severest hazard analysis situation exists because of the unacceptability of inadvertent or false inflations of the air cushion.

Summary

The automotive industry continues to examine new electronic technologies for their applicability to the automobile. Today, 16 electronic systems can be found on the automobile, and future engine and emission control systems will soon be added. Truck systems of interest include wheel-lock control, vehicle weighing systems, and tire pressure warning devices. Digital electronic displays and multiplex wiring systems are expected to be near-term developments and, on a longer-range basis, it is expected that automatic radar brakes and intoxicated-driver interlocks will receive considerable attention.

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Electronic Mail

Electronic communication of information is more rapid than conventional transportation of documents.

Robert J. Potter

The concept of an organized mail system is believed to have emerged in about 400 B.C. in the Persian Empire. Queen Elizabeth I issued a proclamation in 1591, which prohibited carrying of mail to and from England except by messengers authorized by the Master of the Posts. In America, the first postal system was authorized by the colonial legislature of Massachusetts in 1639.

Efficiency was gained by faster transmission and, subsequently, by faster distribution at the terminals of the system. The pony express increased the extent of the postal system. Airmail reduced the time of transit. And now our society is in the midst of a revolution, the electronic revolution, which makes the delay in transmission of information negligible.

The term "mail" has come to mean the ordinary physical transport of a document, from one location to another in a sealed and addressed envelope. The electronic revolution has made it possible to replace the transportation of the document with the electronic communication of its information—"electronic mail." The decision to use an electronic mail system is primarily sociopolitical and economic. Today's technology can provide a cost-effective electronic mail system under many conditions.

An interesting analogy can be drawn between the evolution of the telephone (from manual switchboards, to electromechanical switching, and now to electronic switching) and mail systems, which also started with manual sorting and human transportation and delivery; they have progressed to automated electromechanical sorting, rapid air transportation, optical character recognition, and have now begun to use electronics for many of their operations.

Several systems on the market today use electronics for communication of information, that is, forms of electronic mail. The telegraph and the telegram (though fading rapidly because of the newer and more advanced forms of electronic communication) were early means of transmitting information electrically. Teleprinter systems, telex/twx, and mailgram, more modern forms of electronic mail, are now used throughout the world. Mailroom and point-to-point facsimile are becoming widely accepted electronic systems for inter- and intracompany mail service. Large interconnected computer centers are used to transmit messages to and from computer terminals. The use of communicating typewriters, word processors, various keyboard terminals, and other electronic devices is predicted to grow rapidly because of their high efficiency in transmitting alphanumeric characters.

Kinds of Mail

The mail can be divided into five major types: (i) transactions, (ii) advertising, (iii) correspondence, (iv) magazines and newspapers, and (v) merchandise in order of decreasing volume (*1*). Much mail contains financial transactions such as

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statements, invoices, check payments, and other documents (Fig. 1).

An analysis of the mail to and from the three main sources and recipients, businesses, government offices, and households, is shown in Table 1. Some weights and costs of ordinary mail are shown in Table 2.

The bulk of business and government communications can be split between alphanumeric and graphic information. Words and numbers constitute 90 percent; 10 percent is graphic (*2*). The graphic portion consists primarily of special forms, such as purchase orders, invoices, and statements. Many of these documents require signatures for authorization, a situation to be discussed later.

Three initial observations can be drawn (*1–4*). (i) Electronic fund transfers can supplement a large part of today's mail volume. (ii) The major sources of mail, in business and government, are highly concentrated and should be able to economically justify electronic equipment. (iii) Most information to be mailed can be encoded, and the formats of most graphic material are fixed.

Anatomy of Electronic Mail

An electronic mail system is becoming practicable (*5*) today because of (i) the wide availability and decreasing cost of electronic communication channels, originally designed for voice transmission but now enhanced with various wider-band systems; (ii) less expensive electronic control and storage systems that can process information at high speed; and (iii) the availability of technology that can translate information ordinarily handled on paper.

