Human Factors **Guidelines**
for the design of CCTV-systems

Revision 1.3

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Content

Foreword

CCTV systems consist of an observed reality, cameras, monitors, recorders, interconnecting IP network hardware, support infrastructure and human operators. Centralised CCTV image observation and supervision is carried out by human operators in control centres.
While doing control centre design projects as Human Factors (HF) consultants, we needed guidance on the ergonomic design of CCTV systems. We expected to find HF guidelines in standards, which was only partially true. HF guidance is scarce and mainly limited to security and surveillance applications. Therefore, a research project ***Human Factors of CCTV in practice*** was initiated. The aim of the project was to develop HF guidelines for the design of CCTV systems, giving answers to design questions that may arise during system development. The leading question is:

> ***What should an operator be able to see, detect or read reliably on CCTV images? And therefore, what HF requirements should be met by the CCTV system*?**

Project scope

The project consisted of seven phases.

1. Orientation and review of published guidelines and literature (2012).
2. Eight case studies, in order to gain insight in relevant CCTV tasks (2012).
3. Field experiments, looking into workplace variables such as image quality and the number of observed images (2013).
4. Development and test of Draft Guidelines (2013).
5. Simulator experiments on perceived image quality (2014).
6. Development of a measure for CCTV operator workload (2014).
7. Revision of Guidelines (2015).

The researchers looked into recent hard- and software, excluding conventional analogue television systems. The scope includes guidelines on how to achieve a HF input in CCTV systems engineering projects. Due to limited funding, topics such as video recording and advanced video analysis could not (yet) be included. Legal & privacy related topics have not been considered.

CCTV application areas

First applications, research, as well as some standardisation efforts have been in the public surveillance and security area, followed by traffic supervision. Other applications of CCTV originate more recently, notably remote control of (complex) installations, off-shore oil & gas production, health care, and many more. Unfortunately, terminology as well as engineering practices, differ considerably between these application areas. For example: security as in building entrance control, will be different from safety, security & reliability, as in chemical process control. Our aim has been to develop guidelines that are useful for all types of applications. However, the user of this Guide should be aware of possible differences between applications and specific terminology.

Guide to the reader

The guidelines cover six main topics: project ergonomics, CCTV system specification, operator tasks, field equipment, control room, and image presentation. The guidelines do not include a full explanation or scientific background. Selected references can be found in Annex A.

Each guideline is indicated by a camera icon on the left side of the page, as shown next to this paragraph. For each guideline, a level of evidence has been indicated: high (H), moderate (M), or low (L). Annex 3 gives definitions for these categories. Also, Annex 3 summarizes standard ISO-terminology for the terms "shall", "should", and "may", as applied in the guidelines.

There are five chapters:

1. **Project Ergonomics**
   How to integrate effectively HF activities in the design of a CCTV-system.

2. **CCTV System Specification**
   Guidance for the specification of a CCTV system including operator tasks.

3 **Field equipment**
   HF requirements for cameras, lenses, camera locations, and transmission.

4. **Control room layout and workplace design**
   HF requirements for control room layout and workstation hardware design.

5. **Image presentation and interaction design**
   Guidelines on information analysis and display, image quality, and navigation.

It is recommended to scan all chapters to get a full picture of HF issues related to CCTV systems. Further reading may differ per discipline, as suggested below.

Profession	Ch.1	Ch.2	Ch.3	Ch.4	Ch.5
project management	read	read	X	X	scan
cctv-supplier	scan	read	scan	X	read
telecom engineer	scan	scan	read	X	read
project engineer - instrumentation	scan	scan	read	scan	read
project engineer - workstation design	scan	scan	X	read	scan
user representative	read	read	X	scan	scan
HF professional	scan	read	read	read	read
authorities (work environment regulators)	scan	read	X	scan	X

The project continues

For some guidelines or topics, the evidence level is low. As a consequence, research is needed to improve (the validity of) the guideline. CCTV technology, hardware and software, are rapidly developing. Most of the guidance is given independent of technology. Nevertheless, a continuous effort to update the guidelines will be needed. Finally, the guide will need revisions based on feed back about its practical usability. The authors will be grateful for receiving feedback (e-mail your feedback to: contact@ergos.nl).

Project partners

The research has been funded by 14 project partners with an active interest in CCTV-system design. The project has been carried out by four research partners with an extensive Human Factors knowledge on control centre design.

Project partners

- Saab-H.I.T.T. Traffic
- IHC Dredgers / IHC Beaver Dredgers
- Nedap Security Management
- NS Concern safety, Security department
- ProRail ICT Services
- Royal Haskoning
- Ministry of infrastructure and environment (RWS Traffic and Shipping)
- Total E&P Netherlands
- Vopak Management Netherlands B.V.
- Waterschap Hollandse Delta
- DG-Organisatie Bedrijfsvoering Rijk/Rijks Beveiligings Organisatie (RBO)
- Province of North-Holland
- Rijksbelastingdienst - Tax authorities.
- HFC forum, Human Factors in Control, Norway.

On behalf of the research partners, I would like to thank all project partners for their valuable contributions.

Ir. Ruud Pikaar Eur.Erg.

Research partners

- ErgoS Human Factors Engineering, Enschede
- HAN University of Applied Sciences, Arnhem
- Intergo Human Factors, Utrecht
- Vhp human performance, The Hague.

1 Project Ergonomics

1.1 Scope of Human Factors

Human Factors (HF) is described as the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize well-being and overall performance.
HF Professionals, contribute to the planning, design, implementation, evaluation, redesign and continuous improvement of tasks, jobs, products, technologies, processes, organisations, environments and systems in order to make them compatible with the needs, abilities and limitations of people. Three fundamental characteristics can be derived from these descriptions (Dul et.al., 2012):

- HF takes a systems approach.
- HF is design driven.
- Focus is on two related outcomes: system performance and human well-being.

HF Engineering draws its knowledge from several fields of human sciences and technology, and has an applied and interdisciplinary nature. A concise definition of ergonomics would be ***user-centred design***, which refers to the user as well as to design. Designers and engineers have a major influence on the prevention of tasks and task situations that do not match the characteristics of the users. ISO 11064 visualizes a user centred design approach as shown in figure 1.1.

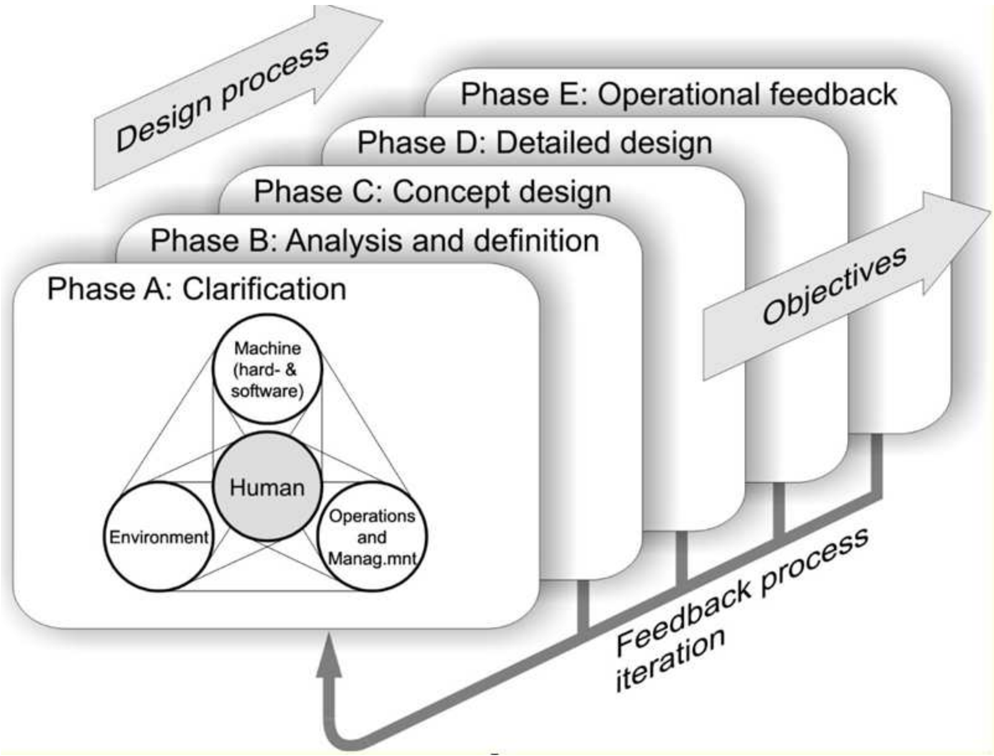

Figure 1.1 Design phases and procedure according to ISO11064-1.

Legislation and to some extent standards specify minimum requirements, in order to prevent unhealthy and unsafe working conditions. Minimum requirements usually do not aim for an optimal design. An optimal design is a complex trade-off between costs, hazards, productivity and quality of the working conditions. Human Factors Engineering strives for optimization.

Guideline 1.1 - HF Design Principles
In compliance with ISO 11064-1 for control centre design, the following HF principles shall be considered for a HF design of CCTV systems.
[Evidence H]

- **Principle 1: Apply a human-centred design approach**
  The combination of humans and machines, in its organizational and environmental context, shall be considered as an overall system to be optimized.

- **Principle 2: Integrate ergonomics in engineering practice**
  HF should be integrated into the project's management guidelines.
  - HF should be accepted by all designers/engineers; to this effect the project owner should issue a statement on the commitment to HF in the project.
  - Project team members should have a sufficient awareness of HF issues.
  - An interdisciplinary design team, including user representatives, should be formed to oversee and influence all phases of the design project.

- **Principle 3: 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. Establishing the validity of a single design element in isolation does not guarantee that the assembled system will be validated. Modifications may cause undesirable side effects even if the modification itself is valid.

- **Principle 4: Conduct a situation analysis and a functional analysis**
  For any ergonomic design activity, a situation analysis of an existing or similar situation (see section 1.2) is recommended, in order to better understand the operator tasks. An analysis of future operator tasks (functional analysis) shall be conducted, considering all modes of system operation (see section 1.2).

- **Principle 5: Ensure user participation**
  User participation is a ***structured*** approach where future users are involved in the design, in order to optimize long-term human-machine interaction by instilling a sense of ownership in the design. Experienced users can offer valuable empirical contributions (operational feedback). The project team should accept that user participation takes time and asks for additional efforts.

- **Principle 6: Document ergonomic design basis**
  Develop and update documents that reflect the ergonomic design basis for the project, for example fundamental reasoning or significant task analysis findings.

1.2 Analyses

HF principle 4 indicates the necessity to perform a task or situation analysis, as well as functional analysis. In Europe, a task analysis is mandatory (Machinery Directive and related standards). Consider two situations:

- ***Existing CCTV control room***
  In case of an extension or modification project, a situation analysis shall be carried out in the existing control room. Based on the results, an overview of functions in the new situation can be deducted by reviewing the tasks that will be influenced by the changes a project brings to the system.

- ***New CCTV control room***
  In case of a new CCTV system, it may be difficult to find an existing, more or less comparable, situation for the analyses. In this case, the functional analysis, is a useful tool to get a rough overview of work tasks.

The situation analysis and subsequent functional analysis consists of:

- **Analysis on site**
  - Specify the CCTV-system: area(s) to be surveyed, hardware, workplace layout, job descriptions, etc. (refer for details to Chapter 2).
  - Observations and interviews; to be carried out by HF Professionals.
    - Direct observation of operator tasks yields workload indicators, such as the frequency and type of communication and estimates of time spent on various tasks.
    - Semi-structured interviews result in a subjective measurement of operator tasks, communication and experienced workload. Also current problems, and any other aspect forwarded by the users, are identified.

- **Presentation and feed back** on findings to operators (users) and staff. After including the comments, an accurate and reliable description of the situation in an existing control room can be achieved.

- **Functional analysis**
  Operator tasks and IT system tasks are both investigated with respect to the changes a new system will bring. Estimates can be made on the effects of the changes from old to new control room situation.
  - Analysing operator tasks up-front the project, may help avoiding costs, low quality jobs and hazards. HF Engineers have the tools to estimate operator workloads, taking into account relevant cognitive aspects.
  - The task analysis methods may vary according to the scope and content of each individual project.

1.3 Verification and Validation

Verification and validation of a design are defined as follows (figure 1.2):

- Validation: confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled.
  - In short: *did we build the right system ?*
- Verification: confirmation, through the provision of objective evidence, that specified (written) requirements have been fulfilled.
  - In short: *did we build the system right ?*

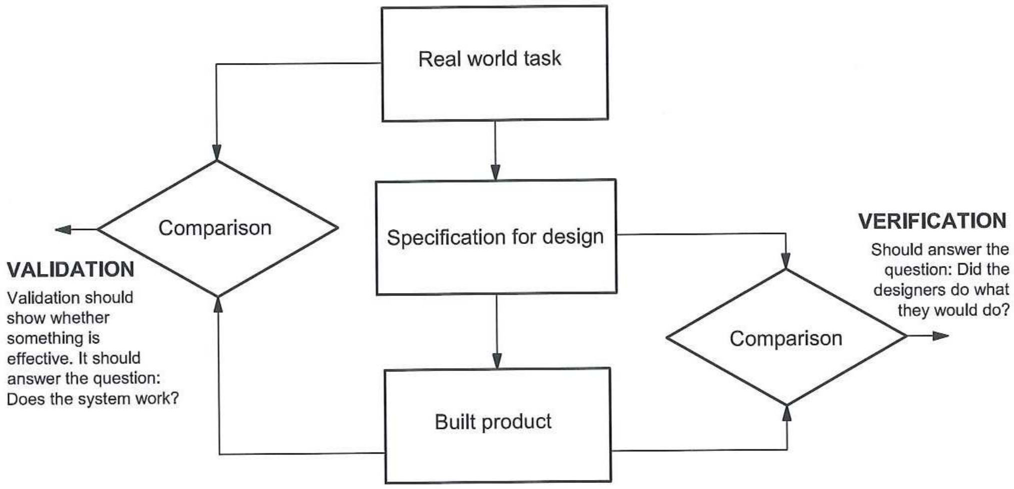

Figure 1.2 Role of verification and validation (reference: ISO 11064-Part 7: *Principles for the evaluation of control centres*).

