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Legal, Economic, and Energy Considerations in the Use of Underground Space

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"Demand Forecasting, Use of Subsurface Space,
Legal Requirements, and Standards,"
of the U.S. National Committee on Tunneling Technology,
National Research Council
and held in conjunction with
the Engineering Foundation Conference,
"Need for National Policy for the Use of Underground Space,"
held June 24–29, 1973, in South Berwick, Maine

NATIONAL ACADEMY OF SCIENCES
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STANDING SUBCOMMITTEE NO. 3*

Demand Forecasting, Use of Subsurface Space, Legal Requirements, and Standards

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Preface

The U.S. National Committee on Tunneling Technology was established in 1972 to stimulate advancement in tunneling technology and in the effective use of the subsurface. Improvements in this technology and increased access to the underground result in benefits to society from the availability of additional mineral resources and in opportunities to use underground space for many purposes. Increased access to the underground, however, gives rise to problems in legal and other social systems that require evaluation and solution if society is to reap maximum benefits from these improved technologies.

Recognizing the need for examination of current and potential problems in allocating ownership of underground resources and in predicting the rate of development of these resources, Standing Subcommittee No. 3—Demand Forecasting, Use of Subsurface Space, Legal Requirements, and Standards—of the U.S. National Committee on Tunneling Technology conducted a workshop at Berwick, Maine, from June 24–29, 1973, in cooperation with the Engineering Foundation. The purpose of the workshop was to examine and discuss these problems and to contribute to their solution. The papers were drafted for presentation at the Engineering Foundation Conference and for discussion by the conference participants. After they had been discussed in the highly interactive sessions, the papers were revised for publication in this report.

Acknowledgments

The workshop, as a project treating problems in legal systems created by advances in science and technology, was supported by the Law, Science, and Technology Program of the National Science Foundation. This is a part of the National Science Foundation program "Research Applied to National Needs" (RANN). RANN, established by the National Science Foundation, under congressional authority of Public Law 90-407, focuses scientific research on societal problems of national importance with the objective of contributing to their practical solution.

Arthur F. Konopka, program manager of the Social Systems and Human Resources Division, NSF/RANN, and manager of the Law, Science, and Technology Program, provided scientific and technical liaison between the U.S. National Committee on Tunneling Technology and the National Science Foundation throughout the workshop project. His substantial contribution to the success of the project is acknowledged.

Mrs. Muriel Duggan, editor for the Division of Earth Sciences, National Research Council, edited the text.

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Introduction

Increased use of underground space offers alternatives that are receiving serious attention in many areas, particularly in the solution of urban problems. Major transportation and water-treatment projects that utilize the underground are currently being planned, designed, and constructed. In some areas of the United States, such as Kansas City, underground space created as a by-product of limestone-quarrying operations is being used very profitably for commerce, industry, and storage. Other specialized activities, including deep-well disposal of industrial wastes, underground mining, and defense operations, also use underground space. These activities are usually not located in urban areas.

Some developing uses of underground space are entirely isolated, and there is no competition for the space to be utilized. For other applications, particularly those at shallow depths in urban areas, there are current or potential competing uses that should be considered in allocating the space for uses now making demands.

The National Academy of Sciences sponsored an *ad hoc* study group meeting on May 1 and 2, 1972, to consider developing competition for use of underground space and the feasibility of a more coherent national policy for governance of this space. The study group concluded ". . . that it is feasible, practical, and urgent to formulate more definitive and coherent national policies governing the competing uses of underground space and that related research in the natural, social, and applied sciences should be encouraged."[1]

Taking note of the NAS *ad hoc* study group recommendations, the Engineering Foundation scheduled a conference in June 1973 to discuss developing competing uses and need for development of national policy for the use of underground space. Cooperating with the Engineering Foundation, with the support of the National Science Foundation, the U.S. National Committee on Tunneling Technology organized a workshop in conjunction with the Engineering Foundation Conference and invited a number of specialists who have studied developing competition for space, both above and below the earth's surface, to prepare papers for presentation and discussion at appropriate sessions of the conference. This publication is a compilation of these sponsored papers.

Robert R. Wright, in his lead paper, "Development of Policy for Use of Airspace," considers the Model Airspace Act—and its development of policy pertaining to airspace above the surface of the earth—as a basis on which to develop, by analogy, a policy for the use of underground space. He sees grounds for applying to underground space many of the legal principles concerning airspace. More specifically, and as a result of his work on drafting the Model Airspace Act, he suggests that much of the research and work that has been invested in that Act should be applicable to underground problems; for example, he sees an interesting parallel between the problems of tunneling under surface rights-of-way with respect to utilizing underground space and the problems involved in using airspace above surface rights-of-way.

Robert W. Swenson discusses "A National Policy for Mineral Development on the Federal Public Domain" in the second paper. He emphasizes that for over 100 years Congress has failed to adopt a consistent national policy for the exploitation of fuel and nonfuel minerals on the public domain. Despite the shortages at present being experienced, and with the probability of a more severe shortage of vital minerals in the future, Congress has taken no significant action since the exhaustive report of the Public Land Law Review Commission in 1970. Swenson's paper makes no attempt to describe specific changes that are needed in mining law, because he thinks that it would be inappropriate to do so at this juncture.

Albert W. Stone, in his paper, "Strip-Mining Coal: Unsettled Legal

Problems," deals with one of the important unsettled legal problems relating to the vast formation of low-sulfur strippable coal situated in Wyoming, Montana, and the Dakotas. Usually, the coal resource is owned by a single party (e.g., the United States, a state, or a land-grant railroad), but the surface interest in the land has been home-steaded or otherwise acquired by one or more ranchers. This type of severed ownership of the two interests occurred before strip-mining was practiced in the West. The central question discussed in the paper is whether the owners of the underlying coal rights have the legal right to strip-mine the ranches or whether the coal-resource owner's rights are limited to mining methods that were common in the West when the surface rights were acquired by the ranchers.

The recognition of underground space as a natural resource whose scarcity is just now being realized provides a point of departure for A. Dan Tarlock's discussion of some of the "Legal Aspects of Use of the Underground." He argues that no persuasive case has yet been made for a comprehensive administrative allocation of the underground, and he therefore considers that the resource should be allocated by the free market, except in those cases where market failure would lead to an inefficient allocation. He surveys several examples of market failure, such as deep-well injection, as well as several situations in which the law should remove impediments to free-market allocation.

In "Planning the Underground Uses," Donald G. Hagman questions the fundamental assumption that excavation efficiencies should lead to increasing utilization and conflict in underground uses, except in the case of mass transit. He further questions the need for complex controls, because conflict concerning the uses of underground space, particularly at deep levels, is at present minimal compared with the conflict concerning surface uses. He urges adoption of an "anti-windfall-and-wipeouts" system to control externalities and, on a broader basis, suggests models for reforming land-use control that would be adaptable to the underground as well as to surface uses.

In "Economic Trends and Demand for the Development of Underground Space," Irving Hoch argues that the use of underground space will probably increase because of price declines, increased concern about the environment, and increases in urban density. There is some evidence suggesting price declines for underground space; although this evidence is somewhat speculative, the other factors are of considerable importance. Environmental concern is likely to lead to greatly expanded investment in underground rail transit. Increased urban density can be forecast because of measures aimed at enchancing environmental quality and because of the playing out of the impact of the automobile. With increased density, the use of underground space becomes more economical. It should be possible to incorporate these factors into quantitative forecasts, which will probably show pronounced increases in both short- and long-term demand for use of underground space.

