Emergent Roles for Optical Media in Transport Engineering

MARCUS WIGAN

Computer-based systems for the delivery of engineering information are beginning to become cost-effective for a growing number of road and civil engineering applications. Optical media, mastering, and authoring requirements are explored, and the serious problems inherent in the evaluation of the use made of such systems are considered. Examples of the appropriate use of analog (Laservision) and digital (CD ROM) forms of optical storage in various transport applications are given. The ability to handle high-quality images and text, to access standards-approved computer programs for specific applications within the context of a certified Standard, and the rapid changes in accessibility to digital terrain and cadastral data are about to have a major impact on road engineering and training. Examples of hypertext and expert systems for this purpose are now being tested as part of a project evaluating an enhanced version (the third edition) of *Australian Rainfall and Runoff*, and these methods are being evaluated for their ability both to deliver information more cheaply and for their potential to improve engineering practice. CD ROM optical disk delivery forms a key part of this process. The locational requirements of pavement, traffic, road, and transport information systems all point to greater use of GIS methods. As a direct result of several Australian reviews of transportation survey data needs and uses, the use both of GIS methods for data integration and of optical media for collated and economic distribution and archival access have emerged in Australia as widely recognized requirements of all future such surveys.

The requirements for mass storage devices both with imaging and data capacity have been growing for some time. The combined ability to access visual information randomly, associated with selected items of information drawn from a mass of data, is attractive to many different road application engineers. A parallel thrust has been the world-wide growth of the 300-mm Laservision disk format in the markets for computer-based training and museum collection recording and display. Road and transport applications include

- Photologging,
- Mapping,
- Terrain data,
- Water resources data,
- Transportation and spatial movement data,
- Navigation,
- Training, and
- Vehicle operator environment simulation (with landscape montage creation).

Each of these applications makes special demands that can be serviced well by making various data and processing services available on optical media of various types. A number of these applications, and the associated issues of image processing and geographical and graphics data bases, are covered in a national workshop for operational road organizations held at the Australian Road Research Board (ARRB) in 1987 (*1*).

The document delivery and educational aspects being tested in the water and flood estimation field as a joint Monash and ARRB project are documented elsewhere (*2–4*). This project will be considered as the first of the application domains to be discussed.

DISTRIBUTION AND EDUCATIONAL SUPPORT USING OPTICAL MEDIA

Professional engineers now face an overwhelming amount of information that must be integrated in the options for, and solutions to, any particular problem (*2*). This trend is leading to a substantial need for more effective means of keeping practicing engineers up-to-date and in touch with recent developments (and in a better position to discharge their legal liabilities in this direction—an issue that can no longer be ignored).

The methods, format, and effectiveness of both novel and different forms of release of substantial bodies of information (e.g., structural or operational codes of practice or standards) in engineering are therefore issues demanding serious and practical attention. This problem is relevant to all engineers. There is a continuous need to update professional knowledge throughout an engineer's working life.

Unfortunately, much of the currently useful information is presently held in forms that are not easily accessed. For example, even though engineering codes contain a vast amount of knowledge in a particular area, they are paper based, and generally poorly indexed and badly cross-referenced. There are often maps, nomograms, and reams of specialized design charts to be obtained as well. These aids are usually also expensive to publish. Consequently, the information is difficult to access, and the user must be experienced if his design is to satisfy the high standards set by the quality of the information.

The issues that need to be addressed and potential contributions include the following:

	Computer/optical Media Contribution	
Issue	*Computer*	*Optical media*
Quantity of information	High	High
Organization of information	High	Neutral
Accessibility of information	Mixed	Mixed

Australian Road Research Board, 500 Burwood Highway, Vermont, Victoria 3033, Australia.

Issue	Computer/optical Media Contribution: Computer	Optical media
Interpretation of the information	High	Neutral
Economic distribution of the materials	Medium	High
Quality of design assisted by the materials	High	Neutral
Means of effective updating	High	Medium
Ability to integrate the materials with other tools	High	High
Suitability for self-study	High	High

The educational effectiveness is to be tested (*3–5*).