An electronic mail system has three fundamental characteristics—origination, transmission, and printing. Electronic mail can be originated by conventional means (typewriter, handwriting, printing), or the information can be entered on a keyboard device ("keyboarded") capable of either transmitting the information directly or recording the information on some medium (such as paper tape, magnetic card, or magnetic tape) for subsequent transmission. The transmission can be accomplished through a number of channels, such as the direct distance dial (DDD) telephone network, microwave systems, satellites, and packet-switched (*6*) networks. The mail can be printed in any of several ways; by, for instance, impact printers or raster printers using xerographic, electrographic, thermal, or ink-jet technologies.

Reasons for Adopting Electronic Mail and Message Systems

Urgency. The delivery time for traditional mail is measured in days. Transmission of facsimiles and through most keyboard terminals reduces this transmission time to minutes. As "word processing" becomes more and more prevalent, communicating word processors will be increasingly used as electronic mail, particularly when the needs for graphics and requirements for signatures are small in comparison to the urgency for transmission.

Economics. Economics increases the pressure for the development of electronic mail and message systems. One can analyze the comparative cost of transmitting a page using traditional mail methods versus electronic means. The amortization costs of the terminal have been omitted, because there is wide variance of rental costs and selling prices among the various facsimile and communicating keyboard terminals; in addition, some of the devices can be justified for reasons other than their applicability to electronic mail. If we make the assumption that two pages will be mailed in a traditional envelope, the cost is 6½ cents per page. Although the cost of electronic transmission is not competitive, such transmissions are immediate as opposed to requiring days. The equivalent transmission by teletype would cost $1.76, with 4000 characters per page. However, given a 300-mile transmission after 11:00 p.m. on the DDD and multiple documents per call, a facsimile terminal with a transmission time of 2 minutes per page can send these two pages more economically at 26 cents each. If we take a communicating terminal as another example, at 1200 bits per second, the transmission cost per document is now 4½ cents per page. One could envision future generations of communicating equipment using magnetic media, such as disks, or high-speed tapes with higher throughput capability and high-speed modems. This would further reduce the cost of transmission and provide a tremendous communications savings for the user, providing his volume can justify the investment in the terminals and systems.

Table 1. Sources and recipients of mail during fiscal year 1968 (*1*). Numbers in parentheses are billions of pieces of mail. For fiscal year 1968, the Postal Service estimate of the total was slightly lower, 82 billion pieces of mail.

Recipient	Source (%)			
	Businesses and other organizations	Households	Government	Total
Business and other organizations	25.8 (21.6)	5.8 (4.9)	1.8 (1.5)	33.4 (28.0)
Households	46.6 (39.1)	14.0 (11.7)	3.8 (3.2)	64.4 (54.0)
Government	1.2 (1.0)	0.4 (0.3)	0.6 (0.5)	2.2 (1.8)
Total	73.6 (61.7)	20.2 (16.9)	6.2 (5.2)	100.0 (83.8)

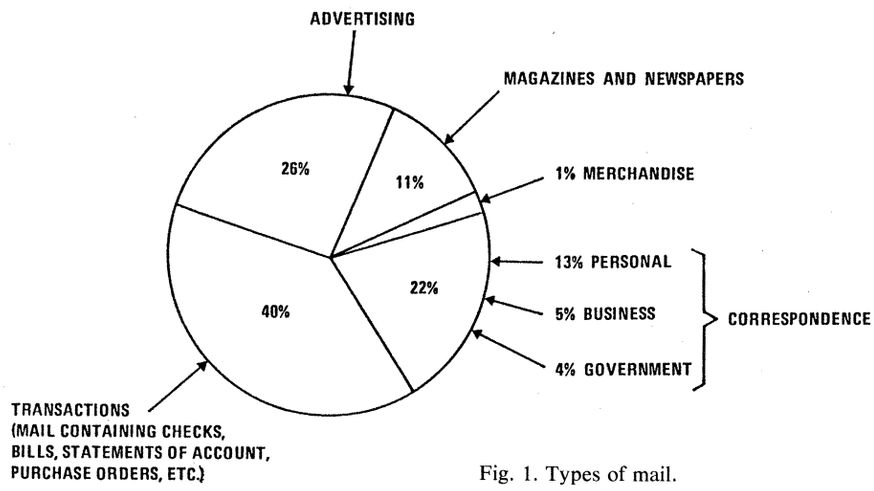

Fig. 1. Types of mail.

