Scenario Modelling of Demand for Future Telecommunications Services

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Abstract:

It is widely believed that the world is entering the Information Age , and telecommunication companies must make critical investment decisions based on how much information customers will want to move in the future. Understanding and preparing for the range of possible customer demand scenarios is vital for long-term success in an increasingly competitive market. However, detailed forecasts are impossible to make since the market is as yet undefined. Scenario modelling is useful in developing the understanding telcos need to achieve this success.

We have developed a system dynamics model to investigate the effects of different business and technological drivers on the demand for future telecommunications services, using the software tool *iThink*. Drivers include the number of people teleworking and increasing computing power. These interact to produce usage dynamics for generic services covering conversation, messaging and data transfer, which are then used to calculate resulting network traffic.

Our results suggest that the key uncertainties are the rate of improvement in general IT sophistication, and the extent of teleworking. High growth in both of these produces rapid growth in peak traffic, whilst low teleworking delays that growth. Slower improvement in IT sophistication severely limits growth, since increasing computing power could stimulate large volumes of traffic. Small increases in the use of video applications also produce significant traffic growth, and these factors combine to give large uncertainties. The behaviour of this system is discussed with reference to individual business sectors, demonstrating system dynamics as a useful approach for investigating telecoms supply-demand systems.

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1 Introduction

The telecommunications market is changing rapidly, with widespread predictions that demand will grow by orders of magnitude over the coming decades (eg Gilder 1991, Lyons et al 1993a and 1993b), and almost weekly reports of new collaborations between established telecommunication companies (telcos), cable TV companies, computer organisations and consumer electronics giants. Telecoms operators therefore face a complex environment experiencing rapid change, resulting in large uncertainties and consequent risks associated with any course of action.

These elements suggest the demand for telecommunications services as an ideal problem for scenario modelling using system dynamics techniques. We have developed a number of models aiming to explore the risks associated with alternative deployment strategies for "broadband" (ie fast, high capacity) networks and to analyse sensitivities to varying demand scenarios. Seminal work in system dynamics has stressed the benefits of applying the techniques to investigate supply-demand systems (Senge 1990), and the telecoms problem outlined presents an especially interesting example due to the long lead-times (about 5 years) required for national roll-out of upgrades to the "access network" (the final link from the network operator to its customers).

Here, we present an example of this work in which we have developed an *iThink* (Peterson 1992) model to investigate demand scenarios for business customers in different industry sectors, based upon top-level business and technological drivers. We have aimed to develop the modelling approach and understanding of the system, rather than to formulate predictions, and our results show example sensitivities.

We begin with a brief description of the background to this modelling work, and then introduce the demand drivers investigated, with a description of their dynamics and interactions. Scenarios are then developed to encapsulate uncertainty within the system, and top-level results from the model are presented. We describe the application of these results to individual business sectors using simple metrics to characterise the telecoms activity of a typical employee in each, and present sample results for the usage of several generic services by people employed in different industries under alternative scenarios.

We conclude with a discussion of the understanding gained from the modelling process, identifying the key uncertainties and noting the broad scope for further applications of the drivers modelled. Topics of continuing work are described, including the application of results from the model to sample customer data and visualisation of these results using a Geographical Information System (GIS). Finally, we present ideas for further development of the modelling approach to improve understanding of the whole supply-demand system for broadband networks and services.

2 Background

To investigate the system dynamics approach, we decided to apply it to model the demand for broadband telecommunications services in the UK market, with particular attention to the supply-demand system.

Initial work built from the classic analytical market diffusion models such as that proposed by Fisher and Pry (1971) and Bass (1969). These models are based upon biological population studies (Mahajan and Wind, 1986), assuming that the decision to purchase a product is an imitation process with a probability proportional to the product's market penetration. Bass divided the market to give 1-2% "innovators" whose purchase probability is constant and "kick-starts" the diffusion process. We applied this approach to telecoms services, realising that the degree of interconnection of a service is as important as its market share (Lyons, 1994). An example of this is today's videophone, where the full functionality is only available when calling another videophone; a standard telephone can call a videophone in the same way as it calls another voice-phone, so it is fully interconnected.

