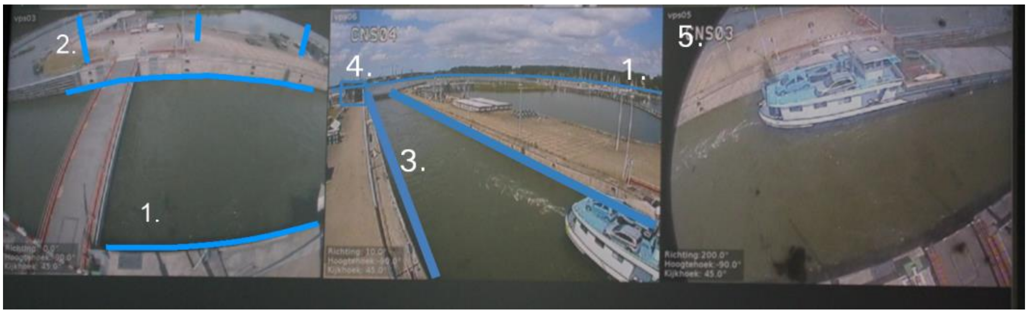


Figure 10: Several types of image distortion due to wide angle lenses

1. *Barrel distortion*
2. *Edge distortion*
3. *Converging lines (instead of parallel lines)*
4. *Relative depth (object seems to be farther away than actual distance)*
5. *Camera housing visible (left side).*

Figure 11: Barrel distortion

NOTE 4: with reference to figure 11 the number of pixels per meter of the wall to the left and the right of the middle entrance is lower than the number of pixels per meter area in the centre.

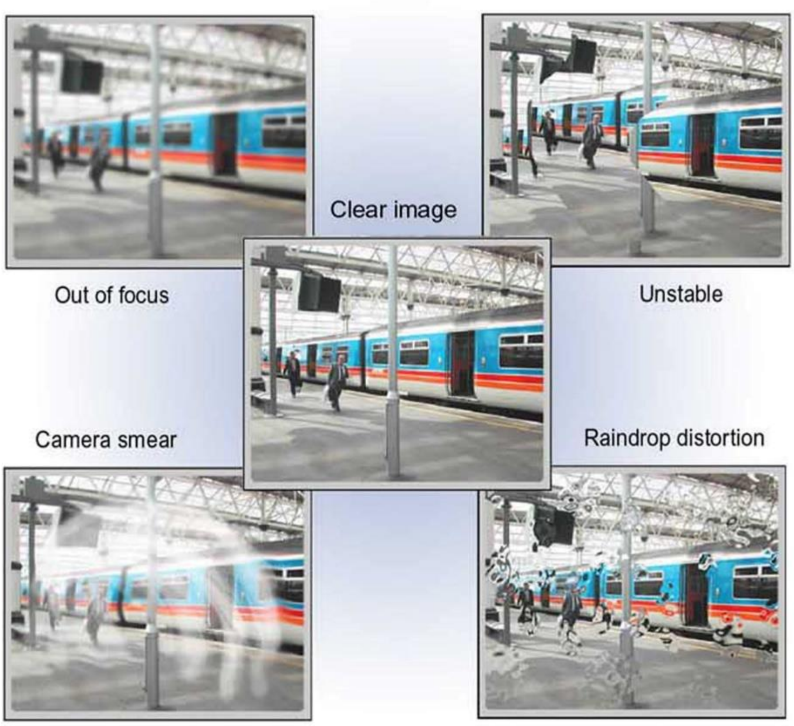
Use standard lenses, unless there are specific reasons to apply wide angle lenses.

When introducing wide angle lenses the following requirements apply:

– Check minimum resolution needed to be able to see task related objects
– Do not use wide angle lenses for objects at a short distance.
– To minimize barrel distortion, the vanishing point of the camera should be aimed at the horizon.
- Take care that the most important objects are to be found in the centre of the image (distortions are largest at the edges of the image).

8.4 Degraded Images

Whether by design, or by appropriate maintenance regimes, image degradation at source should be minimised, Fig 12.