A suitable test example is the third edition of *Australian Rainfall and Runoff* (AR&R) (*6*), a document of considerable relevance to local government engineers and those working for state road authorities for the design of such constructions as bridges, culverts, and floodways. The first volume of the third edition has 350 pages of text, and the second volume adds 110 pages of A2 size maps. Because this represents a 350 percent increase in size over the second edition, the costs of production, printing, reproduction, and distribution already show compact disk read-only memory (CD ROM) as a potentially cost-effective alternative even before the additional opportunities offered by a computer environment plus mass (optical) storage have been exploited to add value and improve accessibility.

Monash and ARRB have been building hypertext (i.e., reauthored nonlinear text) versions of various chapters of the *AR&R* (*6*) using the Guide hypertext authoring product by OWL International (*7*), which is based on the work in the U.K. (*2*). The users of the current AR&R have also been surveyed for their experience both with this document and other sources of hydrology data and with computers in general (*3*).

In order to make effective use of engineering information, text, diagrams, programs, and advice in a machine-readable format, it is simply not enough to do what has already been done: namely, to transfer unaltered and unstructured text, numbers, programs, and graphics to a CD ROM—however useful as an archival base for wide distribution, access, and security of the data base and its documentation (*8*). US West Inc. already produces mass hydrology data on CD ROM, and the printed text version of AR&R is supported by a range of hydrology programs available from third parties.

The special features of optical media are

- The capability of cutting the cost of reproduction of this massive package of material as a single convenient unit, and
- Enhanced accessibility to the material thereby collated, as access is now mediated by a computer system, with all of the nonlinear, graphics, and other capabilities that the computer can potentially provide.

In order to gain these benefits, it is necessary to create and build some additional structure into these basic materials.

The authoring of the chapters in hypertext has required much additional structure to be added to the basic text. It is clear that the requirement to provide multiple paths through the information, to identify the overall structure and linkages in the material, and to provide sensible graphics to the material all add up to much the same task as reauthoring the basic material into a form more suitable for a paper, a lecture course, or a full teaching workshop. In each case, the interactive features must be built in, and the teaching and communication aspects require greater attention than is usual in most manuals or textbooks, which rely on such added interpretation when being used as set books.

PHOTOLOGGING OF ROADS AND ADJACENT FACILITIES

The value of visual forms of recording road surface and environment and condition have long been known (*9*). However, the costs of large quantities of records on 35-mm film are high. The monitoring of roads and their surface condition and adjacent facilities has been approached by many bodies using 35-mm slides and film, but usually with mixed success as a result of the difficulties in accessing the materials once captured. Video tapes appear to offer a good method of cheaply and economically capturing large quantities of such material, and several road authorities have tried it, but with mixed success (*1,10–13*).

The most significant problems found with the videotaped photologs of roads were

- No one wanted to use them because of the difficulty in finding target information, and
- The resolution of the images was too poor for most practical purposes.

The underlying problems were that the access to the individual frames on the video tapes was a slow and cumbersome process that took a lot of time and effort on the part of the users, and the typically 200-line resolution of the domestic VHS video tapes used just was not good enough to justify the effort.

The state of Connecticut, which is quite small (by U.S. or Australian standards), has had an active photologging unit for some time. This unit has addressed both of these problems (*13*). It has been using 35-mm film to log the visual surface of the roads, and transfer this to 300-mm Laservision disks for storage and access. Note that Laservision is a trademarked specific standard for 12-in. analog optical disks. They also provide some numerical data overlaid on the top of the video screen to key the information otherwise available at a given location straight onto the video record. A Connecticut photolog video disk loaned to the author was manufactured in 1985, long before the refinements now available could be used. It is therefore the lowest quality that would be obtained by anyone using this type of approach to road inventory systems, and the control and searching facilities now available or also in use in Connecticut. Details of some of the locations and their frame index numbers are available from the author.

