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Information infrastructure and the connected city

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GLOSSARY OF TERMS

3G, 4G	third generation, fourth generation
AARNET	Australian Academic Research Network
ARPANET	US Defence Advanced Research Project Agency Network
ADSL	asymmetric digital subscriber line
ATM	asynchronous transfer mode
ATT	American Telephone and Telegraph
CATV	cable television
CDMA	code divisional multiple access,
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DSL	digital subscriber line
DSTO	Defence Science and Technology Organisation
DTT	digital terrestrial television
ESA	exchange service areas
GDP	gross domestic product
GSM	global system for mobile communications
HCF	hybrid fibre coaxial
ICT	information and communication technology
ISDN	integrated services digital network)
ISDN	integrated services digital network
ITAC	International Telework Association and Council
MFP	Multi function polis
NICTA	National ICT Australia
PDA	personal digital assistants
RIM	remote integrated multiplexors

VDSL very fast digital subscriber line

VOIP voice over internet protocol

INTRODUCTION

Most definitions of the city are based on the idea of human communication, and conceptions of the city as an enormous information network are now commonplace (Meier 1962 and Abler 1970). The infrastructure for a society based on knowledge work is coming into place rapidly, if unevenly, and major changes to the nature of work and leisure, the structure of industry and employment, the design of organisations and the character and purpose of social movements are resulting.

As wealthy countries describe themselves as information societies and poorer countries seek development through information and communication technology (ICT), the field of urban information infrastructure has moved to the centre of our effort to understand today's cities and how they might develop in the future. This is the year of the world summit on the information society (WSIS 2003) and its private sector counterpart the global commission on information infrastructure (GCII 2003). We are buzzed with studies of the wired city, the intelligent city, the global city, the virtual city, the information city, the cyber city and the city of bits. Some of it was millennial promotion of the 'new economy' that is fitfully coming into being (e.g. Horan 2000, Wheeler et al 2000, Mitchell 2000) and some of it is an effort to understand social and economic change and use this understanding for better urban and telecommunications policies.

Thirty years ago the author reviewed prospective communications technology and speculated on its impact on urban form and function (Wilmoth 1972, 1973). Even then the elements of today's ICT could be forecast with reasonable accuracy but envisaging their impact on cities was more like science fiction than science. Tracking prospective technological changes directly through urban analysis such as communication-transport substitution, trip redistribution, linkages and economies of agglomeration, office and residential relocation could anticipate some changes to urban form, through what Gold (1991) called the 'unproblematised' impact of technology, a kind of technological determinism. Understanding of the less direct but ultimately more important impacts through social, institutional and economic change, the relative strength of different technologies, the patterns of their convergence and

their take-up or rejection was less well developed (Hillis 1998). The prospects of socio-political management of communications technology and its urban infrastructure were seen but not clearly delineated. In those pre-post-modernist days science and technology were not often seen as socially constructed.

This paper briefly reviews the relationship now between ICT and the cities, particularly in Australia where data permit, and surveys the role that communication and information infrastructure might now play in the future form and function of cities. The paper identifies a number of issues for further research. Inter-urban and global dimensions of information infrastructure are well covered elsewhere and not addressed here (eg see Malecki 2002, Leamer and Storper 2001, Gorman 2001, Zook 2002, IBM 1997). Such studies tend to treat cities as single nodes, as in 'we have assumed that backbones terminating in a metropolitan area are equally accessible to all parts of a metropolitan area via local telecommunications infrastructure which is typically more robust than that which connects metropolitan areas to each other' (Moss and Townsend 1999, 8). This study focuses on intra-urban issues such as changes to urban form and the distribution of activities in cities. It also focuses on point-to-point communication rather than mass media, though through webcasting and interactive television for example there is now less of a clear distinction.

Castells (1996) demonstrates how the dominant activities of society may be organised around the 'space of flows' to comprise (1) the technological infrastructure of information systems, telecommunications and transport systems, (2) a set of nodes and hubs in given locales, (3) habitats for the social actors who operate the networks and (4) the electronic spaces of point-to-point or broadcast communication. The historic feature of this age of information is the extent to which this domination is now mediated by technology, but as he later points out, the 'autonomous construction of meaning and social and political resistance to the powers that be', initially constructed around places, have also come to occupy networks as purposeful on-line communities and new social movements (Castells 2000).

COMMUNICATION TECHNOLOGY

Foundations

The history of communications technology is built into the evolving form of modern cities. A procession of inventions marks the changing roles of cities, particularly for nodes of information intensity like business districts and technology parks. The telegraph, telephone, radio, radar, television, transistor, integrated circuit, satellite communication, microwave transmission, digital transmission, facsimile, packet switching, optical fibre, computer networking, the internet, the personal computer and mobile telephony have each had different direct and indirect impacts on city form. In the main, however, they have *enabled* changes to activity patterns, land use and urban development, and have not *determined* them. Perhaps for this reason the cables and ducts, wires and dishes, exchanges and control centres of telecommunication infrastructure have been out of sight from most urban planners and generally out of controversy apart from occasional issues of tower location, electromagnetic interference and local levies on cable reticulation.

Telecommunications infrastructure may be defined as 'the organisations, personnel, procedures, facilities and networks employed to transmit and receive information by electronic or electrical means' (ATIS 2001).

The pace of invention and development of communications technology continues strongly if discontinuously, whether or not it can be described as getting 'faster' (Gleik 1999). Communications remain a 'disruptive' cluster of technology (as defined by Christensen 1997 to characterise changes of a tenfold or greater order of magnitude). Miniaturisation of transistors and very large-scale circuitry are approaching molecular size and using radical new materials. New encoding, transmission, switching and routing inventions continue apace. The product cycle is shortening. Digitalisation is extending to all realms of media and new applications are being invented for more and more purposes and they are generally becoming user-friendlier.

