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Technical Considerations Regarding the "Size" of PCS Licenses

Charles L. Jackson

November 9, 1992

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Technical Considerations Regarding the "Size" of PCS Licenses

Charles L. Jackson

1 Qualifications

I am a communications engineer with substantial experience in telecommunications and policy issues. My biography is attached.

2 Introduction and Overview

Before granting any PCS licenses, the Federal Communications Commission (FCC) must first decide how it will subdivide the PCS spectrum into individual licenses. The two principal subdivisions are (1) bandwidth -- how many megahertz wide each local license will be -- and (2) area -- how large the geographic area covered by a single license will be. These are fundamentally economic and social decisions. However, technological considerations can inform these decisions. The discussion that follows considers first technological constraints on the efficient bandwidth of PCS licenses and then shifts to focus on the efficient geographical area of licenses. The analysis below reaches three primary conclusions:

- Technological considerations, such as control of interference from adjacent bands or minimum efficient scale, do not provide significant guidance of the choice between three, four, or five PCS sub-bands in the 90 MHz the FCC has proposed,

- Under some reasonable assumptions about future cost structures, providing additional spectrum for PCS lowers the cost of providing PCS services, and

- Technological considerations strongly favor wide geographic license areas for PCS services -- with a nationwide license being the optimum.

3 Bandwidth of PCS Licenses

3.1 Introduction

The FCC faces a difficult decision when allocating spectrum for PCS-like services. It is generally agreed that any exclusive licenses should be "cellular-like" covering multiple

channels and a reasonably large geographic area. The issue for the FCC is determining the bandwidth to allot to individual PCS operators.

The FCC has proposed allotting three licenses, each with 30 MHz, in every geographic region. However, other plans -- such as two 45 MHz licenses or five 18 MHz licenses are possible.

This report considers technical issues surrounding the choice of the bandwidth of individual PCS licenses and concludes that the technologist can offer little guidance here, since there appears to be little loss of technical efficiency in moving from the FCC's proposed three operators to as many as six or seven operators. Similarly, there is little efficiency gain in moving to one or two suppliers. Other, non-technical criteria, should be controlling on this issue.

3.2 Technological Issues

I see four important technical questions that affect the question of the efficient bandwidth for PCS licenses. They are

- To what extent do harmful externalities from adjacent bands reduce the utility or value of a band?
- Are there issues of minimum efficient scale that dictate a minimum bandwidth?
- How does the availability of additional spectrum affect the economics of a PCS service provider? and
- What efficiency tradeoffs are implied by trunking considerations?

3.2.1 Interference between bands

Transmissions outside a band, but near the edge of the band, can impair the performance of receivers tuned to transmissions near the band edge. These impairments arise from two sources. The out-of-band transmitters actually emit some energy into the adjacent band. Additionally, most receivers will be impaired by strong transmissions on frequencies near the frequency to which they are tuned. Such concerns normally extend for a few channel

widths from the desired channel. In television, this effect causes the FCC to skip channels in assigning TV channels to a city -- thus Washington, D.C. has TV channels 7 and 9, but not 8.[1] The systems operating in adjacent PCS spectrum will probably be low-power, relatively narrowband systems. Harmful externalities and the need for significant interband coordination of operations should be restricted to regions less than 100 kHz wide near the edge of the band.[2] Thus, if a PCS band is, say, 10 MHz wide, such externalities will directly affect only about two percent of the band. One can see, without substantial further analysis, that the issues posed by such adjacent channel operation are not significant for bands wider than a few megahertz.

3.2.2 Minimum technological scale

All but one of the proposed PCS systems I am aware of can operate in 10 MHz of spectrum or less. That one exception is the proposed wideband spread spectrum system that requires a 48 MHz channel bandwidth. The other major systems under consideration (e.g., narrowband CDMA, DCS-1800, the Bellcore Framework Advisory, digital cellular systems translated to 1800 MHz) can all operate in regions smaller than ten megahertz.[3] Even if the analog AMPS technology were translated to 1800 MHz, it could technically operate in bands as small as 18 MHz -- which would result if the proposed 90 MHz were divided among five operators.

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[1] Channels 4 and 5, although designated by consecutive numbers, do not denote physically adjacent channels in U.S. television.

[2] The FCC is aware of this well known problem and has taken steps to reduce the effects in the proposed PCS rules. For example, all PCS base stations are located together in the range 1850-1895 MHz. This prevents a mobile unit from transmitting on a frequency close to the frequency to which another mobile unit is tuned. Similarly, the FCC currently regulates the out-of-band emissions from cellular base and mobile stations and has proposed similar limits for the 1800 MHz PCS operations (NPRM Appendix A (proposed rules), Section 99.413 Emission Limits for the 1850 to 1990 MHz bands).

[3] For example, QUALCOMM's literature claims that their CDMA system can operate in a minimum of 1.8 MHz of spectrum. The DCS-1800 standard uses 200 kHz channels. If we assume a seven-cell reuse pattern and three 120 degree sectors inside these cells for a 21 channel-set configuration, this technology requires 4.2 MHz.

