Lambert & Associates

The True Cost of Going Digital

White Paper

in association with

IndigoVision

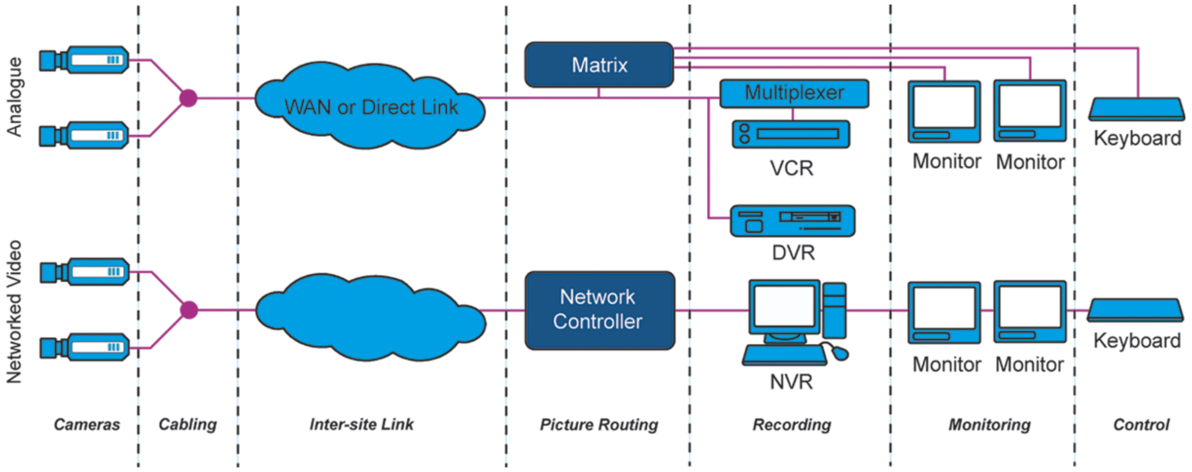
Abstract

There is a widely held view across the CCTV industry that despite the convenience and flexibility of digital technology, it has not yet taken off as the dominant industry platform because some quarters consider it to be too expensive. Lambert & Associates and IndigoVision have, for the first time, studied the actual lifetime costs of owning and running a complete CCTV system in order to develop this debate into one of fact rather than fiction. This paper summarises these study findings, looking at the initial and long term financial impact of the analogue and digital CCTV categories below, across a variety of scenarios, from single sites to multi-site applications.

Overview

Many specifiers, consultants and purchasers of CCTV solutions have expressed uncertainty over competing claims about the comparative capabilities and costs of analogue and digital CCTV. Historically, the problem has been one of partiality, which is perhaps inevitable with claim and counter claim driven by people with a vested interest on one side or other of the argument.

This white paper detaches the analogue/digital cost-benefit argument from the realms of anecdote and subjectivity and concentrates on the specific costs and functionalities within analogue, analogue hybrid and fully digital CCTV implementations. The research conducted behind this paper is an independent perspective of the relative costs of ownership of these technologies taking into account cameras, cabling, inter-site links, video switching, video display monitors, recording, staffing and systems maintenance:



For those less familiar with live networked video/fully digital solutions, these have been defined as "the technology to view and analyse both live and recorded video from networked cameras anywhere".

The key findings can be summarized as:

- Live networked video based CCTV systems allow high frame rate viewing and recording at comparable or lower costs than time-lapse technologies.
- Live networked video is particularly cost-effective in meeting the requirements of multiple and remote sites, complex deployments or those required to accommodate growth over five and ten years.
- With full network deployment, capital expenditure and running costs for hybrid analogue solutions using still capture DVRs are consistently more expensive than either pure analogue or live networked video solutions.
- Analogue systems remain cost-effective at the lower end of the market, estimated as fewer than 25 cameras, or single sites with one monitoring location using time-lapse CCTV, but show that beyond this, live networked solutions offer dramatic cost advantages.

This paper does not specifically address the impact of Moore's Law, which describes reducing cost of digital technology as production increases. This will further improve the commercial attractiveness of live networked video over time.

CCTV Comparative Cost Calculator Model

Cameras

Currently, the vast majority of CCTV cameras used for security surveillance are of the ‘analogue’ variety. These usually have a solid-state CCD sensor upon which the image is formed; a composite video signal then emerges from a standard BNC socket. Co-axial cable can carry this for immediate switching over a distance of several hundred metres, for displaying upon a standard video monitor or for recording by a VCR, for instance. The cost of these cameras has dropped rapidly for a number of years, partly due to the associated technological advances made in consumer electronics and camcorder technology, and models are widely available at prices ranging from tens to a few hundreds of pounds.