Pixellated image

Figure 12: examples of image degradation at source

9. Organisational requirements

9.1 Competencies

The following competencies and skills are amongst those considered desirable for CCTV operators:

- competent operation of all equipment
- detailed knowledge of camera views and the camera numbering systems
- good geographical knowledge of the site(s) and premises to be monitored
- appropriate decision-making skills
- ability to assess a situation accurately
- ability to work under stress and pressure
- understanding of team goals, roles and responsibilities
- timely and accurate passing of information to colleagues and external stakeholders
- recognition of overloaded colleagues and provision of appropriate support

- forward thinking and contingency development

NOTE: CCTV monitoring staff may be tasked with other activities which are not directly related to monitoring (e.g. providing a customer information, rotating duties with ground floor security guards etc.). These might require additional skills and competencies.

9.2 Training

Appropriately designed CCTV training should be provided for operators.

NOTE: this will maximise detection rates and enable operators to cope better with distractions.

CCTV operators shall be provided with a clear and detailed understanding of their tasks, role and responsibilities including unambiguous definition of what they are expected and required to achieve with CCTV systems.

Training programmes should include protocols to follow in the event of an incident, such as how to report a target, what action to take in the event of a detection and who has what responsibilities.

NOTE 1: reporting of targets can be significantly influenced by suitable instruction.

NOTE 2: work shadowing, with experienced operators, is an effective way to pass on operational knowledge, such as activity 'hot spots', coverage anomalies, likely sources of error, etc.

With highly structured CCTV tasks the implementation of an operator scanning protocol should be considered.

NOTE - instruction in the most effective scanning procedure may help to increase detection rates. Example of scanning protocols for checking railway level crossings, motorways and the passenger-train interface for metro systems are presented in appendix XX.

Training should cover recognition of when fatigue occurs and when to change tasks or take suitable rest breaks.

NOTE – it is recognized that operator performance in CCTV monitoring can drop off dramatically over time. For baggage X-ray monitoring, where performance of 100% is demanded, operators work in periods of 20 minutes.

Benchmarking 'expected' or 'average' target detection rates over time should be used to highlight where operators do not meet expectations.

9.3 Recruitment and Selection

System designers should recognize that different groups of operators may demonstrate different strengths in relation to CCTV operation.

NOTE 1: younger operators (below the age of 30) tend to detect more incidents than those over 45, and tend to make less false detections.

NOTE 2: older adults tend to have more difficulty switching their attention than young people.

NOTE 3: older people tend to have a more mature focussed approach to a job and may be more suited to supervisory roles.

Colour vision may be important where the task requires specific detail to be considered (e.g. identifying clothing).

Depending on task requirements, operators should be tested for appropriate levels of:

- Attention Span
- Reaction Time
- Multi-tasking ability
- Memory skills
- Object tracking ability (probably only relevant when using PTZ cameras)
- Hand/Eye Co-ordination (probably only relevant when using PTZ cameras)

NOTE: high performers on vigilance assessment tasks have been found to identify up to twice as many incidents as those deemed low performers.

For tasks requiring highly focused observation and/or detailed image scanning or searching operators should be competent in:

- Scanning efficiency
- Focussed attention
- Attention to detail
- Use of peripheral vision
- Visual search techniques

Competence testing of operators should be performed using one or more of the following - simulation, real life observations, or various commercially available competency tests.

NOTE - the Surveillance and Monitoring Assessment Exercise (SAMAE) may prove to be a useful competency test, containing a scanning exercise, a dynamic attention exercise and an incident detection exercise (Donald 1999).

9.4 Health and Welfare

The design and operation of CCTV systems shall take full account of relevant, and applicable, health and safety legislation. To minimise health problems associated with CCTV work, the following additional good practice is recommended:

Prolonged fixed focussing on a single activity should be avoided.

> NOTE: fixed focussing in excess of 5 minutes would typically be considered prolonged.

Contrast between the screen and the environmental lighting should be carefully controlled.

> NOTE**:** background to screen contrast ratios in excess of 100:1 have been shown to lead to performance decrements and/or operator discomfort.

Prolonged monitor viewing should be avoided; operators should not look at CCTV monitors for extended periods without either a rest break or alternative task activity.

Where appropriate the employer should provide free eye tests and contribute to the price of spectacles if these are required.

10. Appendices

10.1 Appendix 1: Workload and number of scenes

Task time can be used as a measure for operator workload. It is easy to understand and provides a relatively good estimate. Determining the number of scenes an operator can handle can either be undertaken through a) observation or b) by calculating task times for each scene.