Guideline 1.2 - Verify and Validate the design
Verification and Validation (V&V) shall be an integral part of the design process, throughout the life of a project.

- A V&V plan shall be prepared early in the project.
- Each major design phase should include a V&V activity:
  - after completion of the Conceptual Design,
  - near the end of Detailed Design and
  - after implementation (during the operational phase).

[Evidence H].

The CRIOP Analysis (Johnson, 2011), provides a V&V procedure for control rooms. Key elements of the method are a description of a review procedure, checklists, and a scenario analysis. The CRIOP documents can be obtained free of charge. CCTV related items are not (yet) included.

A HF V&V might be required in an otherwise technical oriented CCTV system design project. Typically the HF Professional would first perform a situation analysis to find out about the quality of all human factors related to the operator job, workplace, control centre, and so on. Next a CRIOP procedure could be started.

1.4 CCTV - Task topology

A (project) commitment to HF means that we need to consider operator tasks. This section gives a brief introduction to CCTV operator tasks.
In published CCTV research, a 4 step cognitive framework for human image processing tasks is dominant. The framework is based on typical surveillance and security tasks. For the purpose of CCTV guidelines, we have adopted this common terminology as a starting point. For application areas such as remote (process) control, an additional approach is introduced, discerning so called triggered and non-triggered CCTV image processing tasks.

Four consecutive cognitive tasks are distinguished in the framework:
Monitor –> ***Detect*** –> ***Recognise*** –> ***Identify***

where the following descriptions, taken from literature, apply:
- Monitor observe the flow of traffic or movement of people generally
- Detect detect the presence of a person without needing to recognise or identify them
- Recognise recognise somebody who is known to the user, or determine that somebody is not known; monitor or track an individual person, object or vehicle
- Identify capture enough detail to identify a person, object or vehicle beyond reasonable doubt.

This framework does not address
- set-up tasks: control cameras, and select images for presentation.
- follow-up tasks: acting (or not) upon specific information.

A general model of the operator cognitive tasks includes the set-up and follow-up tasks. A follow-up task such as "planning" or "action" may lead to an intervention in reality, which leads to new data (input), interpretation, etc. Combining both the four step framework, and the "additional" tasks leads to two types of tasks (also illustrated in figure 1.3).

- Type 1 task. ***No trigger***
  If there is no attention signal, the predominant task is **monitoring** images for unusual or pre-specified events. The operator scans images until such an event takes place. The operator detects the event, analyses the situation, and may start a (non-CCTV) follow-up task. This is the typical pattern for **surveillance tasks**, as indicated in the process: observe - detect - recognize - identify.

- Type 2 task. ***Trigger***
  The operator starts a CCTV task upon receiving a trigger (notification signal). Hence, there is no monitoring task. CCTV tasks start either with **detection**, **recognition** or **identification**, depending on the information of the trigger signal. This is a typical pattern for a **control task.**
  Examples of trigger signals:
  - a phone call from an employee in the field, who notices an incident;

- a ship to be locked through a sluice radios the lock master about his arrival;
- an alarm message for a process operator ("pressure is dropping").

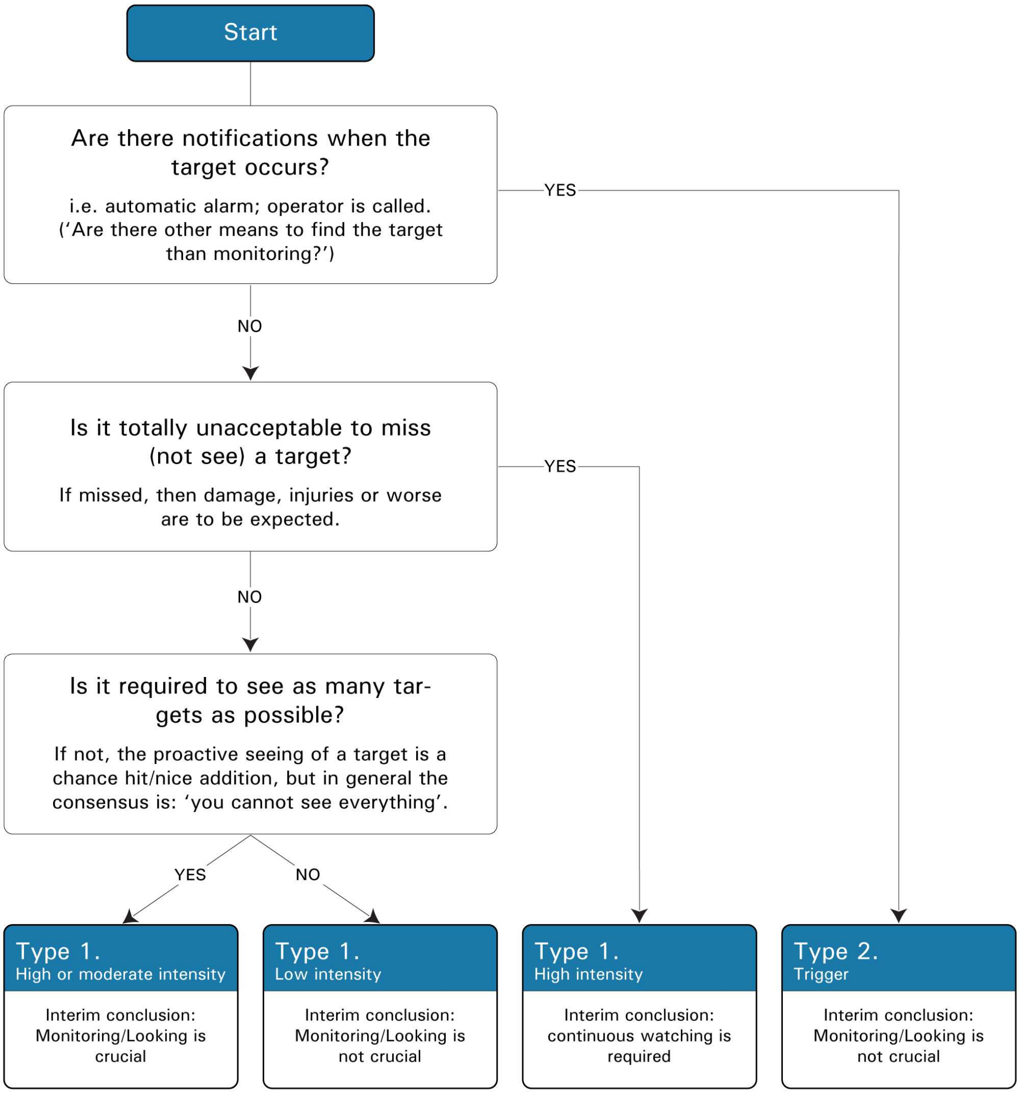

Figure 1.3 Determining type of CCTV image processing task.

2. CCTV System specification

A CCTV system specification can best be seen as a gradually developing document, emphasizing HF issues (i.e. it is not a full technical system specification). As a first step of this development, a specification of existing situations serve as a reference (situation analysis). Next, task related system variables can be determined, such as the number of areas to be monitored, the number of cameras or images presented to the operator, the time it takes to do a typical operator task, and the number of tasks an operator handles.
While a project progresses, the system specification develops towards the intended new control room situation. This chapter gives the reader guidance for a first draft of a system specification, including a workload assessment. Guidance for further design can be found in the Chapters 3 (equipment), 4 (control room) and 5 (image presentation) of this document.

2.1 Situation analysis and functional analysis

A CCTV system consists of equipment (cameras, transmission, displays), the observed reality, CCTV operator(s), and work tasks. During a project, a full specification of the CCTV system will be developed as a basis for purchasing equipment and building the system.
In a HF approach a specification of the operator tasks, CCTV images needed for the tasks (observed reality), etc. shall be included in the system specification. Typical HF characteristics of a system can be found by doing a situation analysis and a function analysis (refer to section 1.2). Summarizing:

- ***Situation analysis***
  1. Determine the physical area covered by CCTV, including an inventory of the area, objects and/or events to be observed or controlled.
  2. Determine the CCTV camera specifications
  3. Make an inventory of the workplaces in the control room, including instruments, CCTV image processing, and display.
  4. Summarize the operator tasks, including non-CCTV related tasks.

- ***Functional analysis***
  For a new control room, there is a need to know the number of operator workstations and their approximate measurements (or size and number of displays). Hence, we need to determine which system characteristics can give a good estimate of operator workload or the required number of operators, etc. Hence:
  1. list (potential) key system variables
  2. describe objects to be observed by their visual characteristics; list the number of (field) locations to be observed.
  3. list other available and relevant process information (than CCTV-images).
  4. determine operator workload indicators.

2.2 Guidelines for the specification of a CCTV System

A CCTV system is defined as a human-machine system, including the observed reality, camera(s), transmission, display(s), work station(s), and operators. The control room is part of the CCTV system. The guidelines in this section serve to build an inventory of CCTV system components.

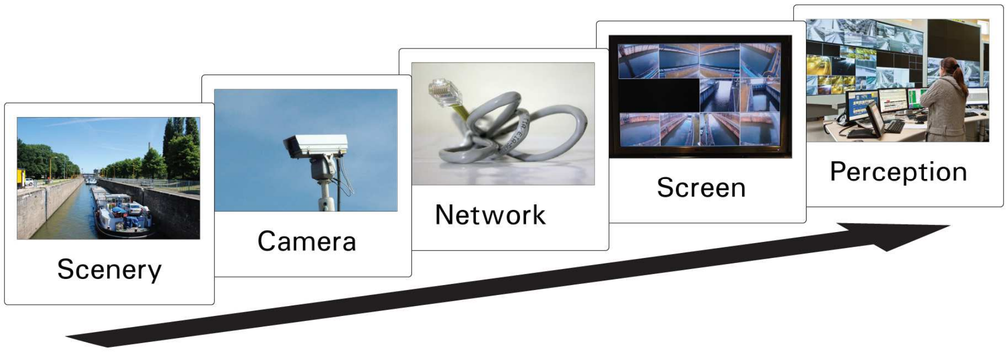

Figure 2.1 Chain of CCTV system elements.

Guideline 2.1 - System Goal
System goal and system tasks shall be established.

- Leading question: do we need CCTV images, and if so, for what purpose? It is essential to establish the goal and tasks of the CCTV-system.

[Evidence H]

Guideline 2.2 - Physical area
The physical area covered by CCTV shall be specified. The specification should consist of area(s), objects and/or events to be observed or controlled from a remote control room.

- For existing situations (CCTV installed), make a list of
  - 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).

[Evidence M].

Guideline 2.3 - Cameras
For existing systems, an inventory of CCTV camera characteristics shall 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);
- determine the level of data loss due to coding and transmission

    - lossless transmission: camera output format, and image format at control room are the same
    - otherwise, estimate reduction of image detail due to data compression.
  - identify specific environmental conditions, such as day/night or the influence of (bad) weather conditions.

[Evidence M]

Guideline 2.4 - Existing control room

A general overview of the control room shall be compiled, including:

- room layout, location of workstations
- layout of workstations, including number and size of screens
- specification of large screen displays ("videowall": technology, brightness, pixel size, and total pixel area.
- Image processing for presentation on displays, such as cropping or resizing.

[Evidence M]

Guideline 2.5 - Overview of operator tasks

An overview of operator tasks shall be compiled, including:

- CCTV task(s), such as supervision, surveillance, process control, inspection
- non-CCTV related operator tasks; CCTV tasks may not be the only or primary tasks of an operator.
- overview of "field tasks" in the system: the eyes at the location, such as a highway inspector at an incident area, a field operator in a process plant, a police officer in the street.

[Evidence M]

Guideline 2.6 - An inventory of CCTV images shall be made.

The image information content is an essential system characteristic.

- describe objects the operator needs to see (observe/recognize/identify) in terms of their visual characteristics (shape, contrast, colour, specific details)
- list for each type of CCTV information the number of locations to be observed.

[Evidence M]

Guideline 2.7 - An inventory of non-CCTV data sources shall be made.

- Of particular interest are data sources providing an alternative for the information content of camera images. This type of data gives a degree of freedom in design solutions, or may offer redundant data sources.
  - describe the type of data available (i.e. database, message/alarm signal)
  - if possible, indicate tasks for which the data would be usable.

[Evidence M]

Example: traffic speed and traffic density can be estimated on the basis of CCTV images. Road sensors might be available to measure speed and/or the number of vehicles passing; software could detect traffic speed slowing down.

2.3 CCTV Operator tasks

Human Factors emphasizes the operator job. The previous guidelines lead to an overview of operator tasks. The amount of work for the operator depends on system characteristics, such as "what happens in the observed reality", and "how is this visualized in the control room". Operator workload depends on image content and complexity, as well as the total number of images. In literature, the number of images is used as a workload measure, also indicating a maximum of 12-16 images per operator. Practice shows (much) larger numbers of screens, as well as satisfied users. In order to get a better understanding of this issue a new concept is introduced here, called “scenes”.

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

- the visual information of a scene is coherent, hence a scene can be looked upon as one “unit“ of operator workload.
- a scene consists of one or multiple images, and may also include other types of information (such as a process data).
- all images of the same task related observed reality are considered to be one scene.
- the scene, a set of camera images (and additional data), is task related ("monitoring with a specific aim").