A weakness of the Bass model is that it produces positively-skewed S-growth, as opposed to the negatively-skewed curves found in real data (Simon and Sebastian, 1987). The positive-skew is due to the continued influence of innovators through the diffusion process, whilst the negative-skew could be due to a number of factors, including limited supply. These effects are difficult to treat analytically, but are easy to simulate, and we investigated them taking the example of limited supply due to slow deployment of a broadband network, and its effect upon demand for broadband services.

Supply and demand for network connections is only part of the story, though, and the next step was to investigate demand for services and the requirement for network upgrades. This led us to focus on service demand drivers, which is the work we present here.

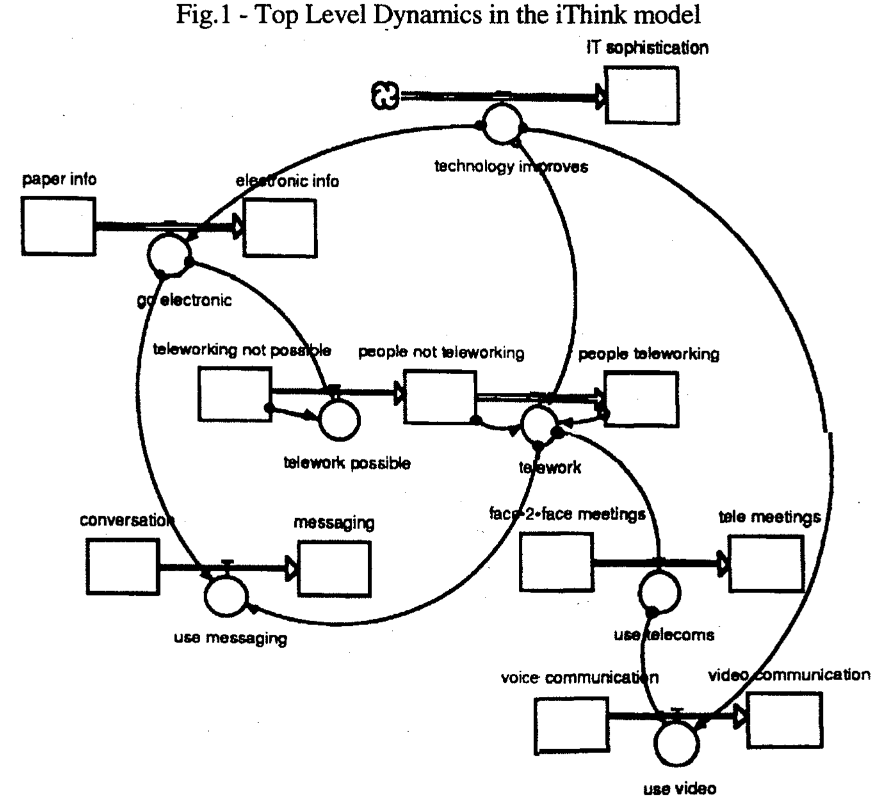
3 The model

One of our early objectives was to investigate the influence of external drivers on demand for telecoms services by constructing scenario models (Wack, 1985 and de Geus, 1988), and, having investigated the dynamics of the top level telecoms supply-demand system, iThink was again used to focus on this area. Work to date has yielded some interesting results, and further development will incorporate these with the effects of limited supply.

3.1 Top level dynamics & interactions

We have noted that significant growth is predicted for telecoms traffic. Fig.1 shows the top-level iThink map of a number of drivers likely to influence this growth for business use, and a description follows for each:

Fig.1 - Top Level Dynamics in the iThink model



° **Improving technology (IT sophistication):** According to Moore's Law (Greenop et al, 1993), the ratio of processing power to price doubles roughly every 18 months in the computing domain, but it is uncertain whether we shall see an equivalent increase in the IT sophistication of the average person, at work or at home.

° **Networking information (Electronic info):** We assume that the greater the proportion of information that is available elect ronically, the greater the incentive to network remaining information, ie for publishers and other information providers to move into the emerging electronic media market.

° **Shift to teleworking:** When a person teleworks, traffic currently carried by company private exchanges (PBXs) and Local Area Networks (LANs) moves to public networks. This is modelled as a modified Bass diffusion process.

° **Substitution of telecoms for travel (telemeetings):** People already substitute telecoms for travel whenever they make a phone call, and further substitution could occur as a result of telework and displacement of business travel.