The ‘new’ alternative – live networked video – can be produced in two ways. Firstly, the signal from an analogue camera can be fed to a ‘codec’ (a contraction of coder/decoder) that will digitise the incoming images and output a stream of binary data into the network. Such codecs currently cost more than all but the most expensive CCTV cameras, and the requirement to equip each analogue camera with one means that financially, this can be unattractive. However, as this white paper aims to demonstrate, the balance may shift back in favour of network video.

Secondly, ‘network’ or ‘IP’ cameras may be employed, perhaps as replacements for existing analogue cameras. These are almost identical to analogue cameras in may respects, except that the codec element is built-in and binary data emerges directly from the camera itself. Currently, these cameras are commonly several hundred pounds more expensive than analogue cameras of similar performance (in respect of light sensitivity, image processing, signal-to-noise ratio, etc.). As above, this does not compare well with the tried and tested analogue alternatives. In addition, the current marketplace does not yet offer high-performance IP cameras that can match the capabilities of the high-end analogue cameras widely used in CCTV security applications today. However, when combined with a video codec comparable functionality can be achieved.

Over time, IP camera prices can be expected to drop significantly as manufacturers’ volumes increase. As with many emerging technologies, however, there is a catch-22 factor where these volumes may not increase quickly until the price falls.

Summary

- Analogue cameras are perceived as very capable, and agreeably priced.
- Networked cameras are perceived as less capable, and high-priced.
- Combining analogue cameras (for performance) and codecs (for networking versatility) is expensive.
- The price of emerging networked video equipment is expected to fall.

Cabling

This is one of the elements of a CCTV system where the price balance can be tipped in favour of live networked video when compared with analogue techniques.

Generally, analogue CCTV systems are configured so that each video signal is carried on an individual cable, for example, from camera to switcher, switcher to multiplexer, multiplexer to VCR, switcher to monitor, etc. Commonly, this cable is a co-axial type and is reasonably inexpensive. It may be used over distances of a few hundred metres before boosting is required. In such cases, separate amplifiers are often avoided as they require power to be provided in possibly inaccessible places.

Sometimes ‘twisted-pair’ cable is used. While this is cheaper than co-axial, and multiple pairs can be bundled within a convenient single outer sheath, the additional expense of interface units at each end of each cable must be met. This may only be economic over long or difficult runs (which can be over a kilometre), or where such cabling already exists and may be dedicated to CCTV signals. An example of the latter is the use of Cat5 data cabling within premises.

More expensive still, and providing high quality transmission, are optical fibre cables. As with twisted-pairs, these require special interfaces at both ends between the regular video signal and the cable. Over long distances, or where a single-sheath bundle of fibres that can carry multiple video signals is preferable, this may be the most appropriate approach. It is commonly used in town centre CCTV surveillance systems, airports and very large commercial sites owing to the long distances between cameras and centralised monitoring equipment. Distances of a few kilometres may be realised.

It should not be forgotten that free-space transmission, for example, microwaves, laser, radio, etc., is commonly used where cabling would be difficult. These technologies are fairly expensive and tend to be selected when conventional cabling would be even more costly. However, they do rely on a clear line-of-sight between transmitter and receiver, and can be susceptible to signal degradation when obscured by bad weather.

While all of these methods of carrying analogue signals have been in use for a number of years, the complexity of the CCTV scheme can have a significant effect on the cost of the cabling infrastructure. In the case of an airport where 700 cameras need to be viewed by 100 viewers scattered around the premises, the traditional analogue approach will probably involve 800 individual cables running over long distances owing to the nature of the site.

By contrast, live networked video schemes can vastly reduce the latter owing to their ability to carry multiple video signals within single data streams, each of which can be carried along suitable twisted-pair or optical fibre cables. Here, a single cable may simultaneously carry as many digitised video signals as the bandwidth allows. For instance, a single cable capable of carrying 40Mbps can carry around 40 video signals if each camera produces 1Mbps in order to give the picture qualities that the particular user demands. Otherwise 40 separate cables would be needed in the analogue solution.

Because networks can ‘concentrate’ multiple video data streams onto fewer ‘highways’, the infrastructure needed to provide the user with all required capabilities can be vastly simplified in comparison to that required of the ‘1-signal, 1-cable’ analogue configuration. This is most significant where cabling is difficult, expensive or impossible (for instance, burying cable around a long perimeter fence, or over a river or railway line).