Figure 2.2 indicates the steps to be used to determine a scene.

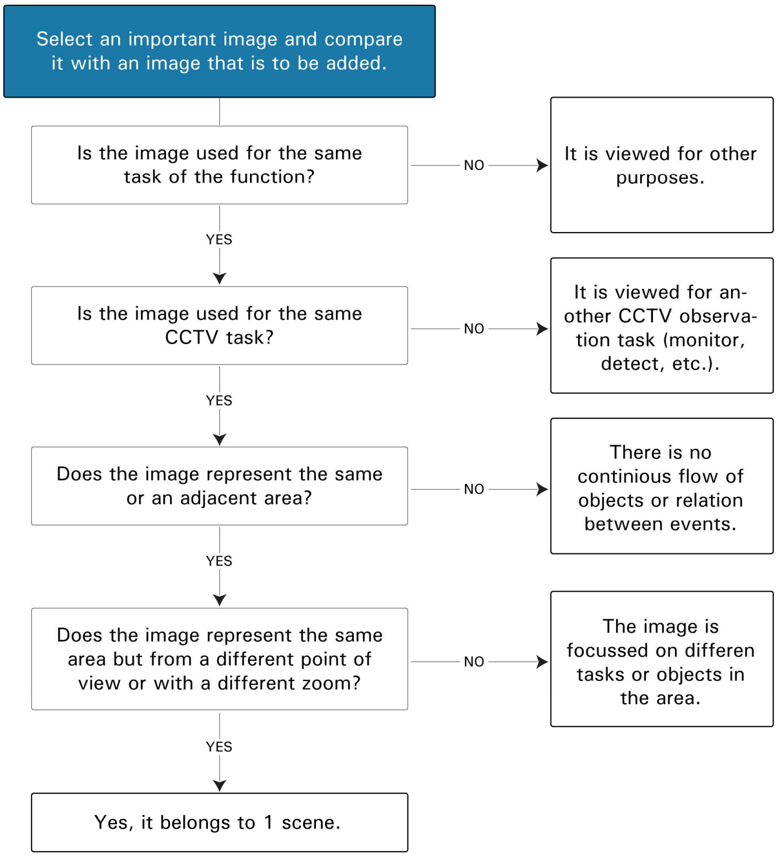

Figure 2.2 Flow diagram - how to select images for one scene.

Guideline 2.8 - Build an inventory of scenes

An inventory of scenes shall be made for existing situations (camera plan available), or a specification of images per scene shall be developed for a new design (no camera plan available).

[Evidence: M]

Guideline 2.9 - Estimate operator workload

Estimates for an acceptable workload shall be based on workload indicators.

- Workload is the ratio of the amount of work to be done and the available capacity. This is a time based workload indication. In addition, consider the complexity of the cognitive task, the level of training, and operator experience.
- For some tasks, workload may be relatively constant. For other tasks, workload may vary due to (unpredictable) outside events.
- Consider an inventory of non-CCTV related tasks.

[Evidence H]

Example - workload estimates

- Count of messages requiring operator attention (and possibly action); the number of messages times the average time to perform a suitable action, gives a workload estimate (in minutes). Each typical message may be related to one scene.
- Number of ships to be locked through, i.e. average lockage time and all monitoring and controlling activities needed.
- Inspection of a rush hour traffic lane, before opening; inspection time may be related to the length of the lane x viewing rate (speed).
- The number of “hot spots” in a town centre may be a valid indicator for operator workload. Suppose that a situation analysis reveals that one operator can handle 4 “hot spots” by checking 30 images/hot spot (one scene!) within a 5 minute cycle. A new CCTV system will be build for 7 comparable “hot spots”. Based on the system variable “number of hot spots”, we estimate a need for 2 operators in the new system. As a consequence we need to realize (at least) 2 workplaces.

Guideline 2.10 - Task duration for monitoring tasks

The maximum duration of monitoring (surveillance) tasks depends on task intensity.

- Low intensity monitoring may be reliably carried out continuously up to three hours. A cumulative total of six hours per day is the maximum.
- High intensity/continuous monitoring: maximum 20 - 30 minutes.
  - after this period, operator attention tends to decrease significantly with a consequent increase in errors and loss of performance.
- Operators remain more attentive when working in 20 - 30 minute blocks with 5 minute rest breaks in between.
  - 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 also provide effective rest period.

[Evidence M]

Guideline 2.11 - Consider job design
Operator job design shall be explicit. Workload indicators enable an estimate of operator workload for a (new) CCTV system. To achieve this, each task needs to be identified including a (first) workload estimates. Next, operator tasks are combined into jobs (a full time activity).
Individual jobs should preferably have the following characteristics:

- a variety of different tasks;
- self control over task execution and work pace;
- no repetitive or boring tasks;
- opportunity to learn new tasks or improve performance (based on feed-back);
- communication with others;
- a proper balance of tasks.
  - for CCTV task with a low workload, non-conflicting tasks can be added; these secondary tasks should not make visual demands on the operator.
  - 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.
- an overall workload of 80% of working time should be aimed for, the remaining time being available for personal care, social contacts, rest, etc..
- a peak load of 100% of working time can be maintained over a certain period of time, in case of handling a calamity.

[Evidence H - general; job design criteria are well known and researched].
[Evidence L - application of criteria to CCTV-related jobs]

Remark
Details on job design, i.e. allocating tasks to operators, can be found in ISO11064 - Part 1, and will not be elaborated in detail in this CCTV Guideline. You may consult a HF Professional for further support.

3. Field equipment

The field equipment guidelines relate to those HF topics, that determine image quality. This chapter does not intend to give a full account of CCTV camera technology, transmission systems or camera mounting requirements.

3.1 Cameras and lenses

Background

Traditionally, cameras are specified on the basis of a conventional 35 mm photo film. The image on the photo film is 24 x 36 mm. A digital sensor of 24 x 36 mm is called a full frame sensor. The conventional 35 mm photo camera has a 50 mm lens (=focal length). The image projection on the film compares well with the visual properties of the eye, or the area we can see in one glance and without apparent image distortions. Most digital (CCTV) cameras have smaller sensors than 24 x 36 mm. The factor by which the sensor is smaller is the "Crop-factor".

Example: Crop-factor 2 means that the sensor chip is a factor 2 smaller than the reference surface of 24 x 36 mm (in both directions): 12 x 18 mm (see figure 3.1). The image on the sensor compares to the image of a 100 mm (traditional) lens (crop factor 2 times 50 mm standard lens) The other way around: taking a 25 mm lens and a sensor of 12 x 18 mm, yields the same result as a traditional 35 mm camera equipped with a 50 mm lens. Both the 25 mm lens at crop-factor 2 and 50 mm lens at crop-factor 1, have the same angle of view.

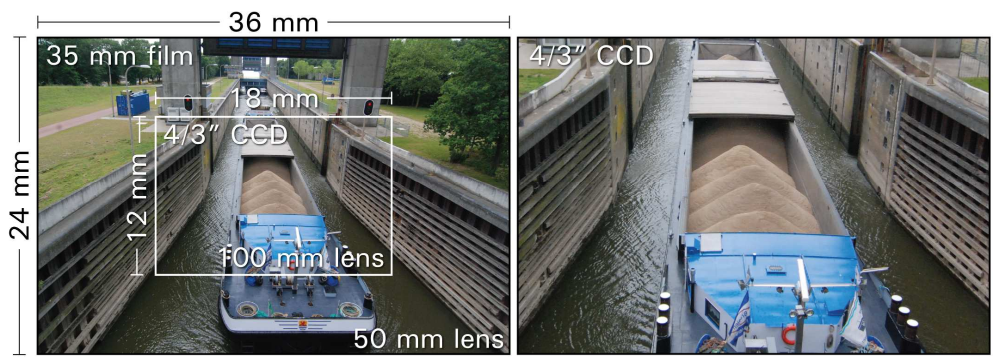

Figure 3.1. Illustration of crop factor 2 picture.

At a smaller focal length (and the same sensor size), the angle of view of a lens becomes wider (see figure 3.2). By reducing the size of the sensor or enlarging the focal length, the angle of view becomes smaller. See for additional background http://en.wikipedia.org/wiki/Angle_of_view

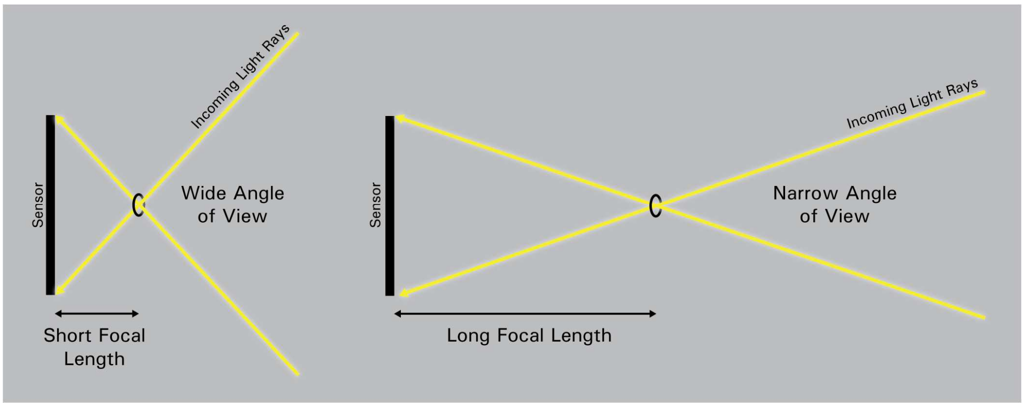

Figure 3.2 focal length and angle of view.

Two types of problems may occur due to the angle of view:

1. Wrong interpretation of object distances (as illustrated in figure 3.3).
2. Image distortions (figure 3.4 and 3.5).

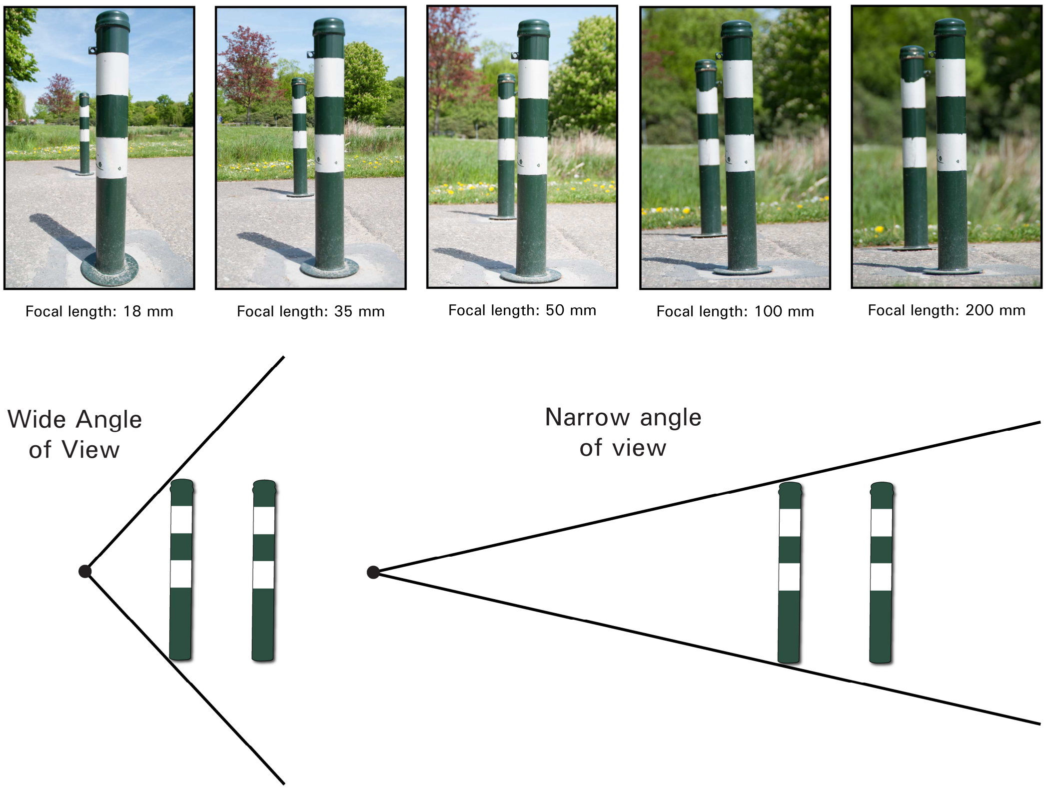

Figure 3.3 Influence of angle of view on distance perception.

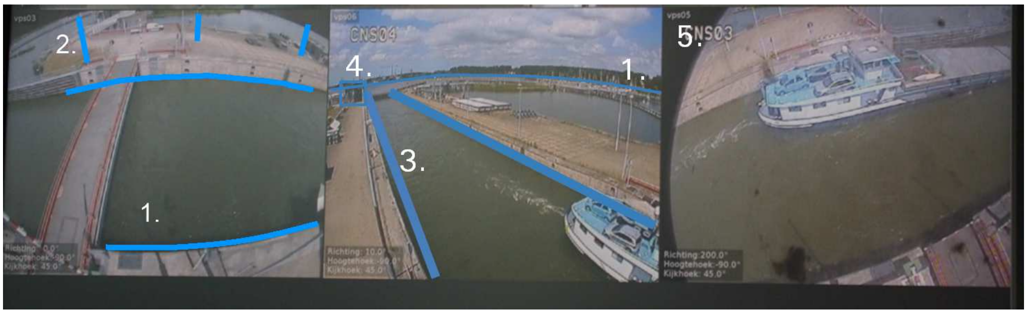

Figure 3.4 Several types of image distortion due to wide angle lenses

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 3.5 Barrel distortion

Note: you are looking at a straight line of entrance gates at the train station. The number of pixels per metre of the wall to the left and the right of the staircase - is lower than the number of pixels per metre area in the centre.