The debate as to whether computing power or telecommunications capacity would ultimately limit the other (see Armer 1966, Brown 1971, Licklider et al 1968, Maddox

1969) continues but is now more complex: still capped by the inherent limits of available technology but with supply and demand causing boom and bust cycles for the two overlapping industries. Recent examples are the dotcom crash of April 2000 and the larger telecoms crash that followed it. The growth of computing power and the reduction in size of computers have continued according to 'Moore's law', i.e. an exponential growth in the number of transistors per integrated circuit. The proliferation of computing devices has exceeded early expectations, for example with grid computing growing strongly, whereby massive computational power can be harvested from millions of computers all over the world connected by the internet, some of them small (see The Economist 2001b). This was foreseen in Baran's original concept of 'distributed communication' (see Baran and Greenberger 1967) and in the creation of the first computer network to use packet switching in 1962 (ARPANET), but not to the scale now in operation (IEEE 2003). Machine-to-machine compatibility, seen as a key limiting factor on the growth of distributed computing, has been greatly assisted through the development of open and interoperable systems, standards and platforms, just as much a part of urban infrastructure as pipes, wires and cables.

Convergence and competition

Uneven development: Like vehicles onto widened roads, the new computer applications expand into the processing capacity available, and in ways often not envisaged by their inventors. In turn, new applications and users expand into available telecommunications infrastructure and promote its development. Despite its dramatic growth, computing capacity is being outstripped by transmission capacity; hence 'Gilder's law' by which bandwidth consistently grows at least three times faster than computer power. From 1998 to 2002, the amount of fibre in the ground worldwide, most of it in the cities of the developed world, increased five-fold, and the means of improving its transmission capacity 100-fold. While total capacity thus increased 500-fold, demand for transmission capacity during that period 'only' quadrupled. Internet traffic doubled once a year, not once every 100 days as earlier believed by investors. Partly as a result, over that period, USD 200bn was spent building unnecessary telecoms networks worldwide (Andrew Odlyzko, quoted in The Economist, 2003, 4), including 100 million miles of optical fibre, more than enough to reach the sun. The high prices of telco bids for future infrastructure options (auctions

for bandwidth, for 3G mobile licences, underestimates of internet telephony using voice over internet protocol) have been a source of massive cyclical destruction of capital in telecommunications around the world (The Economist 2003).

Convergence and aggregation: This pattern of uneven development is compounded by immature convergence, telecommunications media competing to host the dominant channel for voice, video and data, telecoms and information technology – whether through telephone, ASL, cable, satellite, mobile telephony, fixed or cellular wireless, power line technology or DTT (digital terrestrial television). However, competing transmission technologies are not yet giving cities robust integrated communications infrastructure. This has been recognised in broadband policy proposals in Australia, for example by the National Office of the Information Economy which seeks ‘to develop a national broadband infrastructure planning framework, in order to identify the ways in which individual broadband infrastructure elements should be aggregated to create a national broadband network’ (NOIE 2003, 18).

In Australia the part-privatisation of Telstra and policy attempts to separate its community service obligations (including important regional coverage requirements) from profitable business service and the staged introduction of competition have seen the issue of over 100 telecom carrier licences and justification of consequential benefits of \$5.5 -12 bn to Australian consumers (Caslon Analytics 2003). Though Telstra domination of trunk provision remains, the ‘public goods’ argument for monopoly provision of telecommunications infrastructure is barely contested. At the same time as Australian cities have seen massive duplicating cable TV networks, for cost reasons ISDN (integrated services digital network) services have been confined more to business districts, with only 3.4 percent of Australian subscribers (Australia 2002, 218).

Telephones: Publicly-switched telephone networks of paired copper wires are expensive items of sunk investment and a cost constraint on urban expansion, and in Australia have been the subject of some argument over common carrier status, the most rational staging of urban expansion and the boundaries of metropolitan unit fee areas. Fixed-line telephony is now declining in some advanced mobile-friendly

markets like Finland, is being bypassed in some cities in developing countries, and is seriously challenged by voice over internet protocol (VOIP). However, the plain old telephone service is far from obsolete: its universality and reliability in Australia and internationally have allowed many innovations to run through it (Prater et al 2002).

Picturephone: The Bell picturephone, once the urban vision splendid and the central device in several experimental cities and many office-based experiments in USA, UK, Japan and Germany is another cautionary tale, and an instance of 1970 forecasts badly out. The venture failed spectacularly by 1978 (Noll 1992, Newstead 1999) because of lack of common standards and 'network externalities' by which too few initial subscriptions discouraged further subscriptions (Rohlf's, 1974).

Cable: The capacity of cable television or CATV, a group of widespread broadcast media established in the USA for many decades (eg see Sloan Commission 1971), to extend to interpersonal communications or 'narrowcasting' (see National Academy of Engineering 1971) was poorly taken up until the internet provided universal protocols for interconnectivity and the limits of the 'tree' structure of cable television were overcome. Australia started late with few cable sites (enabling legislation was as late as 1992) and its introduction has been driven by the search for profitable pay TV provision by a concentrated media industry rather than provision of point-to-point connectivity or the wider social benefits of good urban infrastructure. Optus and Telstra built largely duplicating HCF (hybrid fibre coaxial) networks in metropolitan areas and some other urban areas through the 1990s using existing telephone ducts (in Telstra's case) and using access (both) to overhead electricity infrastructure (Brown 2003).

DSL: The technological life of telephone twisted copper pair infrastructure is being extended through DSL (digital subscriber line) technology, particularly but not only ADSL (asymmetric DSL). This is seen by some as a diversionary technology intermediate on the path to a higher-capacity broadband society (Isenberg 2002), much as Negroponte (1996) saw facsimile a diversion from digitisation. However, ADSL is a good current alternative to other more expensive ISDN (integrated services digital network) services (Cooper 1998). Though the staged provision of

DSL services and the limits of proximity to exchanges (typically under 3.5 km) have created unequal access in many cities, just like other technologies requiring new infrastructure, in Australia ADSL is available in virtually all metropolitan exchange service areas (ESAs) and many rural ESAs, such that over 70 percent of the population now has access to the service (Australia 2003a, 207). Limits of proximity to exchanges are being extended to 30 km for ISDN-enabled exchanges, but even so some parts of metropolitan areas cannot be connected because of the use of remote integrated multiplexors (RIMs) designed otherwise to extend telephone service. As a matter of policy, access to Internet services to at least 64 kbps is guaranteed on request under Telstra's digital data service obligation. In some cities, notably Canberra through TransACT, VDSL provision is based on high-capacity copper pairs. However, the future wired city is expected to rely on optical fibre (see Brown 2003).