3.2.3 PCS bandwidth and the cost structure of PCS firms

As a general rule, giving an enterprise more resources -- money, buildings, people -- increases the enterprise's capability to provide service. This is exactly the case with radio spectrum -- giving a PCS service operator access to more spectrum gives the PCS service provider more options without imposing any more costs. But, the exact effects of additional spectrum on the economics of PCS service providers are hard to identify at this time. Under one, admittedly extreme, set of assumptions giving a PCS service provider twice as much spectrum will cut capital costs of providing PCS service in half.

The general considerations are straightforward. With more spectrum and any technology, a PCS service provider can serve more users from a single cell site. If the costs of a PCS system vary with the number of cell sites rather than merely with the number of radio channels installed in an urban area, then the PCS service provider's capital costs decline as more spectrum is made available. Conversely, if radio channels are the dominant cost and cell sites impose little additional cost on the PCS system, then additional spectrum lowers capital costs relatively little.

These general considerations are shown graphically below for several varying technological assumptions.

In the first case, cell-related costs dominate radio system costs.
Consider a technology with the following characteristics:

- 10 KHz spectrum required per active conversation,
- 5 mile maximum cell radius,
- 0.3 mile minimum cell radius,
- a 7-cell reuse pattern,
- 0.1 busy-hour Erlangs[4] per user, and
- Capital required for cell sites but <u>no</u> additional capital for radio channels.

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[4] A Erlang is a measure of traffic intensity. One person talking all the time on the telephone generates one Erlang of traffic.

These characteristics describe a service that is technically much like second-generation cellular. The key economic assumption is that the radio gear is relatively inexpensive compared to the total of the cell site rent, any tower, antenna and waveguide costs, and the fixed costs of cell site interconnection. For any given amount of spectrum one can consider the relative capital costs of this technology for a range of user densities. At low densities, there are more radio channels available at a cell site than there is customer demand -- even for a maximum-size cell. Consequently, the per-user costs decline sharply with increasing density -- until the cell is fully loaded. At this point, cell splitting begins and the per user cost levels off. Cell splitting continues with increases in density until the minimum size cell is reached -- at which point capacity can be increased no further. Figure 1 below illustrates this change in per subscriber cost with increasing subscriber density for three different spectrum allocations. The per carrier allocations chosen are 18 MHz, 22.5 MHz, and 30 MHz -- corresponding to a five-fold, four-fold, and three-fold subdivision of the 90 MHz the Commission has proposed for such PCS services.