Guideline 3.1 - Avoid false interpretation of object distance

Do not apply wide angle or long focus lenses, in case the operator task(s) require good estimates of object distances. See also figure 3.3.

- Use standard lenses, which are specified by a horizontal angle of view of 40º - 60º (which compares to 36-60 mm focal length for a full frame).

[Evidence: H]

Guideline 3.2 - Avoid image distortion

Clearly visible image distortions should be avoided (which compares to a >60° horizontal angle of view).

- As a general rule, distorted images ask for more mental efforts of the operators while processing the information; for a predominantly image processing task, an increase of mental efforts shall always be avoided.
- There is less detail visible near the edges of the image (see figure 3.5).
- In case an object moves across an wide angle image, a continuously changing of the shape of the object occurs, which is discomforting for the users and shall be avoided.

[Evidence: H]

Guideline 3.3 - Requirements when applying wide angle lenses

Use standard/normal lenses, unless there are specific reasons to apply wide angle lenses. For some applications wide angle lenses may be advantageous, to reduce the number of cameras needed. However, this comes at a cost: reduced image resolution and image distortion. Therefore, the following requirements apply:

- Check minimum resolution needed to be able to see task related objects. Figure 3.6 shows that for the same camera sensor (each 750 pixels horizontal resolution), the smallest detail to be visible will be reduced by a factor 2 for the wide angle camera (there are less pixels to cover the full area).
- Do not use wide angle lenses for objects at a short distance. Wide angle cameras are more suitable for large distance applications (images are less hampered by distortions).
- To minimize barrel distortion, the vanishing point of the camera should be aimed at the horizon (as a consequence: this is a more or less horizontal line of sight; looking downwards - as shown in figure 3.4 - should be avoided).
  - Take care that the most important objects can be found in the centre of the image (distortions are largest at the edges of the image).
- Do not apply two (or more) wide angle images next to each other on displays.

[Evidence: M]

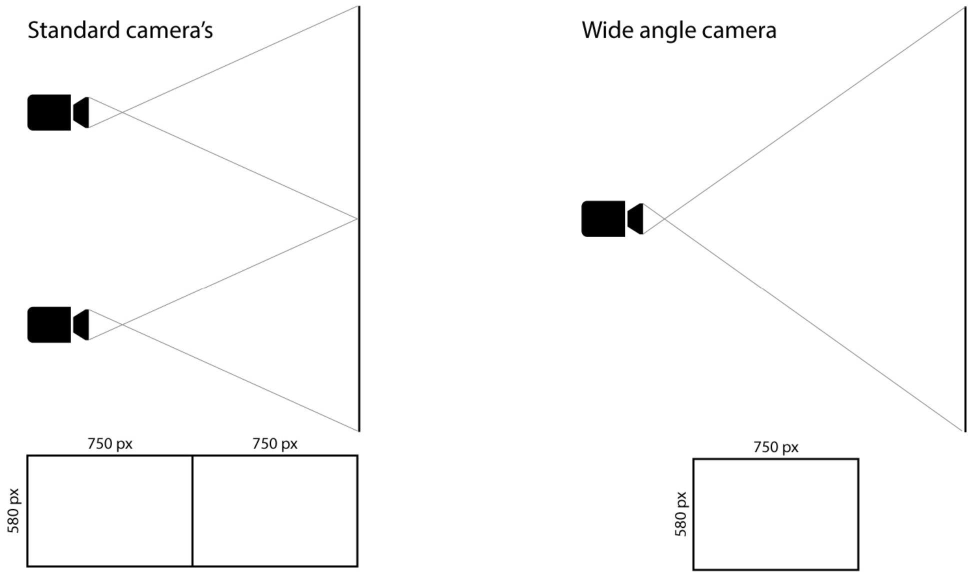

Figure 3.6 Two standard cameras versus one wide angle camera.

Remark 1
Nowadays, advanced image processing software will be able to correct images for distortions or may stitch images (combine adjacent images into one image). However, this comes also at a cost. The complex calculations take some time, which may not be allowed for by task requirements, or may not fit into the frame rate (number of images per second) of the video stream. Reduced resolution, in particular near the edges of the original images, can not be removed.

Remark 2
Several other lens specifications may have an impact on image quality. For the purpose of the guidelines, these will not be discussed in detail. It concerns:

- Lens aperture, indicated by the f-number of the lens.
- Depth of Field (DoF): distance range for which an image is acceptably sharp.
- Exposure time (shutter time), determines the illumination of the sensor (in combination with lens aperture).
- Switching from day light to low light situations. For example, sensor resolution may be reduces, in order to get “the picture” at low light condition.

3.2 Camera position

The Field of View (FoV) of a camera is the area observed, measured both horizontally and vertically, that can be seen through the camera. An on-line calculation sheet is provided by www.jvsg.com/online/#. (see figure 3.7).

Guideline 3.4 - Determine camera position based on task requirements

- Determine the smallest object detail that should be visible for the operator in order to perform his task(s). Based on object detail, a suitable choice of camera sensor resolution, lens (angle of view), and distance to the object should be made.
- Determine direction of view towards the object(s). Consider:
  - direction of view by direct sight (the way an operator used to look at a scene in a situation without CCTV cameras)
  - avoid glare and/or direct sun light.
  - check for possible obstruction between camera position and object.

[Evidence: M]

There are several degrees of freedom: different cameras, different lenses, different camera locations. If any of these variables is fixed, adapt the others to it.

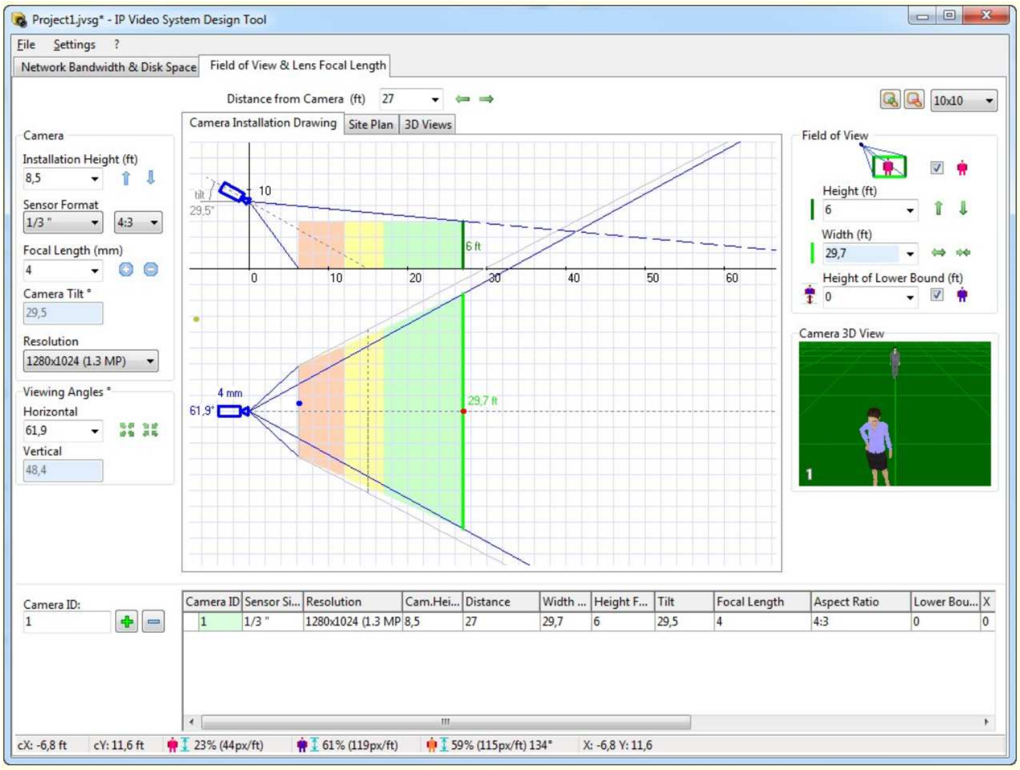

Figure 3.7 Example of a field of view calculation tool.

Guideline 3.5 - Vibration of camera mounting position shall be minimal

Cameras are frequently mounted on poles. Vibrating images on display shall be avoided as best as possible, because it causes hindrance (additional mental effort) to the observer.

[Evidence: H]

Guideline 3.6 - Accessibility for maintenance and cleaning
Cameras need maintenance and lenses need cleaning. Therefore, easy access should be considered.
[Evidence: H].

Caution
There are software tools to simulate camera output from 3D models of the real world. The models allow you to vary lense, sensor size, and camera location. However, the simulation does not show lens distortion, nor environmental influences (rain, fog, bright lights).

3.3 Image pre-processing

Image processing technology is developing rapidly: sensor resolution (number of pixels) is increasing as well as image processing rate. The sensor-chip produces a data stream, for example 1280 x 1024 pixel images at a frequency of 25 images per second. The data stream is transmitted from the camera to the control room. In order to reduce the amount of data, a data compression scheme is needed.

There are two types of data compression:
- Lossless transmission
  All the information to reproduce every pixel of the camera output is transmitted to the control room and reconstructed without any loss of image quality.
- Lossy transmission
  The reconstructed (decompressed) signal cannot exactly re-create the original video signal. Depending on the level of compression, details get lost which can be noted by a reduced image sharpness (the image gets blurred).

An important feature of a video stream is, that consecutive frames (images) look a lot like each other. Therefore, methods to encode consecutive frames are based on transmitting differences between individual frames, every now and then alternated by a full frame image for referencing.

Guideline 3.7 - Lossless or lossy transmission
Determine the smallest object detail that should be visible to the operator in order to perform his task(s). Determine its shape, size (in pixels), and contrasts as output of the camera sensor. Next, estimate (or test) the image quality reduction due to encoding and decoding.
- For large CCTV-systems (many cameras) with a limited transmission capacity lossy transmission can not be avoided. These systems are mainly found in surveillance & security applications.
- For relative small CCTV-systems, lossless transmission may be achieved, and therefore should always be considered from the HF point of view.

[Evidence: M]

Guideline 3.8 - Reduce amount of data of video stream
Technology and software nowadays offer possibilities to reduce the amount of camera output data before encoding. Thus it allows for lossless transmission (or systems with a limited loss of image quality). Pre-processing of images (at the camera processor) is in line with a Human Factors approach: do not present data to the user that is not needed. If it is not needed, do not send it. Consider:

- to crop images (at the camera processor) to the area needed for the task.
  - for many applications there is no need to stick to the standard 3:4 format.
  - example: remove a large area of sky (above the horizon)
- to reduce the resolution at parts of the image, that are not important for task performance.
- to reduce image frequency; 15 frames/second may be sufficient to give the observer the image of a continuous video stream.
- not to use high resolution cameras, if there is no need for much detail in an image.

[Evidence: M]

Caution
It is not always a good approach to select the best camera there is on the market. Transmission and image processing may not be able to handle high resolution images. As a result, there will be a low(er) image resolution presented in the control room.

4. Control room layout and workplace design

4.1 Control room layout

A control centre includes a control room and all functionally related rooms, such as a pantry, rest area, team leader office, and server room. This chapter only discusses control room and workplace design. Guideline 4.1 describes a general approach to control room design. Next sections are limited to HF guidelines for a control room including CCTV systems. For all other tasks and situations, refer ISO 11064 *Ergonomic design of control centres* (2000-2004). All guidelines in this section are considered to have a high level of evidence.

Guideline 4.1 - Control centre design steps
The following design steps are recommended:

1. List control room tasks and control centre tasks.
2. Specify a "task area" for each task: the estimated area size and the expected instrumentation. It is useful to add specifications of equipment, as far as available, such as screen sizes, type and shape of input devices, etc.
3. Allocate task areas to locations in the control room. Consider:
   - relationships between task areas (on the basis of requirements for communication or the use of shared displays)
   - accessibility of task areas
   - environmental constraints (for example the location of outside windows).
   - spare room for future modifications and extensions shall be taken into account; typically allow for up to 25 % additional space.
4. Determine the expected user population (male/female, disabled, etc.); this data is needed for workplace engineering.
5. Arrange equipment (=workplace layout). Visual tasks take priority.
6. Design cross-sections of the workplaces at several locations, respectively in several viewing directions from the operator location(s) towards primary displays, secondary displays, and other workplaces.

Guideline 4.2 - Communication
Layout design shall be based on easy verbal communication.
with each other shall be located close to each other.

- Control room equipment shall be placed such that visual contact between operators is possible where and when needed between task areas.
- Communication shall not disturb persons that are not directly involved.

Guideline 4.3 - Routing
Routing considerations shall be taken into account.

- Walking routes should be logical and planned according to the importance and frequency of use. Reduce the possibilities for unplanned short cuts.
- Access should be easy for shift and other operations personnel, whilst difficult for other personnel or visitors.

- Consider the functional links to task areas outside the control room, including supporting task areas (rest area, toilets).
- People feel uncomfortable when sitting with their back to an entrance or walking routes. It should be possible from a normal position to observe persons entering the control room.
- Consider easy and fast accessibility of first aid equipment, emergency equipment and the location of emergency exits.
- Professional visitors could be allowed inside a control room, provided this does not cause distractions and disturbances to the operators.

Guideline 4.4 - Maintenance and cleaning

Maintenance and cleaning shall be considered.

- Instrumentation shall be easily accessible for maintenance and cleaning.
- Cabling shall be properly concealed, as well as easily accessible for maintenance and future extensions.