Broadband fibre: In some markets such as Japan and South Korea telcos are, at great expense, starting to bring next-generation networks or 'fibre to the premises' i.e. universal high bandwidth to work establishments and homes. In Singapore fibre connection is mandatory for classes of new buildings. In Australia very high capacity fibre connectivity is yet to be widespread in the cities, with Telstra and Optus investment in CBD areas and smaller providers (eg Agile, Ipera) in smaller cities. A new venture in Perth, Bright Telecommunications, has been established by Western Power, an electricity company, to use fibre optic technology direct to households and businesses in some of the wealthier (and connectable) suburbs with television, video, Internet and telephone.

Mobile: The present extent of penetration of mobile telephony was not foreseen in 1970 and particularly its spectacular growth as a medium in developing cities without telephone network infrastructure. Mobile telephony in Australia is mainly second-generation digital (either code divisional multiple access, CDMA, which has replaced analogue service particularly in non-urban areas, or global system for mobile communications, GSM, best in metropolitan areas), with early adoption, by world standards, of 3G (third generation). Elsewhere, the administered price of spectrum allocation and bidded-up licence rights for fast broadband packet-switched communications are continuing. Mobile telephony has overtaken fixed-line telephony for number of subscribers in Australia. Competing to be the integrator of the new

information utility, with the popularity of DoCoMo in Japan and 4G (fourth generation) in development – the economic and social uses of mobile telephony have exceeded the expectations of the technology planners. Smartphones attempt to integrate many of functions of handheld computers and now outsell personal digital assistants (PDAs).

Broadband wireless: As mobile telephone services stumble to provide new bandwidth-greedy applications, wireless broadband becomes an option for integrated urban services, including in poor countries where there is little cable or fibre infrastructure (eg see UNDP 2003). The rapid expansion of high-frequency wireless local area networks (Wi-Fi), enabled by specific protocols, is providing a new mesh of overlapping hotspots, a patchwork of connectivity and non-connectivity again favouring higher-density business nodes in the cities and bypassing poorer areas. Under Australian conditions wireless data services are limited by distance (needing expensive repeaters or base stations), signal attenuation through rain, fog and vegetation, security breaches, lack of access to the best and most expensive urban locations, and interference especially on the usable public bands in urban areas (Australia 2002).

Satellite, microwave and other advanced services: The two-way satellite internet market in Australia (Australia 2002, 207) has been used mainly by business, who are also the main users of higher bandwidth ISDN services, private local area networks via ISDN or xDSL service, satellite and dedicated asynchronous transfer mode (ATM) and frame relay link services. Two-way satellite systems are very expensive to install and use, but Telstra is obligated to offer two-way satellite Internet services to the 28,000 customers living in Australia's most remote areas under an extended zones agreement (Australia 2002, 211). In these extended zones over 30 percent have taken up the offer (Australia 2002, 211). This service is also available throughout Australia and the use of satellite is increasing as a means of distributing pay TV.

The information utility

The full forces of ICT are being felt less through any one channel than through their convergence into an unprecedented broadband network carrying the internet – a

network of networks enabled by the internet protocol – and other innovations. The extent of applications is practically unlimited. Even when not technically integrated, for customers different services can be ‘bundled’ together competitively. The potential of an ‘information utility’ was envisaged in the 1960s, though held back by cumbersome and incompatible standards. The origins of the Internet in military strategies for network computing to withstand nuclear attack are well known (eg see Lessig 2001) and by the 1970s growing networks of email users were in place (See IEEE 2003 for a useful history). Australia may be at the geographic edge of global GDP (Leamer and Storper 2001) but has tended to be an early adopter of technology and a lead user of ICT in workplaces and the rest of society.

The extent to which the Internet is space-bound or beyond space – a new stateless realm (Negroponte 1996) or even the emergence of the collective intelligence of humankind, de Chardin’s (1961) noösphere – is an issue for understanding its urban impact. Of course information infrastructure and internet data have spatial attributes, as efforts to enforce the laws of various jurisdictions, target advertising and prompt the appropriate internet language to users all demonstrate (The Economist 2001a). Geolocation services provided by firms such as Quova in Silicon Valley pinpoint Internet protocol addresses and link them to postcodes for fine-grained marketing and targeted services.

An integrated broadband ‘information utility’ was seen as a vital development for cities but the vision of its urban form was limited by precursor technologies and its reliance on cable and telephone infrastructure. Discussion of ‘electronic neighbourhoods’ hierarchically linked into larger constituencies confused the tree form of the network with the freer social form of its use, though there are now strong locally grounded applications of the Internet. Discussion of the physical infrastructure presumed separate networks where today the parallel media and information channels are being integrated, if slowly and wastefully. The Academy of Engineering (1971) identified four basic networks of the future: a random two-way fully switched public network (like the telephone system), a bulk information distribution network with limited callback (like broadcast cable), information ‘expressways’ with virtually no switching linking major institutions (and thus not identical to the later ‘information superhighway’ of the internet) and a network of one-way environmental sensors for

environmental monitoring, traffic management etc. The extent of creation of virtual social networks and metropolitan social movements (eg, mobile organisation of demonstrations, urban 'swarming', chat groups, blogging and more enduring on-line associations) was underestimated. Foreshadowed services and applications available tended to be utilitarian – travel bookings etc – and with some interesting exceptions (eg Kenzotaki's prefiguring 'cybersex' and 'intersex' in 1971), failed to anticipate the explosion of information resources able to be accessed, and thus the present-day coverage of 'information infrastructure' to include the mobilisation of information resources and knowledge management.