There are two types of video disk: continuous longplay video (CLV), which can only be randomly accessed at time or chapter intervals, and computer active video (CAV), which is recorded slightly differently, with 54,000 still images on each side of the disk, as the recording method permits a single image to be displayed with complete stability indefinitely. Recently the addition of digital frame stores, digital sound tracks, and other refinements have blurred the differences between these two styles of disk, as digital frame stores can

be used to capture any frame into a frame buffer for stable display. These newer players are still expensive and in short supply, and the CAV format will continue to be used by the cheaper players.

The equipment that can most readily be used in Australia is the Pioneer LV4200 NTSC 50/60 cycle and LV 4100 PAL industrial computer-controlled Laservision player with analog sound tracks only. Both are readily available in Australia, and about 100 examples of the NTSC equipment are in daily use at the Sydney Powerhouse Museum. NTSC has gained a lead in the Australian domestic and display markets, whereas professional training uses both PAL and NTSC players and material. It is worth noting that the Sony command set can also be used with its dual standard Laservision player, which reads both NTSC and PAL disks and outputs PAL signals to the display.

The Pioneer LV4200 and the Sony LDP1500 are the two players most widely supported by Apple Computer HyperCard stacks. Optical Data Inc. has created both programs for the IBM PC (under the MS-DOS operating system) and HyperCard controller stacks and data bases (on the Apple Macintosh) for large collections of NASA space and air travel images and motion clips, with a considerable amount of ancillary material added on the computer data bases attached to the MS-DOS or HyperCard host programs. The Voyager Co. of Los Angeles has a series of HyperCard tools for the Pioneer and the Sony, and also authors a whole range of CAV disks. The advent of HyperCard and its clones for Unix and MS-DOS, together with Apple Computer's and IBM's steady moves toward multimedia and educational applications have begun to provide a new foundation for Laservision disks, as well as for CD ROMs (which Apple now manufactures). The graphical orientation of the Apple range of computers provides the obvious link between optical media and its product marketing interests. It remains to be seen if the market will respond.

Meanwhile, the costs quoted in Australia for premastering a videotape, mastering a pressing, and producing the first ten 300-mm Laservision disks in PAL or NTSC format are already less than $10,000 (Australian dollars) for continuous videotape transfers—but up to $50,000 for the premastering of 54,000 different still images on a CAV disk designed as an image database, typified by the NSW Printing Office art collection disks. (All prices shown here are indicative, and refer to early 1989; major movements, generally downward, have already occurred, and can be expected to continue.) This high cost is incurred by the synchronization of the eight-field PAL video images with the recording process. The manpower required for such a large quantity of information individually addressed will always be substantial. The costs of CD ROM mastering, premastering, and disk production are roughly comparable, but are already drifting noticeably lower.

Laservision mastering costs are still noticeably greater than for CD ROM mastering, but CD ROM is not as yet a good basis for large numbers of still or moving full-color images. Uncompressed 24- or 32-bit full-color images could require more than 2 MB of disk space, only about 500 still images on a CD ROM. The Sarnoff Laboratories/Intel DVI format for compressed still and full-motion imaging on CD ROMs, which will still take some time to reach the field in an economic form, may be an improvement. Laservision 300-mm disks in CAV format handle up to 108,000 still images per disk, or 2 GB of digital data. Data compression and expansion schemes based solely on software, yet running fast enough for real time use in many cases, are now also beginning to appear in increasing numbers.

A range of different encoding and decoding systems are readily available to add several hundred megabytes or more of digital or audio data to this massive inventory of images.