Guideline 4.5 - Civil engineering and architecture

- To create a quiet and balanced atmosphere, the control room should display a consistency in design and decoration. Excessive changes in style and contrast should be avoided. Materials used for floors, walls and ceilings should be such that glare, reflections and contrasts are controlled.
- A single finished floor height is recommended in view of flexibility (future changes), movement of equipment, (no) safety hazards and accessibility for those with disabilities.
- Slab to slab heights should allow for false floors, false ceilings, and indirect lighting systems. Minimum free walking height shall be 2.5 m.

Guideline 4.6 - Arrangement of workplaces

The arrangement of workplaces shall reflect the functional relationships between task areas (e.g. the expected communication pattern).

- If there is a strong functional link between task areas, unobstructed visual contact and direct voice communication shall be possible; distance for acceptable voice communication is maximal 7 m.
- In case close cooperation between two operators is needed (operator has to know exactly what his colleague is doing) a double workstation is recommended (one workstation fully equipped for two operators).
- Consider identical functionality for all consoles, to improve operational flexibility.

Guideline 4.7 - Overview information

- In a control room several persons may use the same information, such as general CCTV-images. This can be achieved either by:
  - shared large screen displays
  - additional displays at each workplace.
  - additional displays outside the control room, in case of non-operators (also) requiring the same information.
- The following guidelines apply for locating shared large screen displays

  - for regular or continuous use, the shared display shall be located in front of its users and within a 70° horizontal viewing angle of all users.
  - viewing distances shall be determined on the basis of readability of textual information or recognition/identification of objects (Chapter 5).
- Images with a considerable amount of movement preferably are presented at larger distances, i.e. on a shared display.

4.2 Visual anthropometry

Measurements of the user population determine workstation design. Of particular interest are the visual characteristics or visual range of the human eye.

Guideline 4.8 - User population data set
The user population of the workplace shall be determined. The anthropometric data set of the user population shall be determined from published standards (www.dined.nl). The data set should be based on the balance of male and female workers, currently and expected in the lifetime of the workplaces.
Critical workplace dimensions are:

- vertical, horizontal and lateral clearance of the legs, knees and feet under the work surface.
- work surface at or slightly below elbow height; a suitable working height equals approximately the elbow height, which in turn depends on the seating height (i.e. feet on the floor or placed on a foot rest).
- controls within normal arms reach
- instruments and displays within normal visual access.

[Evidence H]

Guideline 4.9 - Adjustability
Adjustability of the desktop height for sitting work postures should be provided

- if user population has a large variability (i.e. a male + female population, or a mix of users originating from several countries); or
- if the work surface is, besides observation tasks, also frequently used for writing (or typing) during periods exceeding 30 minutes at a time.
- adjustment devices shall be easy to use.
- adjustability range of furniture should be based on the 5th-95th percentile of the user population.
- an adjustability range of desktop height for sitting and standing working postures is not recommended, as standing working postures do not fit typical observation task characteristics (job design shall allow for work posture changes, i.e. having a walk to a rest area, a colleague, etc.).

In other situations a fixed desktop height is allowed, provided an explicit HF design or review of workplace measurements is done, regarding:

- sufficient clearance for the tallest users' legs (95th percentile).
- availability of an adjustable foot rest for the smaller users (5th percentile)

The obvious advantage of a fixed operator workplace is, besides costs, that operators cannot adjust the workplace wrongly.
[Evidence: H]

Guideline 4.10 - Controls
Controls should be located within normal reach of the seated operator. Consider all instruments needing frequent control (keyboards, communication including telephone horn, if available). Guidance:

- for engineering purposes the 5th percentile arm reach minus 50 mm may be applied (typical outcome for Europe: 500 mm reach distance).
- input devices (keyboard, other input devices, telephone), should be freely moveable over the work surface in front of the displays.
- emergency stop buttons shall be considered separately regarding
  - the need for immediate control (short distance)
  - to allow for some consideration time (larger distance).

[Evidence M]

Guideline 4.11 - Visual range
Visual tasks take priority and should be arranged first. Information display should be within the visual range. The visual range is specified by viewing distance, direction, and angle of view (also see figure 4.1).
[Evidence H]

- Normal visual range for **monitoring** (defined as actively seeking information)
  - Main working posture (monitoring) is a reclined seating posture. The normal line-of-sight Sn in the vertical plane is approx. 15° below the horizontal.
  - The position of eyes is approx. 150 mm behind the edge of desktop.
  - The primary work area for visual tasks is given by the acceptable area (indicated in figure 4.1 by the areas A + B):
    - vertical plane: between 40° above and below Sn
    - horizontal plane: approximately 35° left and right of 0° line.
    - area A does not require eye movement; to look at area B eye movement is needed; area C requires head and/or body movement.
    - monitors for primary information (frequent use) shall be located within the area A+B; in the vertical plane, the lower part of this area cannot be used for displays (table top, reserved for input devices, etc.)
  - Secondary displays (i.e. to be used every now and then) may be located within the visual range requiring head movement:
    - horizontal plane: up to 80° to the left and right of Sn;
    - vertical plane: an angle of up to 30° above the horizontal can be used for secondary information display.
  - Guidance on legibility (related to viewing distances): refer to Chapter 5.

- For detection tasks, all areas are smaller (figure 4.1) than for monitoring.

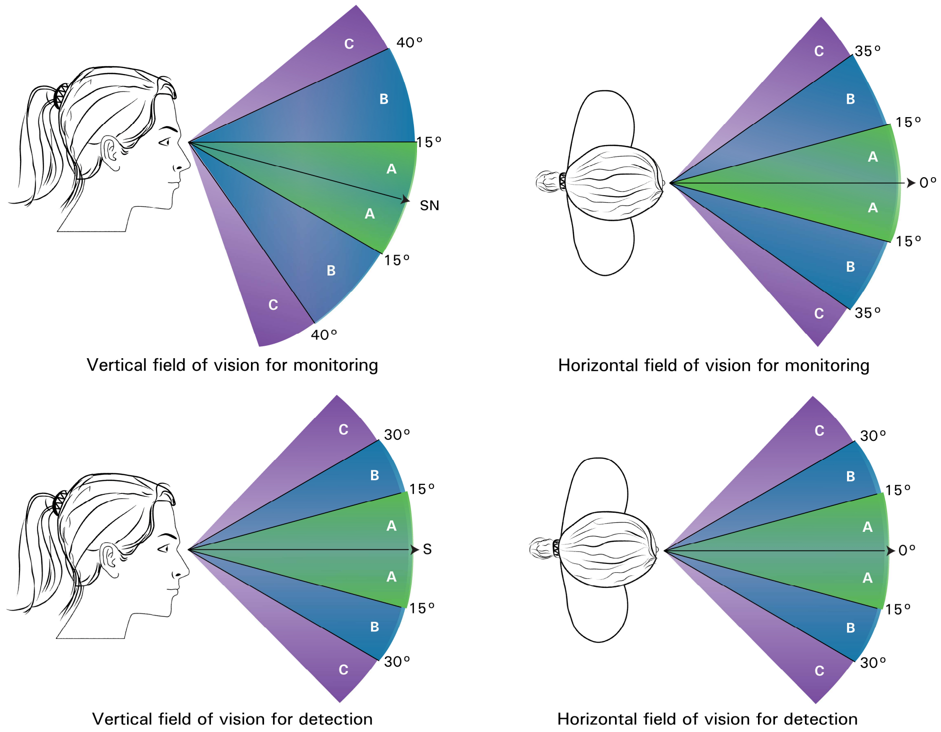

Figure 4.1 Field of vision (reference: ISO 9355-2).
S: Line of sight, direction is imposed by external task requirements
SN: Normal line of sight, 15° below the horizontal
Area A: recommended (to be used whenever possible)
Area B: acceptable (may be used if area A cannot be used
Area C: should not be chosen.

Notes for the designer:

- Balancing all HF workplace guidelines, the usual outcome for viewing distances is 800 - 1000 mm, provided legibility allows for this distance.
- In case of 4 displays, a slightly curved operator desk, each two displays having an angle of approximately 165° in the horizontal plane is recommended. Both screens in the middle should be allocated to primary tasks; screens to the left and the right to secondary tasks. Viewing distances to secondary screens become larger and the angle of view on the screens becomes worse, however within acceptable limits (see figure 4.2).
- It is almost impossible to locate 3 or more displays at an average viewing distance of 900 mm, from one fixed operator chair position. The result would be a cockpit like, half circular arrangement (figure 4.2, left side).

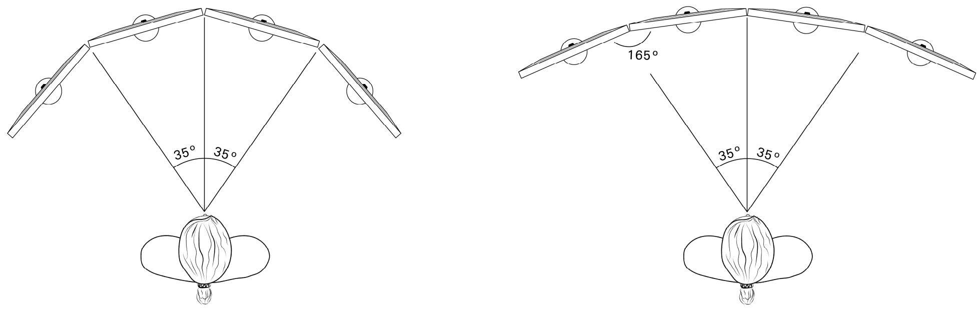

Figure 4.2. Examples of display arrangement (refer to text above)

4.3 Hardware

Technology changes rapidly. Therefore, the guidelines of this section have been formulated independent of technology. In particular, this concerns large screen displays. For example: instead of specifying a video-wall, we would rather specify an appropriate pixel area. The following definitions will be used:

- Image — visual information on a monitor, recorded by a camera (also indicated as “picture”).
- Monitor — The physical surface, on which images are displayed (also indicated as “visual display unit” or "display").
- Area — Geographical area or structure to be observed
- Subject — Person or object the operator observes.
- Pixel — Single point in a graphic image (“picture element”)
- Pixel area — Area made up by x horizontal and y vertical pixels.
- 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).

Guideline 4.12 - Minimum viewing distance
The operator should not be able to see individual pixels on a monitor. This requirement specifies a minimum viewing distance between operator and display. In addition, minimum viewing distance should never be less than 500 mm. *[Evidence M].*

Example: the viewing distance towards a TFT monitor with a 0.24 mm pixel pitch should be larger than 0.24 x 3.4 m =0.82 m. This calculation is based on the starting point, that the (average) human eye will just be able to see a 1 mm gap between to black dots at a white background, at 3.4 m distance (= one minute of arc). Object size and viewing distance have a linear relationship.

Guideline 4.13 - Determine pixel area

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

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 4.3)
   - 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.
   - the area above the horizontal may be considered for use, in case a free line of sight to a colleague, entrance, or an outside view is not required.
   - the primary visual field will be 400 mm (height) at 750 mm viewing distance (or 1600 pixels at 0.25 mm pixel pitch).
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.

[Evidence M]

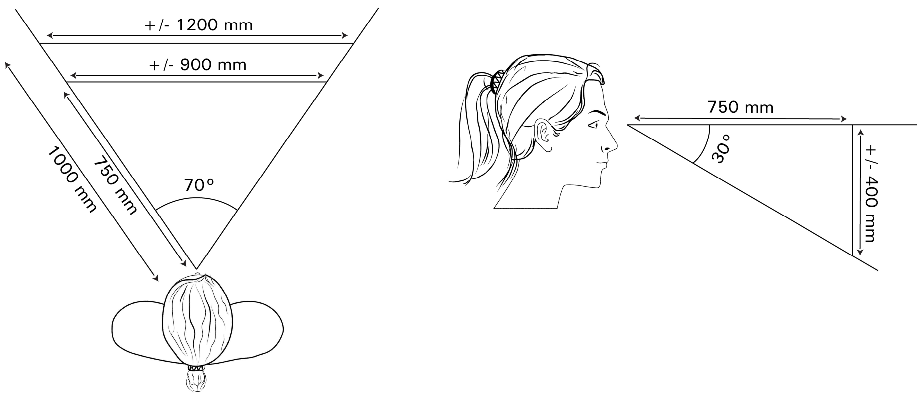

Figure 4.3. Examples of viewing distances and measurements.

Guideline 4.14 - Shared pixel area

A shared (large) pixel area should only be used:

1. Provided a group of users frequently refers to information of common interest and is required to interact as a team.
2. In case some team members move about, yet must frequently refer to information required to make decisions - information they cannot carry with them or do not have displayed at their assigned position(s);
3. When it is desirable to have general information available to other personnel, who shall not interrupt operator activities.
4. When the spatial and environmental conditions allow satisfactory observational geometry to ensure that all critical users have good visual access.
5. If alternate use of a shared pixel area and workplace monitors has a frequency less than 30 x / minute.

6. Gaps between adjacent monitors (of the pixel area/videowall) are <10 mm wide.

[Evidence H].

Guideline 4.15 - Moving images
In case of images with a considerable amount of movement the pixel area should be located at a viewing distance > 2 m.
[Evidence: M].

Guideline 4.16 - Input devices
Guidelines on standard input devices can be found in ISO 9241-4 Keyboard requirements, ISO 9995 Alphanumeric keyboard, ISO 9241-9 Requirements for non-keyboard input devices. Specific guidelines for camera control devices are considered in Chapter 5.
As a general rule, reduce the number of input devices on the desk by shared use of one keyboard + pointing device for one pixel area.
[Evidence H].

4.4 Physical environment

Requirements for the physical environment of the control room can be found in ISO 11064 - Part 6 and related literature. It concerns topics such noise, ventilation, and lighting.