The flowchart presented at the end of this Appendix offers a suggested protocol for dealing with different CCTV tasks.

10.1.1 Estimate workload and number of scenes by observation

Identify operator tasks and related scenes. Observe time spent at each task, and/or interview experienced CCTV operators about each task. For type 2 tasks, that start at a trigger signal, this approach is recommended.

<u>Example 1 – Lock control</u>

For remote lock-control, 9 to 12 images provide a full picture of the situation at one lock, equivalent to one scene. Depending on experience and the amount of shipping traffic, an experienced operator can handle 2 scenes, i.e. the control of two lockage processes. (Safe control of three lockage processes (3 scenes) was observed not to be possible).

<u>Example 2 – Tunnel traffic monitoring</u>

Tunnel traffic monitoring; the operator monitors for low speeds or developing traffic queues. Each tunnel direction could be considered one scene. Practice shows that 4 scenes (for which the number of images may differ considerably depending on the local situation) can be monitored by one operator until an incident occurs. Then the operator switches to incident handling, using one scene (the incident). Another operator has to take over the remaining monitoring task.

<u>Example 3 – Railway station surveillance</u>

At the central halls of six large railway stations surveillance cameras have been mounted. One operator is able to handle only one scene (one full overview of a hall).

10.1.2 Estimate workload and number of scenes by calculation

For type 1 tasks (no trigger), where monitoring is crucial, the time span in which a target must be detected, equals the (average) time the target (event, or specific target behaviour) is visible. This may be called the *interval time*. Follow-up tasks, related to the target, that cannot be postponed require an estimate to be made of the time needed to perform this task. A check should then be carried out to see whether the interval time is long enough to scan the scene as well as complete the follow up task. Where it is found that this sequence is greater than the interval time it is likely that one operator cannot successfully complete the task.

NOTE: For a type 1 task (no trigger), where monitoring is not considered crucial, workload estimates are less useful.

Example 1; Motorway safety lane checking

The stretch of motorway has CCTV camera coverage along its length and signals on gantries for controlling the traffic. The safety lane can be used as a ‘live’ lane, and traffic diverted onto it, provided it has been previously checked as clear of obstructions.

The operator’s tasks are to check that there are no obstructions along its length before opening the safety lane for traffic.

The signals advising drivers that it is safe to use the safety lane are downstream from the stretch of road being checked.

The operator ‘opens’ a stretch of road once the it has been fully checked – this checking should be done as quickly as possible whilst maintaining minimum standards of detection.

Example 2: Bridge control

– A scene consists of several images, covering the bridge deck between barriers (at both sides of a bridge).
– After closing the barriers, there is a 5 second time span, before the bridge deck starts opening.
– The operator needs to verify whether there is any person left between the barriers. He has 5 seconds available for this check, including pressing an emergency stop button, in case of seeing somebody.

Example 3: Level crossing control

– A distant train is bearing down on a series of level crossings which it has to pass over.
– The signaler has to check each level crossing to ensure that the crossing is clear and safe for the train cross.
– The time available for this check is bracketed by the initiating alarm to the signaler of the arriving train and the very last time that the signaler can instruct the train driver to safely stop the train prior to its’ arrival at the level crossing.