Remote and large volume. Electronic transmission of information is particularly useful when the volume is large or the source is remote and the material is already encoded. A good example is a time-shared computer system in which the information is generated in one place but the printing is required elsewhere. The data are communicated electronically to the recipient and are never printed at the origin.

Operational features. In a business environment, the originator conventionally dictates or gives handwritten information to the typist. A draft is typed, returned to the originator, and revised. This cycle can be repeated two or three or many times if the material is complex or particularly important. After the letter is prepared and approved, copies are made and envelopes are addressed and stuffed. Whether by internal mail or the U.S. Postal Service, hours or days elapse until the mail is received.

In a hypothetical electronic mail process, the writing and typing times are the same. However, with a word processor, revisions can be made very quickly, since the letter is stored, rather than retyped each time.

In addition, the typist can use stored documents from which standard paragraphs, distribution lists, contract clauses, and so forth can be retrieved by using codes (thus avoiding retyping), inserting any portion of the stored material into any part of the newly generated letter. Once the revisions have been made and a final copy has been approved by the sender, the letter can be transmitted in seconds or, alternatively, stored if low cost or other considerations suggest a delayed delivery. The sender of electronic mail is not always its writer; in many cases, one sends mail that someone else wrote. Sometime in the future, the recipient of a document who wishes to pass it on to others, will be able to have access to the electronic file of the sender and direct the transmission of the document to the secondary recipients.

Remote transmission of alphanumeric code is advisable for the bulk reproduction of many copies of a report, procedure, repair manual, or instruction book (among others) when the content has been heavily edited, proofread, or revised, and when reproduction is required at a distance; such documents are ideal candidates for electronic remote printing of the coded information. Although issues of privacy, security, editing, and confidence will arise, it is the way some electronic mail will eventually be handled.

Table 2. Mail findings for 1976 [averages as described in (*4*)].

Type	Ounces per piece	Pages per piece	Postal cost per:		
			Ounce	Piece	Page
Letters	0.55	1.95	18.2	10.0	5.13
Bulk mail	2.20	7.20	4.4	9.7	1.34

Another form of electronic mail exists when (i) information is handwritten or graphical, (ii) the information on the document has not been encoded electronically (that is, a routine typed memorandum or letter), (iii) when special forms are necessary, or (iv) signatures are required.

There are certain documents which originators want delivered exactly as approved, for example, monthly reports, financial reports, personal memoranda. Most people would not accept a communication of such information in electronic form without being assured that the hard copy will be received exactly as sent with respect to form, format, typographical accuracy, and so forth. In these cases, the electronic transmission of a copy of the document is more appropriate than the electronic transmission of the information on the document.

These documents can be entered into an optical scanning terminal. The electronic image of the document would then be transmitted over either conventional telephone systems or wide-bandwidth channels to a receiving terminal capable of reproducing the scanned image of the original (facsimile or electronic copying). The terminal might be in a mailroom, for subsequent local distribution of the documents, or at the recipient's location for immediate reception. The preparation time is the same as that for conventional documents, but transmission time can be seconds or minutes, unless store-and-forward features (*7*) are desired.

The handling of approval processes is changed if character-encoded content from nonvisible magnetic recordings is transmitted without inspection by the originator. In addition, laws require a signature on certain documents; unless raster scanning is used, it is impossible to electronically transmit the actual signature. However, it is possible to solve this problem and take advantage of the higher efficiency of alphanumeric transmission by using identification codes. Secret codes, similar to access codes on a time-sharing computer, can be assigned to each sender. Upon completion of the document, that identification code can be placed in the terminal, directing that a copy of a signature be printed from raster memory at the remote printer or that an indication of signature authority be typed. In addition, a signature is often unnecessary; many business communications today could eliminate the signature and simply substitute the name of the sender.