In Australia, where 54 percent of households are online (6th in the world) but only 4 percent connected to broadband, (11th in the world, Australia 2003b), the recommended broadband policy seeks to aggregate demand without a necessary regional footprint, i.e., 'to seek to balance the competing requirements of initiatives for particular sectors (such as health, education and general government) across a state or region, as opposed to area-based strategies aggregating demand from multiple sectors and consumers within that local area' (Australia 2003c, 17). This would build on the 'Networking the Nation' program to reduce disparities through funds derived from the partial sale of Telstra, though that program has been criticised for not focussing sufficiently on regional distribution of service (Crowe 2003). In terms of adults accessing the internet, Canberra is on a par with San Francisco, further down Sydney, Melbourne and Hobart are on a par with Atlanta, and Brisbane and Adelaide with New York (Australia 2001). To aggregate demand, priority would be given to building on existing special purpose infrastructure, which could then be used to bridge infrastructure gaps where private sector investment is lacking, particularly in regional areas. Possible special purpose infrastructure that could be used to supplement general telecommunications infrastructure includes state-owned railway fibre, utility infrastructure and the Australian Research and Education Network (AREN)', the successor to AARnet. However it is unlikely Australia will emulate the Netherlands in refurbishing disused milk pipelines for broadband links... (Budde 2003).

INFORMATION INFRASTRUCTURE

The urban implications (if no longer the one-way impacts) of communications technology work through a complex web of causation and as our ways of thinking about this causation have developed so have the issues identified and constructions of the field of study. To set the scene for an understanding of urban issues, this section reviews the emergent information infrastructure of cities, the relationships between transport and communications, and the incidence of telework and telecommuting.

Information infrastructure

The elements that make up information infrastructure are the current and future public and private high-speed, interactive, narrow-band and broadband networks, the satellite, terrestrial, and wireless communications systems that deliver content to homes, businesses, and other public and private institutions, the information and content that flows over the infrastructure whether in the form of databases, the written word, media objects or computer software, the computers, televisions, telephones, radios, and other products that people will employ to access the infrastructure, the people who provide, manage, and generate new information, and those that will help others do the same (Hyperdictionary 2003).

This infrastructure is all too seldom taken into account in understanding urban form and in the planning of cities. Australian urban plans typically provide a general discussion of the importance of the information economy and provision for telephony and cable. As urban development releases created demand for copper-wired suburbs, public telecommunications planners in the PMG, Telecom and Telstra made hardheaded judgments of the likelihood of success of urban plans to protect their investments, in practice ignoring the idealised forecasts underlying the official plans. Now, as fibre optic cable is rolled out, as new services become differentially available, as telcos compete for position after another 'tech-wreck', and as standardised public information infrastructure is replaced by what Graham (2000) calls the 'uneven overlaying of new, customised, high performance urban infrastructures onto the apparently immanent, universal and (usually) public monopoly networks', the urban forms of telecommunications are becoming important

once again. Metropolitan plans in Australia reflect no better the telecommunications infrastructure issues than they did 30 years ago, but some local plans for particular developments have made sophisticated provision for communication technology (eg see Docklands Task Force 1990).

Transport and communications

The relationships between transport and communications are complex and do not yield easily to empirical research let alone reliable forecasting. Document movement and freight are important; for example Ferriera et al (2001) notes that the new 'etailers' in Australia who went out of business in the dotcom crash are being replaced by traditional retailers who still trade from storefronts but use communication technology intensively, that this will bring a small increase in overall urban shopping travel through increased consumption (i.e. not trip substitution), and that between 1999 and 2005 light commercial vehicle travel business to consumer can be expected to grow 50 percent. The role of ICT is central to the effectiveness of urban transport and logistics, as Melbourne's CityLink demonstrates.

The movements of people dominate most estimates of urban impact of telecommunications. Much as the paperless office has generated increasing use of office paper, telecommunications traffic and the number and length of trips have risen with technological applications as the two sectors have reinforced each other's growth and diversification.

In Cairncross' words (1997), the death of distance loosens the grip of geography but does not destroy it. Early expectations of trip substitution have given way to multivariate approaches and studies that attempt to differentiate trip substitutability, generation and modification in respect of trip timing (eg enabling more off-peak trips), trip length (eg distributed information on more distant opportunities), routing (eg IT-enabled instant re-routing) and mode choice (eg public transport timetable information enhancing transit reliability) (Niles 1997). On the latter point, Australian work on the transport impacts of e-business indicates that conventional fixed route / radial public transport will suffer relative to more flexible private means (Ferriera et al 2000). Intelligent transport systems enable ICT to change the accessibility profile of

cities through a combination of information, navigation, safety, tolling, monitoring and control devices (Hodge and Kosky 1997).

As a UN Habitat survey concluded,

Universal connectivity complements, supplements, and improves, but does not generally replace, the mobility of people and goods that is provided by transport systems. However, there are certainly applications of telecommunications that afford individuals an opportunity to reduce travel that is personally undesirable or unnecessary. Furthermore, there are mid- and long-term opportunities for restructuring the delivery of goods and services to consume fewer transportation resources.

Telework and telecommuting

Most people in developed cities use advanced telecommunications at workplaces, homes, service establishments and elsewhere. The typical organisation, whether dominated by knowledge workers or not, has been transformed by ICT. Teleworking and telecommuting have proved difficult to study in part because definitions vary widely as the proportions of information and knowledge workers in the workforce increase and as telematics become ubiquitous. To an extent, almost everyone is a teleworker now.

The essential characteristics of telework are that the work is undertaken away from the designated place of work and that it is enabled by modern ICT. More strictly it is defined by the International Telework Association and Council (ITAC) to cover 'workers at alternative worksites on average at least eight hours every two weeks'. There are well-developed procedures for setting up telework programs (eg see Oregon 2003). Where telework replaces the daily journey to place of work, it is called telecommuting. Whether home-based, office-based, mobile, on-site or in a telecentre (see Helling and Mokhtarian 2001, 513 for a more detailed classification), telework has grown in a manner foreseen by earlier forecasters but generally at a slower pace.

Because telecommuting 'probably has the highest potential for travel reduction of any of the teleapplications' (Mokhtarian 1998), it has attracted most policy and local planning attention, including an ABS 2001 special survey in NSW. Public benefits of shorter and fewer trips and reduced air pollution (ATT first sponsored telecommuting under US Clean Air Act 1990 amendments) are often claimed alongside the private benefits of time and cost savings, employee independence, employment flexibility, productivity and retention of employment (eg for the disabled, or those sharing home duties with telework, or those otherwise unable to work).

Results can be generalised from a large number of studies in US and Europe and some in Australia (see Helling and Mokhtarian 2001 and Schallaböck et al 2003 for reviews of those regions respectively and Walmsley 2000 for Australia).