° **Substitution of video for plain voice:** Further significant substitution of telecoms for travel could require levels of interaction which can only be achieved using high-quality video links.

° **Substitution of messaging for functional conversations:** Some proportion of current conversations are mainly functional and therefore vulnerable to substitution by messaging. Examples of this are the growth of voice mail, and ordering a pizza by fax.

These demand dynamics are represented by fractions of the working population, except for IT sophistication, which is measured in arbitrary units normalised to an initial value of 1. Most of them use a diffusion equation, and the interactions between dynamics can be seen in Fig.1. Experience has shown that in soft models such as this, it is easy to mistakenly double-count these influences, so we summarise each chain of interactions as follows:° **Technology** - Improving technology will drive the migration of information from paper and isolated electronic storage to networked media servers (modelled by "go electronic"). Improving power:price ratios for technology could also stimulate teleworking and hence telemeetings by providing affordable terminal and network equipment.

° **Information** - Improving information systems may be expected to facilitate telework, since although technology solutions are already available at realistic prices, difficulty of access to information from remote locations remains a major limitation (Huws et al, 1990).

° **Messaging** - Information that is already networked is more likely to be communicated using messaging, and flexible (remote) working could mean that people will share fewer common working hours, making conversations less easy to establish and therefore encouraging people to use messaging for functional communications.

° **Video** - If telecommunications are required to take the place of an increasing proportion of face-to-face meetings (eg, for teleworking), ever-improving qualities of interaction will be required. Continuing advances in technological performance:price have recently given huge growth in the desktop multimedia market, and both drivers are likely to contribute to an increa
sing proportion of video communications.

These demand dynamics are featured in the iThink model, and then applied to individual business sectors as described in §3.4.

3.2 Scenarios

IT sophistication is the basic driver for the demand system. There is little doubt that technology will continue to improve exponentially, but it is uncertain to what extent increasing computer power will translate into increasing demand for public network capacity. This is the subject of much current debate, for example in the question of whether "multimedia" will become a mass market in the near future (The Economist, 1993).

Another topic of current debate is the likely future extent of teleworking. Some claim that the combination of a growing number of knowledge workers, plus economic and environmental considerations, makes widespread telework inevitable. Others feel that the initial expense of home equipment and network connections, plus practical difficulties in changing working patterns may be too much for most organisations to overcome.

The other dynamics are driven by IT sophistication and uptake of teleworking. If Moore's Law doesn't apply for mass market IT sophistication, it is unlikely that there will be widespread teleworking in the near future. But even with such sophistication, teleworking is by no means guaranteed to become the norm - other factors may well prevent it.

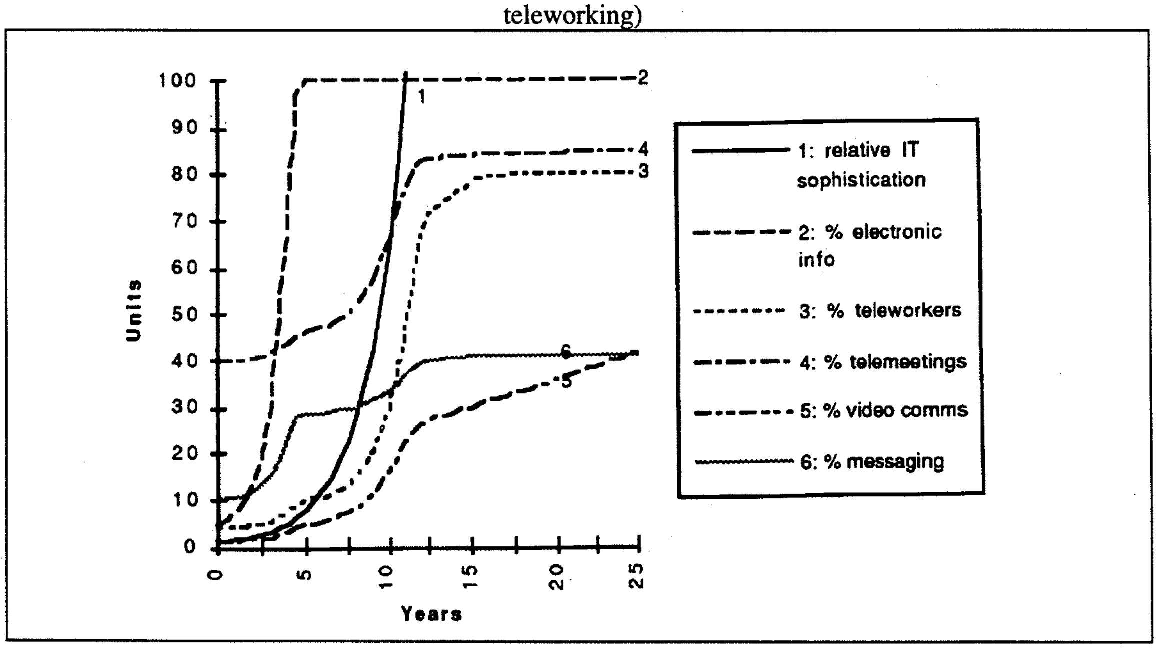
From this discussion, we can formulate the following scenarios:

1 "High Growth": IT sophistication follows Moore's Law, and high latent demand for teleworking

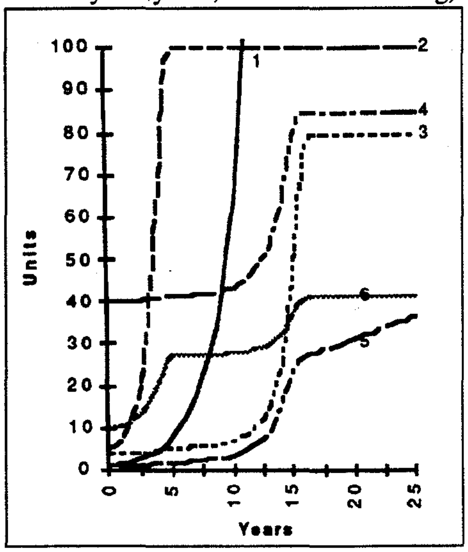
2 "Medium Growth": Moore's Law growth in IT sophistication, but low demand for teleworking

3 "Low Growth": Slow improvement in IT sophistication and (resultant) low teleworking

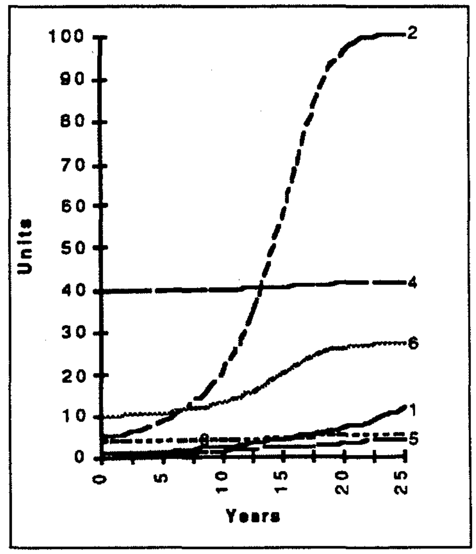
Fig.2 - Top Level Dynamics
a - High Growth (IT sophistication doubles every 18 months, ie Moore's Law growth, and high teleworking)



b - Medium Growth (IT sophistication doubles every 2.5 years, but low teleworking)



c - Low Growth (IT sophistication doubles every 5 years, but high teleworking)



3.3 Top level results

The top level results for the three scenarios are shown in Fig.2. A long (25 year) timescale is shown deliberately in these graphs to illustrate longer-term trends. It is important to remember that the objective is to investigate demand scenarios, not to make predictions.

The effect of the different dynamic interactions modelled can be seen clearly in these results. In all cases, the initial driver is electronic information, giving an increase in messaging. Increasing telework and hence telemeetings and video comms also result in the high and low growth scenarios (high latent demand for teleworking), although in the low growth scenario, the growth in electronic information is much slower due to low growth in IT sophistication.

In the high and medium growth scenarios, improving IT sophistication also has direct effects as its growth rate accelerates. This is first seen in increasing telework, which begins to grow rapidly from year 15 even in the medium growth (low telework) scenario, entirely due to improving technology. Under high growth, telework accelerates from year 8 after being jump-started by high latent demand. Obviously, telemeetings and hence video communications follow the telework dynamic rather closely, and telemeetings, telework and messaging approach saturation at year 25 as we have assumed some practical limits to growth in these applications.