As with the analogue free-space transmission methods listed above, radio or laser equipment can be used to carry data where economics or practicalities dictate. Again, the concentration of many camera signals onto one data stream is a major advantage. Also, wireless LAN equipment does not rely on line-of-sight transmission and may be used for up to approximately 100 metres distance. It even provides the facility to feed video and audio to mobile personnel.

Summary

- Analogue signals are generally carried on individual co-axial, twisted-pair or optical fibre cables.
- Multiple networked video signals can be ‘concentrated’ onto fewer twisted-pair or optical fibre cables.
- Where cabling is difficult or costly, the above advantage can be significant.
- Long cable runs require signal boosting. Network data may require this more frequently than analogue.

Inter-Site Communications

To date, the majority of CCTV systems are self-contained and, consequently, located on single sites. The owners of these systems are likely to demand that their pictures are sent to places they have never been sent before, in the same way that commuters now expect to drive many miles along motorways (cheap to use, ‘high-bandwidth’ roads) to a place of work that in the past would have been too time-consuming to reach along (‘low-bandwidth’ A-roads).

Optical fibre technology and high bandwidth digital links now allow individual analogue video signals to be transmitted from town to town across the country. However, installation and annual rental costs are often seen as prohibitive.

The falling cost of bandwidth means that the demand for such links will increase. Networked video has an advantage over analogue video because it is already a digital form that can be transmitted directly to the outside world. Many see the Internet as a route to cheap video communication, but with its current level of reliability, Virtual Private Networks (VPNs) may be a better alternative.

In the same way that codecs are required for analogue cameras, these also need to be present at the transmitting and receiving end of the analogue link; this extra cost tilts the balance in favour of the networked video solution.

Current codecs still require considerable bandwidth to send a reasonable quality stream of CCTV surveillance images, and a 2Mbps WAN link can only accommodate a limited number simultaneously. However, a large corporate WAN can offer plenty of spare capacity at no extra cost to the CCTV manager, which makes it a commercially attractive option. For instance, high street banks may already have the necessary infrastructure in place to permit night-time remote surveillance at a time when the WAN is carrying little other data traffic.

Summary

- Falling telecoms/bandwidth costs should continue to increase demand for long-distance video transmission.
- Analogue video requires codecs to use this bandwidth, whereas network video does not.
- Network video has a growing cost advantage over analogue video as camera numbers increase.

Display Routing

At this point the video signals are brought to a common point to be assigned their destinations. In a simple scheme this may be in the central monitoring and control room. In a more elaborate scheme, there may be 'satellite' facilities where sub-groups of signals are switched before being sent on to outlying destinations, or routed to the central monitoring point after this pre-selection.

In the analogue world, these central and satellite switchers are sized to accommodate the number of required video inputs from which a number of independently switchable outputs will be taken. Each switcher needs to be controlled by an operator's keyboard. The switcher itself may be a 'matrix' unit where any input can be routed to any output. These units can become very large and expensive.

It is common in small CCTV systems to dispense with the expense of such a matrix switcher and instead use the much simpler built-in switching capabilities of the multiplexers that will almost certainly be present in the recording equipment (see later). While there are no clear guidelines as to where this approach becomes unwieldy, it is common for systems that possess more than 32 inputs (for example, as 2×16-way multiplexers, or maybe 4×8-way) to make the leap to a small matrix. More generally, when more individual video outputs are required than can be supplied by the multiplexers, or more multiplexers are used than can be comfortably controlled by an individual operator, then it is time to consider a matrix switcher.

One of the principal benefits of a networked video configuration is that IP data can re-route and seek its destination when links in the signal path are found to be missing. To route images, a piece of software running on a PC is required to permit the users to specify the destinations for each stream of data packets produced by each camera. Indeed, each packet may be given multiple destinations, and this permits 'multicasting' where several users can receive the same images simultaneously. Cabling economies can be enjoyed because any cluster of monitors can be fed by a single cable carrying numerous streams of data.

Summary

- Analogue picture switchers are often the centre from which cables 'radiate' to cameras and monitors.
- Small systems often use the switching capabilities of the multiplexers associated with the recording.
- Analogue video matrix switchers can grow rapidly as the number of inputs and outputs multiply.
- Networked video schemes can offer versatile picture routing options with redundant paths.

Recording

Analogue Recording

The traditional approach to storing CCTV images has been centred on VHS videocassette recorders for many years, as these provided a picture quality that was considered acceptable for the expenditure by the majority of owners.

