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Systemic Bottlenecks in the Information Society

"As we move from the traditional situation – information scarcity – to a new and unfamiliar era of information abundance, we must be willing to consider new approaches to information. ... If our individual and organisational attention is a limited resource, why should it not be allocated as other scarce commodities are?"

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The Paradox of Information Technology

Sometimes the worst that can happen is to get what one wants. And perhaps this is happening to us with the revolution in information and communications. While this revolution is progressing quite successfully, success, just as failure, has a way of creating its own problems.

We live in the information age, work in the information economy, and are surrounded by an information technology of astonishing performance and price. And yet, with all these technological marvels, we feel less than ever in control of information.

Information Technology paradox: more knowledge but less control

This may be called the Paradox of Information Technology: the more information technology we have and the more knowledge we produce, the further behind we are in coping with information. We invent and build new technologies to help us, but they set us back still more.

Why do we have such a problem? The reason is that we have created a systemic imbalance in the information environment of the kind that leads to new bottlenecks. A communications process, to simplify considerably, consists of three major stages: the production of information, its distribution, and its processing. These three elements have to exist in some relation to each other.

How will we process available information?

In recent decades, technology has made giant strides in the distribution end of information. We are near the point, historically speaking, when the cost of information distribution becomes both negligible and distance-insensitive. Distribution has contributed, in an interrelated fashion, to the production of information, which has been spurred by the evolution of advanced economies to services and knowledge-based manufacturing. One of the characteristics of post-industrial society is the systematic acquisition of and application of information which has replaced labour and capital as the source of value, productivity, and profits. The weak link in the chain is the processing of the produced and distributed information. These bottlenecks are both human and organisational – the limited ability of individuals and their collectives to mentally process, evaluate, and use information. The real issue for future technology therefore does not appear to be production of information, and certainly not transmission, but rather processing. Almost anybody can add information. The difficult question is how to reduce it.

There is a reinforcing relationship between the stages of information: production, distribution, processing. If I produce a piece of information, it will stimulate distribution and use. Similarly, distribution increase stimulates information production and processing. And information production creates demand for still more such production. The relationship between the stages of information with each other and themselves can be summarised in an input-output matrix, in the same way as has been done in the past for the interaction of

industrial production such as for steel, coal, electricity, etc.. Where bottlenecks in growth occur, they are likely to have ripple effects throughout the other stages and beyond.

In the past, the three stages of information grew slowly and more or less in tandem. By sometime following World War II, the parallel trends diverged, and things have never been the same. The driving technologies were advanced by that war – computers (from code-breaking efforts); microwave transmission (from radar technology); satellites (from missile development); and television (from superior electronics).

Imbalances in processing the increase in produced information increase

The production of information in the U.S. economy rose at a rate of about 6%, and the growth rate is itself increasing. Distribution is growing even faster, by an estimated 10% and more. The rate of increase in processing capacity needs to keep up with that. To reach a similar growth rate is very hard, and is not being achieved. It is hard, because of the limited capacity of the processing channels of individuals and organisations, and the difficulty of increasing it.

This has serious implications. Virtually all aspects of society are changing due to that imbalance, and in the ensuing attempts to adjust the individual and social processing rates of information to the demands that growth in the other stages have put on them.

We all know that the quantity of information and of information producers has grown prodigiously. It has been said that 90 percent of all scientists who ever lived live today. The same holds for other information professions such as lawyers, journalists, or engineers. The number of scientists and engineers in the U.S. grew from 557,000 in 1950 to 4,372,000 in 1986, an increase of nearly 800%. By the late 1980s, their numbers roughly equalled the entire information workforce of 1900.

Information output of sciences accelerates exponentially

Most branches of science show an exponential growth of about 4-8 percent annually, with a doubling period of 10-15 years. To get a sense of the trend: the number of chemical abstracts took 32 years (1907 to 1938) to reach one million. The second million took 18 years; the third, 8; the fourth, 4 years 8 months; and the fifth, 3 years and 4 months. If we assume that before 1907 a full million of chemistry articles had not been produced, this means that in the past 2-3 years more articles on chemistry have been published than in humankind's entire history before the 20th century.