After the growth in the 3-7 year period already discussed for high and medium scenarios, messaging plateaus, and further growth is also dependent upon increased telework. This takes effect from about year 12 under high growth, and from year 17 under medium.

The low growth scenario shows no effect of IT sophistication within the 25 year period, other than as a consequence of increasing electronic info (which is slower than under the other scenarios). This scenario is identical to high growth, but with the first 7 years stretched to fill 25.

3.4 Application to individual business sectors

To be applied to sample customer data, the top-level dynamics must be related to service usage by customers in different business sectors. A small number of generic services were chosen for modelling, and the influence of the top level drivers upon the usage of each service within different business sectors has been assigned using four metrics to characterise each sector. The peak traffic generated by a customer in each business sector under the different scenarios outlined can then be calculated. Business sectors are identified using the first digit of the UK government's 1980 definition of Standard Industrial Classification (SIC), giving the 10 sectors shown in Fig.3 - Agriculture (SIC 0) through to Government (SIC 9).

The model aims to relate the top-level technological and market drivers to the usage of five generic services:

- voice telephony
- video telephony
- fax
- email
- data transfer

We have modelled the service dynamics identically for each business sector, with the influence of each top level dynamic depending on four simple metrics used to characterise each SIC. The variation of these metrics by business sector is shown in Fig.3:

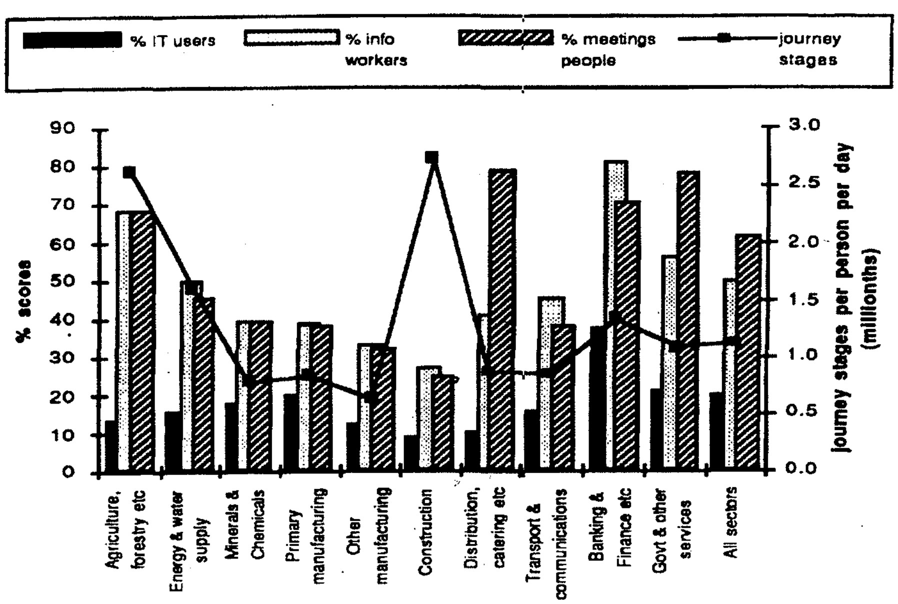
- IT intensity - the percentage of employees who use a computer for more than just word-processing (internal source).

- Information intensity - the percentage of employees who are in information-based occupations (Employment Dept LFS, 1993)

- Interaction intensity - the percentage of employees who are in interaction (eg meetings) intensive occupations (eg managers, sales representatives, some clerical... - Employment Dept LFS, 1993)

- Travel intensity - the average number of journey stages per employee per year (a "journey stage" is a standard travel metric used by the Department of Transport to measure journeys made for the purpose of transporting people - Transport Dept, 1991)

Fig.3 - Metrics to characterise business sectors



To illustrate the approach taken in applying the top level dynamics to service usage within business sectors, the equations modelling the use of conversational services (ie voice + video telephony) are as follow:

$$t_{conversion} = f_{meeting\_people} F_{telemeetings}(f_{teleworkers} t_{av.meeting} + n_{av.journeys} t_{av.remote\_meeting})$$

where $f_{teleworkers} = 1/3(f_{time\_out\_of\_office} + f_{info\_workers} + f_{IT\_workers})F_{teleworkers}$ and