To enable CCTV system owners to simultaneously record images from multiple cameras, industrial VCRs were developed. These are capable of running in 'time-lapse' mode, where the tape runs slowly and captures a small fraction of the number of images that are actually received from the cameras. In addition, 'multiplexers' were developed separately to permit the pictures from a number of cameras to be sequenced or interleaved into a single stream that could be recorded onto a single tape. The combination of these two important techniques commonly results in analogue CCTV systems that are designed to record a sometimes sparse sequence of 'stills' from each camera.

The total cost of ownership of analogue time-lapse recording methods comprises the falling capital expenditure associated with the VCRs, the purchase of multiplexers that are becoming more capable with advances in their internal digital electronics, the cost of overhauling the electro-mechanical VCR parts annually to maintain picture quality, and the cost of replacing videocassettes that are usually deemed to be overly degraded after approximately 12 uses.

The time taken by staff to perform the required tape changes is the subject of a later section in this paper.

In the UK, VHS VCRs record a combination of the number of images per second (ips) that the user demands. The interval between staff tape changes determines the minimum number of VCRs (each with a separate multiplexer) required to accommodate the number of cameras in the CCTV system. Using this calculation it becomes apparent that the number of VCRs required increases rapidly as the owner's stipulation of ips increases from 1 to 2 to 3 to 4, etc. Hence, the associated capital expenditure, staff effort and annual running costs grow in leaps and bounds. For this reason, historically, the majority of analogue time-lapse recording users have settled for 1 ips (often less, resulting in large gaps between captured 'snapshots', increasing the likelihood that important visual evidence is lost for good). Sometimes they have 'pushed the boat out' to ensure that 2 ips are achieved.

As a contemporary alternative to VCR storage, the main advantage of digital hard-disk video recording is the ability to review recorded footage without having to stop the recording process. This makes for better surveillance practice, and also permits the user to quickly access material to review with a few key-pushes or mouse clicks.

Summary

- Time-lapse 'snapshot' recording is used to extend videocassette duration from 3 to 12, 24, 72 hours, etc.
- Multiplexers are used with VCRs to interleave several cameras' images onto any single tape.
- Multiplexed time-lapse recording limits images per second (ips) captured. Specify minimum acceptable.
- Recording must be interrupted to permit retrieval of tape for playback of recorded footage.

Digital Video Recording

Modern computer technology has recently permitted the development of digital video capture and storage devices at prices that make feasible the direct replacement of the VCR technology described in the preceding section. These systems often incorporate the aforementioned multiplexers to permit the interleaved recording of streams of images from multiple cameras. Higher-grade systems have been designed to incorporate enough hardware to capture all images from all cameras simultaneously without the need for multiplexers.

To make a worthwhile comparison between the VCR and digital video recorder (DVR) approaches to recording the otherwise unchanged analogue video signals from the cameras, it is important to begin by comparing like-with-like, only allowing the recording practices to diverge after these initial comparisons have been fully considered.

Regardless of the time-lapse mode in which a 3-hour videocassette is used, it is capable of storing just over 500,000 snapshots. Considering that the digitisation of incoming video is most often carried out with a number of samples (pixels) that correspond to the vertical and horizontal resolution of an analogue VHS recording (of video 'fields', each of which are one half of the interlaced 'frame'), the size of each still image can be between 20KB and 40KB.

The equivalent storage to an ordinary videocassette is ~30KB $\times$ 540,000 images $\approx$ 15GB, which currently costs around 100 times more when in the form of hard-disk storage. So what are the advantages of the digital storage methods that make the investment worthwhile?

Firstly, the cheap videocassette probably needs replacing annually, whereas the relatively expensive hard-disk does not. Over a 5-year lifetime, this alone reduces the cost difference down to a factor of 20. Secondly, the DVR does not need annual electro-mechanical overhaul in the same way as VCRs. This reduces the difference again by an amount that is too difficult to calculate here, but is not an insignificant difference in lifetime running costs. Also, the costs of staffing the system might be differently accounted for, as less direct intervention is needed to maintain the recording facility.

In the future, the cost of digital storage is expected to fall by orders of magnitude in a number of years, shifting the balance fundamentally. Currently, digital storage costs are frequently considered to be very expensive. However, as practical demands made on CCTV systems and their operators increase, the flexibility of digital recording and displays are often considered to be worth the premium price. The facility to replay footage almost immediately after inputting its time and location, while maintaining the ongoing recording process is particularly valuable.