Telecommuting increases with income and education and decreases with age, much like the use of ICT generally (including in Australia). Those who telecommute substantially reduce the number of their trips and distance travelled and spend less time on fewer non-work trips. Their urban activity spaces typically contract (Helling and Mokhtarian 2001). They shift travel mode from public transport to private, whether by not working at transit-accessible workplaces or eliminating discretionary difficult trips. Despite major travel changes among telecommuters, there appears little effect of telecommuting on urban transportation overall, because the proportions of telecommuters are small, because commuting trips are only a share of total trips – and a declining share – and because non-telecommuters can expand their travel behaviour to take up any capacity released.

Both routine teleworkers and more intensive knowledge workers are able to undertake a growing share of their transactions on-line and remote from urban activity centres, potentially enabling location factors other than proximity to work to come into play. Telework, telecommuting and communication technology can open the way to the relocation of households, offices and other establishments. The dynamics of household and family linkages, leisure or lifestyle preferences and engagement in face to face business, professional and labour market activities that telework can bring to influence residential location are not well understood. While overall they may be characterised as centripetal forces (eg aversion to city traffic), the net effect has been to bind telecommuters to metropolitan labour markets through

economies of agglomeration. The growing literature on such forces points to a loosening of the metropolitan structure through the replacement of direct inter-firm or inter-establishment linkages with indirect economies of agglomeration, but a retention of the attractive force of metropolitan regions (encompassing extended exurban realms) which will decidedly not disappear into a non-place urban realm.

Studies show some worker productivity gains from telecommuting. Employers benefit from savings on office space and its services, and can shift occupational safety and other risks onto telecommuters. Office space is freed for face-to-face dominated activities (Chabrow, 1985). Of course, some employers extend teleworking to cheaper labour in developing countries or in countries such as Australia with a good multilingual labour force and complementary time zones (Cross, 1986).

The NSW Roads and Traffic Authority began a major teleworking trial in December 1993 (Lynch, 1994b), which showed that Australian companies were slow to adopt teleworking. The current NSW transport database retains telecommuting data thus enabling trends to be followed. In the 3 months to October 2001, an ABS survey of NSW (2002b) showed 8 percent of employed persons teleworked (defined as employed persons aged 15 years and over in NSW who worked at a fixed workplace, for a business that was not based at their own home and in the last 3 months worked at home during normal business hours for a full or part day). Most teleworkers (72 percent) lived in Sydney, 58 percent male and 42 percent female, broadly the same distribution as employed persons overall. Younger and older workers were less likely to telework, with the most common age group being 35-44 years. A further 12 percent of employed persons only worked at home after normal business hours. More public sector employees teleworked compared to those employed in the private sector. The main reasons for teleworking were that work commitments or job required it (33 percent), there were fewer distractions (15 percent), childcare or family considerations (13 percent) and greater productivity (12 percent). When not teleworking, 87 percent of teleworkers used a car for at least part of the trip to work, with train (12 percent), walking (9 percent) and bus (8 percent) the other modes. Forty seven percent of teleworkers would like to telework more often, and 38 percent of those working at home only after business hours would also like to telework. Of

those workers who do not do any work at home for their job or business, 27 percent indicated they would like to telework. For many, however, it is a choice between telework and no work, particularly in areas of high unemployment.

It is difficult to generalise about telework because of the different types of work, media of communication and modes of employment. More flexible arrangements between work and family, positive effects on family life and improvements to productivity are consistently reported in surveys though not necessarily more time with family – indeed, longer working hours among teleworkers are reported vis a vis equivalent non-teleworked jobs. For full-time teleworkers, particularly in routine work, isolation and lack of ‘soft’ face-to-face learning opportunities (as distinct from enhanced e-learning opportunities) are cited. Clearly, there is a latent demand for more telework but not a dramatic take-up and little discernible effect of telecommuting on urban form.

URBAN STRUCTURE

The previous sections explored the first dimension, infrastructure and accessibility, of Castell’s ‘space of flows’. While analysts have developed an understanding of urban form (say, the city’s anatomy), the dynamics of circulation and change (say, its physiology), are less well understood. This section looks briefly at the pattern of urban establishments and clusters, Castell’s second category of ‘nodes and hubs’, through changed contact patterns and linkages, economies of agglomeration and counter-tendencies towards fragmentation. Some of the recent urban forms taken by the ICT industry itself are of interest. The use of communications technology as an instrument of urban planning or social policy is left to the next section.

Information nodes and activity centres,

Fundamental changes to the character of organisations and workplaces are being enabled by ICT. Business processes for producing goods and services can be automated and simplified through enterprise-wide intelligent systems, enabling firms to relocate processes to lower-cost locations, reorganise outlets to locate near customers or suppliers, or reassemble functions to bring together those needing high

information intensity including face-to-face presence, prestige or security, (even if not otherwise linked). The casualisation of the workforce, its outplacement and re-engagement through new individual enterprises or franchises, and unceasing internal reorganisation mark many organisations dependent on ICT. Multi-location organisations and flexible forms of establishment – eg, temporary offices, incubators, telecentres and home telework – make contact patterns among firms and inter-establishment linkages weaker explanations of location. The displacement of middle management from many organisations may cause groups of ‘refugees from communications stress’ to relocate to suburban locations or for whole groups of leading technical staff to relocate to environmentally desirable towns (Meier 1985). Despite some movement to coastal towns, Australian experience of this remains primarily intra-metropolitan.

Attempts to study the communication patterns among offices with a view to promoting a well-informed office location policy have resulted in interesting research findings (eg see Goddard 1971), but Australian experience shows that the major programs for office relocation (eg Federal government employment location in the 1970s, NSW centres policy in the 1980s) were not based on research on inter-establishment linkages. An interesting result of work on inter-office communication linkages has been to explain comparative differences in the structure of metropolitan regions partly through cultural differences in contact linkages, eg the requirements for face-to-face contacts to set up business meetings have contributed to intensive office districts in Seoul notwithstanding Korea’s hosting the world’s highest per capita take-up of broadband connections (The Economist 2003, 12).

The freeing up of business location by looser direct linkages has brought more attention to the forces of agglomeration – pools of skilled labour, availability of venture capital, knowledge institutions like universities and environments fostering creativity and shared security. High bandwidth is a necessary but not sufficient condition for many information-intensive activities, and new types of establishment are forming: telecentres, telecottages, learning centres, incubators, game centres, cyber cafés, call centres etc.