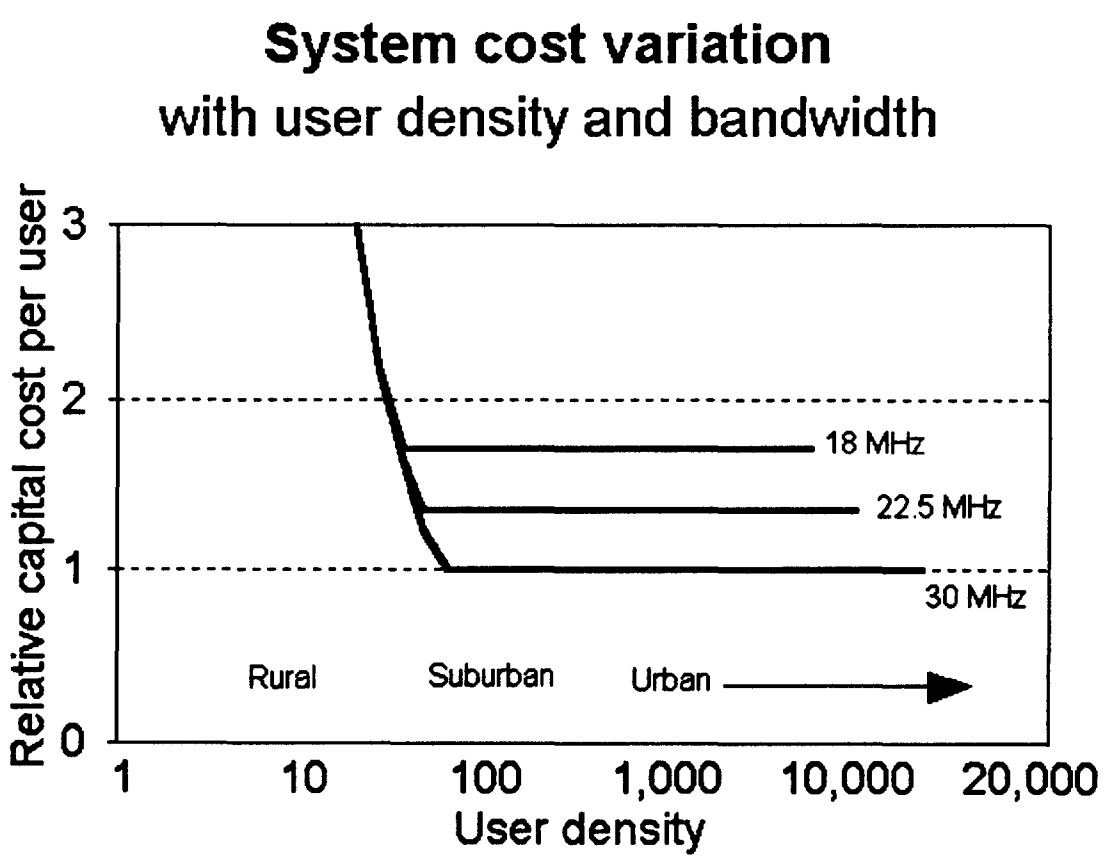

Figure 1

Under the assumptions of this model, all PCS operators have equal capital costs at low user density. As user densities increase per subscriber costs decline. As user densities approach suburban levels cell splitting begins and the decline in cost per subscriber levels off. The relative costs for a system with only 18 MHz are almost twice those of a system with 30 MHz. (The model used to calculate costs did incorporate queuing effects as well as other average loading effects.) Notice also that the 18 MHz allocation runs out of steam -- is unable to accommodate additional users -- before the larger allocations do.

Of course, the total capacity of five 18 MHz PCS systems is roughly the same as the total capacity of three 30 MHz systems.

Considering the case where cell site costs totally overwhelm radio equipment costs is admittedly extreme. While it may be a reasonable approximation to the ultimate structure of the industry, it is not necessarily a good approximation to the cost structure in the next few years. Figure 2 below displays the same graph except that each radio channel is assumed to cost one two-hundredth as much (0.5 percent) as a cell site without radios. That is, a cell site with 600 radios would cost twice as much as a cell site with 200 radios.

Including these radio-channel related costs reduced the cost difference between the various allocations, but, as shown in the graph, the differences remain significant.

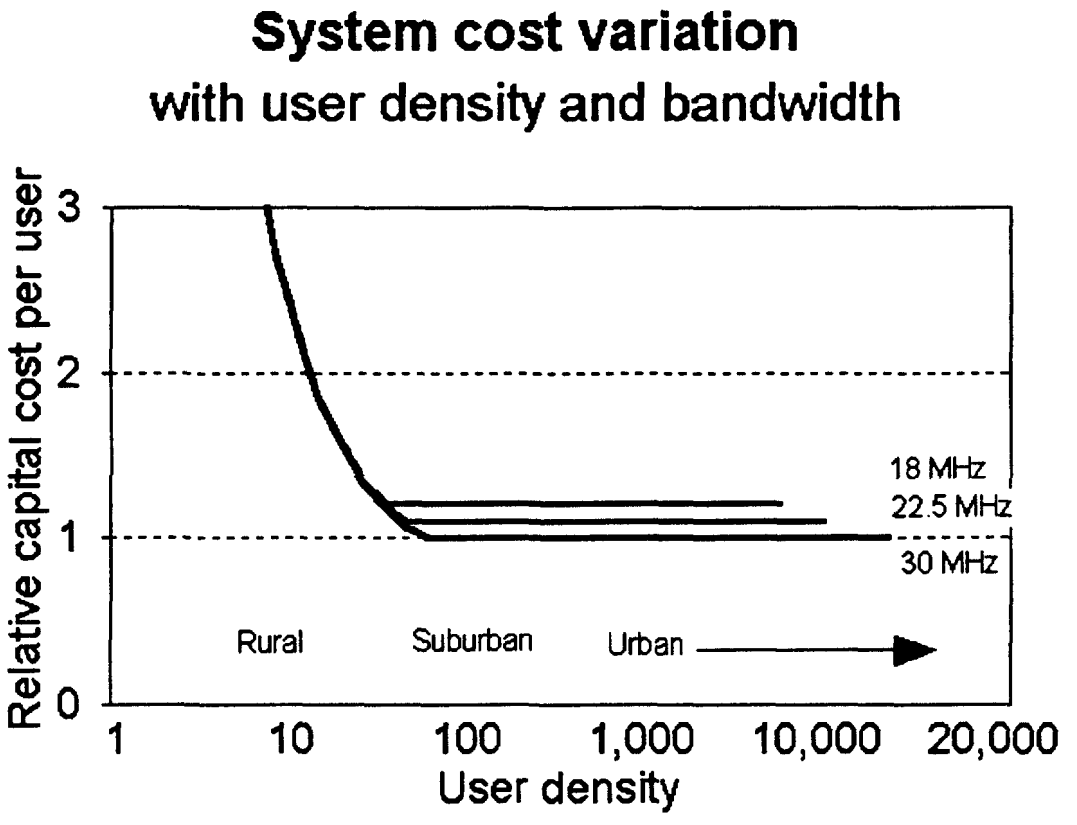

Figure 2

There is a third way to look at the results of this model. Using the same cost and traffic assumptions as in Figure 2, Figure 3 below shows how capital costs per user vary with increases in density as the assumed maximum cell radius varies from three miles to five miles to ten miles. Notice that the larger cell radius makes a substantial difference in low density areas. Such areas of low subscriber density will occur in rural areas and in urban areas during the start-up phase of PCS operations. Giving the PCS operator sufficient flexibility to employ technologies supporting such large cells may significantly improve rural service and the economics of the PCS firm during the start-up phase.