Summary

- Digital video recorders (DVRs) replace the VCRs that record traditional analogue CCTV images.
- Hard-disk storage is currently much more expensive image-for-image than analogue videocassette.
- The flexibility of image recording/playback motivates users to pay a premium price for DVR systems.

Networked Video Recording

The fact that the IP data streams from each network camera do not need to change form to be recorded in a digital form on a hard-disk, or data tape, etc., means that video capture and digitisation circuitry does not have to be included in the Network Video Recorder.

However, in the same way that the analogue video signals are digitised and compressed (in JPEG or wavelet formats, for instance) before being stored on hard disk, the images captured by the network cameras undergo a similar compression process before being carried in the IP data that emerges from these cameras. The amount of spatial resolution (for example, ‘blocking’) and temporal resolution loss (increase time-lapse interval or skipped frames) that afflicts the moving images increases with the amount of data compression.

The network video recorder (NVR) stores the incoming video stream from each camera in the CCTV system. Unlike the aforementioned DVR that records time-lapse snapshots and discards the majority of incoming images, by contrast the NVR maximises the temporal compression offered by the camera’s codec (such as H.261, H.263, MPEG-4, etc). This permits much more footage to be stored per gigabyte. After the user has specified the qualities of the moving camera pictures by specifying the bit-rate range, less storage is required than that needed by the DVR.

For instance, a DVR capturing JPEG stills would fill 32Kb per second of storage to record just 1 image-per-second, whereas a 256Kbps video stream would require the storage of ~32Kb per second and would also probably provide 2, 4 or 6 ips. A clear advantage.

Many DVR manufacturers have begun to use similar codecs to those listed above due to the benefits of reduced storage volumes and increased images-per-second recorded. The MPEG-4 codec is now seen in several products. However, the user would be wise to carefully investigate the effectiveness of the chosen codec in replaying clear freeze-frame images where such a capability is operationally important, as some codec implementations have a tendency to blur fast-moving objects.

It is also important to note that high frequency noise in the video signal, which may be due to the camera struggling to give a clear picture in low light conditions, may cause the codecs mentioned above to output much higher bit-rates than expected, to produce inferior pictures where the bit-rate has been capped, or to create less predictable oddities that degrade the pictures.

Summary

- Network video codecs, for example, H261, give very compact digital video storage compared with DVR time-lapse.
- Picture resolution and images-per-second are affected by the chosen data bit-rate (hence, data volume).
- Some DVRs recording analogue CCTV signals are now using H26x or MPEG codecs for efficiency.

Video Monitoring

The number of monitors employed will vary widely from system to system. It will depend upon the number of operators who need to view images, how many images each operator needs to see simultaneously and how many separate locations are to be equipped.

In an analogue video scheme, including many that use DVRs, the number of monitors is likely to be closely linked to the number of available independent video outputs. The nature of networked video systems is such that cabling to multiple monitors has a relatively simple configuration. The routing of video streams is controlled by a network controller PC that hosts the appropriate software.

For ergonomic or economic reasons the display of network video images may be accommodated by multi-tasking desktop PCs at the operators’ workstations. However, if a conventional ‘video wall’ array of monitors is required for group viewing then the networked video solution may have few advantages over analogue video switching, as the cabling element will be minimal and the IP data will have to be converted into analogue signals compatible with the monitors. The cost of each of these converters is significantly greater than the cost of each monitor.

Summary

- Analogue monitoring becomes expensive when requiring a large matrix video switcher.
- Networked video monitor cabling configuration can be simpler than that for a large analogue system.
- Networked video may be sent to users’ existing workstation PCs for ergonomic and economic reasons.
- Converting network video to analogue for ‘video wall’ displays is more expensive than the monitors.

Staffing

A CCTV surveillance scheme is said to be “active” when staff are present to monitor live pictures, and deliberately control the system in immediate response to events. With such a staffing regime, it is common to argue that the manual management of numerous videocassettes each day adds nothing to the wage bill, and that the use of time-lapse VCR recording has no staff cost implications. Some accountants or managers may disagree, but the former school of thought has been accepted here.

To highlight the differences between analogue and digital recording technologies we will consider 'passive' operation of the CCTV system. In contrast to the above, this is where the recording and monitoring equipment operates unattended. Pictures are only reviewed after the event where an incident precipitates further investigation. In such a regime the daily management of videocassettes is a task that must be specially undertaken, and therefore an operational cost may be assigned to the function. This is particularly true if contract security guards are employed to take responsibility for this.