The advent of S-VHS (400-line resolution) domestic video recorders and low-cost 500,000-pixel CCD cameras has now—in 1989—brought road system (and bridge structure) photologging to an economic position. Sime and Hudson (*11*) emphasized that this level was about the lowest acceptable level of resolution to achieve really useful logging results. They used 35 mm with careful transfer to the disk in the first few rounds of their work, and found that the 400-line resolution or better of a Laservision disk itself was acceptable—and that the random access nature of CAV laser disks made the photolog records a product in demand. The serial slow access of video tape was apparently the major blockage to wider takeup of the earlier cassette-based logging system in the state.

The association with data bases under MS-DOS, Apple, or Unix provides the other component required to make optical media really useful and effective in the field. The association of a high-quality visual image with an accident location or intersection contains far more information than can normally be captured in a data base efficiently by any other means. Random access to high-quality still images recorded in analog form on a Laservision disk still provides the best results at the most economic cost.

The addition of a Laservision-based directory of photographic-quality images and maps of the streets of Melbourne to the recently completed ARRB detailed accident data base for Melbourne (*14*) would be a typical—and well worthwhile—example of the added utility that it is now economically possible to provide.

If this Melbourne visual data base were to be installed (say under Oracle or Titan) on an MS-DOS machine, then queries to the data base could easily be arranged to invoke a particular still frame (or motion sequence) stored on a Laservision disk. There are several methods for simultaneously storing the digital data required—perhaps even for the data base itself—on the same Laservision disk, thereby making the Laservision disk an extremely high-quality random access archive system, which could still be easily replicated and put into high-activity use in many locations at an economic cost. The compact, complete, and accessible random access record thereby produced would normally require only a microcomputer and a video monitor for self-documented (and possibly even self-running) large-scale data bases. The role and economics of such enhanced and robust forms of mass data delivery now justify close examination, as the trend to networked distributed data base systems gathers pace.

The addition of data to a Laservision disk can be achieved by a range of methods: some affect the use of the disk as a mass still image frame store, others do not. For example, EnVision cards in a PC AT (*15*) would permit the entire current data base to be encoded onto a single disk inside a subset of the still-frame image tracks, or the LV ROM system

adopted by Phillips and the BBC (for the 1 GB of ancillary information recorded on the three-disk Laservision set comprising the Domesday Book) could be used.

Phillips uses the audio tracks, whereas EnVision and their kin provide for a fluid mastering mix of data, audio, and image in any combination by using the full video bandwidth of the Laservision disk. In either case, a specialized encoder and decoder are required, but in the case of the Domesday Book the disks can still be read as a series of still-frame and moving images. A further form of encoding is to utilize the video bandwidth reserved for the blanking interval on a videotape recording. This technique was used, for example, by the Melbourne Royal Children's Hospital for videotape records for which the coincident recording of the simultaneous data logging digital and analog information was required to be available with (and therefore on) a visual record.

There are wider implications in the use of high-quality Laservision analog color image records: the geographic information system (GIS) has grown up in the land information and surveying field as means of handling multiple overlays of information over a fixed two-dimensional cadastral geographic map or three-dimensional full-terrain specification. These systems still have some major deficiencies, but have more and more to offer land and transport engineering and planning organizations. Standard genlocked output from microcomputers (typically,the Videologic MIC–2000 and MIC-3000 interface cards for IBM PC, and Torch for Apple Macintosh II, both of which permit full-quality video to be displayed in synchronization with computer-generated text and graphics) can be used to overlay live video graphics from a data base retrieval over a high-resolution Laservision-stored image of a map (thereby saving a massive amount of storage, computation time, and cost).

This mode of operation is used by military aircraft laser disks of various types, where the coincidence of a head-up display or terrain feature map underlay from the disk is synchronized with the computer-generated selective information overlay. Using the mixed-media style of low-cost data base, it is straightforward to include still-frame pictures of specific targets, features, or other visual imagery to be associated with particular situations or locations.