In a paper that involves a consideration of the dynamic aspects of analyzing demand for construction in underground space, Richard T. Newcomb first describes several factors that could substantially influence the longer term demand for underground construction. He then emphasizes the importance of taking into account the major changes in demand that may be occasioned by these factors in any long-term forecasting of underground space requirements. Examples follow of the manner in which simple dynamic models can be used to test the sensitivities of demand in energy utilization and in urban applications. Professor Newcomb completes his discussion by emphasizing the implications of civil construction demands for the use of underground space.

Thomas P. Bligh and Richard Hamburger, in "Conservation of Energy by Use of Underground Space," report that preliminary investigation has shown that substantial amounts of energy can be conserved through greater use of underground space for storage, refrigeration, manufacture, and commerce and for semiunderground dwelling units. Improved insulation for above-ground buildings cannot conserve energy nearly as efficiently as underground building. Bligh and Hamburger discuss some of the policy issues bearing on the use of subsurface space, from which they then make recommendations.

REFERENCE

1. Report on the *Feasibility of a More Coherent National Policy for the Governance of Underground Space* (A report of the Study Group on the Uses of Underground Space). National Academy of Sciences, Washington, D.C., June 1972.

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Development of Policy for Use of Airspace

BACKGROUND

In his famous *Commentaries on the Laws of England,* Blackstone wrote:

> Land hath also, in its legal signification, an indefinite extent, upwards as well as downwards. *Cujus est solum, ejus est usque ad coelum,* is the maxim of the law; upwards, therefore no man may erect any building, or the like, to overhang another's land: and, downwards, whatever is in a direct line, between the surface of any land and the centre of the earth, belongs to the owner of the surface. . . . So that the word "land" includes not only the Face of the earth, but every thing under it, or over it. And therefore, if a man grants all his lands, he grants thereby all his mines of metal and other fossils, his woods, his waters, and his houses, as well as his fields and meadows.[1]

Blackstone's primary authority for this rule was *Coke on Littleton,* in which Coke had written that "the earth hath in law a great extent upwards, not only of water as hath beene said, but of ayre and of all things even up to heaven. . . ."[2] Coke stated also that a landowner owned down into the center of the earth beneath his land.[3]

I shall not explore underground land ownership, underground uses, or the urban underground environment, because those matters will be dealt with in succeeding papers. I shall, however, deal with the use of airspace. As defined in the Model Airspace Act, currently pending before the House of Delegates of the American Bar Association and already approved by the Section of Real Property, Probate and Trust Law of the ABA, airspace is "that space which extends from the surface of the earth upward and which is either occupied or utilized or is reasonably subject to being occupied or utilized or is otherwise necessary for the reasonable enjoyment and use of the land's surface. . . ."[4]

There has obviously been some substantial change in the legal attitude toward airspace since the time of Lord Coke, most of it caused by the rise of aviation. However, aviation was not the only significant influence on the modern law of airspace. In our larger cities, there has been at the same time an increasing use of airspace for permanent buildings, which has resulted largely from the economic situation involved. I shall explore this situation at length later.

Essentially, the background of legal rights in airspace may be found in two historical developments. The first goes back at least as far as Lord Coke and possibly into more ancient times, and the second relates to the "upper chamber" as it is described in the old English cases. In the "upper chamber" we may see a parallel in Anglo-American law to the development of the condominium in the civil law. With respect to airspace ownership, one English authority makes reference to the expression of the maxim quoted from Blackstone and Coke in even more ancient times. He refers to passages in the Old Testament and to an ancient Jewish rabbi who gave expression to essentially the same legal maxim.[5] Still another legal writer reports that a conveyance around the year 1280, in which an English Jew was the grantor, stated that the rights of the surface owner extended "from the depth of the earth to the height of the sky."[6] A Roman law scholar concluded in 1931 that a landowner in ancient Rome was expressly given "control of the air column above his property at low altitudes" and that this control could be extended to any height.[7] Another American aviation authority observed that "at least since Roman times, states have continually recognized, regulated, and protected rights in space held by the owner or occupant of lands on the surface below."[8]

Hugo Grotius, the great international lawyer, was cited as recognizing that a landowner had rights in airspace over his property and that the law pertaining to the land would be applied to the space.[9] Although scholars have disagreed on whether Justinian's

Digest allows for the separate ownership of airspace above the surface, it is obvious that Roman law recognized the control or ownership by the landowner of the space above his land.[10] Consequently, it is apparent that at least some basis for the maxim existed before the time of Lord Coke.

Nonetheless, for all practical purposes, the acceptance of the maxim pertaining to ownership of airspace and ownership of the soil beneath was largely due to Lord Coke. With regard to airspace, the authority cited by Lord Coke was *Bury* v. *Pope,*[11] a case decided during Coke's lifetime. As best we can discover, *Bury* v. *Pope* is the first case to enunciate the maxim. *Bury* v. *Pope* does make reference, however, to the existence of the maxim during the time of Edward I (1239–1307).[12] Lord Coke also cites certain passages in the yearbooks that are supposed to affirm the maxim,[13] although some leading English legal writers have argued that these references were erroneous.[14] Coke's citations are somewhat garbled in spots, although one case that Coke intended to cite suggests (as best I can translate some rather old Norman French) that the landowner owns the space (l'aire) that extends outward from the land surface.[15] There is no question that Coke made the maxim and the rule a part of English law because of his great influence on the development of the English common law. Numerous legal writers have commented on the tremendous influence that Coke had on the development of the English common law and on how his reputation prevailed not only during his lifetime but also for many years to come.[16] His maxim was followed not only by Blackstone but by Chancellor Kent[17] in the United States and passed easily into American law.

The English cases that applied the rules expressed by Coke were generally cases that involved overhanging limbs, cornices, arches, or other types of trespasses.[18] American cases were of the same kind and might cite Coke, Blackstone, or Kent, or perhaps all three.[19]

The other basis for airspace ownership that we have discussed relates to the "upper chamber" and the separate ownership of it in a structure or dwelling. According to a pioneer writer on air law, the Romans apparently recognized only full and absolute ownership of the airspace column and "permitted no ownership in a limited stratum" of space.[20] As we have stated, some more recent writers have disagreed on this point.[21] Be that as it may, the development of the Anglo-American law on this point is such that ownership of space is regarded in much the same manner as land-surface ownership. The result is that a landowner may sell, lease, or otherwise divide the rights in a parcel of space just as he would deal with an open field. A landmark New York case on this subject, *Butler* v. *Frontier Telephone Company,* pointed out that "space above land is real estate the same as the land itself,"[22] a view that was also manifested in the writings of legal scholars in the 1920s.[23]

The separate ownership of space above the land surface has definable roots that extend back into Coke's time and probably before. Coke wrote that "a man may have an inheritance in an upper chamber, though the low buildings and soile be in another, and seeing its an inheritance corporeall it shall passe by livery."[24] An authority of about the same period as Coke wrote that a "feoffment may be made of an upper chamber over another man's house beneath."[25] From these two sources, it may be concluded that the rule was well established by the seventeenth century. An example of separate ownership or legal rights in the space column was well known to lawyers of that period. Before the time of Lord Coke, the chambers in the Middle and Inner Temples of the Inns of Court had in effect been leased to the various members. When more space for these apartments was required during the reign of Elizabeth I, the fellows of the Inns built on certain sites and possessed a life estate in the chamber with the power to assign or devise the chamber to another fellow. The recipient of such an assignment or devise would also take a life estate with a similar power of disposition.[26] One English case, decided in 1637, actually involves separate ownership of one of these chambers in an ancillary way.