Despite their mixed blessings (eg Saxenian 1994), many regions seek to promote clusters driven by ICT industries through understanding the economics of agglomeration and nurturing nascent industry clusters. A recent review (Australia 2003, 15) recommended networks and clusters as follows:

State and Territory governments should take the lead in bringing together major focal points of R&D activity and the innovation infrastructure (such as CSIRO, DSTO, NICTA, CRCs, the Building on IT Strengths (BITS) incubators, and the GrangeNet, CeNTIE and mNet test networks) with potential industry partners, to drive cluster development.

In increasing scale, from wireless hot spots and airport lounges through teleports and incubators with high capacity datapoints (Mitchell 1995), university and research parks, technology zones like MFP (multi function polis), and large regional clusters like Sophia Antipolis and Hsinchu, regional policies are promoting clusters of linked ventures rather than discrete precincts.

All Australian metropolitan plans contain district centre policies in different forms, pursuing a better match between the distribution of employment and the residential workforce, invoking ICT and transport infrastructure policies in support. The most intense points, the respective CBDs, have been supplemented through promotion and investment in linked ICT infrastructure – eg Sydney's Australian Technology Park, Melbourne's Docklands and Digital Harbour, Brisbane's Southbank, Adelaide's Mawson Lakes (néé MFP). Policy support for creative clusters – eg lab3000 in Melbourne – is also growing as cities look for competitive positions in innovation and the use of universities and new knowledge industries to generate economic advantage (Berry 2003).

Dispersion, concentration and fragmentation

As noted, communications technology is generally an enabling force in urban change rather than a compelling one. Dispersal can be through differential rates of growth at core and periphery, through relocation outwards from a core or through lowering

density of employment or activity at certain nodes. Metropolitan regions take so many different forms that centripetal and centrifugal forces play out in many different ways, so that the effect of ICT on the polynucleated and discontinuously urbanised regions which characterise Australian cities may be different from cities elsewhere. As many analysts have shown, the spatial unbundling of organisations, the international division of labour and more generally the forces of globalisation, all mediated by and at least in part driven by ICT, are breaking up local linkages in large urban regions (Saxenian 2002).

Early forecasts of high dispersal, the virtual disappearance of cities as we know them (eg Toffler 1970, Webber 1964), have not eventuated. Most communication technologies have tended to reinforce prior spatial patterns of concentration and dispersal through early adoption at nodes and the economies of initial advantage (Leamer and Storper 2001). The intensification of knowledge-based activities in headquarter and R&D parts of organisations in part through the electronically enabled dispersion of branch and back office activities have intensified some business districts (Zook 2001). Agglomeration in downtown areas of a few large metropolitan regions is driven by attraction to skilled staff, density of linkages (for contracts and technical support), uniquely configured office space and, to an extent the availability of sufficient reliable bandwidth (Gorman 2001).

Communication technology and the global integration of most sectors of the economy have therefore enabled fragmentation to occur within urban regions, perhaps into an 'archipelago economy' (Graham 2000) of interlinked networked enclaves of high connectivity and intensive knowledge work, typically 'cherry-picked' areas for private telecommunications services aided by the breakdown of urban planning and the facilitation of special development zones. These powerful 'premium networked spaces' of high backbone bandwidth also rely on handshakes and tacit exchanges of knowledge for their special character (Leamer and Storper 2001). Such information nodes are often surrounded by 'network ghettos' (Thrift 1995), which continue to be bypassed by the provision of new infrastructure services, access to skills, and discriminatory geodemographic targeting of social and spatial groups.

Some still argue that the ubiquity of advanced telecommunications is minimising the competitive differences among areas based on infrastructure alone, and so destroying communications differences among places (eg see USA 1995), and that urban information nodes are really only passive places of information assembly contrasting with deeper knowledge and intelligence that is widely distributed (Atkinson 1998). However, these arguments confuse the periphery of *virtual* networks (where indeed most new applications are being developed – eg VOIP providers) with disadvantaged peripheries in real urban space.

Indeed, by now most analysts see, on balance, an opposite, centralising tendency in cities. The roll-out of new technology is usually spatially constrained, and early infrastructure is not universal: cables and fibres remain expensive to install and vary in capacity, ISDN remains limited in coverage, new mobile and broadband wireless services have limited cover at their beginnings, satellite ground stations and microwave relays are localised and expensive, and even ADSL requires proximity to telephone exchanges (Australia 2002, 218-225).

In Australia rural-urban disparities in telecommunications have dominated the debate partly because of the planned ICT benefits to 'regional Australia' (an unfortunate term excluding metropolitan and major urban regions) have been promised from the sale of the public carrier (Australia 2002, 2003, Telstra 2002) and in part because basic telephony is near-universal.

Meanwhile, the technology-enabled unbundling of enterprise functions and the spatial fragmentation of organisations are pulling activities towards new centres. Berry (2003) reviews how intra-metropolitan differences in information intensity in Australia are associated with discontinuous industry and activity clusters and strongly influenced by globalisation.

The ICT industry

The ICT industry itself has become a growing part of cities in developed countries and some regions in developing countries. Though R&D clusters and manufacturing

facilities are highly concentrated, the distribution, sales and service functions are widespread. The pattern of trunk Internet infrastructure reinforces the pattern of urban infrastructure by using previous cable or telephone lines and indeed by often using rights of way of power lines, railways, roads and sewers. Computer service and communications firms tend to cluster in existing business districts.

The Internet itself is an important new industry in some cities, as Malecki (2002) demonstrates, with different levels of infrastructure and a remarkable new economic geography. The counterparts of interfirm linkages are transactions that link individual networks into the Internet. Contrary to popular impressions of a spaceless realm, Internet support is highly concentrated because of need for interconnection, 'peering' among equivalent backbone providers and financial settlements among them. There are only a few very large IX (internet exchange) points in the world, though there are many smaller hubs such as those for AARNET in Melbourne and Sydney.