Until GISs—such as ARCInfo and TIGRIS—improve significantly (*16*), this approach is likely to add more practical value to accident and transport data bases at low cost with a short lead time than a move to GIS integration (worthy though that would be), and also to drastically simplify the means of access to such large bodies of data, and provide it in a more usable and assimilable form.

The software requirements for effective mixed-media graphical and digital data bases are not yet clear. The benefits of using a graphical paradigm for responding to queries made of a pavement information data base have been demonstrated (*17*), but it is clear that a significant convergence between GIS, road information data bases, and visual records is now imminent and should be used in any new transportation survey: recommendations to this effect have already been made this year (1989) by consulting teams (both including the author) for the two largest Australian states. Relational data bases have their problems, and the new generations of hypertext structures and object-oriented data base systems [arising from the current wave of artificial intelligence input into data bases and information retrieval (*5*)] will be considerably more suitable. To apply some effort to understanding and investing in the software aspects of this new type of information resource is timely and will play a large part in building the demand for (and reducing the cost of using) large-scale optical media and their associated services.

OPTICAL STORAGE REQUIREMENTS FOR TRANSPORTATION DATA SETS

The value of optical storage systems lies both in their capacity and in the economy in providing a genuinely archival storage medium. Transportation surveys have been carried out since the early 1960s, and have long been known for their demands of large numbers of magnetic tapes and substantial computer processing times.

This perspective has been radically altered by the development of fast microcomputers with gigabyte storage capacity. However, the fragility of these data sets has continued to be a problem. It is all too common for tapes to be released unintentionally, for parity errors to emerge on older tapes, and—even more common—the basic documentation required to identify and describe the contents of the tapes becomes disassociated with the tapes themselves, thereby rendering the information virtually useless (*8*).

Transport is not the only field to suffer from this type of problem, and the SSRC Social Science Data Archive at Essex University in the U.K. has encountered all these problems and more. The user demand for their information product is now such that they have created a number of 12-in. Laservision disks that are permanently on line. Such systems provide the easy opportunity for high-integrity backup, random access, and the integration of the textual, graphical, and numerical information for each survey in a form that provides a sound and easily replicable archival or access unit. The ability to add computer programs, video, and other forms of motion and still-frame imaging to these records also exists.

In this field, Wigan (*7*) has previously recommended the use of optical media to cover the first group of goals, and it is clear that the economics of this process are indeed excellent with the market and technical developments of a scant 2 years. It should not be assumed that CD ROM would be the only medium (*18*). Worm and erasable optical disks also offer the ability to do direct mastering of large numerical data bases, specially now that hard disks of 600-MB and larger are readily available for microcomputers. The questions about interchangeability and error correction standards agreements still dog Worm and erasable optical disks, and until these are cleared up (as has been done for CD ROM with High Sierra and ISO 9660, the distribution potential of such in-house mastering will remain problematical.

The current existence of CD ROM drives for Apple and IBM PCs, both capable of reading the High Sierra and ISO 9660 formatted files and file systems, establishes CD ROM as the medium of choice for the present. Erasable optical disks meeting CD ROM form factors and High Sierra data formatting conventions may yet appear, but do not materially alter the present market position of CD ROM. ARRB is

continuing to work on finding and testing methods of realizing these potential benefits for transportation and text data bases. The first such CD ROM scheduled to be mastered in the first quarter of 1990 (*19*) includes one of the *AR&R* hypertext prototypes integrated with hypertext versions of the technical papers describing the project (*2–4*).

The marketability of this type of data is becoming strongly established. The BBC Domesday Book is now being marketed in two tiers: one for the schools for which it was originally aimed—and the other, at a substantial premium, for the commercial interests that are finding this type of integrated graphics, visuals, and numerical data base a tool of major marketing significance. The Museum of Victoria has already moved to a Laservision disk basis for the visual records in this collection, and uses the Titan large-scale data base system to index and cover the collections: the links between Titan and the laser disks have now also been forged. Titan is a data base developed by Melbourne University and RMIT specifically for large databases. It is now marketed by Knowledge Engineering.