Thieves invaded a chamber in the Inner Temple and made off with 40 pounds, and the court commented that "a chamber of any Inns of Court or chancery broken open may be said to be *domus mansionalis* of him who is owner of the said chamber."[27] A case before that time, which did not involve a chamber in the Inns of Court, held that, since there could be a "franktenement" in an upper room, ejectment would lie in that particular situation.[28] In a King's Bench case, decided in 1787, an English judge commented that there were several freeholds owned by different persons over the same spot in London.[29]

No one knows when this rule began. Hilliard, an early nineteenth century American writer states that at one time it was held there could be no freehold estate in the chambers of a house, but "it seems to be now settled otherwise."[30] Whenever the rule began in England, it seems to have been well entrenched by Coke's time, and to the extent that there was any doubt about it, his previously quoted statement provided the definitive rule.[31] The concept passed into

American law in the natural course of events, and early cases in the various state jurisdictions make it abundantly clear that upper chambers are subject to separate ownership.[32] Massachusetts,[33] New Hampshire,[34] and Connecticut[35] so held, and states in the Midwest subsequently followed suit.[36]

A late nineteeth century Oregon case, *Hahn* v. *Baker Lodge,* stated that a person "did not acquire any right of ownership in the building or any part of it, but in the room or space inclosed by that part of the building which was described and identified," and the destruction of the building by fire left "nothing remaining upon which the defendant's conveyance could operate, and its rights at once terminated."[37] This case has been cited as a clear recognition of the power to divide space ownership vertically. A commentator stated, "As long as the structure remained, the defendant owned a bit of space called a room, which is not to be confused with the physical structure surrounding it. His ownership was of fee dignity, although subject to untimely dissolution. For the time being he was the owner of a portion of cubic space, shaped like a child's block, intangible and impermanent as a mirage."[38]

Cases in the early twentieth century continued this approach. An example was *Pearson* v. *Matheson*,[39] in which the South Carolina court held that Matheson had the right to divide his property by lateral lines and reserve for his own use the space that lay above the 14-foot line parallel to and above the soil. In a Washington case in 1923, the court held that the airspace 16 feet above an alley could be vacated, thereby permitting the adjoining property owners to take title to the airspace over the alley and erect a structure in the space.[40] The Tennessee court held in a 1931 case that an upper story of a building, which was owned separately from the lower story, was subject to partition.[41] It was stated that real property is subject to horizontal as well as vertical division, "each separate layer or stratum becoming a subject of inheritance, taxation, incumbrance, levy, or sale precisely like the surface."[42]

These and a number of other cases illustrate the process by which the upper-chamber rule was translated into American law and applied in this country. The upper-chamber cases, Lord Coke's statements about ownership of an upper chamber as well as airspace ownership generally, and the cases generally involving rights in airspace all combine to form the background for the modern utilization of airspace in urban areas.

Before turning to that aspect, we should briefly compare the upper-chamber concept with the modern condominium. From the foregoing discussion, it seems that what we call the condominium could have been developed out of the common-law background presented by the upper-chamber cases. Both involve essentially the same concept: the ownership of a parcel of space existing separately and apart from the land surface. By combining contract and property concepts—something that is not particularly unusual—the common law version of the condominium could have originated in the prevailing rules. That it came instead to the American mainland from the civil law heritage of Puerto Rico[43] indicates that few lawyers were apparently aware that the civil law condominium was simply a codified version of the common law upper-chamber concept. The condominium, it may be said, also involved common or joint ownership of certain parts of the total structure, but this too would have been possible under common law theories. The great advantage of the condominium statutes was that they combined in a single body of written law, readily available through the statutes, all the rules and principles needed to establish the ownership of space parcels combined with the common ownership of other parts of the building; they further provided a set of rules governing the problems that might stem from such ownership.

We are a common law country, except for Louisiana's civil law background, and yet we tend more and more to look to statutory law for guidance and to resort to common law where only the statutes are silent or where judges have interpreted the statutes so as to extend, limit, or modify them.

Airspace, we have seen, is a form of real property governed by essentially the same rules as land. It may be divided vertically and horizontally, and various estates and interests may be created in it. Ownership of it may be separated from the land surface and vested in separate owners.

With the rise of aviation, of course, Coke's old maxim on ownership of airspace was limited to reasonable size. As a result of *United States* v. *Causby*,[44] it may be said that a landowner's airspace is limited to that which he occupies or uses, as well as to that which is reasonably capable of being occupied or used, plus something of an additional protective or buffer zone to insulate the landowner from being adversely affected in the use of his property by airplane overflights. With regard to the latter, *Griggs* v. *Allegheny County*,[45] which the United States Supreme Court decided in 1962, made it clear that a taking could accrue from landings and takeoffs that were in federally defined navigable airspace. Thus, although aviation may have limited the height of airspace ownership as opposed to Lord Coke's "to the sky" or "to the heavens" maxim, the landowner still owns all the airspace that was ever of any value to him—and that is the space that is subject to his use or occupancy. This is obviously an elastic concept of ownership.

The economic utilization of airspace in heavily concentrated urban areas of the United States began almost contemporaneously with the rise of aviation. The first large-scale development in this country was triggered to some extent by environmental factors. Because of the problem caused by excessive smoke from locomotives in the Park Avenue area of New York City, the New York legislature passed an act directing the railroads to operate their trains by electricity in that area.[46] This factor, combined with the need for larger facilities to handle increased traffic, led to the plan to enlarge the Grand Central Depot in 1903. The new station was opened in 1913, with Grand Central Station and the Post Office constructed over the train yards. In the 8 or 10 years that followed, the Biltmore Hotel, the Commodore Hotel, a power plant, apartment buildings, the Yale Club, the Hotel Chatham, and streets were erected over the rail yards.[47] The entire Park Avenue area in that section of midtown Manhattan was developed in airspace, with supporting structures down to the actual surface of the earth.[48] Normally, the owners of a building would own the space in fee simple and would have an easement for the supporting structures. Of course, today there are numerous airspace structures in New York City, including the Pan Am Building, the Union Carbide Building, the Seagram's Building, the new Madison Square Garden, the Columbia Broadcasting System Building, the Washbridge Apartment development over the approaches to the George Washington Bridge, and many others.[49]

Developments began in Chicago in the late 1920s. The Chicago Daily News Building was constructed over the Milwaukee Railroad tracks.[50] By the end of the 1920s the famous Merchandise Mart was nearing completion. The building that was for many years the world's largest, with 4 million square feet of floor space, was an airspace structure that cost Marshall Field and Company $2.5 million dollars for the airspace alone.[51] Today, numerous other buildings in Chicago reside in airspace, including the Post Office, the Prudential Building, the Marina Towers, the Chicago Sun-Times plant, McCormick Inn, various apartment houses, Illinois Center, Gateway Center, and others.[52]

Despite any local statutes that now exist, the early airspace projects were predicated on the basis of the common law background that we discussed earlier. Illinois did pass a 1927 statute that purported to increase the rights of railroad companies to deal with this subject matter, but a commentator noted, with respect to an early airspace project there, that this statute was only an "additional and welcome guaranty" whose passage "did not affect the plan which already had been adopted by us."[53]

Today, at least hundreds of airspace buildings or other forms of airspace utilization exist in the United States. The movement began in the two largest cities, but rapidly spread to other heavily concentrated urban areas and from there to more moderate-sized cities. New York and Chicago, or cities almost as large, are now not the only places that exhibit this phenomenon. You will also find buildings in airspace or other forms of airspace utilization in El Paso; Birmingham; Little Rock; Hartford; Oklahoma City; Bethesda, Maryland; Fall River, Massachusetts; and in other cities.