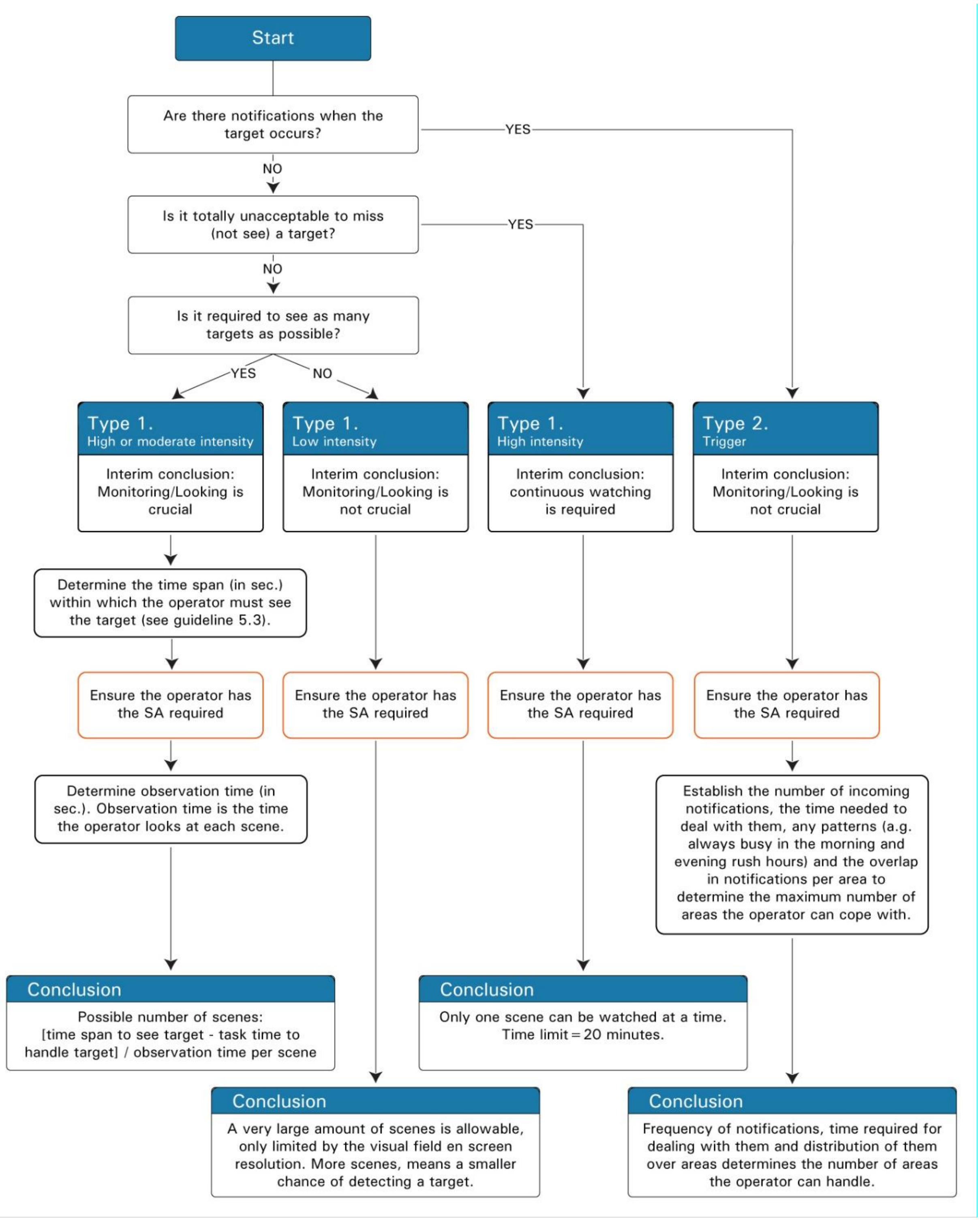


Figure 13: Process to determine workload and number of scenes per operator

10.2 Appendix 2: Process for selecting images for a 'scene'

A scene is a logical and meaningful set of related and coherent images and other visual information, to be monitored with a specific aim. A 'scene' is likely to exhibit the following features:

– the visual information is coherent

– a scene consists of one or multiple images, and may also include other types of information (such as process data).

– all images of the same task related observed reality are considered to be one scene.

A process which can be adopted for identifying 'scenes' is presented in the flowchart.