New services and industries are emerging, such as the huge data centres and web hosting facilities where many Internet service providers locate in web hosting 'hotels' and are supported by server 'farms'. The web hotels tend to concentrate in nondescript buildings in or near downtowns that can accommodate multiple fibre connections to different backbone providers, space for cables, and advanced equipment for fast switching. By contrast, the server farms that host the websites of global organisations are located at suburban or exurban locations to take advantage of the rising demand for managed hosting and dedicated power supplies. For example Exodus in Santa Clara County in 2001 hosted 49 of the top 100 websites (The Economist 2001a). The largest server farm in Europe, iXguardian has its own 24 MW gas-fired power station to assure supply (The Economist 2001). The demand for managed hosting is also driven by security considerations and the growth of mobile devices through which networked software is housed at a central point with globally distributed caching nearer customers and users (eg Akamai from Cambridge Mass manages 11000 caching servers in 62 countries).

In Australia the importance of linkages and clusters for ICT industries has been recognised for example by the Framework for the Future Steering Committee (Australia 2003a, 59-60), but not strongly acted upon:

In a modern knowledge-based economy, linkages and networks between leading-edge users and producers of ICT products and services, and between firms and research organisations, are particularly important for establishing and maintaining the competitiveness of businesses within the ICT industry...

Industry clusters are an important way of building and adding value to linkages between firms and with the research sector. Clusters promote a blend of competition and cooperation which can result in a dynamic environment for building firms. In many countries, clusters of innovative firms are driving growth and employment. Innovative clusters of economic activity are becoming magnets for new technology, skilled personnel and research investment. Thus a positive self-reinforcing cycle is established, providing the support conditions for sustained economic growth.

RESEARCH ISSUES

Urban telecommunications in Australia does not constitute a major field of work despite the international attention it now receives, and there is only a small body of research results specifically on Australian issues. However the attention given to communications policy in Australia and the advanced but uneven direct take-up of new technologies, the remoulding of organisations, new urban activity patterns, the changed nature of work, the invention of new communities and new forms of exclusion all cry out for specific research. Some of the possibilities are as follows.

Planning for technological changes

Thirty years ago most of the communications technologies now implemented were clearly foreseen, though the specific patterns of convergence, the dead end of Picturephone and the power of protocols and standards in creating the Internet were not clear. Likewise, the next waves of technological change are now documented in

diverse literatures and patterns of scholarly communication. It is most important the possibilities, consequences and policy implications of these changes be researched and better understood by the urban sector. Wiser and more sceptical social sciences, a greater desire to communicate science and technology, tangible community frustrations with special interest dominated communications policy and lack of national urban policy are strong bell-weather for this research.

Urban patterns of broadband convergence

Without closing possibilities for new combinations of media or detracting from the effort to extend telecommunication services to non-metropolitan or remote regions, there is an opportunity to understand better the likely and possible patterns of urban communications infrastructure. The issues raised by the National Office for the Information Economy (NOIE) towards aggregation of demand for broadband can be extended to a thorough examination of how Australian cities can best take advantage of and provide for telecommunications infrastructure, new media convergence, distributed ICT applications and services, and abundant and rich content. Such work may entail devising new strategies for planning and managing urban communications infrastructure so as to be effective and robust technically and socially, resourcing more experiments with new high-capacity bandwidth, finding cost-effective means to extend broadband access to bypassed areas, and adapting existing programs better to the uneven and fragmented conditions of Australian cities as they are.

Planning for telecommunications

At a practical and local scale, such limited research results as exist point to massive inefficiencies and duplication, needless local conflict and lost opportunities for coordinated provision for current or potential future local infrastructure. Too often the privatised telcos fail to see joint opportunities with separate infrastructure providers – water, power, transit for example – or, if they do see them, fail to overcome the considerable regulatory, investment and timing challenges. Too little is understood of such opportunities among urban managers and policy-makers, and applied research involving them in devising effective local and district strategies for communications infrastructure could likely yield considerable social returns.

Transport, access and telecommunications

The emerging interrelationships between transport, urban accessibility and communications make up a particular area of research promise. Urban form is important for reasons of social and economic access rather than for its own sake, as Webber (1996) reminds us:

Despite the attention urban planners and geographers assign to spatial pattern, it should be clear that little, if any, value resides in spatial distribution per se. If there are desirable attributes associated with locational pattern, they are overwhelmingly the consequences for conducting social and economic activities. The attribute that matters most is accessibility – the ease with which individuals and groups can reach and deal with each other. It continues to amaze me that so much attention is directed to describing and prescribing geographic pattern, rather than to explaining and tracing its consequences. I was amazed by the planners' and geographers' preoccupation thirty-odd years ago. I continue to be amazed today.

State and commonwealth agencies and a number of private providers collect data and undertake some research but it is typically based upon simplified notions of telework, conventional classifications of business districts and commuter movements of people rather than goods and information. New types of urban establishment are forming to cope with integrated supply chains and disaggregated enterprises, and the forces of urban agglomeration are strong but indirect: reviewing the relationships between transport, accessibility and communications is a most important prospective area for urban research in Australia.

New-generation urban activity centres

All metropolitan plans and many other urban plans for Australian cities contain strategies for promoting activity centres, business districts or employment centres. None of them adequately address communications and yet the new forms of establishment – eg telecentres, back offices, call centres, server farms – new patterns of dispersal and new forces of agglomeration demand a re-thinking of whether such activity centres are appropriate, if so how regional economic

development and social integration would best be served, and what arrangements for telecommunications infrastructure and services would be most effective for the future. As an active participant in global supply chains and an early adopter of technology, Australia should host globally significant hubs.

This work would include coming to a better understanding of the ICT industries – which are reasonably well documented in Australia but not from a locational or infrastructure perspective – and seeking to meet or modify industry and service needs and to develop or attract clusters of ICT-related enterprises. International research on such issues is in an exciting phase and Australian cities are the worse for not being subject to leading-edge research in this field.