THE DEVELOPMENT OF POLICY TO DEAL WITH THE PROBLEM OF AIRSPACE STRUCTURES

Although airspace structures can be created under the common law, a number of problems present themselves. For one thing, the early tendency to build over railroad tracks has been expanded in recent times to include construction over or around highways or freeways. The modern multilane highway often stretches through congested urban areas, occupying substantially valuable space in much the same way that the railroad did in the early twentieth century. As space becomes more scarce, the tendency is to want to make use of highway rights-of-way or highway space. By doing so, moreover, other problems are lessened—such as the displacement of and necessity for relocating low-income and lower middle-income families, as well as the problem of deterioration of the value of land adjoining a controlled-access freeway. Problems arise in the utilization of highway airspace owing to various state constitutional and statutory provisions and to some common law pertaining to highways. A further difficulty is that much of this law is obscure insofar as many lawyers are concerned.

One basis for a comprehensive statute that attempts to solve the problems pertaining to airspace utilization is the Model Airspace Act. This Act has been approved by the Section of Real Property, Probate and Trust Law of the American Bar Association (ABA), and is currently pending before the ABA House of Delegates. Final approval, with little or no modification, is anticipated at the 1973 annual meeting of the ABA in Washington, D.C.* The Model Airspace Act is primarily the result of my own work, with modification and improvements suggested by the committee and by the Task Force on Joint Development of the Highway Research Board.†

As I have mentioned, the Model Airspace Act defines airspace as extending upward from the surface of the earth and "which is either occupied or utilized or is reasonably subject to being occupied or utilized or is otherwise necessary for the reasonable enjoyment and use of the land surface and any structures thereon by the surface owner or owners, his or their heirs, successors or assigns. The airspace owned by a surface owner or owners is that which lies within the vertical upward extension of his or their surface boundaries."[55] The basis for this definition is the development of the common law earlier discussed. In two different places in the Model Act, it is stated that the Act has no effect on aviation, air transportation or commerce, airport operations, and so forth.[56]

Section 3 of the Act states that airspace is real property belonging to the persons holding title to the land surface until it is severed by the transfer of rights or interests in it. It is made clear in Section 4 that the purpose of the Act is to permit all the legal acts to be done with airspace that can be done with other real estate and that the same rights, limitations, etc., that apply to other real property will apply to airspace. Under Section 5, any title, estate, right, or interest that may be created in real property may be created, conveyed, and transferred in airspace. Section 6 gives power to the adopting state and its various agencies and subdivisions, as well as to private persons, corporations, and others, to exercise the same powers and rights that they can exercise with other realty.

Section 7 permits airspace to be divided horizontally and vertically and in any geometric shape or design. Section 8 provides for devolution of airspace on death of an owner, either by will or in the same manner as other realty if he dies intestate.

Section 9 is an optional (bracketed) section that would allow taxation of severed airspace parcels.

*The ABA House of Delegates, at its annual meeting, August 6-8, 1973, passed a resolution approving in principle the Model Airspace Act and authorizing transmission of the Act to state and major bar associations and advice to such associations that the Act was approved in principle by the ABA as legislation appropriate for consideration by their respective legislatures.

†Now the Transportation Research Board of the National Research Council.

Section 10 provides that powers granted by the Act are not to interfere with federal regulations pertaining to federal aid rights-of-way, or constitutional limitations, or the right of the public to unobstructed use of rights-of-way.

Section 11 is an important, lengthy provision that effects cooperation of state and local highway and other authorities with other agencies of the federal, state, or local governments, or with private parties in handling airspace matters. The provision includes the multiple use and joint development of rights-of-way and adjoining property. Numerous powers are conferred that generally relate to development and effectuation of a joint-development and multiuse plan. These powers contemplate joint efforts of different kinds of agency, the employment of professional or advisory personnel, contracting for various services or to effectuate the plan, the receipt and expenditure of funds of various kinds, and the execution of legal documents. An optional, but necessary provision would either mandate or permit coordination with urban or regional planning agencies. Under one version of this provision, approval by the planning authority would be required. Another optional provision permits condemnation of land or airspace in excess of that needed for highway right-of-way purposes to carry out a multiuse or joint-development plan. This condemnation may be carried out jointly with other agencies.

Airspace disposition is permitted in section 12, allowing unneeded space to be sold or transferred publicly or privately for not less than a certain percentage of the appraised value.

Section 13 is another important provision pertaining to ownership of easements for rights-of-way. If only an easement is owned, the public has a right to full and unobstructed passage over the improvement. Several alternative provisions are then provided under which, in one alternative, the owner of the fee interest would possess all other rights and powers over the airspace, provided that he does not interfere with the public use of the right-of-way. In another alternative, the fee owner could not, without express permission of the state or city, exercise any powers in the airspace. In still a third alternative, the public could make full use of the airspace, provided that the residual fee owner's rights were not limited or additionally burdened; in the event of the latter, the fee owner would have to be additionally compensated.

Section 14 indicates that the state's eminent domain laws are to remain unaffected, except as the act makes provision for airspace condemnation. The same condemnation procedures that currently apply to public agencies apply to their airspace-condemnation activities. Two final sections leave other laws unaffected, except as specifically provided in the Act, and provide for severability.

In drafting the Model Act, we attempted to provide some flexibility in its provisions that were to be selected ultimately for enactment in a particular jurisdiction. For this reason, some sections contain alternative provisions. For example, it may be deemed that the constitutional provisions of a given state will prevent certain alternatives from being pursued. Moreover, it should be kept in mind that this is only a *model* statute and that some states may wish to deviate from it or rewrite certain provisions.

For the most part, the Model Act is simply a codification of common law. In some parts, however, it chooses or provides a choice between conflicting rules, particularly in the section on right-of-way easements and in some of the optional provisions of the Act. Also, some of the provisions may not be adopted in some jurisdictions. Some may choose to delete the excess condemnation provision, for example. Be that as it may, the Act provides a vehicle whereby states may proceed to engage in joint development and multiple use of highway rights-of-way.

This development of policy pertaining to airspace provides, in my opinion, the basis for development of a policy for use of underground areas. Many of the same legal principles apply. In airspace considerations, of course, the problem of dealing with minerals or natural resources does not arise, but the somewhat similar parallel of tunneling under rights-of-way, compared with use of space over rights-of-way, has to be considered. Although the Model Airspace Act does not provide a perfect answer to many of these problems, much of the research and work that have gone into it and form the background for it can be applied to underground problems.

As we solve these problems, we must always keep in mind the complexity of urban life and the need to arrive at solutions that will provide a happier environment for modern man. We must consider the utility of various legal devices, but we must never lose sight of the aesthetic considerations that can create a higher quality of life. Urban congestion, urban sprawl, and urban interaction will continue, and the problems will grow. We must seek to anticipate, to think beyond our time, but as we think and act, we must never forget that our goal is to preserve and maximize the individuality of man in a setting hostile to individuality; the beauty of life in an atmosphere that promotes bleakness and, at times, despair; the values of civilized man in an environment that seems overmechanized and undercivilized. Those of use who deal with legal and technological devices must remember that the end is not to dehumanize man but to advance the enjoyment and recognition of those humane qualities that make man unique and make his life worthwhile.