A weekday edition of The New York Times contains more information than the average seventeenth-century Englishman came across in a lifetime. The Sunday edition far exceeds that.

For all the talk about "paperless" offices due to electronics, the per capita paper consumption in the United States has increased from two hundred pounds in 1940 to six hundred pounds in 1980. Ten years later, per capita paper consumption had tripled again.

In 1991, Congress received more than 300 million pieces of mail, up from 15 million in 1970. In 1980, 5 billion catalogues were mailed in the United States, 50 catalogues for every person. By 1990, the number was 12 billion. In the 1980s, growth of third-class bulk mail (junk mail) was thirteen times faster than population growth. An average upper business manager received more than 225 pieces of junk mail a month. The number of satellite-delivered channels increased from 4 in 1976, 43 in 1983, to 112 in 1995. This trend continues unabated. In 1992, 20 new programme channels were offered to cable operators, and in 1994, over 70.

The growth of mobile communications provides much wider and more convenient reach in terms of time and place. In the past, one could be reached by phone only near a wireline, which covered in geographic terms only about 2% of the land area of the U.S.. Now, radio-based communication ends most white spots on the map of communications ubiquity.

The quantity of information is most pronounced in big cities. One estimate is that in a metropolitan area like San Francisco, people receive about 100,000,000 bits per capita per year, 100 times as much as in a place like Addis Ababa (with less literacy). The "symbol economy" makes the physical economy look puny. In New York City, the CHIPS communications network transfers $1.5 trillion in financial transactions per day. In London, foreign exchange transactions exceed $100 billion a day. A single day's trading in London is about to exceed the annual GNP of the United Kingdom.

A growing amount of noise accompanying information has to be filtered

A critical point is that information is always accompanied by "noise". In technical terms, noise is the interference in a channel with the primary signal. Noise also includes unwanted information that must be filtered out. The more information we produce, the more noise we produce, too. Conversely, as noise increases (including unwanted information), the filtering must increase, as the information signal must gain in strength. Both activities require substantial resources. Thus, the creation of noise by information affects information, and this is a serious matter.

Shannon and Weaver (1949), pioneers of information theory, identified noise in communication with entropy. This obscure mathematical point gave noise a central role in social analysis. Entropy is the essence of the second law of thermodynamics. It is deeply pessimistic in that it sees the world eventually and irreversibly losing its energy potential and becoming, in Boulding's words, a "lukewarm pea soup." Accordingly, the world would eventually not go out with a bang but with a whimper.

Information as a counter-force to entropy in communication

Entropy uses up the potential of energy and of life. But life's ability to create information and organise itself can oppose entropy. Thus, information is perhaps the one major counter-force to entropy. Society's inability to manage its information resources therefore means that noise increases more rapidly than

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information, and this has many implications on the individual, organisational, and social levels.

To deal with the problem of inadequate processing and the noise it generates, society has a variety of responses and coping strategies. They will now be discussed.

Strategies to cope with information problems like its processing and noise

Response 1: Increased Heat

More information, more noise, and more clutter lead to a need to amplify and/or repeat a signal message. This can be seen best in advertising. Between 1930 and 1990, advertising expenditures per capita in the U.S. increased by over 2,200%, whereas the population increase was 200%. A quarter century ago, the average American was targeted by at least 560 daily advertising messages, of which only 76 were noticed. In 1991, the average American received 3,000 daily marketing messages. Viewer retention (part of processing) of television commercials dropped. In 1986, 64% of those surveyed could still name a TV commercial they had seen in the previous four weeks. But six years later, in 1990, only 48% could do so. This lessened attention leads to an increase in the "heat" of messages, whether in advertising, politics, or the general culture. It also affects media programmes, which also must be more intense. It favours visual themes, simple stories, and pseudo-facts. In politics, it has led to the emergence of the pseudo-event and the 15-second sound bite.