$F_{telemeetings}$	is the top-level fraction of telemeetings
$F_{teleworkers}$	is the top-level fraction of teleworkers
$f_{info\_workers}$	is the information intensity
$f_{IT\_workers}$	is the IT intensity
$f_{meeting\_people}$	is the interaction intensity
$n_{av.journeys}$	is the travel intensity
$t_{av.meetings}$	is the average manager's 3-4 hours per day spent in meetings (Young, 1986)
$t_{av.remote\_meetings}$	is the average length of a meeting away from base (estimated at 2 hours)
$f_{time\_out\_of\_office}$	is the fraction of time spent away from the office (from travel intensity)

Thus, a proportion of the time currently spent in face-to-face meetings at and away from the normal workplace is transferred to telecommunications according to the top-level dynamics for telework and telemeetings, modified by the interaction intensity, travel intensity and fraction of teleworkers in a business sector. The fraction of teleworkers is determined by the top-level telework dynamic, adjusted by the information, IT and travel intensity for a business sector. Some of this total conversation is then transferred to messaging according to the top-level dynamics for messaging and conversation, modified by the ratio of information:interaction intensity for a business sector. The remaining conversation time is then split between voice and video according to the top-level dynamic for video, adjusted by IT intensity for the sector.

A similar approach is taken for messaging (fax + email) and data transfer, and bit rates for each service type are applied to calculate the total traffic per person employed. Busy hour fractions for each service are also used to calculate peak traffic per person, and some sample results are given in the following section.

3.5 Results for service usage by business sector

Fig.4 shows the relative growth of service usage in the Construction sector (SIC 5) and in Banking and Finance (SIC 8) under the high growth scenario over 25 years. We emphasise that these traffic figures are estimates based upon sample traffic data, rather than hard figures for current network usage, but plotting traffic rather than direct service use immediately shows the effect of even a rather small amount of video (hence the logarithmic scale). This is because a second of video at 2Mb/s gives about 30 times the traffic of a second of voice (64kb/s).

Referring again to Fig.3, it is apparent that Construction and Banking & Finance are interesting sectors to compare, since SIC 5 has the lowest proportion of IT users, information workers and meetings people, but the highest travel intensity. In contrast, SIC 8 has the highest IT users and information workers, and amongst the highest meetings people, with slightly above average travel intensity. The effects of these differences can be seen from the results in Fig.4, most obviously in the difference between the two sectors in orders of magnitude for each type of traffic, but also in the dynamics themselves, which we now discuss.

The most obvious contrast in the results is perhaps in the difference in video traffic, which exceeds voice traffic by year 5 for SIC 8, but not until year 17 for SIC 5, whilst in both cases voice grows at a similar rate. This is a matter of scaling, and is entirely due to the difference in IT intensity between the two sectors. The shape of the video curve in each case is identical (cf the video curve in Fig.2a), since the IT intensity (in common with the other three metrics) is a constant, and this is raised as a subject for further investigation. Note again that a small increase in video usage produces a large increase in traffic, and that by year 25 in SIC 8, the average time spent using video is still only 60% of that for voice. In both sectors, voice has saturated by year 25, and in SIC 8 is actually declining from year 22 onwards.

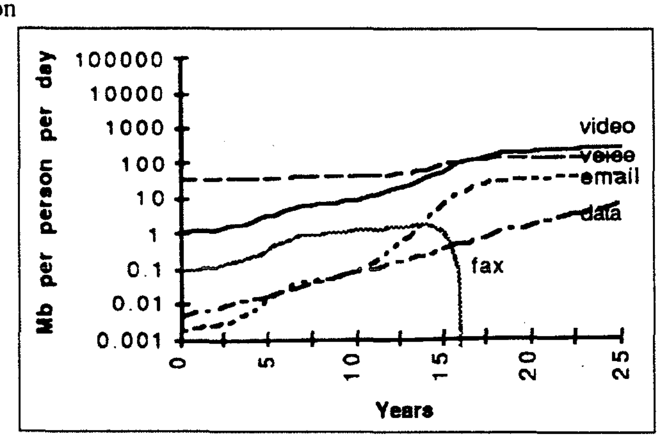
Rather more interesting are the dynamics for messaging (fax and email), which we have seen are strongly dependent upon both the IT intensity and the extent of teleworking within a sector, which is itself dependent upon the information, interaction and travel intensity. The immediate observation is that email substitutes fax rather more quickly in SIC 8, with fax vanishing by year 13 compared with year 16 in SIC 5. Meanwhile, total messaging traffic continues to grow in both sectors throughout the 25 year period, and it is worth noting that although email is a much more efficient medium than fax for text transmission (requiring some 16kb per uncompressed A4 page compared with 300kb for a fax), email systems increasingly support multimedia messaging. This is likely to lead to significant increases in email traffic, which is modelled by relating the email bit rate to the penetration of video at the top level.