An urban digital divide

The current global effort to reduce inequalities of availability to information and connectivity recognises big gaps by level of national development, gender, age and location. Disparities in technical access within cities are initially widened by the introduction of new technologies through diffusion and policy settings, and over a short time intra-urban differences are reduced relative to regional and global differences. However, it is not so much availability but practical access, and access not just to bandwidth but the knowledge and creative opportunities through communications media that rely on education and awareness. Cairncross (1997) identified the winners: the distant, the young, the creative and skilled, niche players and the United States. The ICT landscape of the Australian city is made up of generally good universal core infrastructure, the overlaying of globalisation and international supply chains, the agglomeration of information-intensive and face-to-face reliant activities into nodes if not clusters, the fragmentation of organisations and establishments and the continued marginality of areas that might be technically connectable but which for a host of other reasons are not part of the connected city. Within industries, those that are the heaviest users of ICT are recording the most rapid increase in wage disparity. While there are data on the spatial and social distribution of telecommunications usage in Australia, telecommuting and other factors, Australian research has not given adequate dimension to a possible urban digital divide in Australia, to social disparities in access to or benefit from ICT. How

such disparities can be understood, measured and remedied, and how digital inclusion can be promoted as a social goal for Australia, are tasks to be addressed.

Re-establishing the commons

Webber (1963) famously forecast ICT-enabled 'community without propinquity'. The radical opportunities presented by the internet to create or host new virtual communities, a new political realm, new markets accessible to small startups and new media have given hope for the creation of a new commons, an accessible, democratic realm that replaces more rigid organisational and political structures, and perhaps compensates for the break up of place-based communities. There is a large literature on how the virtues of the early Internet, a free domain of ideas, might be restored, protected and enhanced. While the focus should be on applications and regulation of information and innovation, urban infrastructure measures can be taken to protect and promote virtual communities. For example Lessig (2001) recommends ways of selectively freeing up spectrum and encouraging cities to provide massive 'dark fibre' along the lines of Chicago, fibre optic cables unconnected to any particular service and so not yet 'lit' by dedicated services. The potential exists in Australia where both Telstra and C&W Optus have left a significant proportion of dark fibre in their networks and this constitutes a reserve capacity.

The creation of virtual places may be of some interest to urban development but the application of ICT to the retention and transformation of real urban spaces is of greater importance to city development. As social groups and political movements seek grounding in local space, there are ways that ICT can enrich rather than obliterate contiguity of linked urban functions and local identity. Even 'smart mobs' look for smart places (Rheingold 2002). Aurigi (1997) sees the prospect of tele-mediated exchanges complementing telematic policies that are grounded in particular towns and cities, a counterforce to the fragmentation of communities. The European study cited above recommends that policy-makers 'identify where online communities can make a contribution to local social capital as part of a more joined-up approach to community initiatives' (Schallaböck and Utzmann 2003, 7). In Australia some of the Rural Telecommunications Infrastructure Fund projects ('Networking the Nation') are aimed at using broadband infrastructure to enhance

communities, but mainly in rural areas (Goggin 2002). Adaptation of virtual support for actual area-based organisations in cities, whether business or community, would benefit from Australian research.

Planning technology and technology in planning

The use of ICT in the practice of urban planning and management, like many other sectors, is deep and widespread, including in Australia. The use of ICT as an instrument of urban planning, say high bandwidth infrastructure as a locational attractor, is also common but best practice is not well defined. So much of effective development promotion is through creation of external conditions and environment rather than ensembles of specific ICT support (but see Helling and Mokhtarian 2001, 511).

Urban planning for effective ICT infrastructure provision likewise is not well developed. The ICT industry is a major part of some city plans (eg see Corey 1990 on Singapore). Competition among cities for the industry itself is intense, particularly high value-adding activities like R&D, new applications and creative product development. In Australian cities the industry is relatively little represented in manufacturing but this should not be neglected. Research on planning with and for ICT, whether infrastructure or the industry in its diversity, warrants further attention.

Developing cities

Many cities in the developing world seek to yoke ICT to their sustainable development process. For example Vietnam seeks to develop an international-standard software development industry despite its low connectivity ranking. Given the understandable priority of meeting immediate humanitarian needs, development assistance programs have not given ICT sufficient priority, including the development policies of Australia. Some countries or cities are seeking from their own resources and foreign investment to leapfrog over the expensive media and methods of developed countries, through the use of mobile telephony, the wide distribution of low-cost on-line education and training, the deployment of learning resource centres near disadvantaged prospective learners and other means (see for example Nkwae

2002 on Africa). Some developing countries, and certainly groups within them, seek to engage positively with globalisation, for example through 'transnational civil participation [through virtual civil society] for a differentiated cosmopolitanism in a process of globalisation from below' (Gomez 2003). The recent world information summit on ICT and development offers visionary glimpses for developing cities but the strategies will need further development (WSIS 2003).

We... declare our common desire and commitment to build a people-centred, inclusive and development-oriented Information Society, where everyone can create, access, utilize and share information and knowledge, enabling individuals, communities and peoples to achieve their full potential in promoting their sustainable development and improving their quality of life...

We recognize that education, knowledge, information and communication are at the core of human progress, endeavour and well being. Further, Information and Communication Technologies (ICTs) have an immense impact on virtually all aspects of our lives. The rapid progress of these technologies opens completely new opportunities to attain higher levels of development. The capacity of these technologies to reduce many traditional obstacles, especially those of time and distance, for the first time in history makes it possible to use the potential of these technologies for the benefit of millions of people in all corners of the world...

We are aware that ICTs should be regarded as tools and not as an end in themselves. Under favourable conditions, these technologies can be a powerful instrument, increasing productivity, generating economic growth, job creation and employability and improving the quality of life of all. They can also promote dialogue among people, nations and civilizations.

We are also fully aware that the benefits of the information technology revolution are today unevenly distributed between the developed and developing countries and within societies. We are fully committed to turning this digital divide into a digital

opportunity for all, particularly for those who risk being left behind and being further marginalized...

Connectivity is a central enabling agent in building the Information Society. Universal, ubiquitous, equitable and affordable access to ICT infrastructure and services, constitutes one of the challenges of the Information Society and should be an objective of all stakeholders involved in building it...

A well-developed information and communication network infrastructure and applications, adapted to regional, national and local conditions, easily-accessible and affordable, and making greater use of broadband and other innovative technologies where possible, can accelerate the social and economic progress of countries, and the well-being of all individuals, communities and peoples...

Engaging with ICT opportunities in developing cities could be a further direction for collaborative Australian urban research along with greater involvement by Australian government and civil society aid agencies.

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