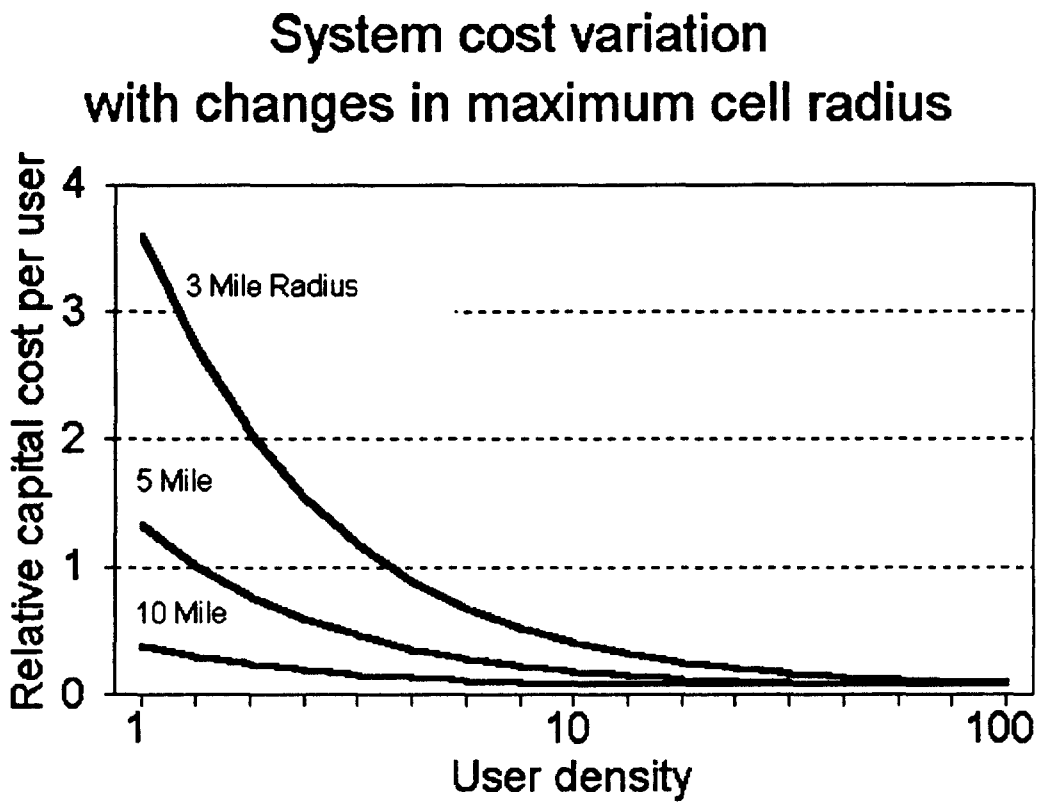

Figure 3

Two conclusions can be drawn from this analysis. First, it is highly likely that providing PCS operators with additional spectrum will allow them to offer services at lower cost. Second, adopting technical rules that permit PCS operators to employ large diameter cells in rural areas and during the start-up phase of their urban operations appears likely to reduce the costs of rural service and the capital commitment required during the initial phases of urban operations.

3.2.4 Trunking efficiency

One traditional argument against dividing spectrum into too many bands for cellular-like services has been the loss of trunking efficiencies that this would cause. The FCC faced essentially this same problem of license bandwidth a little more than a decade ago when it had to decide how to divide up the cellular spectrum.

In 1974, the FCC originally decided to allocate 40 MHz to a single cellular provider. In 1980, it reconsidered this decision and proposed that two firms operate parallel cellular systems each on 20 MHz of spectrum. Balancing economies of scale against the benefits of competition, the Commission suggested that two firms in each market struck the proper balance but asked questions about alternative divisions. In 1982, the FCC concluded that two 20 MHz systems best served the public interest, convenience, and necessity.

Consider the tradeoff facing the FCC back in 1982. The cellular technology available in 1982 used 30 kHz channels operating in a full-duplex fashion and FM modulation. Thus, each active conversation occupied 60 kHz of spectrum. The entire 40 MHz of spectrum could carry only 667 active conversations.[5] "Cellular" systems gain that name from the cellular reuse pattern. A frequency is used to support communications in a single cell and is not used in nearby cells. One commonly studied pattern is the seven-cell reuse pattern whereby a region is divided into a network of hexagonal cells. A cellular frequency used in one cell is not used in any of the neighboring cells. This leads to a repeating pattern of seven cells and permits a frequency to be used in one out of seven cells. Thus, the original pool of channels must be divided into seven separate frequency pools. Doing this with the 667 channels available for the entire 40 MHz yields 96 channels[6] in each cell.