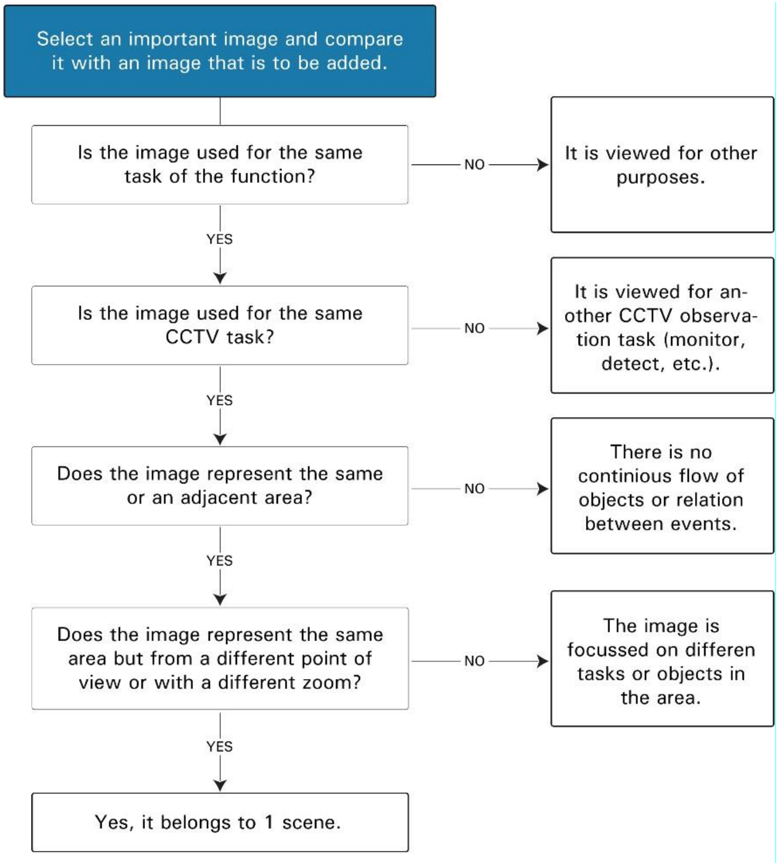


Figure 14: Process for identifying 'scenes'

10.3 Appendix 3: Types of 'trigger' and types of CCTV monitoring tasks

CCTV tasks can be categorized into four types, see flowchart below. Each type may require a different ergonomic approach relating to interface design, job design and operator training.

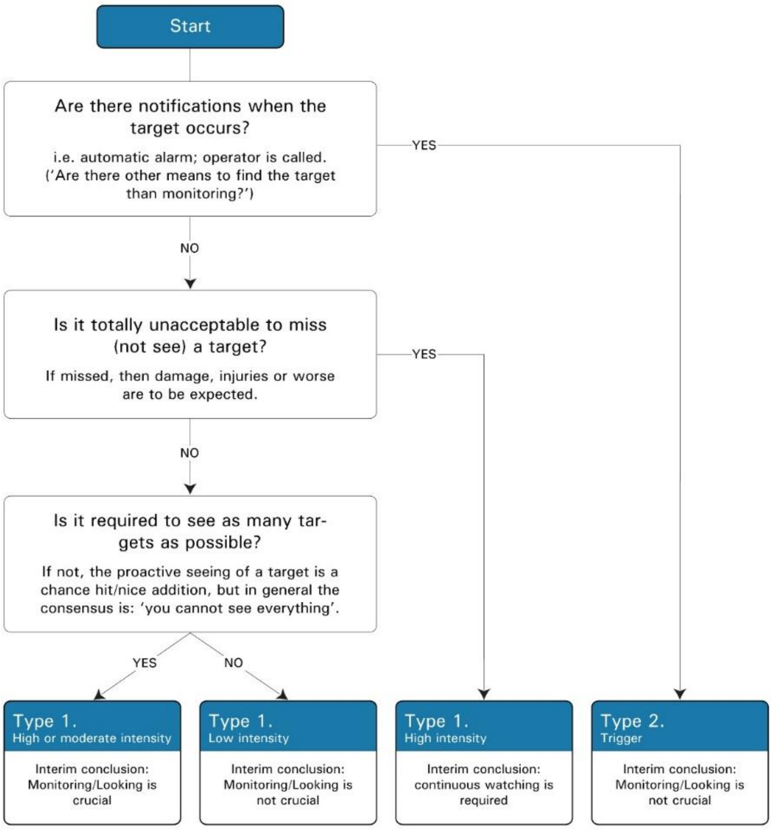


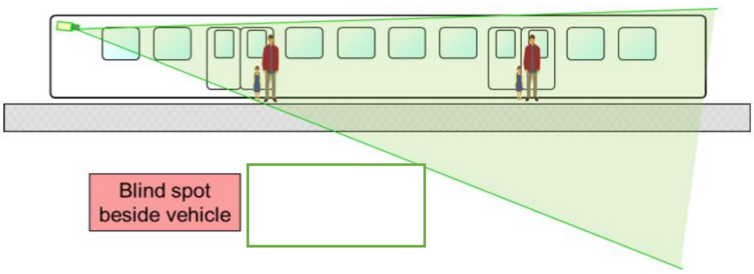
Figure 15: Determining type of CCTV image processing task

10.4 Appendix 4: Examples of CCTV image grouping and presentation

The following examples illustrate how the presentation of CCTV images can be arranged such that they support and facilitate the operators task.