Guideline 4.17 - Brightness of pixel areas
Preferably the pixel area (all monitors) should have comparable brightness levels. High(er) brightness levels are preferred above lower levels, because they allow for higher levels of workplace and room illumination.
[Evidence M]

Example: a large brightness difference may occur when applying TFT LCD displays (600 Cd/m² and more) and projection (beamer) technology (as low as 50 Cd/m²).

5. Image presentation and interaction design

5.1 Introduction

Two types of CCTV operator tasks have been distinguished (see Chapter 2):

- ***Type 1 - no trigger (surveillance tasks)***
  The predominant task is **monitoring** images for unusual or pre-specified events. The operator scans images until such an event takes place. After detecting the event, the situation at hand is analysed, and probably followed by a non-CCTV follow-up task.
  The process is: observe –> detect –> recognize –> identify.

- ***Type 2 - trigger (control tasks, process supervision tasks)***
  The operator starts a CCTV task upon receiving a trigger (external message). CCTV tasks start either with **detection**, **recognition** or **identification**, depending upon the information content of the attention signal. This leads to the following processes:
  external trigger--> Detect --> Recognise --> Identify
  or: external trigger--> Recognise --> Identify
  or: external trigger --> Identify

In addition there will be ***Set-up tasks***, such as area, image and camera selection, and ***Follow-up tasks***, such as communication or control actions.

Control room operators process large amounts of data (process data, images). All data presented is processed, whether it contains useful information or not. In a control room environment it is always important to reduce the workload due to data processing. This can be achieved by avoiding presentation of data that is not informative, i.e. useful for the task.
As a consequence, data has to be analysed to find out which part is informative, and which part is not. Next, information presentation (here mainly CCTV images), can be optimized. The concept of scenes will be helpful for optimization. A scene consists of one or more images, which shall be presented in a structured (coherent) layout on a pixel area.

5.2 Viewing tasks

Relevant factors of a viewing task are:

- Visual characteristics of **objects** (or persons), which determine whether these visual elements can be seen.
- Characteristics of the **scene**(s) to be observed determine the complexity of the viewing task and therefor workload.
- Procedural factors or operator job description
  What are the things the operator should do (for instance, should he look for pick pocketing, or also for signs of vandalism).

Guideline 5.1 - Estimate viewing task time
Practice shows that CCTV operators look on average 1-2 seconds at a CCTV image or scene.

- less viewing time is needed, if the target is moving on an otherwise still image.
- more time is needed
  - if the operator is novice or not experienced for the specific task (situation)
  - if the target is small, and has to be found in an image with similar or distracting objects that are not a target.
  - if more complex task behaviour is involved than usual
  - if image quality is less than usual (fog, large contrasts, noise in signal).
- viewing time may depend on target behaviour, for example behaviour with a certain time lapse (example: opening of a bridge).

Experienced CCTV operators are hardly effected by the factors mentioned here. Due to their rich experience, even complex targets are recognized quickly and with little effort. The operator knows exactly what to look for.
[Evidence L - M]

Guideline 5.2 - Perform a detailed information analysis
A detailed analysis shall be made of the visual elements the operator needs to observe. It is suggested to table tasks and related visual elements/characteristics. See for guidance Guideline 2.5 - *Overview of operator tasks* and 2.8 - *Determine Scenes*. Now, within scenes the essential visual elements shall be identified.

- for **monitoring** or **detection** of visual elements, the overall size and shape of such visual elements (as shown in the image) will be determinative.
- for **recognition** and **identification** of visual elements, the minimum number of pixels needed to be able to recognize the visual element within an image is determinative.

[Evidence M].

Examples:

- If a bridge operator needs to verify whether there are any person walking or cycling on the (far end of a) bridge, the size of a person (or a person on a bicycle), as it is shown on the image, will be determinative. There are no exact rules for specifying this size. You may need to rely on personal judgement of users (or others).
  There is some evidence related to security tasks, that a person:
  - can be monitored/observed (for example in a flow of traffic or movement of people generally; not individual figures), if its size is at least 5% of image height.
  - the presence of a person can be detected (without a need to recognise or identify the person), if the size is at least 10% of the image height.
  - note: this guideline does not specify the actual measurements of the image as it appears on a screen.
- If a traffic operator needs to be able to read a car license plate of cars at a certain location, the visual elements to be read are alpha numerical characters. There are specific rules for readability of character sizes (see Guideline 5.20).

Guideline 5.3 - Workload and the number of scenes
Task time should be used as a measure for operator workload. It is an easy to understand and relative good estimate. To determine the number of scenes an operator can handle, you can either perform a situation analysis (observe), or calculate task times for each (possible) scene.

- ***Estimate workload and number of scenes by observation***
  Identify operator tasks and related scenes. Observe time spend 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.
  Examples
  1. For remote lock-control, 9 to 12 images provide a full picture of the situation at one lock: 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 be possible.
  2. Tunnel traffic monitoring; the operator monitors for low speed or developing traffic ques. 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.
  3. At the central halls of six large railway stations surveillance camera's have been mounted. One operator is able to handle only one scene (one full overview of a hall).

- ***Estimate workload and number of scenes by calculation***
  For each task (Guideline 5.2), time estimates can be added. The flow diagram in figure 5.1 gives guidance to this activity (left column). 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 will be called the *interval time*.
  - In case there is follow-up task related to the target, that cannot be postponed, determine (or estimate) the time needed to perform this task.
  - Next, check whether the interval time is large enough for 1) time needed to observe the scene, plus 2) follow-up task time.
    - If not, it is likely that one operator cannot successfully do the task
  - Otherwise, scene observation and follow-up task fit into the *interval time,*
    - and you may check, whether there is sufficient time for an additional observation task (observing an additional scene), etc..

- For a type 1 task (no trigger), where monitoring is not considered crucial, workload estimates are less useful.
  Example
  - 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 he sees somebody.

[Evidence M]

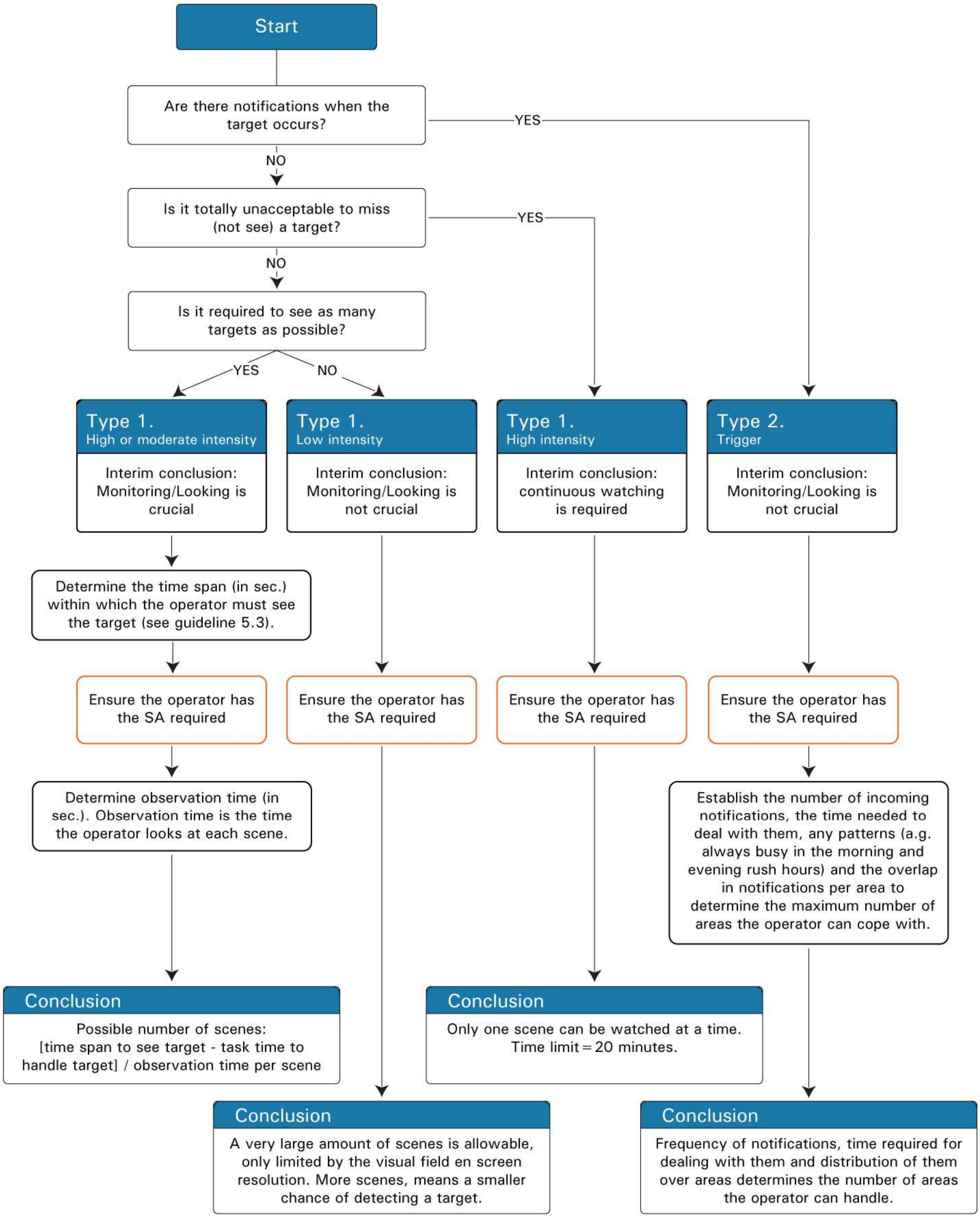

Figure 5.1 Process to determine workload and number of scenes per operator.
Note: the item "ensure SA" will be discussed in section 5.3.

5.3 Situational awareness

CCTV technology is used to present images of an observed reality. A scene shows a part of the reality. Some details or parts of the area may not been covered by camera. The operator may be able to do a better job, if he has (some) knowledge of the area and what might be going on in the area. The images shown may support the operator in retrieving a full picture of the area from his memory. Other information may be added: a printed area map, incoming communication, etc.
The term Situational Awareness (SA) refers to this, and is defined as follows:

> *SA is the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future*.

> Example
> An unmanned off-shore gas production platform is monitored by CCTV and process control instrumentation from a central control room. It is impossible to cover all areas by CCTV. At regular intervals, a maintenance crew visits the platform. Once, the central control room operator gets a message from a maintenance crew getting on board, his SA of the platform will change.

The key to support the CCTV operators' SA is to provide reference, such as a well chosen name of a camera position or scene. An effective tool to enhance SA is a suitable selection and a logical mapping of images on the pixel area. In addition to SA, the term *Reference Graphic* will be used to indicate an on screen presentation format for reference information. This section will focus on on-screen information. However, other information sources may also enhance SA, such as a drawing of a building layout, a process flow diagram, or a process unit layout drawing.

Guideline 5.4 - Determine the required level of Situational Awareness.
Depending on the required level of SA, additional information shall be designed into the scene. The level of SA should be determined as follows:

- Low level of SA: if a target looks the same everywhere, or is always clearly defined (little or no additional information needed)
  Example: the presence of patients in a waiting room, or cars at the entrance of Parking area.

- Moderate level of SA: if the appearance of a target varies and its definition depends on the context.
  Example: persons standing near a parking ticket vending machine are common, however, may be suspect in the car park itself.

- High level of SA: if a target needs to be followed on a large area.
  Example: to be able to predict possible routes the person may take in the area.

[Evidence L]

Guideline 5.5 - Indicate camera positions in a reference graphic
Provide a reference graphic, indicating camera positions of a scene. To select or develop an appropriate format (see figure 5.2) for a reference graphic consider following options:
- a list or table (of images/camera positions) gives a compact overview, which is particularly suitable for sorting or filtering of many images;
- a spatial/geographical presentation gives a graphical context of the locations of cameras within a specific geographical area, building layout, etc.; this presentation format may require considerable space on a pixel area.
- in case of a large number of images/cameras, the use of an hierarchical presentation is recommended;
- embedding of miniature (live) images in a graphic, such as a layout drawing or area map. Hereby, a direct link between the image and its location can be created (also refer to the section on hybrid information presentation).

[Evidence L]

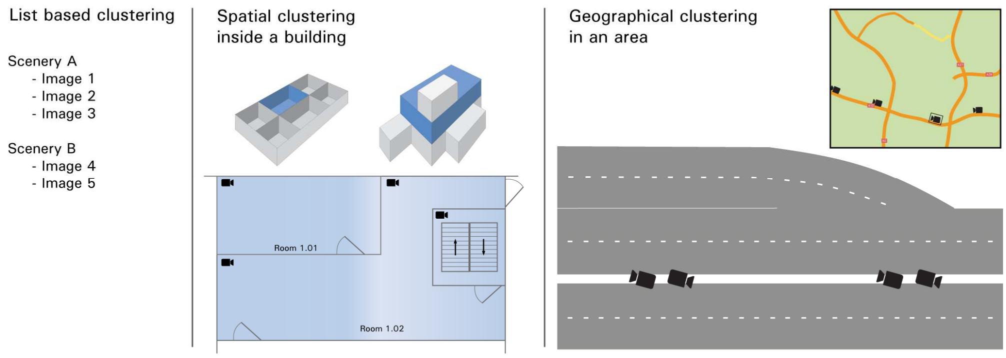

Figure 5.2 Some examples of reference graphics; on the left side a table of images, in the middle and to the right side spatial presentation formats.

Guideline 5.6 - Scene - a structured group of images
The images belonging to one scene, shall be grouped/structured considering:
- Guideline 2.8 and figure 2.2: determine images that belong to one scene.
- Structure images belonging to one scene:
  - locate related images next to each other, showing logical relationships
  - in case of images with moving objects (for example traffic), create a row of images, emphasizing a natural flow of movement over consecutive images;

Example - moving objects:
Assume that an operator needs to know the movements of ships in a canal. There are cctv 4 images of the canal. Because it concerns a canal, the four images may be positioned in one row on the pixel area (camera 1 - 2 - 3 - 4).
- a ship passing through the canal should be presented first on image 1, next on image 2, 3 and 4 (or passing in the other direction 4 –> 3 –> 2 –>1).