People don't schedule their telephone calls; they call and are called at unpredictable moments. Such fluctuations in telephone traffic prompted the development of a mathematical technique called queuing theory which can predict how many conversations can be served, on average, from a cell site having 96 channels and still insure that there is a good chance that other subscribers will find a channel available to place a call. If the 96 channels are divided into two groups of 48 channels (as would happen if the traffic were divided between two firms) and with each user able to access only one of the two groups of

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[5] In fact, the number of conversations that could be carried is somewhat less because some of the cellular channels are control channels used to set-up calls. We will ignore the complexities posed by these control channels. They would not change our results significantly.

[6] Actually, it yields 95.3 channels. But, if we "round up," we obtain 96, a number which is divisible by two, three and four which simplifies the following exposition. This adjustment reduces the negative effects of splitting the frequencies among multiple service providers.

channels, and service quality is kept the same, then the total traffic that can be carried declines. There is an efficiency loss when one divides the single group of channels into two separate groups. The efficiency loss becomes greater as the channels are divided into smaller and smaller pools.

The table below illustrates this tradeoff as it faced the FCC in 1982. The two system alternative chosen by the FCC has a nominal efficiency of 100 percent. All other entries are referenced to this standard. The measure of efficiency is the number of conversations that can be carried by the entire 40 MHz without any frequency reuse, but assuming a cellular design with a seven-cell reuse pattern.[7]

TECHNICAL EFFICIENCY[8] OF CELLULAR SYSTEMS OPERATING IN 40 MHz SPECTRUM (1972 Technology)

Number of Systems	1	2	3	4	5
Technical efficiency in percent (Compared to the two-system case)	111.2	100	91.5	76.2	70.65

[7] Use of a larger number of frequency sets, say 21, as would be required in a seven-cell pattern with three sectors in each cell, would make the efficiency loss demonstrated here even more extreme. We judge that the basic seven-cell pattern offers a reasonable view of the fundamental tradeoff facing the FCC then and now since omni-cells are still widely used in cellular radio.

[8] The specific assumptions are 672 channels (7*96), seven-cell reuse, and the Erlang-B (M/M/N/0 or blocked calls lost) queuing model with one percent blocking.

As the table shows, the FCC faced a difficult decision. Adding competitors imposed significant efficiency costs.[9] While the FCC has faced criticism for choosing only two firms, one must recognize that significant costs were associated with the decision to have two suppliers rather than a single supplier. Going to a three-firm industry structure would have been even more problematic.

Comparing today's many possible technical standards in a similar fashion is difficult. However, one can consider simple cases which provide reasonable bounding calculations. Digital cellular systems using TDMA effectively offer a three-fold capacity increase over analog-FM cellular. Improved voice processing can be counted to increase this advantage to six-fold. Use of speech interpolation techniques would increase capacity by a separate factor of two and a half, for a total increase of 15 over analog cellular. QUALCOMM claims that their CDMA system offers 10 to 20 times the capacity of existing analog.[10]

Assume, conservatively, that PCS systems will be only ten times as bandwidth efficient as the original AMPS standard, and that they will use a narrowband technology similar to IS-54 -- the current CTIA digital cellular standard. Under such a system, each active conversation would occupy about 0.006 MHz of spectrum (down a factor of ten from AMPS 0.06 MHz per conversation). The entire 90 MHz could thus support 90/0.006 = 15,000 active conversations without reuse. If one divides this spectrum into seven cells, then there are about 2,160 channels per cell.[11]

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[9] Other authors offer similar estimates for the loss of technical efficiency in going from one to two (analog) cellular carriers. See Henry Ergas, *Liberalisation of Cellular Mobile Telephone Service*, Monash University, Melbourne, October 1989, at 75. See also Jürgen Müller and Saadet Toker, *Mobile Communications In Europe*, September 1992. Muller and Toker state, "The scarce resource of the radio spectrum is reduced by between about 5% and 15% when two suppliers are licensed . . ."

[10] QUALCOMM, Inc., News Release, June 4, 1992, p. 1.

[11] Actually, 15,000 divided by 7 is 2,142. But, adding an additional 18 channels simplifies the calculations because 2,160 is divisible by many factors. This corresponds to assuming that the new technology actually offers a 10.08 decrease in occupied bandwidth when compared to cellular, rather than the factor of ten discussed earlier in the text.

What are the efficiency losses associated with dividing this capacity among multiple service providers? The table below shows the answer.