The operator intervention required for a fully digital recording system, either DVR or NVR, is insignificant where recording is performed on internal hard-disks or auto-loading data tape carousels. Specialist maintenance of such IT equipment is outsourced to the maintainers of the CCTV system and is detailed in the next section. For large video networks, especially those with an infrastructure maintained by in-house IT personnel, a small allowance may go to IT department staff labour for regular operational checks.

An allowance for wage inflation should not be underestimated, as annual wage rises as low as 2% will have a significant cumulative effect over 5-year and 10-year total running costs.

Summary

- Daily analogue VCR tape handling only impacts staffing costs where 'passive' CCTV operates unattended.
- Auto-loading digital data tape systems (for DVR or NVR) offer zero CCTV staff costs.
- Networked video infrastructures may require occasional checks from IT staff.
- Wage inflation compounds to provide significant running costs over the life of the CCTV system.

Maintenance

It has been common practice in the CCTV industry for many years to price annual contracts for service and maintenance by calculating the figure as a percentage of the original capital expenditure.

The cheaper service and maintenance contract will provide engineers to carry out scheduled preventative maintenance and attend emergency breakdown calls, and charge extra for the parts and labour required to fix the fault. However, this makes the annual budget difficult to predict as the number and nature of the breakdowns and repairs cannot be reliably estimated. To provide a fixed fee for the annual service and maintenance, a 'fully comprehensive' contract is usually offered at a price premium. To allow comparable total cost of ownership figures to be calculated over the life of the CCTV system, the latter 'fully comprehensive' schemes should be considered.

For analogue VCR recording schemes the cost of replacing worn videocassettes is added to the engineers' fees. These figures can be significant where large numbers of units and tapes are in circulation. DVR and NVR systems do not bear these costs, as they can be operated without regular intervention. However, total running costs can be high as maintenance fees are based upon a percentage of what is probably a higher capital expenditure than would be the case for an equivalent VCR recording scheme.

The maintenance contract fees affect the total cost of ownership figures simply by magnifying the differences between the original capital expenditures as the systems age. It is quite feasible that cross-over points will emerge where technologies that are more costly to buy initially and cheaper to run eventually undercut their competitors after a number of years of running.

Summary

- 'Fully comprehensive' maintenance provides useful predictable annual outgoings, at a premium price.
- Running costs of VCR recording systems require the addition of fees for VCR overhaul and tape renewal.
- Running costs for DVRs and NVRs largely comprise maintenance fees.
- Low running costs may override high purchase costs over the expected life of a system.

Conclusion

Some CCTV users are more concerned by the purchase price than the running costs. This research has shown that networked video solutions can be cheaper to install than conventional analogue systems where cabling to cameras and monitors is extensive, inter-site video relay is required, picture switching/routing is complex, and the advantages of digital recording are necessary, or staff intervention needs to be minimised.

The true pros and cons of analogue versus networked video can only be weighed against each by combining *all* of the elements discussed in this paper. When the running costs of the CCTV system are taken into account to complete a cost-benefit analysis, it is very possible that the figures will intersect at a point in time, beyond which the system that costs more to install actually costs less to own in the long run.

One of the by-products of this research was a CCTV Comparative Cost Model, which is freely available to enable those in the industry to test its conclusions for themselves. The software calculator in CD-ROM format allows a comparison of all the elements discussed in this paper, resulting in a graphical representation of the total cost of ownership. It is designed to enable security and IT managers, specifiers, CCTV distributors and value added distributors to evaluate the long-term savings from moving from analogue to fully digital networked CCTV solutions.

In the early days of networked video in the CCTV surveillance industry, fear and uncertainty obscured the decision-making process for many prospective users. This research and supporting software now allows the various factors to be weighed up against each other, often leading to some surprising conclusions.

A copy of the CCTV Comparative Cost Model is available from IndigoVision who sponsored the creation of the software tool and the research behind it. The software can be downloaded from www.indigovision.com or ordered by calling 0131 475 7200.

About IndigoVision Group plc

Founded in 1994, IndigoVision is the leading developer of live networked video technology. The company develops live networked video technology around its VideoBridge protocol which communicates between networked video devices that view, record, retrieve and analyse video from networked cameras anywhere. Focusing initially on surveillance and monitoring, the company has licensed its technology to leading vendors including Ultrak, Baxall and Panasonic. Floated on the London Stock Exchange in August 2000 (symbol IND.L) the company is headquartered in Edinburgh, UK, with offices in London, Tokyo, San Jose and Boston.