Growing output, but less retention

Increasing heat and frequency, however, do not solve the problem of the processing bottleneck, because almost everyone resorts to the same methods of amplification. Thus, like the onlookers to a parade that are all standing on their toes, we end up less comfortable, with more noise, and with even less processing relative to information.

Response 2: Closing and Specialisation

One way people protect their processing channel is to shield it from too much information by selective attention, stereotype, even prejudice. People tend to notice communications favourable to their dispositions. Voters do not want information but confirmation. Leon Festinger introduced the concept of cognitive dissonance as coping mechanism. John Locke in his Essay Concerning Human Understanding wrote: "Where in the mind does these three things: first, it chooses a certain number (of specific ideas); secondly, it gives them connexion, and makes them into one idea; thirdly, it ties them together by a name." This is done "for the convenience of communication."

Another form of closing is specialisation. As the volume of information rises relative to any individual's ability to handle it, specialisation takes place. There is nothing new about this. Tasks were divided from the earliest days. Long before Adam Smith wrote his famous description of the needle factory, the sons of the

original Adam specialised already, the Bible tells us. As the body of knowledge grew, the evolution of fields of expertise continued into ever-narrower slices. German has an apt term, the "Fachidiot" (Speciality-moron).

Nietzsche mocked it a century ago. "A scientist was examining the leeches in a marsh when Zarathustra, the prophet approached him and asked if he was a specialist in the ways of the leech.. O, Zarathustra,...that would be something immense; how could I presume to do so!... That, however, of which I am master and knower, is the brain of the leech; that is my world!... For the sake of this did I cast everything else aside, for the sake of this did everything else become indifferent to me..."

Selective attention: shielding through specialisation, stereotypes or prejudices

The result: the inexorable specialisation of scholars means that universities cannot maintain a coverage of all subject areas in the face of the expanding universe of knowledge, unless their research staff grows more or less at the same rate as scholarly output, about 4-8 percent a year. This is not sustainable economically. The result is that universities do not cover anymore the range of scholarship. They might still have most academic disciplines represented – whatever that means – but only a limited set of the numerous subspecialities. Many specialised scholars find fewer similarly specialised colleagues on their own campus for purposes of complementarity of work. In other words, the collaborative advantages of physical proximity in universities decline. Instead, scholarly interaction increasingly takes place with similarly interested but distant specialists of similar specialisms, i.e., in the professional rather than the physical realm.

Response 3: Reorganisation

Organisations grow in order to process more information

An organisation transforms inputs – resources, messages – into outputs. Groups, like individuals, have channel processing capacity and points of overload. Laboratory studies also show that decision makers seek more information than they can effectively use. Management studies show that the typical executive can receive and absorb only 1/100 to 1/1000 of the available information that is relevant to his or her decisions. Additional information may actually reduce performance because it increases the decision maker's confidence.

There were hardly any middle managers in the United States before the mid-nineteenth century. But by 1940, managers and clerks accounted for almost 17 percent of the U.S. work force. Their number grew by 45% alone between 1900 and 1910, far outpacing the growth in the general work force. In the same decade alone, the number of stenographers, typists, and secretaries, the staff workers for middle management, increased by 189 percent.

Organisational complexity raises informational complexity

One way for organisations to increase information processing capacity is simply to grow. As information increases, control mechanisms require still more information, leading to excess load and even potentially to general breakdown. An

organisation's response to informational complexity is usually to increase organisational complexity-management layers, procedures, and controls. The result are organisational pathologies, such as tensions between the field and the centre; depersonalised leadership; fragmented understanding; take-over of rigid procedures.