EXAMINING THE COMPETITION/TECHNICAL EFFICIENCY TRADEOFF IN PCS										
Number of Service Providers	1	2	3	4	5	6	7[12]	8	9	10
Channels per cell	2,160	1,080	720	540	432	360	308	270	240	216
Individual cell capacity (Erlangs) at one percent blocking	2,133	1,051	692	514	407	336	285	248	219	195
Combined single-cell capacity of all systems	2,133	2,102	2,077	2,055	2,034	2,016	1,998	1,982	1,967	1,952
Efficiency relative to the FCC's proposed three system standard (percent)	102.7	101.2	100	98.94	97.96	97.07	96.23	95.46	94.72	94.01

[12] Since 7 does not divide into 2,160 evenly, the calculations have been made as if the channels are divided among 7.013 systems.

The graph below compares the tradeoff between relative efficiency and number of competitors facing the Commission today with the tradeoff it faced when adopting the rules for cellular.

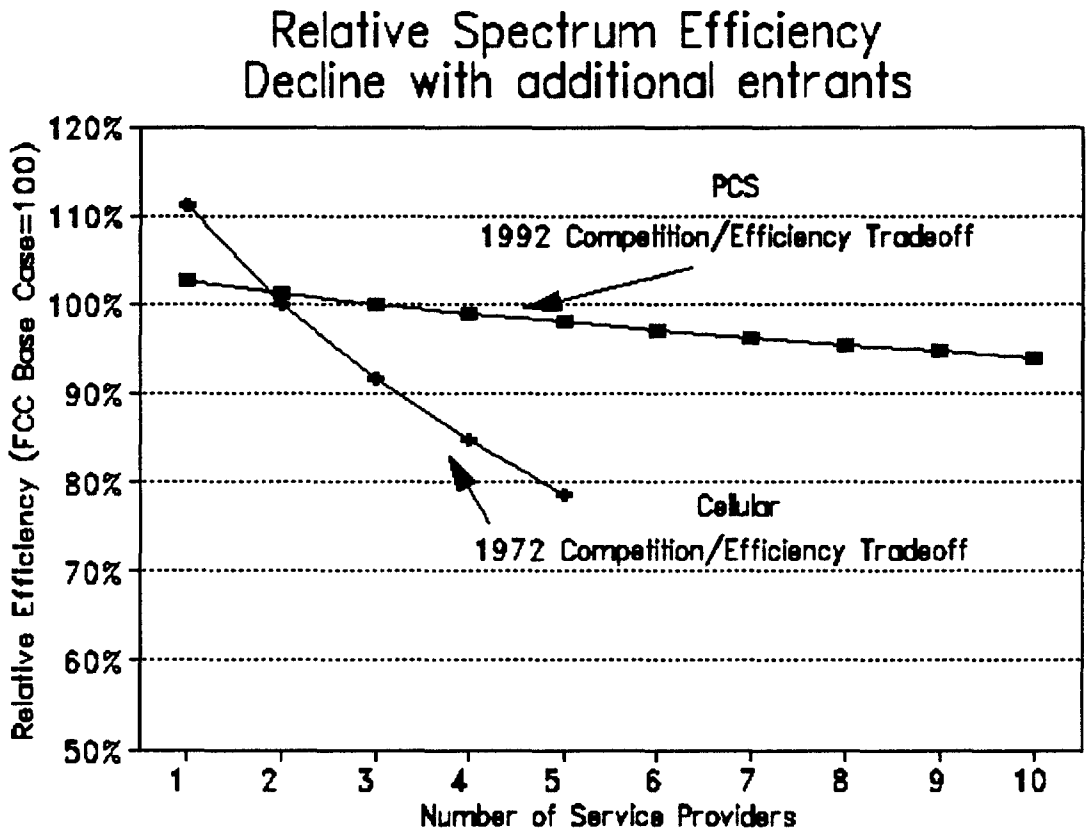

Figure 4 Relative Spectrum Efficiency Decline with Additional Entrants in PCS and Cellular

3.3 Conclusions on PCS Bandwidth

The minimum scale of PCS systems appears to lie in the five to ten MHz range -- significantly below the bandwidths the Commission has proposed in the Notice of Proposed Rulemaking (NPRM).

Queuing efficiencies are maximized and efficiency losses due to boundary effects are minimized if the entire 90 MHz of PCS spectrum is devoted to a single system. Because of these twin considerations, technical efficiency declines as spectrum is divided among more

and more service providers. However, the losses in efficiency from these effects are relatively modest when the number of systems lies in the range of three to five suggested by the Commission in the NPRM.

Under some reasonable technical and market assumptions, increasing the bandwidth available to an individual PCS licensee lowers the capital costs per subscriber by a corresponding amount. This factor argues for the allocation of more spectrum to the PCS service.

Given that technological measures of efficiency do not vary significantly over the bandwidths of interest, non-technical criteria -- criteria founded in economics or in social considerations -- should be controlling on the decision of the number of PCS service providers.

4 Geographic Area of PCS Licenses

4.1 Introduction and Overview

The geographical area covered by PCS licenses affects the ultimate efficiency of PCS services. This section considers two effects of geographic area, the effect on the standards selection process and the needs for coordination between separate PCS license areas -- and shows that in each case, larger geographic license areas serve efficiency. In contrast, I have not identified any technological effects whereby efficiency is enhanced through the choice of smaller geographic regions.