Forms such as purchase orders, invoices, and insurance forms have fixed graphic formats. They can be stored in a buffer memory at the receiving end and triggered by a code that is typed into the originating terminal. Some mail can thus be handled by alphanumeric transmission augmented with graphic and alphanumeric printing. Certain graphic transmission will always be necessary and could be handled by strategically located facsimile terminals.

Concern for privacy. The protection of privacy in electronic mail can be ensured in several ways if the system is properly designed. For example, the printer could receive information, not print it, but store it so that only the recipient would have access to it. People will use special or unusual configurations when necessary. For example, during World War II, V-mail was an acceptable way for civilians to communicate with members of the armed forces in remote locations, although privacy was lost and freedom of format was inhibited. Some electronic mail systems may compromise the necessity for a signature or the sealed envelopes in favor of reduced cost or increased speed.

In short, the more impersonal the content and style of the document, the more eligible it is for character-encoded transmission; the more personal or sensitive it is, the more important are the envelope, signature, and actual image.

Applicable Technology

The technology required for electronic mail is becoming sufficiently advanced to break through the cost/performance barrier. While many technological and engineering challenges remain, an awareness of the technology trends convinces us that electronic mail is a realistic possibility. Therefore, it is useful to examine the relevant technology and understand its implications.

Electronic technology. The development of digital electronics is essential to the success of an electronic mail system. The advantages of decreased cost, greater speed, smaller size, and improved reliability of electronic components enable the speed, automation, and cost/performance ratio of electronic mail. Happily, these elements all occur together as circuit elements become smaller and more of them are squeezed onto a single chip. Large-scale integration (LSI) has decreased cost and power consumption by several orders of magnitude while increasing density, reliability, and speed. Electron-beam or x-ray lithography will improve the processes of manufacturing semiconductor chips and thus permit further increases in the number of gates or bits per chip. One can now envision very large solid-state memories at very low cost (*8*).

The effects of these trends are several; for example, it is becoming increasingly attractive to distribute processors (or microprocessors); moreover, localized processors can be made more powerful, permitting a greater range of electronic functions in a terminal at lower costs.

Scanning technology. An input scanner converts the images on a document into raster or bit-by-bit electronic information; scanner resolution is one of the first determinants of image quality. Typical resolutions range from 50 to 500 pixels (picture elements) per centimeter for applications ranging from facsimiles to graphic arts. Fortunately, two-dimensional digitized images contain considerable statistical redundancy, and data-compression techniques have been designed to reduce the number of bits to be stored or transmitted.

By the use of digital processors, time-domain or transform-domain encoding techniques have now become practical. Depending on the content and resolution of the scanned document, compression by as much as 20 : 1 is possible. Still, efficiency of encoding can be further increased by increasing the complexity of the encoder and decoder.

Recent scanning advances have permitted the use of laser sources with electromechanical deflection. For the near future, the trend may be toward solid-state scanners such as charge-coupled devices (CCD's) and photodiode arrays because of their higher reliability and lower cost of the subsystems in which they are a part. Vidicons and cathode-ray tubes (CRT's) approaches do not appear to be cost-competitive.

Storage technology. Recording a page of a raster-scanned document typically requires a million bits. Information storage in electronic mail is, therefore, important. During the past 10 years, cost (down 20 to 30 times) and typical on-line data capacity (up 20 to 30 times) have changed reciprocally. The cost of magnetic disk storage, at present 10^{-3} cents per bit, is expected to decrease further in the next decade, permitting more economical store-and-forward electronic mail.