REFERENCES AND NOTES

1. 2 W. Blackstone, Commentaries 19 (Cooley ed. 1899).
2. Coke on Littleton 4a (1628).
3. *Idem.*
4. Model Airspace Act para. 2A (1972).
5. A. McNair, The Law of the Air 396 (3d ed. 1964).
6. Klein, Cujus Est Solum Ejus Est . . . Quousque Tandem?, 26 J. Air L. & Com. 237, 243 (1959).
7. Lardone, Airspace Rights in Roman Law, 2 Air L. Rev. 455 (1931).
8. Cooper, Roman Law, and the Maxim "*Cujus Est Solum,*" in International Air Law, 1952 U.S. Av. Rep. 600, 602.
9. *Idem* at 622.
10. *Idem* at 615–616. See generally the discussion in R. Wright, The Law of Airspace 13–14 (1968).
11. Cro. Eliz, 118, 78 Eng. Rep. 375 (1587).
12. The reference to the maxim is contained in a note appended to Bury v. Pope, which reads "Temp. Ed. I," meaning that the maxim stemmed from that time. See generally, R. Wright, *supra* note 10 at 15–16.
13. Coke on Littleton, *supra* note 2.
14. 7 W. Holdsworth, A History of English Law 485 n. 9 (1926); A. McNair, *supra* note 5 at 31 n. 2. See also, C. Rhyne, Airports and the Courts 94 n. 37 (1944).
15. R. Wright, *supra* note 10 at 19.
16. See, e.g., T. Plucknett, A Concise History of the Common Law 284 (1956); M. Radin, Anglo-American Legal History 285 (1936); Roscoe Pound stated that Coke's Institutes became "books of authority wherever the common law obtains." 3 R. Pound, Jurisprudence 428 (1959). See also 5 W. Holdsworth, *supra* note 14 at 423–493 (2d ed. 1937) for a lengthy review of Coke and his times.
17. 3 J. Kent, Commentaries on American Law 487 (7th ed. 1851).
18. These cases are reviewed in R. Wright, *supra* note 10, at 19-30.
19. See R. Wright, *supra* note 10 at 36–65, for a review of the American cases.
20. H. Hazeltine, The Law of the Air 74–75 (1911).
21. Compare Berger, Condominium: Shelter on a Statutory Foundation, 63 Colum. L. Rev. 987–88 n. 5 (1963), with Bergin, Virginia's Horizontal Property Act: An Introductory Analysis, 52 Va. L. Rev. 961, 963 n. 7 (1966).
22. 186 N. Y. 486, 491, 79 N. E. 716, 718 (1906).
23. See Stuart S. Ball, The Vertical Extent of Ownership in Land, 76 U. Pa. L. Rev. 631 (1928); Ball, Division into Horizontal Strata of the Landscape above the Surface, 39 Yale L. J. 616 (1930); and Laird Bell, Air Rights, 23 Ill. L. Rev. 250 (1928).
24. Coke on Littleton 48b (1628).
25. W. Sheppard, Touchstone of Common Assurances 206 (1651).
26. See Ball, *supra* note 23, 39 Yale L. J. at 620, citing 1 Middle Temple Records 207 (Hopwood's ed. 1904). See also J. Williamson, The History of the Temple, London 227-228, 234-236 (1924).
27. Evans & Finch's Case, Cro. Car. 473, 474, 79 Eng. Rep. 1009 (1637).

28. Ford v. Lerke, No. 109, 74 Eng. Rep. 1074 (K. B. 1604).
29. Doe d. Freeland v. Burt, 1 T. R. 701, 99. Eng. Rep. 1330 (K. B. 1787).
30. 1 Hilliard, Real Property 3 (1st ed. 1838); 1 Hilliard, Real Property 51 (2d ed. 1846); 1 Hilliard, Real Property 4 (3d ed. 1855).
31. *Idem.*
32. See generally, R. Wright, *supra* note 10, at 71–83.
33. Loring v. Bacon, 4 Mass. 574 (1808).
34. Mills v. Pierce, 2 N. H. 9 (1819).
35. Cheeseborough v. Green, 10 Conn. 318, 26 Am. Dec. 396 (1934).
36. For example, Illinois in McConnel v. Kibbe, 33 Ill. 175 (1864); Iowa in Rhodes, Pregram & Co. v. McCormick, 4 Iowa 368 (1857); and Ohio in Winton v. Cornish, 5 Ohio 477 (1832).
37. 21 Ore. 30, 33, 27 P. 166, 167 (1891).
38. Ball, *supra* note 23, 39 Yale L. J. at 625.
39. 102 S. C. 377, 86 S.E. 1063 (1915).
40. Taft v. Washington Mutual Savings Bank, 127 Wash. 503, 221 P. 604 (1923).
41. Townes v. Cox, 162 Tenn. 624, 39 S. W. 2d 749 (1931).
42. 162 Tenn. at 628.
43. Puerto Rico passed an enabling act in 1951. P. R. Laws Ann. tit. 31, para. 1275 (1955). It adopted its Horizontal Property Act in 1958, which provided the model for most of the statutes of the American states. See P. R. Laws Ann. tit. 31, para. 1291–1293k (1967).
44. 328 U.S. 256 (1946).
45. 369 U.S. 84 (1962).
46. See Schmidt, Public Utility Air Rights, 54 A.B.A. Rep. 839, 843 (1929).
47. *Idem* at 843–844.
48. *Idem;* see generally R. Wright, *supra* note 10 at 224–227, 261.
49. R. Wright, *supra* note 10 at 261–263 lists many of the New York City airspace structures.
50. *Idem* at 229. See also Schmidt, *supra* note 46 at 841.
51. Schmidt, *supra* note 46 at 852; Bell, *supra* note 23, 23 Ill. L. Rev. at 252; and Drew, Usque Ad Coelum, 4 Conn., B. J. 276, 277 (1930).
52. R. Wright, *supra* note 10 at 263–264, lists many of the Chicago airspace structures.
53. Schmidt, *supra* note 46 and 847. The statute was Ill. Ann. Stat. ch. 114, para. 174a (1973–74 cum. supp.)
54. R. Wright, *supra* note 10 at 267–268, lists most of these cities.
55. Model Airspace Act para. 2A (1972). The Act, as approved by the A.B.A. Section of Real Property, Probate and Trust Law, is reproduced in Wright, The Model Airspace Act: Old and New Law for Contemporary Land Use Problems, 1972 Law and the Social Order 529, 554–557.
56. Model Airspace Act para. 2B, 4C (1972).

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A National Policy for Mineral Development on the Federal Public Domain

Incredible as it may seem, for over 100 years Congress has been unable to establish a consistent national policy relating to the development of fuel and nonfuel minerals on federal lands. Mining claims for solid minerals are still being located under a federal statute enacted in 1872. Most fuel minerals are now exclusively leasable under a 1920 act. The 1872 act's philosophy of "free mining" is strangely at odds with the fact that we are likely to face a serious shortage of vital minerals in the future.