- in addition, camera positions (and viewing direction) should be such that the operator sees the ship moving in the same direction on each of the images.
- as a consequence, all cameras will be on the same side of the canal.

Example - logical grouping
Figure 5.3 shows an example of a pixel area, without a logical structuring of 3 groups (a, b, and c) of images scenes; the relationship between images can not easily be recognized. Figure 5.4 shows a structuring of images that assist in an easy identification of clustered information.

c	a	a	c	b	a
b	c	b	c	a	b

Figure 5.3 Three groups (a, b, and c) of related images without a logical presentation structure.

a	a	a	a	c	c
b	b	b	b	c	c

a	b	b	b	b	c
a	a	b	b	c	c

Figure 5.4 Examples of logical image clustering.

Guideline 5.7 - Camera parameters
Camera parameters should only be shown, when the operator task requires a high level of SA (you need to see or to know a lot of local details).

- Useful camera parameters depend on the operator task and may include
  - camera status (on/off, stand-by, failure),
  - actual settings (direction, viewing angle; i.e. what part of reality is shown),
  - camera potentials (pan, tilt and zoom freedom of movement)
- Camera parameters may be presented in (or next to) the image, or in a reference graphic, depending on their use.

[Evidence L]

5.4 Set-up tasks

Guideline 5.8 - Scene selection

A graphical representation, structured list and/or a direct input of a location code, should be provided to give direct access to a scene.

- A trigger to change scenes may originate from the operator when he spots something. The trigger may also originate from people in the field (visitors, security officer), or from an automated system.
- Do not use auto cycling of images or scenes, as it undermines the ability of peripheral vision to detect movement or status changes at the pixel area. It also undermines recognition of the location of the views.

[Evidence H]

Guideline 5.9 - Compose scenes

As a general rule, it is always better to reduce the amount of information in case of predominantly information processing tasks as much as possible.

- Criteria to select images/cameras to compose one scene are:
  - is there a need to show the whole area continuously?
  - are there any dead corners, that should (or should not) be covered?
  - what is the area objects need to be seen, or are most likely to appear?
  - what is the required visual angle for the visual element to be seen (relative to the image size)?
- There is no need to present a scene as one integrated image. A comprehensive presentation (logical mapping of images) on a pixel area suffices to create one scene.

  Example: stitching (software procedure to combine images into one larger image) is not required and may have some disadvantages (signal delay). Human information processing is capable of combining images.

5.5 Perceived image quality

The quality of images projected on a pixel area depends on camera resolution, encoding & decoding for transmission, image processing and pixel area specifications.

Guideline 5.10 - Guarantee acceptable image quality

To guarantee an acceptable image quality, the following procedure shall be applied. Starting point will be the inventory of visual elements and critical details, as compiled earlier. The leading question for this procedure is:

What does the operator need to see to do his job correctly ?

1. Determine critical situations, i.e. when the highest resolution (most detail) of a visual element is required.
2. Select cameras that are able to produce the visual element at least in the minimum required resolution as an output signal (see Chapter 3).
   - to improve resolution, a camera can be located closer to the visual element (or may have a zoom function);
   - whenever possible, one should design for twice the minimum required resolution, in order to compensate for variability in operator - screen distances and operator visual acuity.
3. Check for lossless or lossy transmission.
   - for lossy transmission, compensate for a loss in resolution by sufficiently enlarging the visual element the operator needs to see.
   - enlarging should be realized at the camera (lens selection or adjustment; output resolution)
4. Check viewing distance operator - pixel area.
   - Will the operator be able to see the image at (approximately) the required minimum resolution? If not, return to step 2.

[Evidence M]

Guideline 5.11 - Image cropping

Image cropping is reducing the image size by removing pixels at one or more sides of the image. Cropping does not lead to image distortion. Image cropping may be considered for several reasons:

- reduce the image content to an area of interest to the operator (remove parts of the image not needed for the operator task);
- to fit several images adequately on a specified pixel area;
- to fit standard 4:3 sensor output format, to for example wide screen displays.

Cropping reduces the area the camera is "seeing". Always check whether all objects are still visible after cropping; otherwise compensate by changing lens adjustment. Image scaling, should be avoided (refer to Guideline 5.12).

[Evidence M]

Examples and remarks:

- A 720 x 540 pixels camera output may be cropped to a 640 x 480 pixel image by cutting of 40 pixels at left and right side of the image, and 30 pixels at the top and bottom side of the image.
- Assuming a standard wide screen of 2560 x 1600 pixels, by cropping the image width to 640 pixels, it will be possible have 3 rows of 4 images on one screen (and a blank area of 80 pixels between rows).
- Some applications could benefit from cropping, for example by removing a large are of sky above a horizon, not relevant for a particular operator task.
- Cropping may be possible by camera software, which would reduce the amount of data to be send to the control centre.
- Cropping should be possible at the control centre, by dedicated image processing software.

Guideline 5.12 - Image scaling

As a starting point, image scaling should be avoided, considering:

- for a lossless system and no scaling (= scaling at 100%), the on-screen presentation compares 1:1 to the original camera output; presentation is at maximum quality; refer to this as *native resolution*.
- if scaling is <100%, the image resolution is reduced below the minimum requirement for a critical visual element as determined earlier; this is not acceptable for the given task situation (it may be acceptable for other task situations).
- if scaling is >100%, the number of pixels by which the image is displayed, increases. However, this does not necessarily improve image quality. At exactly 200% there will be a 1:2 mapping of pixels on the pixel area: native pixel is shown by a 2 x 2 pixels square (300%: 3 x 3 pixels square). For all other % of scaling, the processed image shall be checked for undesired scaling effects.

  For example at 150%: what happens when a black and an adjacent white pixel are displayed on 3 pixels? one black pixel, one white pixel, and one grey tone in between?
- scaling software is not standardized: image quality can only be determined by testing (see Guideline 5.13).

Guideline 5.13 - Test charts
Image quality, as perceived by the operator, should be tested. For this purpose several test methods can be found. Some methods, though presented in standards or mentioned in regulations, may not be valid for the CCTV task.

- In order to get indications for the perceived image quality, we have to measure what the operator actually sees. Opto-metrics provides us with measuring techniques. The Landolt C chart is one of them, normally used for measuring the smallest critical detail a person can see (i.e. perceived quality in direct observation).
- The Freiburg Vision Test (FrACT) (Bach, 1996) is a digital version of Landolt C, also measuring visual acuity by displaying single optotypes directly on screen.

Comments:

- For face recognition, the so-called Rotakin test allows subjects to develop strategies to determine correct answers, by-passing the actual image quality.
- Damjanovski (2005) presents the so-called Vidilabs test chart; a usable but complex test chart.
- Obviously, more research needs to be done regarding CCTV test charts.

5.6 User interaction principles

For the selection of scenes (or images), or camera control, the operator needs to interact with system software. This section introduces interaction principles for the design of the user interface. Thus, preventing usability problems such as unnecessary selection steps, misleading information, insufficient or poor information presentation, unexpected responses, navigational limitations and inefficient error recovery. General principles can be found in the ISO 9241 series of standards (summarized in Guideline 5.14). Following, CCTV related guidelines on camera selection and camera control are given.

Guideline 5.14 - Dialogue principles
The following principles shall be applied while designing, or implementing the interaction between a user and an interactive system. The guidelines also apply to standard (vendor) software, and can be used for a software review.

1. A system shall be **suitable for the task** it supports, i.e. when functionality and dialogue are based on the task characteristics rather than technology.
2. A dialogue is **self-descriptive** to the extent that, at any time, it is obvious to the users which dialogue they are in, where they are within the dialogue, which actions can be taken and how they can be performed.
3. A dialogue conforms with user **expectations** if it corresponds to predictable contextual needs of the user and to commonly accepted conventions.
4. A dialogue is **suitable for learning** when it supports and guides the user in learning to use the system.
5. A dialogue is **controllable** when the user is able to initiate and control the direction and pace of interaction until the point at which the goal has been met.
6. The dialogue is **error-tolerant** if, despite evident errors in input, the intended result may be achieved with either no, or minimal, corrective action by the user. Error tolerance is achieved by means of (1) error control (damage control). (2) error correction. (3) error management, to cope with the errors that occur.
7. A dialogue is capable of **individualization** when users can modify interaction and presentation of information to suit their individual capabilities and needs.

[Evidence H].

Guideline 5.15 - Select a camera selection method
A balanced choice should be made regarding camera selection methods. There are three different types of selection: manual, location driven, and system-driven.
[Evidence L]

- ***Manual selection***
  Manual camera selection from a reference graphic or hardware control panel, is efficient for simple tasks. Manual camera focus may be time consuming and there are risks of selecting the wrong camera. Operator experience with the technical system and knowledge of reality is of major influence.

- ***Location-driven selection***
  The operator indicates an area or location (for example in a reference graphic), upon which software determines which camera or scene fits best to frame the indicated reality.
  Location-driven image selection is useful in a system with a large number of cameras and a complex reality. This type of selection requires a high level of reference graphics, regarding the correctness of visualisation of the area to be monitored.

- ***System-driven selection***
  A system may be equipped with triggers, generating messages for the operator about a situation within his domain. The availability of a trigger provides a possibility to automatically switch to a suitable scene.
  In case of remote object control, triggers may also be given by the operator. For example, initiating the opening of a bridge, may generate the immediate display of a set of related images, showing critical parts of the bridge (area).
  - Processing trigger signals into a correct selection of images requires intelligent software as well as knowledge on the relationship between triggers and events to be handled by an operator.
  - The operator shall always approve a system-driven switching of scenes.

Guideline 5.16 - Camera control
For camera control, consider multiple camera operation methods, the use of presets and the use of In-image control (see below).

- Provide 2 or 3 methods of PTZ camera operation, such as:
  - hardware controls (a dedicated input/control device)
  - software controls (control within a graphical display (GUI))

  By allowing operators to choose between control methods they will be able to use the control that fits best with their preferences and/or the situation.

- The use of presets enables the operator to quickly focus on the preset area (by one preset selection action).
  - a static preset has a fixed pan, tilt and zoom setting of cameras
  - a dynamic preset is created by choosing an area within a spatial reference graphic, after which the cameras adjust automatically to an optimal setting.

- In-Image control (camera controls are integrated in the image)
  - Software based camera control uses virtual buttons on screen, that allow the operator to pan, tilt and zoom. Each click on a button presents a single movement. The scroll wheel of a mouse (or other input device) can be used to control a zoom function. This type of control is easy to learn, however may not be efficient for getting to the required image.
  - In-Image Pan-Tilt Regions uses different areas of the image as virtual camera control buttons (without actually showing buttons); see figure 5.7.
  - In-Image Dragging: by clicking at any position in the image and dragging the cursor in a specific direction the camera will be panned and tilted correspondingly.
  - In-image control has the advantage that the user controls a camera without the need to shift the focus to a control panel, away from the image.

[Evidence M]

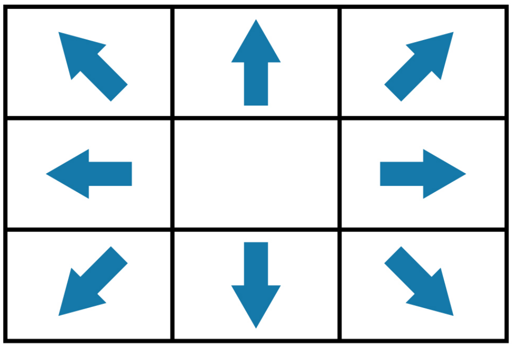

Figure 5.7 Areas for in-image control (the total area is one image); for example, clicking on the left-bottom section of the image makes the camera pan to the left and tilt downwards.

Guideline 5.17 - Feedback on control
Feedback on a single camera control action shall be given within 20 ms. For more complex control actions, such as selection and on screen presentation of a scene, reaction time up to 200 ms is acceptable. Users may accept a "waiting" time of up to 2 seconds, if the computing task is considered by the operators as a very complicated task.

- Signal transmission delays may cause a problem with remote pan/tilt/zoom control of cameras. Accurate control of camera movements may be very difficult if feedback comes relative late. This problem refers to both Guideline 5.15 and 5.16.

Guideline 5.18 - Image shifting at the operator pixel area.
Moving images on a pixel area (to or from the primary visual field, respectively secondary visual field) may be a common phenomenon. Consider the application of a reference graphic, as a metaphor of the workstation pixel area. This enables the operator to interact with the metaphor of the pixel area, instead of the pixel area itself.
[Evidence L]

5.7 Graphics design

This section gives guidelines for graphics design, i.e. data presentation formats other than CCTV images or scenes. Usually graphics or process control graphics will be part of a CCTV operator workplace. For example:
- Reference Graphic (for camera positions)
- Graphics diagnostic tasks, follow-up tasks
- Alarm message (off-normal messages)
- Hybrid graphics: information presentation on CCTV pixel areas.
- Graphics for non-CCTV related tasks, such as process supervision of a plant.

Guideline 5.19 - Simplicity

Information presentation in complex visual environments shall be kept as simple as possible. There are two general design rules:

1. Content — present only task related information.
2. Information — keep presentation formats as simple as possible, or simplify existing graphics as much as possible.

[Evidence H]

Guideline 5.20 - Alternative information for CCTV images

Whenever the relevant part of the content of an image is also available in another data format, this alternative data format should be used first.

- In many cases information processing of graphical data, such as a process variable, an alert message, or a graphical process status overview requires less mental effort than image/scene observation.