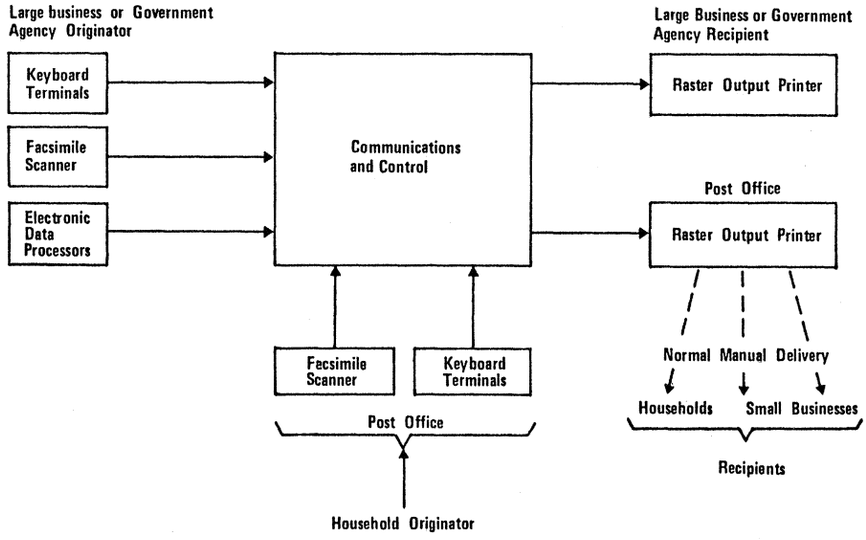

Fig. 2. Hypothetical electronic mail system.

Communications technology. The technology of communications systems is in a period of change and growth. Data rates over conventional telephone lines range from 110 to 9600 bits per second, and sophisticated signal-processing techniques are being employed to overcome the channel-induced distortions at the higher rates. Special wide-band terrestrial and satellite systems are emerging and becoming more economical for electronic mail applications.

Several conceivable configurations could be used with telephone lines or wide-band systems, whether land-based or satellite. Proposals to provide electronic mail systems have been made under a variety of trade and generic names (*9*). It is not the intent to describe here the planned or proposed systems in detail.

Fiber optics promise data transmission with a capacity of 10^9 bits per second. Fibers are expensive now, but their cost may continue to decrease (*10*). Communication satellites will also play an important role in the future of electronic mail (*11*). There are several inherent advantages to a satellite communications system. They include broadcast capability, distance insensitivity, and network capacity on demand. Furthermore, they readily transmit voices, pictures, and data. The use of high-frequency (approximately 10 gigahertz) transmission will avoid conflicts with microwave communications systems as well as permitting the use of small antennas of about 5 meters in diameter, thus allowing earth stations for individual customers and minimizing the need for terrestrial extensions and interconnected systems.

Printing technology. The information contained in a document (after scanning, processing, and transmission) must ultimately be printed. The means used today fall into two major classifications: impact (for example, the mechanical typeface strikes a ribbon transferring ink to paper) and nonimpact (for example, the recorded mark is made by electrostatic, optical, or other noncontact means).

For exclusively alphanumeric, low-speed applications, for which encoded data are captured at the source, single-element character printers have been dominant for years. The print-wheel character printer is becoming more popular today. It will probably continue to be effective because of its inherent print quality, speed, and costs.

Printing of high-resolution raster-scanned images and high-speed alphanumeric information is possible today only with nonimpact printers. Printing resolutions vary with the application and are typically between 50 and 200 pixels per centimeter. (i) Ink-jets provide high-speed serial printing, with print quality that appears to be acceptable for many documents. Further improvements in both print quality and speed are possible. (ii) Laser exposure and xerographic recording are currently used for facsimile and computer printing. They can also be used for combined printing of text and images at moderate speeds. (iii) Electro-

graphics can print at high speeds, but it suffers from several limitations. These include the requirement for expensive special paper and somewhat lower print quality than is now available from impact printers. (iv) Matrix impact printers are faster but produce prints of somewhat lower quality than those that print one character at a time. (v) The electroresistive recording process is cost-effective for low-speed facsimile applications, but the special paper becomes too expensive for large-volume applications. (vi) Thermal printing is still used occasionally, but low resolution (approximately 25 to 50 lines per centimeter), the requirement for special paper, and the lack of archival capabilities appear to limit its future potential.