In May 1973, the United States Geological Survey released, for the first time in 21 years, a report on the availability and magnitude of the mineral resources in this country.[1] The nation's known deposits of mineral raw materials have been seriously depleted, and future production must come, in many cases, from low-grade ores or from as yet undiscovered resources. For the most part, this will mean increased costs of production and some seriously adverse effects on the environment. Statistics on the future availability of minerals most essential to industry point up the problem. The report states that we are now importing 29 percent of our oil and gas requirements, about 33 percent of the iron ore needed, and 87 percent of the aluminum we use. Although we do not import much copper at present, at current rates of consumption the nation's resources will be exhausted in 45 years. The United States produces about 9 percent of the world's zinc; although the metal is relatively plentiful, during the 20-year period before 1970, the world used half of all the zinc ever produced up to that time. This phenomenal increase in the demand for zinc cannot continue indefinitely.

Metals most important to industry are iron, aluminum, copper, and zinc. The fifth most widely used metal is manganese, which is indispensable in steel production. No known reserves of manganese exist in this country at present. In addition to this depressing account of our potential mineral supply, the report points out that vast supplies of important by-products or co-products are literally being wasted because economic incentive to recover them is apparently lacking.

In contrast to the above report, a strange story was recently recounted in the *New York Times.*[2] In a half dozen or so western states, one Merle I. Zweifel recently staked out "mining claims" covering 30 million acres, an area larger than the state of Pennsylvania. To finance this gigantic enterprise, Zweifel advertised in national magazines and solicited "co-locators" who, through small contributions, paid the cost of locating the claims in return for 50 percent of claim ownership. Mr. Zweifel's method of staking his claims was at least unique. Apparently, he went out among the desert sagebrush and every half mile or so simply stuck in a couple of posts. That his mines would require water to be worked was apparently of no moment to him. Although it is true that several of the states involved have, in litigation, canceled these claims for failure to discover any minerals or to make proper locations, and although Zweifel may be convicted of an assortment of mail frauds and for filing false documents, the important question remains: If we are experiencing a severe shortage of vital minerals, how is it that we can countenance a legal system that makes it possible for this sort of thing to happen? The answer is embarrassing. The situation is caused largely by the failure of Congress to revise the mining laws, which at best constitute an anachronism in our modern society. A clear national policy is needed on how and to what extent minerals on the public domain are to be exploited, and a system must be established for their orderly development.

Many people are not aware that the federal government owns over one third of all land in the United States. Most of this land is in the West and was originally acquired by the government by purchase or conquest from foreign countries. The uses of the public domain have been regulated by Congress under the "property clause" of the federal constitution[3]: "The Congress shall have Power to dispose of and make all needful Rules and Regulations respecting the Territory or other Property belonging to the United States. . . ." The federal mining laws form only a small part of the general public land laws.[4] Incidentally, there has not been a great deal of state or federal legislation regulating mineral production in privately owned land. One example, state strip-mining legislation, is discussed by Professor Stone.[5]

In 1964 the Congress established the Public Land Law Review Commission[6] to study the use of the public domain for various purposes and to suggest future policies and necessary legislation. The commission's report to Congress in 1970[7] will be discussed later. I was asked to assist Dr. Paul W. Gates of Cornell University in the preparation of a history of resources development on the public lands. My assignment was to study the way in which mineral resources have been allocated over the years. The volume was published in 1969.[8] What follows is a brief summary of our report on the history of the federal mining laws.

A BRIEF SUMMARY OF THE HISTORY OF THE FEDERAL MINING LAWS

Early in the nineteenth century (1807–1846), the federal government experimented with a crude leasing system for the lead mines in Missouri and in what is now part of the states of Illinois and Wisconsin. The system failed largely because it was incompetently administered.[9] Other factors contributing to its demise were the prolonged litigation over the constitutionality of the federal acts and the fact that about three fourths of the public mineral lands in the western half of the Wisconsin Territory illegally passed into private ownership between 1834 and 1840. After 1846 the federal policy was dramatically reversed. Within a few years, the outright sale of copper lands of inestimable value as "agricultural land" in Michigan and Wisconsin was authorized, despite the known mineral value of the land. Years later, the general public land laws were perverted to allow the Minnesota iron ore mines to pass into private ownership for a nominal price. In the far West, mining law developed after the discovery of gold in California in 1848. With no federal laws regulating mining on the public domain, the miners were forced to improvise their own rules in their mining camps. Although the miners were technically trespassers, Congress failed to adopt any legislation dealing with mining for over 16 years. After years of wrangling, the western block in Congress, led primarily by Senator William Stewart of Nevada, prevailed, and the Mining Law of 1866 was passed.[10] Representative George W. Julian (Indiana), who opposed the legislation, always maintained that it was a "clumsy and next to incomprehensible bill."[11] He was correct, at least if a detailed and comprehensive mining code was what the country wanted. The Act was badly drafted; for example, the requirements for lode locations were distressingly vague.

The Act's main policy determination, however, rang loud and clear: Free prospecting and free mining on the public domain were sanctioned, and after a discovery of valuable minerals, miners could obtain patents in fee simple to their locations from the federal government. Also, claims located before 1866 were validated. In 1870, an act for "placer claims" had been adopted, and there is evidence that it was intended primarily to benefit the California miners whose worked-out claims were now found to be more valuable for agricultural purposes than for mining. In 1872, the two acts were re-enacted with a number of minor changes relating to the details of placer and lode locations.[12] The basic policy of free mining for solid minerals has persisted to the present.

A number of departures from the philosophy of the so-called location laws have occurred. Coal lands, for example, were exposed to sale after 1864 under a series of special acts.[13] Apparently, there was a feeling that coal lands, being more readily discoverable than lands containing metalliferous minerals, presented a greater potential for revenue. President Theodore Roosevelt favored a leasing system for coal lands, however, as early as 1906. When Congress steadfastly refused to revise the coal laws, the President, in a dramatic gesture in 1906, withdrew from entry approximately 66 million acres of known coal land. Congressional reaction was for the most part bitter because of the feeling that the constitutional power to withdraw land from sale lay with Congress, not the President.

In 1897, Congress foolishly decided that oil lands should be locatable under the earlier placer law. The mining law was simply unworkable as applied to oil and gas because of the severe acreage limitations in the placer law and because of the confusion as to what constituted a "discovery" of oil to validate locations. In 1909, President Taft, in what proved to be a most courageous act, withdrew over 3 million acres of oil land from the location law. The government at that time apparently feared that the western oil land would soon pass into private ownership. The Pickett Act of 1910 authorized such withdrawals by the President,[14] and the constitutionality of the Act was upheld by the Supreme Court in 1915.[15]

From 1910 to 1920, most of the unappropriated public domain was withdrawn from nonmetalliferous location under the mining laws. Unquestionably, public sentiment favored leasing the oil lands with royalties payable to the government. Legislation to that effect, however, was not passed until 1920. The principal problem appears to have been what to do about oil companies that were caught, at the time of the 1909 withdrawal, in various stages of prospecting–activities that ranged anywhere from "paper locations" to actual drilling short of a discovery.[16] Leasing for oil, gas, and a few other specified minerals was finally adopted in 1920.[17] It remains the principal departure from the 1872 location law.