[Evidence H]

Example:
A flow of traffic on a highway can be monitored by cctv-images, as well as by speed detection sensors. If the operator task is to detect low speed, this signal could be generated by the speed detection software (instead of the operator observing the cctv-images).

Guideline 5.21 - Content of graphics

Provide types of graphics that support the operator tasks; i.e. show information in an appropriate format. A leading principle is:

- Display task relevant information only, using overview graphics for key readings and other graphics for primary variables; secondary variables to be shown in overlays, pop-up windows, or detail graphics.
  - Minimize hierarchy depth of graphics (three levels being the maximum); when a hierarchy is applied, its structure should be transparent, navigation should be consistent en simple.
  - Reduce the number of graphics and maximize information content of each graphic by careful use of coding, structuring, and labelling; however ensure that displays are not overly complex or cluttered.

[Evidence M]

Guideline 5.22 - Coding and structuring of information

1. Avoid redundant information if there is no real, established, need to use redundancy. Only key items may be emphasized by redundant coding.
2. Structure information by (in order of preference):
   - empty spaces,
   - separation lines,
   - grey levels,
   - colour coding.
3. Structure information by minimizing the number of left/right margins as well as horizontal lines, for text or numerical data items.

4. Modest use of colour coding, also considering colour vision defects
   – minimize the number of colours used
   – consider colour coding conventions (for example red = warning)
   – use a single, non distracting colour for all picture backgrounds; the foreground colour should be distinct against the chosen background.
   – avoid high brightness colours at relatively large areas of a graphic.

[Evidence H]

Guideline 5.23 - Text

For alpha numeric information, including text on CCTV images consider:

1. Legibility
   – maximum viewing distance = 200 x character height (of a capital) for dynamic data (minimum character height = maximum viewing distance divided by 200).
   – maximum viewing distance = 250 x character height (of a capital) for static data.
2. Readability of text
   – Apply upper-case characters for text labels and acronyms. Use mixed case for text messages (first letter of significant words in capital)
   – Text should be written horizontally, justified left (when words are stacked, as in a table) and written in one (national) language.
   – Do not use blinking for text messages or text background; instead consider a blinking symbol next to the text.
3. Abbreviations
   – Do not use abbreviated terms unless this makes them significantly shorter or more meaningful. Minimize the number of abbreviations.
   – Use consistent rules for abbreviations; abbreviations shall be unique.
4. Textual codes
   – Ensure that the most important letter or digit is placed up front of a code sequence.
   – Where codes are longer than 4 characters, split into blocks of 2 or 3 characters; code length should be limited to 6 characters.
   – Do not change an acceptable and known coding system.
5. Text messages
   – messages should be brief, concise and as simple in structure as possible
   – constructed from short, meaningful and common words
   – affirmative and constructive; don't tell the user what he did wrong, tell him how to do it right.
6. Numeric values
   – provide a level of accuracy appropriate to the operator's task.
   – display numeric values consistently and logically
   – ensure that numeric values change slowly enough to be read.

[Evidence H]

Guideline 5.24 - Symbols, lines and arrow
Clarity and meaning of symbols should be tested with the intended user population. Regarding the design of symbols, consider:

1. Construct symbols in a way that they are easily discerned, discriminated and comprehended (like pictograms)
2. The main distinctive feature of a symbol should be the external geometric shape, which in itself should be unique.
3. Lines
   - use straight lines, avoid edges and curved lines
   - avoid lines that run over the full screen/pixel area
   - do not use dotted lines or alternating coloured lines as line coding.

[Evidence H]

Guideline 5.25 - Hybrid graphics
Hybrid graphics integrate CCTV images and other graphics (GUIs)

- To achieve a direct visual link between CCTV images and other data, images may be superimposed on a (process) graphic.
- CCTV images and Graphical User Interfaces may be located next to each other, i.e. presented in separate windows on the pixel area. A logical structure of the layout of all information windows should be developed.
- A GUI's may be superimposed on CCTV images, such a camera identification label, or camera control options.

Example
The pixel area on an operator console may consist of 2 wide screen monitors of 1920 x 1280 (H x V) pixels, resulting in a total pixel area of 3840 x 1280 pixels. Standard IP-mediated images may have a 640 x 480 camera output resolution. Knowing this, there are many possibilities to map up to 12 images at native resolution on the pixel area, also leaving space for other types of information. One or more image areas, may be used for GUI windows with other data. Case studies show that this number of images is sufficient for lock-control, bridge control, tunnel control or rush hour traffic lane inspection.

Annex A - Selected references

An overview of CCTV-standards and other literature related to HF guidelines for CCTV systems can be found in:

- *Human Factors of CCTV - Part 1, Technology and Literature Review* (published by the project team September 2012; available on request).
  The report includes a list of 40 references on HF of CCTV systems.
- DeBruijn, D., et.al (Draft, 2015), The concept "scene". Published research report by the project team, January 2015; available on request.

Research details have been published in several conference papers:

- Bennis, A., Landman, R., Lenior, D. (2014). CCTV mediated observation versus non-mediated observation: investigating perceived image quality with different test systems. In O. Broberg, et.al (Eds.), Proceedings of the XI conference on Human Factors in Organizational Design and Management. Copenhagen.
- Pikaar, R.N. (editor) (2013). Draft Human Factors Guidelines for the design of CCTV-systems. Human Factors Research Group NL, p/a Enschede: ErgoS Human Factors Engineering.
- Pikaar, R.N., D. Lenior, D. De Bruijn, K.B.J. Schreibers (2015). Human Factors Guidelines for CCTV system design. Paper accepted for the IEA2015 World Congress, August 2015, Melbourne.
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- Schreibers, K.B.J.; Landman, R.; Jansen, J.; VanderWeide, R. (2014). CCTV supervision or surveillance - what's in a name? In O. Broberg, et.al (Eds.) Proceedings of the XI conference on Human Factors in Organizational Design and Management. Copenhagen.
- Schreibers, K.B.J., Bouchier, J.L.A. (2014). CCTV - case study traffic management highway tunnel. In O. Broberg, et.al (Eds.) Proceedings of the XI conference on Human Factors in Organizational Design and Management. Copenhagen.

Standards and guidelines related to this HF Guidelines document.

- ISO9241 - *Ergonomics of human system interaction*
  This is a multi-part international standard, applicable to all human computer interaction situations.
  - ISO11064 *Ergonomic design of control centres* (2000-2004)
    This standard will be renamed to ISO 9241-700, as a part of "Ergonomics of human-system interaction" series of standards.
- Johnson, S.O., et.al (2011); CRIOP: A scenario method for Crisis Intervention and Operability analysis. SINTEF Technology and Society, Trondheim.
  - Useful and practical checklist based guide for Validation and Verification of control centre design projects.
- APTA CCTV Standards Working Group (2011); Recommended practice APTA-IT-CCTV-RP-001-11: Selection of cameras, digital recording systems, digital high-speed networks and train lines for use in transit-related CCTV systems.

- FHWA - US Department of transportation - Federal Highway Administration (1999). Preliminary human factors guidelines for traffic management centers. Publication no. FHWA-JPO-99-042 (1999).
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  - Overview of mainly British research on CCTV systems; it is one of the few articles describing some experimental research.
- Stedmon, A.W., Harris, S., Wilson, J.R. (2011); Simulated multiplexed CCTV: The effects of screen layout and task complexity on user performance and strategies. Security Journal, 24, (4): 344-356.
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- Pikaar, R.N. (2012), HMI Conventions for process control graphics. Work 41 (2012) 2845-2852, IOS Press.

Annex B - Summary of guidelines

This annex gives a list of CCTV guidelines and their application areas. The following application areas are distinguished:

A. Surveillance & Security
B. Traffic control and supervision
C. Remote control of marine locks, bridges, gates, etc.
D. Remote control of process installations (chemical, oil & gas)

Applicability is indicated by a X.

Guideline	Keywords	A	B	C	D
Chapter 1	**Project Ergonomics**				
1.1	HF Design Principles	X	X	X	X
1.2	Verify & Validate the design	X	X	X	X
Chapter 2	**CCTV System Specification**				
2.1	Determine System Goal			X	X
2.2	Specify physical area	X	X	X	X
2.3	Inventory of Cameras	X	X	X	X
2.4	Existing control room	X	X		X
2.5	Overview of operator tasks	X	X	X	X
2.6	Inventory of CCTV images	X	X	X	X
2.7	Inventory of non-CCTV data sources		X	X	X
2.8	Describe scenes (images per scene)	X	X	X	X
2.9	Estimate operator workload	X	X	X	X
2.10	Task duration for monitoring tasks	X	X		
2.11	Consider job design	X	X	X	
Chapter 3	**Field equipment**				
3.1	Avoid false object distance interpretation	X		X	
3.2	Avoid image distortion	X	X	X	X
3.3	Requirements for wide angle lenses	X	X	X	X

3.4	Determine camera positions	X	X	X	X
3.5	Vibration of camera mounting position	X	X	X	X
3.6	Accessibility for maintenance	X	X	X	X
3.7	Lossy transmission	X	X		
3.8	Reduce data videostream	X	X		
Chapter 4	**Control room and workplace layout**				
4.1	control centre design steps	X	X	X	X
4.2	communication in control room		X		X
4.3	routing	X	X	X	X
4.4	maintenance and cleaning	X	X	X	X
4.5	civil engineering and architecture	X	X	X	X
4.6	arrangement of workplaces	X	X	X	X
4.7	overview information	X	X	X	X
4.8	user population data set	X	X	X	X
4.9	furniture adjustability	X	X	X	X
4.10	controls	X	X	X	X
4.11	visual range	X	X	X	X
4.12	minimum viewing distance (to monitors)	X	X	X	X
4.13	determine pixel area	X	X	X	X
4.14	shared pixel area	X	X	X	X
4.15	moving images	X	X		
4.16	input devices				
4.17	brightness of pixel areas	X	X	X	X
Chapter 5	**Image presentation and interaction design**				
5.1	estimate viewing task duration	X	X	X	X
5.2	detailed information analysis	X	X	X	X
5.3	workload and the number of scenes	X	X	X	X
5.4	required level of situational awareness	X	X	X	X

5.5	camera positions in reference graphics	X	X	X	X
5.6	scene - a structured group of images	X	X	X	X
5.7	camera parameters	X	X	X	X
5.8	scene selection	X	X	X	X
5.9	compose scenes	X	X	X	X
5.10	acceptable perceived image quality	X	X	X	X
5.11	image cropping	X	X	X	X
5.12	image scaling	X	X	X	X
5.13	test charts (image quality)	X	X		
5.14	user interaction - dialogue principles	X	X	X	X
5.15	camera selection method	X	X	X	X
5.16	camera control	X	X	X	X
5.17	feedback on control actions	X	X	X	X
5.18	image shifting on operator pixel area	X	X	X	X
5.19	graphics design - simplicity	X	X	X	X
5.20	alternative data for CCTV images		X	X	X
5.21	content of graphics	X	X	X	X
5.22	information structuring and coding	X	X	X	X
5.23	text	X	X	X	X
5.24	symbols, lines and arrows	X	X	X	X
5.25	hybrid graphics		X	X	X

Annex C - List of definitions

The level of evidence of a guideline will be indicated as follows:

- ***[Evidence: H - High]***
  Guideline proven by scientific research and published in literature or standards.
- ***[Evidence: M - Moderate]***
  Expert judgement of HF Professionals (registered ergonomists with extensive experience in control centre design).
- ***[Evidence: L - Low]***
  Literature, standards, and common practice, however without traceable or sufficient evidence.

This document uses the standardized ISO-terminology to indicate the importance of a guideline.

- **Requirement**; strictly to be followed in order to conform to the guidelines and from which no deviation is permitted will be indicated by *shall* (other forms used in the text: is required..., has to...., it is necessary...). For example, this verbal form will be used for legal requirements (there is no choice, one must follow the requirement).

- **Recommendations** are indicated by *should* (or: it is recommended...., ought to...). It means that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in a negative form) a certain possibility or course of action is deprecated but not prohibited.

- **Permission**: a course of action or possibility permissible within the limits of this document. Indicated by the verbal forms *may* (alternatives: is permitted, allowed, permissible) and *need not* (it is not required that ..).

- **Possibilities** and capabilities, whether material, physical or causal are given by *can* (to be able to ..., it is possible to ...) or alternatively by *cannot*.

Brightness
Attribute of visual sensation according to which an area appears to emit more or less light (ISO 9241-302:2008; Ergonomics of human system interaction - part 302: Terminology for electronic visual displays).

CCTV System - Closed Circuit Television System
A television transmission system in which live or prerecorded signals are sent over a closed loop to a finite and predetermined group of receivers.

CCVS - Composite colour video signal
The video output signal of an analogue colour camera comprising the burst and colour information (colour), the picture luminance component (video), black reference (blanking) and the synchronisation components (synchronisation).

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).

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.

Depth of field (DoF)
Range of visual focus of images from the distance at which all images are in focus (ISO 9241-302). When you focus on a subject, a certain distance in front of and behind the subject also will be in focus, although not necessarily as sharp. Depth of field increases or decreases based on the focal length of the lens, the distance to the subject, and the aperture.

Display
Device for presenting information that can change with the aim of making things visible, audible or discriminable by tactile or proprioceptive perception.

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).

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.

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).

Preset shot
A function in pan and tilt units and/or zoom lenses, which allows automatic return to one or more predetermined positions. (NEN-EN 50132-7)

Pixel - picture element
A single point in a graphic image.

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).

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.

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).

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).

Validation
Confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application are fulfilled.
(ISO 11064-7).

Verification
Confirmation, through the provision of objective evidence that specified requirements have been fulfilled (ISO 11064-7).

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).
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). 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.