VEHICLE NAVIGATION

An ability to contain a large amount of detailed graphical information in a robust random access format is attractive in all sorts of transport applications. Military aircraft are now able to use the AMOD-II Lockheed laser disk system to deliver terrain and navigation data in an optical disk system "intended specifically for use in high performance aircraft. . . ." Specialized laser disk systems for maritime navigation have also been produced, with the entire world's charts recorded in vector format, and with ancillary information to permit ship alignment assistance under computer control.

Road vehicle navigation systems also aim to use CD ROM techniques, and the ETAK car navigation system company in Silicon Valley plans to use CD ROM to deliver their future services, built on their current geographic data base efforts. Car navigation systems and CD ROM mapping storage are widely expected to become economic for at least part of the motor vehicle market by Phillips and others (*20*). Such navigation systems are also equally helpful for other modes, including pedestrians in suitable circumstances (*21*).

Vehicle navigation applications currently lean towards the 130-mm CD ROM/CD Audio approach as the domestic market has driven the prices down for this type of technology. However, competition between satellite location (communication) and dead reckoning with local updates (on-board computation and mass storage) systems has yet to be joined in earnest. On the road, the AutoGuide system due to be tested in the U.K. would fit best with the on-board optical disk approach in supporting communications and beacon assistance, whereas the French systems lean more towards active location by frequent communications. On the sea, the Disk Navigation Company of Sweden (*22*) combines all these methods, and uses CD ROM to provide navigation and maneuvering assistance through direct interactive control of the vessel, while linking in to satellite, Loran, Omega, and ship-born location and logging devices.

In either case, the economics of mass data transfer mean that an on-board optical disk with large amounts of digital or analog maps or location-specific visual, text, or digital information, will provide a massive boost for the production and distribution of the necessary master optical disks. As the reproduction costs are so low (a few dollars), the existence of a mass market will permit this product to become economically available for the wide range of identified specialized uses in transport engineering.

Large-scale data base systems are required for locational and navigational systems as these, like the other types of transport and land-related data systems, are all turning to cadastral, terrain, imaging, or laser disk support to handle the increasingly nonhomogeneous nature of the items and entities to be indexed.

The convergence of GIS, transportation survey, road, and land information and textual data base requirements means that greater attention should now be paid by those in these fields to such systems as CSIRO's SIRO-DBMS extensions of Oracle, GADD (*23*), and Titan as well as the newer developments in GIS systems such as Intergraph's TIGRIS that are emerging now that ARCInfo is becoming mature in the marketplace. It is difficult to see the next round of transportation surveys' being undertaken without the use of GIS methods for either the survey phase or at least the data base structuring.

SUMMARY

Optical disk applications in transport are already in use, and others are becoming economical quite quickly. All depend on the ability to create compact, robust, and cheap storage units that can contain graphical, video, aural, and digital information in large quantities and with random access.

The most significant new applications to emerge will probably be the simple addition of visual records associated with spatial aspects of road information systems, followed by motor vehicle navigation systems.

The educational and text data base impacts of optical disk technology are likely to appear first in the publishing, educational, and technology transfer areas of engineering, and may have a greater effect than all of the other applications and data bases combined if they can help to maintain, update, and improve the performance of experienced engineers in their job.

ARRB is about to publish a trial information resource CD ROM (*19*) to test several of the application areas. This CD ROM contains a wide range of transportation databases, information retrieval and hypertext resources in addition to a stereo audio track which can be played by a conventional domestic CD audio player.

The rapid convergence of management and operational data requirements in road and transport-related organizations already demands the gigabyte storage scale of optical disks, and the ability to replicate such large data bases and add audio, visual, and analog information will be progressively taken up. Increasing pressure can be expected on GIS software vendors to produce true object-oriented data base systems capable of integrating GIS, graphics, and relational data base models, and set up to handle huge quantities of data in an integrated manner.