Just as individuals, a group also has upper limits for information processing. The larger the group, the more specialisation and task-sharing can be accomplished, but the greater internal information flows become. For Peter Drucker, the First Law of information theory is that: "every relay doubles the noise and cuts the message in half."

One alleged new tool to enhance productivity in organising is "groupware," such as Lotus Notes, which permits many people to communicate among themselves, both within and among companies. One study (J.G. Miller, 1960) found that teams of four participants had actually a lower channel capacity than single individuals at the same task. In these experiments four people were required to cooperate in coordinating information that appeared on a screen. The performance of two teams levelled off at about three bits of input per second, showing the point at which overload occurred.

Response 4: Automatisation

Automatised quality screening by intelligent agents is still rudimentary

Information screening is the key technological challenge for the information sector. The super pipe requires the super screen. But as everyone who has used a data base can tell, the default part of any existing search system is how to suppress repetitive or unimportant information. That is, one needs a screening by quality. Expert systems and artificial intelligence applications will be useful here, but the technology is not even close at hand, if it can ever be achieved.

Some such systems are "intelligent agents," autonomous and adaptive computer programmes within software environments such as operating systems, databases or computer networks. Typical tasks performed by intelligent agents could include filtering electronic mail, scheduling appointments, locating information, alerting to investment opportunities and making travel arrangements. A learning agent acquires its competence by continuously watching the user's performance and examples, by direct and indirect user feedback, and by asking for advice from other agents that assist other users with the same task.

But all agent technology is rudimentary. The so-called intelligent agents are mainly mail filters. Technology can do only the most formalistic information selection. Humans can infer concepts from the words of a document. Computers are bad at that task. They have great difficulties determining what is important. Contextual analysis will have to advance to the point that machines can comprehend the context of information and its meaning. Technological screening is, at present, quite high in its ratio of hype to reality.

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Response 5: Multitracking

Growing channel capacities vs. multi-channelling

With rising information inflows, two coping strategies exist to increase processing rates: either raise the channel capacity by technology and organisation, or use channels in a parallel fashion. Electronic information systems can increase channel capacity, especially in transmission. But biological and social systems of humans cannot increase their channel flow equally dramatically. This suggests the multi-channelling of information. Media have different rates of display and absorption, for different types of information and different senses. One strategy of information processing therefore is to affect the way information gets presented. Eyes can get visual information at a broadband megabit rate. In fact, if the TV action is too slow, one gets bored. On the other hand, written information gets absorbed at the much slower rate of about 300 words/min., or 200 bits per second. Ears are even slower at about 200 words/min. or about 150 bits per second. And the tactile sense can handle up to perhaps 20 words/min., or about 15 bps, using Braille.

What is most likely to happen is a shift to a multimedia form of communications with more visual and symbolic information, each carrying the type of information that can get processed most effectively on that particular channel.

Multimedia transfers more information at once

Visuals are good for conveying emotions. Print is better for abstract facts. This means the simultaneous attention to several information streams. Multimedia thus moulds several inflows, such as vision, hearing, and smell. Children already engage in informational multitasking. Television advertisements are a simple example for multiple information streams. They pack a lot into 30 seconds of picture, voice, music, and written language, all superimposed on each other and very tightly edited. Another example are sales presentations with their increasingly elaborate audiovisual aids.

This multi-channel communication will lead to new forms of communications language. Many more symbols will be used, because this can speed up the processing, and combines abstraction of written language with the speed of visual message. Even the sense of smell can, in theory, be used as a channel. Artificial smells are becoming production items. There are now "corporate identity" smells offered, and no doubt smells can be reproduced over distance. Touch and feel communication are also in development, first for sex applications.

"Virtual reality" technology is today's most sophisticated multitracking medium, filling up much of the user's sensory capacity by creating a simulation that permits the user to "enter" three-dimensional space and interact in it.