What might be called the last chapter in American mining law certainly rivals the earlier days in romantic appeal. After the Teapot Dome scandal in the 1920s, the government found that overproduction, depletion, and wasteful practices in the oil industry caused serious problems. Shortly after his inauguration, President Hoover discontinued the leasing of the oil lands. There followed a systematic program of canceling outstanding permits that failed to comply with the provisions of the Leasing Act relating to the commencement of drilling. When the public domain was again opened to leasing in 1932, prospecting permits were issued subject to certain conservation restrictions. The two systems–location and leasing–eventually collided in the 1950s when the uranium boom hit the country. The conflict came about because the Mineral Leasing Act, which made certain nonmetalliferous minerals exclusively leasable, made no provision for the disposition of other minerals that might be discovered in leased land. Nor was there any attempt to amend the mining laws to stipulate that mining patents must contain reservations of the various Leasing Act minerals. An early departmental ruling precluded any entry under the mining laws where a prospective permit for oil and gas had been issued and still remained alive.[18] Mining entries were also precluded on land classified as valuable for Leasing Act minerals. Stopgap legislation, proposed by the mining industry, provided for retroactive validation of many uranium locations.[19] Later legislation sanctioned a system of multiple use of federal lands,[20] gave the federal government the authority to use certain surface resources on unpatented mining claims,[21] and removed certain "common varieties" from the location laws.[22] In more recent years, the mining industry has led a succession of battles with the government over withdrawals, oil shale, and the classification of public lands. A major current concern is the effect of mining on man's land, air, and water environment; environmental pollution is one of the most pressing problems of the mining industry today.

Because the free-market price of gold has soared in recent months, the West is experiencing a new, if somewhat ludicrous, gold rush. In the Mother Lode Country in California, prospectors under the banner of the 1872 Mining Law are panning again for gold in the fragile rivers where it was first discovered long, long ago.[23]

REPORT OF THE PUBLIC LAND LAW REVIEW COMMISSION ON THE MINING LAWS

The Public Land Law Review Commission, in reporting to Congress in 1970, did not undertake to rewrite the public land laws. Although the report was carefully prepared and contained many far-reaching and interesting recommendations, environmentalists at least were wary of the overall commercial tone of the report. Its emphasis was on the use of the public domain as a commodity rather than recognizing it as an ecological community.[24] Thus, we read that, "Even though we are concerned about various impacts on the environment,"[25] these impacts can at best only be minimized and must often, in fact, yield to considerations such as the national importance of mineral production. Where mineral activities cause a disturbance to public land, restoration and rehabilitation should be required only after a determination of economic feasibility,[26] whatever "economic feasibility" means.

With regard to the commission's recommendations for revision of the mining laws, the majority of the commission would retain the present leasing and locations systems, but the location law would be modified in several significant respects. The following is a brief summary of the recommendations for modifying the location system and some of my observations about these recommendations[27]:

> The Commission would retain the present separate leasing and location programs, but the location laws would be modified in several significant respects. The most important of these include securing from the government an exclusive exploration permit which would give the miner some initial security in his investment. The permit would specify a reasonable rental, and expenditures for exploration and development would be credited against the rentals. When a com-

mercially mineable deposit is discovered, the miner enters into a contract with the government requiring specified development work over a period of time. After production commences, he has a right to obtain a patent to the minerals only and also an option to buy or lease the surface by paying for the land at its market value. If he does not exercise his option to purchase the surface, his title to the minerals would automatically terminate within a reasonable time after cessation of production and would probably be characterized by property lawyers as something like a determinable fee. Under the location contract, fair but modest royalties are payable to the government before as well as after a patent is issued.

I think the new system is needlessly cumbersome, and I believe the minority report, which recommends a general leasing system for all minerals except those which are subject to outright sale under special federal statutes, is obviously sound. Perhaps I am missing something here, but I can find no reason why the mining industry feels that it cannot operate without a right to a patent to the surface and to the minerals. The argument seems to be that this is necessary to protect what is often an enormous investment, but this same security could be achieved under a leasing system as the minority people point out. It may be that the present leasing law will have to be modified in several respects, but this is a relatively simple matter. The provision for a patent is largely an illusion, because royalties are payable whether or not a patent is issued. Of course, with a patent in fee, the miner could temporarily stop production with a view to resuming mining when it becomes more economical to do so. I am in complete agreement with the royalty recommendation. This is about one hundred years overdue.

If we must live with this revised location system, . . . I think the Commission makes a number of good suggestions relating to the acquisition of exploration permits and the development contract. For example, the elimination of the placer-lode distinction and extralateral rights is sound. Gearing locations to government surveys is sensible. Preemption of state legislation on the location and maintenance of valid mining claims should be welcomed by the industry. Here, however, I notice the Report would continue the effect of recording under state law. I personally doubt the wisdom of this. The recording of mining claims in state offices is a notorious mess. Of course, under the proposals, records will for the first time also exist in the federal land agency office. I have no objection to a procedure for clearing public lands of dormant mining claims. Drafted carefully, there should be no serious constitutional problems.

MINING AND MINERALS POLICY ACT OF 1970

The only federal legislation of any importance since the Public Land Law Review Commission report is the Mining and Minerals Policy Act of 1970.[28] In a single section in sweeping language, this Act simply declares that it is the continuing policy of the federal government to encourage private enterprise in (1) the development of economically sound mining and mineral reclamation industries; (2) the orderly and economic development of domestic mineral resources to assure satisfaction of industrial, security, and environmental needs; (3) mining research, including recycling of scrap; and (4) the study of methods of disposal, control, and reclamation of mineral waste products and the reclamation of mined land "so as to lessen any adverse impact of mineral extraction and processing upon the physical environment. . . ." The definition of "minerals" includes all minerals and mineral fuels, including oil, gas, coal, oil shale, and uranium. The Secretary of the Interior is directed to carry out these policies when "exercising his authority under such programs as may be authorized by law other than this Act." He is required to report annually on the state of the domestic mining, minerals, and reclamation industries and to recommend such legislative programs as may be needed to implement the policies of the Act.

The Act is not self-executing and depends on congressional appropriations to accomplish its objectives. A 1971 bill, attempting to specify what aspects of mining are to be emphasized in research and in appropriating funds therefore, passed both the House and the Senate but was vetoed by the President.[29] Other bills in the 92d session include the Jackson–Moss bill, which, as amended, attempted to regulate surface strip-mining and to provide for reclamation of abandoned mines.[30] It died in committee, as did two other bills that would have revised the mining law[31] and the mineral leasing law.[32] Also buried in committee was a proposal to establish a new Department of Natural Resources and eliminate and transfer existing agency functions,[33] and a grandiose public land zoning law proposed by Representative Aspinall.[34]

Mining legislation in the 93d Congress did not fare much better. A raft of new bills was introduced to replace those ignored in the previous Congress. Of special note is Representative Dignall's bill to regulate coal mining[35] and Representative Saylor's bill to provide cooperation between the federal government and the states with respect to environmental regulations for surface and underground mining.[36] President Nixon has listed strip-mining legislation as a major legislative priority in the energy field. At present, the Senate is debating a bill that would attempt to balance the nation's energy needs with environmental concerns by setting up minimum standards for the surface mining of coal.[37] In general, the measure prohibits strip-mining in areas where reclamation is not feasible, requires restoration to the "approximate original contour," and would enable states to designate areas where strip-mining is not suitable. An amendment from the floor would forbid strip-mining where the federal government owns the mineral rights but not the surface rights; this provision is thought to be necessary to protect cattle and wheat ranchers in Montana.