<u>Example 1 – passenger train interface</u>

CCTV cameras are arranged down the length of the train and the driver has to check, using the images brought back into the driver's cab, that no passenger are trapped in the doors. The arrangement of CCTV images on the monitors reflects the order of camera on the train so that the time taken to recognize where along the length of the train the problem arises is minimised.



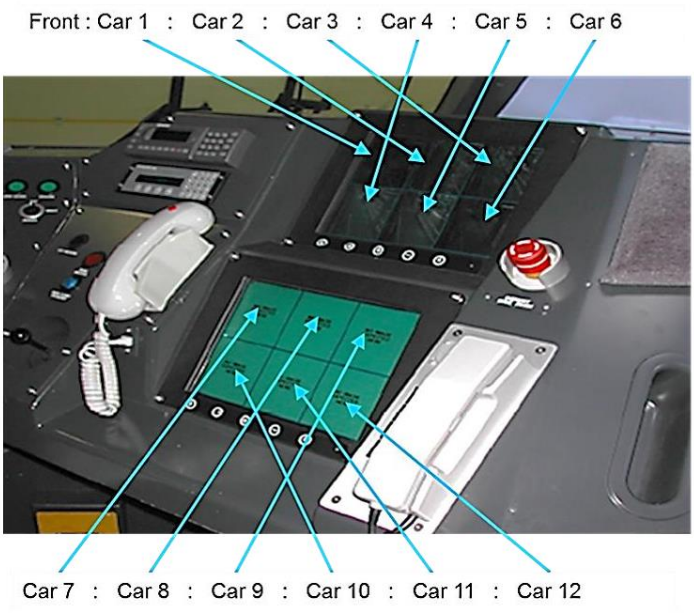


Figure 16: Train cab images ordered to correlate with driver's rearward view

<u>Example 2 – Urban traffic monitoring</u>

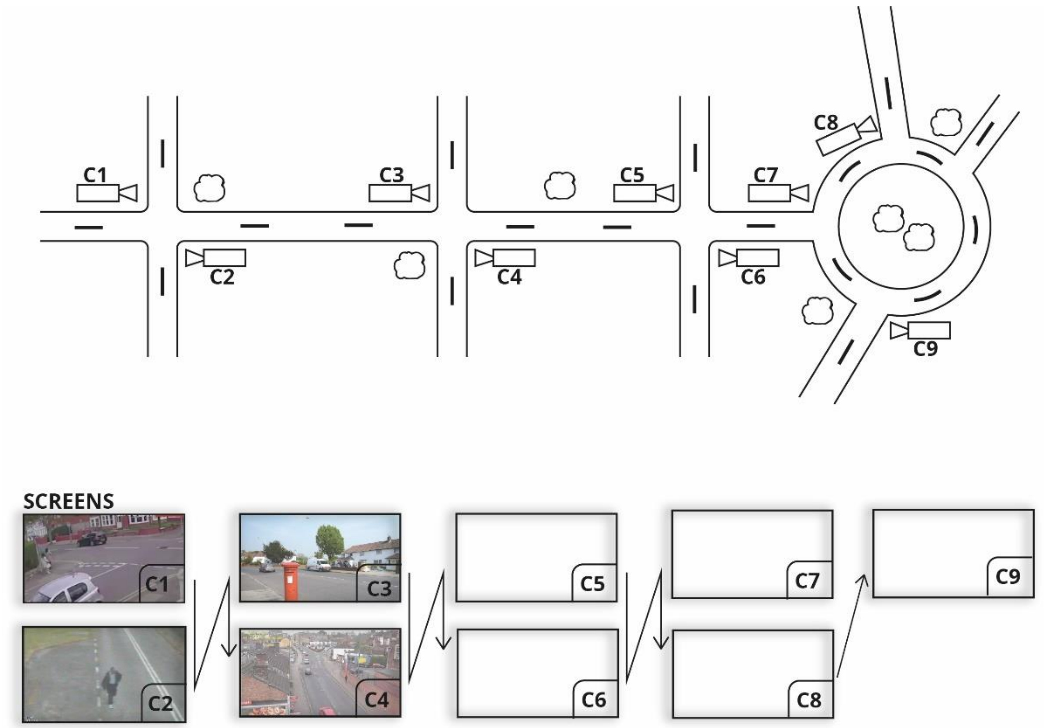


Fig 17: CCTV for urban traffic monitoring

Cameras are located along a stretch of urban roadway. The operators task is to monitor traffic flows and detect problems (such as the pedestrian on camera 2 walking in the centre of the road).

The sequences of sub-images reflect the ordering of the cameras alongside the carriageway. This logical arrangement of pictures makes it easier to identify where a problem has arisen and facilitates a speedy response.

Example 3 – scanning level crossing image

Images from level crossings are brought back to a railway signaller to ensure that the crossing is clear before allowing an approaching train to proceed. A 'figure of 8' regime is advocated for this scanning routine ensuring that each area of the image is scanned.

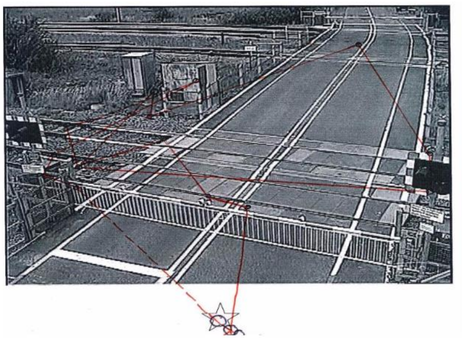


Figure 6: Figure of eight scanning

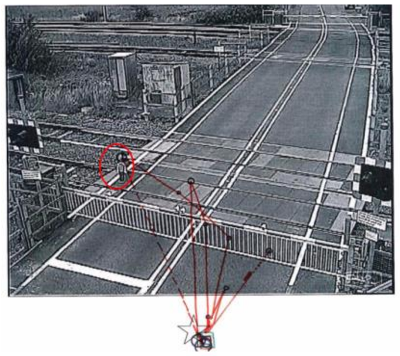


Figure 8: Directly to target

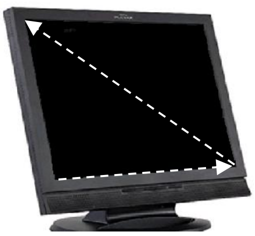


Figure 18: "figure of eight" image scanning pattern.

10.5 Appendix 5: Target and Image Size Estimates

The following series of geometric calculations enables targets to be scaled up for the equivalent visibility in images presented at different viewing distances.

New text proposal by Ruud Pikaar:

For an operator to perform cctv related tasks, there will be a minimum size of objects on a pixel area. The approach is to determine the smallest detail within the picture, that needs to be detected, recognized, or identified by the operator. Next, given the viewing distance to the pixel area, determine the actual size of the object (shown on the pixel area) needed to guarantee that the user will be able to detect, determine, or recognize it correctly (with a very low error rate). General rules are difficult to establish, because there are many different objects and tasks to be considered. While designing a CCTV-system, it is recommended to test different object size presentation in this respect (i.e prototyping).

Consider a comparison with determining the readability of Latin characters (see ISO 9241-303:2011). To be recognize characters, we need to be able to distinguish unique features of each characters. The minimum requirement for character height (capital) has been established at 16' of arc. This equals 16 character details (or pixels) in the character height. Note, that characters can be recognized with fewer details, however the number of 16' of arc, already compensates for a reduced failure rate. Also, it is assumed that the human eye will just be able to see a 1 mm gap between two black dots at a white background, at 3.4 m distance (= one minute of arc).

Based on this, the maximum viewing distance will be 215 x character height (at 16' of arc). Minimum viewing distance is fixed at 500 mm, recognizing reduced eye accommodation, when becoming older.

Object size and viewing distance have a linear relationship.

In this worked example the recommended viewing distance for a monitor with a 0.24 mm pixel pitch, should be larger than 0.24 x 3.4 m =0.82 m. The assumption is that individual pixels should not be discernable by the user.

The following example illustrates the steps in calculating the maximum pixel area.