Will video push print out to a secondary role? Not really. Print works well for abstractions, whereas for images, video is superior. According to Nobel laureate Herbert Simon, the "least cost-efficient thing you can do" is to read daily newspapers. He recommends instead reading The World Almanac once a year. Thus,

each information stream and presentation has some advantages. For me, the information medium of the future is the comic strip. Or rather, the "hyper" comic strip: panels of text with still pictures, some of them moving like film when you touch the screen. There will be sound, and even smell. The text will go into deeper details and connect with other text, like hypertext. One can skim this hyper comic strip or navigate in it. This will be on flat and light display panels one holds like a book, and one could write notes on it, store it, and send it to other locations.

Response 6: Using Economics as a Screen

Allocating information-processing capacities by price

There are other important approaches to information expansion beyond technology and reorganisation. One of them is economics. To an economist, the main problem is the limited presence of economic mechanisms in allocating information processing capacity. If our individual and organisational attention is a limited resource, why should it not be allocated as other scarce commodities are? At least that is the question.

For example, we are being inundated by junk e-mail, each piece imposing some time cost on us, yet outside of a price mechanism. Why is our time a free good for anyone who wants to access our mailbox or telephone receiver? Let them pay for access. Prices are an excellent form of information about information. They provide relative values on time and information. In the upper reaches of power and prestige, access was always paid for indirectly. In advertising, marketers increasingly pay consumers rewards for attention. These payments can also be indirect, through a higher price for watching a programme without further advertising interruptions.

When it comes to telephone calls, people should be able to select among incoming calls electronically only those calls they want, and to assess an access charge for those commercial telemarketing calls they don't normally want to accept. Such a service might be described as Personal-900 Service, analogous to 900-service in which the caller pays a fee to the called party.

Markets for information access

Individual customers could set different price schedules for themselves based on their privacy value, and even the time of day. They would establish a "personal access charge" account with their phone, or a credit card company. The billing service provider would credit and debit the accounts in question. In such a way, markets in information access will develop.

Consumers will adjust the payment they demand in response to the number of telemarketer calls competing for their limited attention span. If a consumer charges more than telemarketers are willing to pay, they can either lower access or will not be called anymore. Because access is of value, exchange transactions would create rational markets instead of the present disruptive calls followed by hang-ups.

A similar principle could be applied to an E-mail, voice-mail, or fax system, with the sender assessing the content's value by attaching "urgent," "standard" or "junk" levels of "electronic postage" on an outgoing message. The postage would be charged against the sender's budget and credited by the recipient. This will cut excessive group lists and junk mail. These are a few suggestions for the general approach. There is no claim that a market mechanism will resolve all problems of the misadjustment in information processing. However, it is an approach that needs to be explored much more than in the past.

Conclusion

Information technologies will have similar impacts on society to the automobile

We may be talking about emerging information technology as if it is just about getting entertainment and study help into the home, and stock market data into the office. But it is naive to think that it will not affect us much more deeply. When the automobile was introduced, it was thought of a horseless carriage. But it did not stop there. Now, our cities, family structures, work, and neighbours are changed. The revolution in information transport will have a similar impact that the earlier revolution in physical transport had.

Information technology and its present advanced expression, multimedia technology, will not rectify the imbalance between information production and distribution, on the one hand, and processing on the other. It will not solve the problem of limited processing and of noisy channels.

A need for economic strategies to (pre-)select informational overloads

So far we have focused on organisational, political, and technological responses to the imbalance of information production and distribution to processing. None of these approaches has worked particularly well. Perhaps, therefore, it is necessary to take an entirely different approach, that of economics, a discipline at whose core lies the question of optimal allocation of scarce resources. Economics will not be the full solution, but we should think much more about economic approaches to information problems.

As we move from the traditional situation – information scarcity – to a new and unfamiliar era of information abundance, we must be willing to consider new approaches to information. Instead of focusing on creation and on flows, we need to give priority to the question of screening and processing. This is the next stage of opportunity and challenge for technologists, entrepreneurs, administrators, and for society as a whole.