The high-quality serial printer will probably continue to use impact character printers. The performance of ink-jet printers will continue to improve, and their acceptance may broaden.

Character-Encoded versus Scanned Information

Systems must be able to accommodate both encoded characters and graphics. Examining the efficiency of character-encoded transmission versus raster-scanned transmission quickly shows why it is important to use character-encoded transmission and record keystrokes whenever possible. In today's business facsimile with a resolution of 96 by 96 lines per inch, an 8½-by-11-inch page will contain approximately 860,000 pixels. If this page is transmitted in digital form (black and white only), 860,000 bits of information need to be transmitted.

With today's technology of data compression, with removal of the redundancy resulting from white spaces in a document as well as image redundancy in both the vertical and horizontal directions, it is possible to encode the information in a more efficient manner. Commercially available systems are capable of about 7 : 1 compression ratios; thus, the technology can now reduce the original 860,000 bits to approximately 123,000 bits. If we assume a transmission rate of 9600 bits per second, the transmission time for a typical page is 12 seconds.

In comparison, consider the time required for a character-encoded system. One page will contain approximately 3,000 characters (or 24,000 bits). The time required for transmission at the rate of 9600 bit/sec is 2½ seconds, approximately five times faster than transmitting the image. This increased speed can result in decreased costs, but the form and format will probably be lost. Whether the system uses the traditional telephone network or a wider-bandwidth system, it will probably be billed in such a way that speed of transmission is desirable. Given the efficiency of character-encoded transmission it is easily understood why a system should record keystrokes whenever possible. Also, the system should be able to handle graphics, for example, schematics, diagrams, written words, and typed material from ordinary typewriters, printers, and secondary sources. To accomplish this, multifunction electronic mail terminals will probably be developed, as both alphanumeric and image information must be handled, separately or together.

An Electronic Mail System

We now can sketch a hypothetical electronic mail system, as shown in Fig. 2. Large businesses or government agencies have communicating word processors, facsimile scanners, and data processing centers can have access to the electronic mail system. Large agencies receiving the messages will have raster output printers capable of handling both encoded information and images. Thus, between businesses and government agencies, an electronic mail system is possible.

However, one cannot overlook the small businessman and the household. It is unlikely that, during the next few years, the cost of a printing terminal will fall so low that they will be available to all private individuals. However, it is possible that an individual post office would have an output printer that would permit it to receive messages from businesses and government agencies, as well as from other postal locations. Such information could then be normally mailed to households and small businesses. Again, the post office is able to accept messages from a household from either a document to be scanned or through the telephone. This would, in turn, be typed on a communicating device. The central electronic mail system will provide electronic message switching, store-and-forward and accounting data, such as traffic volumes and billing.

Conclusion

We are in the midst of the evolution to the electronic communication of information, which will replace some traditional mail. To this end the process of adopting emerging technologies for electronic transmission of the image of documents to be mailed will continue.

The technologies are in hand and can be applied either by the conventional telephone system or the emerging wide bandwidth of the satellite system. Facsimile terminals for image transmission are available and increasing in number. Terminals for printing alphanumeric code are present and becoming more widespread. In the future there will probably be devices that can handle character and images simultaneously.

Since the sociopolitical and economic issues are complex, it is beyond the intent of this article to address the question of who should own or operate the electronic mail system. The evolution is inevitable for the reasons I have discussed. But, in addition, an indirect force will stimulate the growth of electronic mail; physically transporting tons of paper on a daily basis is an inefficient use of our resources if the information can be transmitted electronically. The impact of electronic mail will be first on large companies and large government agencies; it will gradually be felt by individuals and small businesses.

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