4.1.1 Standards Selection

Nationwide PCS licenses will simplify and speed the PCS standards selection process. The discussion below first examines the experience in cellular and then looks at the situation today and considers the likely development of PCS standards under a variety of scenarios including

- FCC selection of a standard,
- Market selection of a standard with many hundreds of small licenses, and
- Market selection of a standard in a market that includes nationwide licensees.

4.1.2 Economic Benefits of Standards Choice

Had the FCC not chosen a standard for cellular, the industry would have quickly settled on one because there existed only the AMPS standard at the time.

However, had the FCC not chosen a standard and there had existed three equally good candidates, the result would have been less certain. Perhaps the industry would have agreed upon a single standard, but this would have required the agreement of dozens of firms just to cover the major markets. Another outcome might have been that all firms would have held back on investment, waiting to see which standard carried the day. Conceivably, different systems could have selected different standards.[13] If different standards had been selected, roaming would have been greatly restricted or much more expensive. Economies of scale in production would have been sacrificed -- raising the cost of both network equipment and terminal equipment. Additionally, the smaller scale of the separate equipment markets might not have attracted as many entrants. With fewer entrants, these markets would have been less competitive, with the attendant consequences. Furthermore, cellular system operators and manufacturers could be expected to hold back investment until a preferred standard had emerged in the market.

In today's environment, early selection of a common PCS standard serves several goals including

- Automatically providing most of the infrastructure needed to support nationwide roaming,

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[13] Which, of course, has happened on a world-wide basis with the three principal standards being AMPS, TACS, and NMT-450. Because cellular systems in the U.K. use TACS, but systems in North America use AMPS, a British traveller cannot use his or her portable unit in New York or Toronto.

- Permitting achievement of economies of scale in the production of network and terminal equipment, and
- Promoting rapid investment by service providers and manufacturers alike.

4.1.3 FCC's Position on Standard Selection

In 1982, the FCC adopted its rules on cellular and imposed a standard on the industry. Later, in 1988, the FCC relaxed this standard, giving cellular licensees technical flexibility.[14] Essentially, cellular licensees can do whatever they want with their spectrum, provided

- They generate no more interference into neighboring cellular systems than they would if they used the original standard, and
- Their mobile service remains primary and they continue to support a nationwide roaming service.

A cellular company can use its spectrum today to provide data services or second-generation digital cellular services, or to experiment with wireless PBX systems. The cellular flexibility option appears to have worked well.[15]

In the PCS NPRM, the FCC proposed similar technical flexibility for PCS from the outset. Paragraphs 105-130 of the NPRM address standardization. The Commission states "... we wish to provide PCS operators with as much flexibility as possible in designing their systems" (NPRM at paragraph 120). The PCS standards proposed by the Commission limit interference from PCS systems into existing microwave systems and set rules for the spillover from one PCS license region into another. The proposed standards do <u>not</u> involve issues such as channelization, modulation, voice coding, control procedures, or a host of other topics that must be addressed in any equipment standardization process. The proposed rules control harmful externalities, not the details of the choice of technologies.

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[14] See *Report and Order*, Gen. Docket No. 87.390, 3 FCC Rcd 7033 (1988).

[15] Such benefits have been shown in the development of ancillary data services and the intense competition over a second-generation cellular standard.

4.1.4 Possible PCS Standards

The table below presents summary information on several possible PCS standards.

POSSIBLE PCS STANDARDS		
System	Technical Characteristics	Comments
Narrowband CDMA (QUALCOMM)	RF bandwidth of about one MHz. Separate frequencies for send and receive.	QUALCOMM has demo system of this technology. Very complex. Voice coding and signal processing reduce battery life.
Wideband CDMA (SCS)	RF bandwidth of about 48 MHz	See Schilling et al., "Broadband CDMA for Personal Communications Systems," *IEEE Communications Magazine*, November 1991, p. 86.
Narrowband CDMA/TDD	CDMA/TDD	See Cylink Reply Comments in Docket 90-314 (January 15, 1991)
IS-54 Translated in Frequency to 1800 MHz	TDMA system using 30 kHz channels.	Probably not optimum technology, but could be deployed quickly. Would permit construction of dual band portables (PCS and digital cellular) at reasonable cost.
DCS-1800	GSM translated to 1800 MHz	Standard for British PCN. Could be deployed quickly. Substantial commonality with GSM standard which will be widely used in Europe. May facilitate global roaming. Complex system which may pose battery life problems in portables for some years to come.
Bellcore Framework Advisory	FDM/TDMA	Low power. Simple voice encoding. May support low-cost terminals with good battery life immediately.
DECT	FDM/TDMA	Optimized for cordless telephones from PBXs. Should give reasonable battery life today.
CT-2 translated to 1800	100 kHz channels using TDD	Original British digital cordless phone technology. Supports public telepoints. Flopped in U.K. first time around but seems to be succeeding in Hong Kong and Singapore.[16] Relatively simple modulation and voice coding should control costs and extend battery life. Not designed to support large number of channels, would require redesign.
N-AMPS translated to 1800 MHz	Analog using 10 kHz channels.	Probably not a serious contender since this is an analog solution. Should have moderate spectrum efficiency, reasonable quality and low-cost. Might be a good technology, but with a limited lifetime.