Optical storage media provide a viable method of creating, managing, storing, distributing, and accessing such multi-agency data bases. The more difficult questions of the types and

nature of the data base software (as distinct from the basic index creation and user interface query software) to make best use of this newly found potential mastery of the basic data are being addressed by Titan and other innovative efforts.

GLOSSARY

Acronym	*Definition*
CAV	Computer Active Video form of Laservision recording that is recorded as 54,000 still images on each side of the disk. This permits a single image to be displayed indefinitely with complete stability.
CCD	Charge-Coupled Device: a robust form of camera design that permits high-speed capture of images with wide lighting tolerances.
CDI	Continuous Data Interactive: a method of compressed image recording and expansion that permits up to 70 min of live video to be recorded on a single CD ROM. Patented by the ex-RCA Sarnoff Research Laboratories (now Intel).
CD ROM	A standard for 1,300-mm digital optical disks, the same size as domestic CD audio optical disks, and read on modified players for that type of disk, thereby reducing the cost of the players and broadening the market from the start.
CLV	Continuous Longplay Video: a form of Laservision recording that can only be randomly accessed at time or chapter intervals.
Expert systems	Advisory or diagnostic computer programs that are designed to mimic or replicate a degree of human judgment, advice, or regulation.
Genlock	A term used to specify the ability of two video signals to be synchronized and displayed as one.
High Sierra	A standard format for digital CD ROM recording agreed at a series of conferences led by Microsoft and others in the mid-1980s. The basis for the ISO 9660 standard, which is High Sierra with some marginal (but irritating) alterations.
HyperCard	An innovative program provided with Apple Macintosh computers that makes nonlinear text and graphics handling easier for nonprogrammers. It has had a wide impact, and is now a common basis for multimedia control programs, including Laservision disks and CD ROMs.
HyperText	Nonlinear text, with many branches and means of navigation through it.
Laservision™	A standard for 300-mm optical analog disks initiated by Phillips, DiscoVision, and Pioneer for consumer and professional usage in the late 1970s.
LV ROM	A form of data encoding on Laservision disks designed by Phillips for use with the BBC Domesday Book project and its successors.
NTSC	The form of video encoding used for video broadcasting and recording in the U.S., Japan, and some other countries. Widely used in Australia for domestic and museum Laservision records.
PAL	A modified form of NTSC, offering more resolution and better color stability. Essentially a modified West German standard, adopted in most of Europe and in Australia for public broadcasting and domestic use in various forms (PAL–I, PAL–D, etc.). The versions of PAL used in Europe and Australia are significantly different in a number of respects.
S-VHS	An enhanced version of the JVC Company domestic VHS standard, which permits up to 400+ lines of horizontal resolution on special material tapes in domestic VHS format. Downwardly compatible with current VHS players. Requires either a special monitor or an RGB adaptor box for playback at the full 400+ line quality level.
WORM	Write Once Read Many optical disks. These are of archival quality and may only be written once. Standards for these removable disks have not yet stabilized.