1. Set primary horizontal visual field at an angle of view up to 70°
   - at 1000 mm distance, the width will be 1200 mm, etc. (see figure 19)
   - at 750 mm viewing distance, total width will be approximately 900 mm
   - example: at 750 mm distance and a 0.25 pixel pitch (4 pixels per mm) the horizontal pixel area will be 900 x 4 = 3600 pixels.

2. Set primary vertical visual field at the area between a horizontal line of sight (0°) and 30° downwards.

NOTE 1: the primary visual field will be 400 mm (height) at 750 mm viewing distance (or 1600 pixels at 0.25 mm pixel pitch).

NOTE 2: where a line of sight to a colleague, entrance, or an outside view is not required the area above the horizontal may be considered for use.

3. An additional pixel area for secondary tasks may be located outside (and adjacent to) the primary visual field.
4. The maximum pixel area needed for the job shall be determined by reviewing a worst-case scenario of images needed.

Once a pixel area has been determined, it may be implemented by suitable display technology.

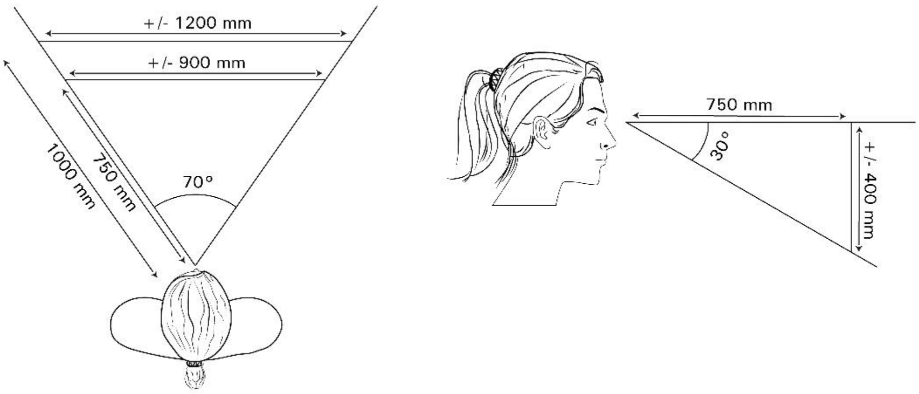


Figure 19: Examples of viewing distances and measurements.

11. Bibliography

Title	Author(s)	Reference	Date
Human Factors Guidelines for the design of CCTV Systems	Pikaar, et al	Revision 1.3	17 May 2015
Rail Industry Standard for Driver Only Operated On-train Camera/Monitor Systems	Railway Safety and Standards Board Ltd	RIS-2703-RST	Jun 2014
Rail Industry Standard for Passenger Trail Dispatch and Platform Safety Measures	Railway Safety and Standards Board Ltd	Issue 2: RIS-3703-TOM	Mar 2013
CCTV Operational Requirements Manual	Home Office	Publication No. 28/09	2009

CCTV Surveillance Systems – code of practice and associated guidance	British Security Industry Association	Issue 4	Jul 2014
Practical Guidelines for CCTV Ergonomics	John Wood et al	Proceedings of the IEA 2006, Maastricht	2006
Human Factors in CCTV control rooms: A best practice guide	User Perspective	Centre for the Protection of National Infrastructure	
Recommended practice APTA-IT-CCTV-RE-001-1: Selection of cameras, digital recording systems, digital high-speed networks and train lines for use in transit-related CCTV systems	APTA CCTV standards working group	APTA-IT-CCTV-RE-001-1	2011
Human Factors Guidelines and Workload Design	DeBruijn D, et al	Human Factors and Ergonomics Society European Chapter	2016
Leaderware	Donald	SAMAE	1999
Monitoring 16 television screens showing little movement	Tickner, A.H., Poulton, E.C., Copeman, A.K., Simmonds, D.V.	Ergonomics, 15, 279-291	1972 This is old: remove. Also remove the 16 monitor ref. in text!
Monitoring up to 16 synthetic television pictures showing a great deal of movement	Tichner, A.H., Poulton, E.C.	Ergonomics, 16, 381-401	1973
Human Factors Guidelines for CCTV system design	Pikaar, et al	Proceedings 19th Triennial Congress of the IEA, Melbourne	2015

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