Of particular interest are the differing shapes of the email curves, with the distinct knee at year 7 for SIC 5. A similar effect can just be detected for SIC 8 a little earlier, and this is again due to the large difference in IT intensity between the two sectors, resulting in a greater delay in transferring to email in the Construction sector. Deeper investigation also shows that telework obviously grows much more quickly and reaches a higher penetration in SIC 8, driving this effect. Comparing these email curves with the top-level messaging dynamic in Fig.2a suggests that much of the growth in messaging is in new email traffic, and the final substitution of email for fax (which occurs over just 2 years in both cases) is combined with the second phase of messaging growth from years 12-17 to give especially strong growth in email over the second half of the 25 year period.

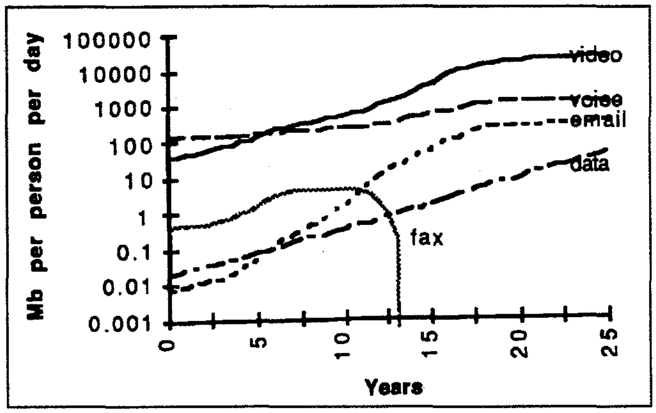
Growth in data is driven directly by top-level IT sophistication, with a delay depending on the IT intensity of the business sector, so both sectors show the expected exponential growth. Data is very much an uncertainty at the top level, and could be the only significant factor in extreme scenarios.

Fig.4 - Traffic growth per person for contrasting business sectors under the High Growth scenario

a - SIC 5: Construction



b - SIC 8: Banking and Finance

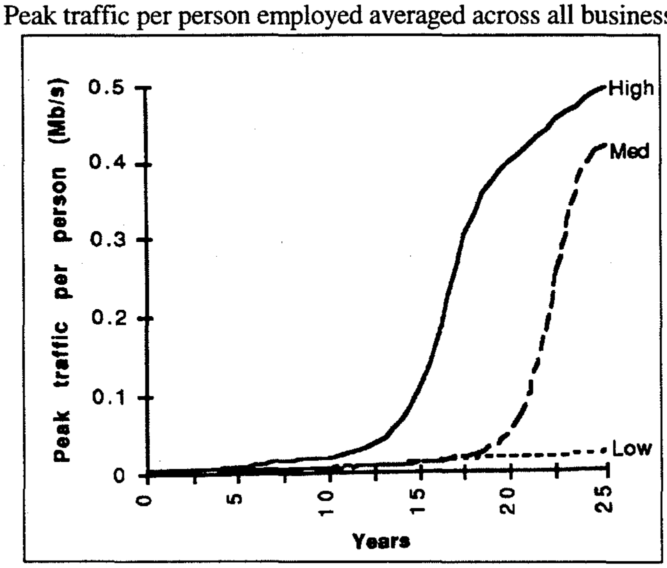


4 Discussion & Future Development

We have shown how we have applied system dynamics techniques to model demand for telecoms services from different business sectors. The modelling approach has been useful in structuring the problem in terms of a small number of top-level drivers and some simple metrics characterising individuals in different business sectors. We shall now discuss the learning gained from the modelling work, based upon the results presented in §3.3 (Fig.2), §3.5 (Fig.4) and in Fig.5, which shows the average traffic growth across all business sectors under the three scenarios proposed.