[16] See John Williamson, "Dragons are still hungry," *Financial Times*, September 8, 1992, Section III, VI.

The table has nine entries. Even if one throws out the analog modulation alternative, that still leaves eight possibilities. Some of these alternatives are essentially paper systems (IS-54 translated to 1800 MHz), some of these alternatives exist as demonstration hardware (QUALCOMM's CDMA system, Bellcore's Framework Advisory), and some of these alternatives are commercially available today (DCS-1800).[17]

The alternatives vary in their performance along several dimensions including

- Range,
- Capacity,
- Battery life (today),
- Battery life (future),
- Weight,
- Commonality with future cellular portables,
- Voice quality,
- Ability to interconnect with facsimile machine and PCs, and
- Cost.

Unfortunately, the nature of these variations is only imperfectly known. For example, we don't know which digital cellular standard will become predominant in the U.S.; hence, we cannot know which PCS standard will have the greatest commonality with cellular practice. Similarly, technological improvements will reduce the battery drain associated with digital speech compression -- but no one knows how quickly this will occur. In fact, there is no commonly agreed upon view of how important battery life is to consumers.

4.1.5 Standards Selection Criteria

The key attributes for choosing a standard appear to be

- Cost,
- Weight,

[17] The two PCN operators in the U.K. are committed to using this technology.

- Speech quality, and
- Battery life.

Additionally, from a public policy vantage point, one should consider spectrum efficiency and ultimate system capacity.

No one knows today how to trade off these attributes. To pick a simple example, I think no one can specify the tradeoff between speech quality and battery life. Specifying the tradeoff between speech quality and spectrum efficiency would be much harder.

4.1.6 Ranking Possible Standards by Selection Criteria

Existing and potential technologies differ vastly on these criteria. Battery life for the Bellcore Framework Advisory, DECT, and CT-2 should be significantly better than for any of the systems that use vocoders for speech compressions (QUALCOMM's CDMA, IS-54, DCS-1800). Speech quality should also be better for nonvocoder systems in many situations. However, the nonvocoder systems do not appear to be as spectrally efficient or to support communications over longer ranges. Spectrum efficiency and the ability to support large diameter cells during the growth phase of the firm may be keys to the economic success of the PCS service provider.

Besides such identifiable differences, there are important areas where data are either completely lacking or can only be obtained today from testing programs that were conducted by the system proponents. Furthermore, no common protocol has been used in such testing, and the results are hard to compare. In many important areas, the necessary data are lacking.

4.1.7 Feasibility of FCC Selection

A testing program capable of producing information that allows the FCC to make a standards decision that would withstand appeal is a daunting prospect. The best example of a similar process that I know of is the FCC's Advanced Television Advisory Committee

process.[18] The Advisory Committee on Advanced Television Systems (ACATS) process has taken five years of effort so far and is expected to result in an Advisory Committee recommendation of a single system by the end of February 1993. This winning system will then be subjected to further over-the-air testing. The ATV test process has had expenses of about $15 million and has been funded by contributions, not FCC funds. The field has narrowed down to five systems -- four digital and one analog.

The case of AM stereo shows the difficulties the FCC can face when making standards decisions.[19] In September 1978, the FCC issued a NPRM on AM Stereo. In the mid-1980's, the FCC's Broadcast Bureau recommended selection of the Magnavox system. The FCC was deluged with complaints and chose to issue a Further Notice of Proposed Rulemaking in September 1980. In March 1982, three and a half years after beginning the process, the FCC officially threw up its hands and left the AM stereo standards decision to the marketplace. In 1992, Congress passed a statute requiring the FCC to pick a single standard by late 1993.[20]

On balance, it is my judgment that any PCS selection process that could meet the FCC's political and legal constraints would take at least as long as the ATV selection process is currently expected to take.[21] If, however, agreement on the desired attributes were difficult -- for example, if one significant faction felt that the best design would be one that combined acceptable sound with the longest battery life while another faction felt that the best design was one that combined acceptable sound and battery life with the greatest

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[18] Note that the FCC rejected the concept of an advisory committee for PCS. PCS NPRM at paragraph 106.

[19] For a fuller account of the AM stereo standards development, see Besen and Johnson, *Compatibility Standards, Competition, and Innovation in the Broadcasting Industry*, The Rand Corporation, R-3453-NSF, November 1986, in particular Chapter IV.

[20] See Telecommunications Authorization Act of 1992, Section 214.

[21] If a standard is selected in late June 1993, then the Advisory Committee process will have taken 67 months.