REFERENCES

1. R. J. Troutbeck and M. R. Wigan (eds). *Workshop on Visual Data Acquisition and Application*. Research Report ARR 151. Australian Road Research Board, Vermont, Victoria, Australia, 1988.
2. R. Hadgraft and M. R. Wigan. Assessment and Improvement of the Codification and Delivery of Engineering Experience. In *Proc., Watercomp '89*. National Conference Publication No. 89/8. Institution of Engineers, Australia, Canberra, ACT. 1989, pp. 160–164.
3. R. Hadgraft and M. R. Wigan. Towards Effective Field Support and Retraining for Engineers Who Use *Australian Rainfall and Runoff*. In *IEAust. Hydrology and Water Resources Symposium*. Christchurch, New Zealand, National Conference Publication 89/19. Institution of Engineers, Australia, Canberra, ACT. 1989, pp. 468–472.
4. R. Hadgraft and M. R. Wigan. A Possible Prototype for a New *Australian Rainfall and Runoff*. In *IEAust. Hydrology and Water Resources Symposium*. Christchurch, New Zealand, National Conference Publication 89/19, Institution of Engineers, Australia, Canberra, ACT. 1989, pp. 481–482.
5. M. R. Wigan. Information Provision and Access: A Users View. *Library Software Review*, Vol. 8, No. 3, 1989, pp. 130–137.
6. *Australian Rainfall and Runoff* (3rd ed.). IEAust, Sydney, 1987.
7. M. R. Wigan. *Australian Personal Travel Characteristics*. Special Report SR 38. Australian Road Research Board, Vermont, Victoria, Australia, 1987.
8. M. R. Wigan. The Secondary Use of Transport Survey Data. In E. Ampt, A. J. Richardson, and W. Brog, *New Survey Techniques in Transport*, VNU Science Press, Netherlands, 1985, pp. 131–148.
9. T. Datta, K. H. Tscuchiyama, and K. S. Opiela. *Cost-Effective Inventory Procedures for Highway Data: Users Manual*. Report FHWA-IP-85-14, FHWA, U.S. Department of Transportation, 1985.

10. M. Perfater and G. Harris. *An Investigation of the Uses of Videotape in Transportation Operation*. Report FHWA/VA-86/20. FHWA, U.S. Department of Transportation, 1987.
11. J. M. Sime and J. H. Hudson. *Photolog Laser Video Disk for Highway Monitoring, Evaluation and Data Storage*. Department of Transport, Wethersfield, Conn., 1986.
12. J. H. Hudson and J. M. Sime. *Procedure Manual for Photolog Laser Disc Production*. Department of Transport, Wethersfield, Conn., 1986.
13. Laser video discs, computer discs for road evaluations. *Better Roads*, March 1985.
14. D. C. Andreasen. *Disaggregation of Accident Data by Road Hierarchy*. Internal Report AIR 1123-1, Australian Road Research Board, Vermont, Victoria, Australia, 1983.
15. M. Fritz. Still-Frame Audio: 300 to 1 Compression Ratio Maximises Disc Space. *CBT Directions*, March 1989, p. 10.
16. J. Dangermond. A Classification of Software Components Commonly Used in Geographic Information Systems. In D. Peuquet and J. O'Callaghan. *United States/Australia Workshop on Design and Implementation of Computer-Based Geographic Information Systems*. IGU Commission on Geographical Information Systems, Amherst, N.Y., 1983.
17. M. R. Wigan. *The Use of Prototyping and Graphics Methods for Road Information Systems*. Technical Manual ATM 25, Australian Road Research Board, Vermont, Victoria, Australia, 1988.
18. T. Hendley. *CD-Rom and Optical Publishing Systems*. CIMTECH Report 26, Hatfield Polytechnic, Hatfield, U.K., 1987.
19. M. R. Wigan. ARRB Information Resource CD-Rom. Publication CD-Rom-1/ISO 9660, Australian Road Research Board, Vermont, Victoria, Australia, and 22-p. booklet as supplied with this CD-Rom separately available, in press.
20. J. K. Beardmore. Laservision Technology as Applied to Route Guidance Systems. In *Vehicle Route Guidance, Navigation and Control*, IEE Colloquium, London, U.K., 1987, pp. 11/1–11/6.
21. Oracle Communications. In *Integrated Transportation Information System*. Report TP 8293E, Montreal, Canada, 1987.
22. V. Karager. La Carte Electronique. *Navigation*, No. 141, 1988, pp. 63–69.
23. C. N. G. Dampney and B. D. Johnson. Database Management Systems for the Geosciences. *Exploration Geophysics*, Vol. 19, No. 1/2, 1988.

Publication of this paper sponsored by Committee on Computer Technology.