Fig.5 summarises the task faced in investigating future telecommunications demand. In planning future networks, telcos need to know how traffic is likely to grow, but the range of uncertainty seen in the results from these simple scenarios illustrates that this task can be extremely difficult, especially over the timescales required for extensive network upgrades.

Fig.5 - Peak traffic per person employed averaged across all business sectors



System dynamics offers an alternative approach. Having investigated the range of possible future applications and their likely maximum usage, the problem has been to investigate the factors likely to affect the rate of growth towards this possible future level of demand. We have achieved this by modelling a small number of drivers, and by constructing simple scenarios based upon varying two of these drivers.

In developing the scenarios in §3.2-3.3, we noted that the key uncertainties seem to be the rate of growth in general IT sophistication, and the rate of growth in telework. The effects can be clearly seen in Fig.5, where high growth is driven by Moore's Law and early demand for telework, medium growth is the same, but delayed by low initial teleworking, and low growth is slow due to IT sophistication advancing far less than under Moore's Law roughly following the current trend for telephony traffic, doubling every 4 years or so (O'Mahoney, 1994). The rapid growth rates obviously mean that the scenarios are sensitive to any delays in the system. In §3.4-3.5, we showed that the IT intensity of a business sector could be a key factor in determining future growth in telecoms demand, and we noted that any growth in video usage is particularly significant due to the vastly higher data rates required. These two points are obviously important in identifying customers likely to require early network upgrades, and also in developing strategies for stimulating new growth.

The flexibility of the modelling approach has also been seen as valuable. Placing the dynamics at the top level means that the understanding gained can also be applied to other problems, for example in investigating demand from residential customers. In future work, we plan to further develop our understanding at this level by investigating drivers including costs for travel and accommodation, changing employment patterns and average leisure time. However, the decision to fix as constants the metrics used to characterise business sectors, although simplifying the model, means that the effects of changing working practices in particular sectors were not investigated as part of this work. Whilst it is possible that, for example, the relative IT intensity of different sectors may remain constant, so that the top-level dynamics can reasonably be applied across all sectors, this is a special case, and it would be useful to be able to investigate the effect of intervening to stimulate such a change in a particular area of business.

Other topics of continuing work include investigating the effect upon demand of alternative broadband deployment strategies, and the application of results from the model to sample customer data, using a Geographical Information System (GIS) for visualisation. Initial results from using the GIS and other visualisation tools have been encouraging, but could increase the risk of output from scenarios being misunderstood as firm predictions (despite cautions from the modelling team; New Scientist, 1994). We therefore believe that the development of system dynamics applications will require ongoing effort to enable decision makers to embrace uncertainty as a constant companion demanding respect, and to support the structuring and investigation of problems in ways which foster learning and reasoned responses.

5 Conclusion

We have described the application of system dynamics techniques to investigate the supply-demand system for telecommunications services, using the software tool iThink. System dynamics has been seen as a useful approach to this problem, given the complexity and rate of change facing established telcos, resulting in large uncertainties and consequent risk.

Our emphasis has been upon investigating the modelling approach for this system and building understanding, rather than making predictions. We have described the development of simple scenarios based upon top-level dynamics, and results from these scenarios have been applied to the use of five generic services in different business sectors. Sectors were characterised by simple metrics, and the traffic for each person employed has been used to calculate the growth in peak traffic under the alternative scenarios.

In discussing this growth, we have noted the significance of even a small increase in video use, which is driven by improving IT sophistication in the model. This means that the results are sensitive to delays in this improvement, and indicate it as a key uncertainty. The extent of teleworking is also suggested to strongly influence these delays, and the relative IT intensities of different business sectors are noted as another possible point of leverage. The broad application of the approach has been recognised, and we have identified possible dynamics for further investigation at the top-level. Other future work may use visualisation systems to aid interpretation of results from these models, but we have emphasised that such applications of system dynamics must continue to facilitate scenario analysis rather than claim Delphic knowledge of future events.

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