Many observers are not particularly optimistic about new mining legislation in the present Congress. In addition to federal strip-mining laws, there is an urgency to revise all the present mining statutes relating to fuel and nonfuel minerals. Even the mining industry itself is now resigned to the fact that the Mining Law of 1872 must go. Whether someone can come up with a major revision, not only of that Act but also of the 1920 Leasing Act, is at the moment doubtful.

REFERENCES AND NOTES

1. D. Brobst and W. Pratt, ed., United States Mineral Resources, Geological Survey Professional Paper 820. U.S. Government Printing Office (1973). The report is discussed in *New York Times*, p. 1, May 9, 1973.
2. *New York Times*, p. 39, May 27, 1973.
3. United States Constitution, Art. IV, §3, cl. 2. For a discussion of the clause as applied to mineral resources, see the recent case of Honchok v. Hardin, 326 F. Supp. 988 (D. Md. 1971).
4. The public land statutes are collected in Digest of Public Land Laws, U.S. Government Printing Office (1968). Prepared for the Public Land Law Review Commission by Shepard's Citations, Inc.
5. See also V. Cardi, Strip Mining and the 1971 West Virginia Surface and Reclamation Act, 75 W. Va. L. Rev. 319 (1973). For popular discussions, see Shall We Strip-Mine Iowa and Illinois to Air-Condition New York?: 232 The Atlantic, no. 3, p. 84 (September 1973), and the accompanying articles, H. Caudell, Farming and Mining: There Is No Land To Spare, p. 85; J. Conway, The Last of the West: Hell, Strip It!, p. 91.
6. 43 U.S.C.A. para. 1391–1400 (1964).
7. One Third of the Nation's Land, U.S. Government Printing Office (June 1970).
8. P. Gates, History of Public Land Law Development (1969).
9. See J. Wright, The Galena Land District: Federal Policy and Practice 1824–1847 (1966).
10. 14 Stat. 86 (1866).
11. G. Julian, Political Recollections, 286–292 (1884).
12. 30 U.S.C.A. para. 21 *et seq*. (1971).
13. 13 Stat. 343 (1864); 13 Stat. 529 (1865); 17 Stat. 607 (1873). The last statute was superseded by the Mineral Leasing Act of 1920.
14. 43 U.S.C.A. para. 141–143 (1964).
15. United States v. Midwest Oil Co., 236 U.S. 459 (1915).
16. Ise, The United States Oil Policy (1926) (2d printing).
17. 30 U.S.C.A. para. 181 *et seq*. (1971).
18. Joseph E. McClory, 50 Int. Dec. 623 (1924).
19. 30 U.S.C.A. para. 501 *et seq*. (1971).
20. 30 U.S.C.A. para. 521 *et seq*. (1971).
21. 30 U.S.C.A. para. 601–604 (1971).
22. 30 U.S.C.A. para. 611–615 (1971).

23. The "boom" is amusingly described in K. Lamott, Gold! Gold! A Visit with the '73ers, *New York Times Magazine*, p. 8, August 19, 1973.
24. The reaction to the report was mixed. The popular reaction is described in D. Schwinn, Public Land Law Review Commission Report–Oracle or Ogre?, 4 Nat. Res. Lawyer 168 (1971). One writer felt that because of the Commission's "commodity approach," the report "gallops headlong in the wrong direction." D. Jackson, This Land Is Our Land, 70 *Life Magazine*, no. 1, p. 32 (January 8, 1971). The chief architect of the report, then Rep. Wayne N. Aspinall of Colorado, was rather unkindly described as out to "curb the ecology binge." *Wall Street Journal*, p. 1, January 21, 1972. For less derogatory comments, see the symposium discussing all aspects of the report in 6 Land and Water L. Rev. 1–457 (1970).
25. One Third of the Nation's Land, *supra*, note 7, at 122-134.
26. *Idem* at p. 127.
27. R. Swenson, Of Mountains and Mice, 6 Land and Water L. Rev. 135, 144-145 (1970).
28. 30 U.S.C.A. para. 21a (1971).
29. S. 635 (July 15, 1971).
30. S. 2542 (Bible, Allott, Moss, September 17, 1971).
31. S. 2727 (Jackson, October 20, 1971).
32. S. 2726 (Jackson, October 20, 1971).
33. H. R. 6959 (Holifield, March 30, 1971).
34. H. R. 7211 (Aspinall, April 6, 1971).
35. H. R. 6709 (Dignell, April 9, 1973).
36. H. R. 4863 (Saylor, February 27, 1973).
37. *New York Times*, p. 21, October 9, 1973.

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Strip-Mining Coal: Unsettled Legal Problems

The several legal problems dealt with in this paper have two characteristics in common: (1) divided land ownership, where the surface of the land is owned by one person, and subsurface mineral rights, i.e., the coal, owned by someone else and (2) strip-mining. Other than those two characteristics, the similarities or differences among these problems await a determination by a court. Here, we only raise the problems and suggest some of the considerations that may guide a court in resolving them.

Most of the legal problems associated with coal strip-mining require determinations of both state and federal laws. Determinations of Montana law, for example, will be required where the two ownerships, surface and mineral, involve two private parties; determinations of federal law will be required where a homesteader under the public land laws owns the surface and the federal government owns the coal.

MONTANA LAW OF EMINENT DOMAIN

Problems that involve principally Montana law include those that involve the Montana law of eminent domain as it applies to strip-mining. Eminent domain is the power of the state to take property for what it considers to be a public use, subject to the payment of compensation to the person whose property is taken. The state, through legislation, may delegate this power to private corporations and may, by similar legislation, designate what activities are to be considered public uses.

In Montana, the principal legislation setting forth the public uses for which eminent domain is authorized was first enacted in 1877 and has been amended and added to from time to time since then.[1] In 1961, mining was added to that statute, as a fifteenth subsection, describing the additional public use in these words:

> 15. To mine and extract ores, metals, or minerals owned by the plaintiff located beneath or upon the surface of property where the title to said surface vests in others.[2]

In other words, to mine the minerals he owns, the owner of the minerals can condemn the owner of the surface property.

In exercising the power of eminent domain to take another's property, however, no more property may be taken than is needed to accomplish the public purpose.[3] In the context of the eastern Montana coal, which underlies many large ranches, the foregoing statute would authorize taking through eminent domain only so much of a ranch as is needed to gain access to the coal and to mine it. The statute does not authorize the use of eminent domain to condemn entire ranches where that is not necessary to the mining operation. In many instances only a temporary easement would be justified. This is a very important qualification, although for any particular ranch the vital fact will be the location of the coal: Does it underlie a meadow or winter hay land? Does it only underlie marginal sagebrush land?

If a coal company can take only the land that is needed to mine and extract the coal, can it exercise the power of eminent domain to enable it to strip mine? Should that power be limited to taking only the land that is needed to mine the coal by shafts and tunnels? This is the most important legal question concerning the strip-mining of coal that remains to be answered by the courts.

But the legislature has provided an answer. The 1973 legislative assembly added the following language to subsection 15 of the eminent domain law quoted above:

> . . . provided, however, the use of the surface for strip mining or open-pit mining of coal (i.e., any mining method or process in which the strata or overburden is

removed or displaced in order to extract the coal) is not a public use and eminent domain may not be exercised for this purpose.[4]

This enactment, this answer to the preceding question, may be challenged on federal constitutional grounds. Coal is only one of several minerals that may be taken by open-pit or strip-mining. Thus the challenge could be based on the law's selection and isolation of coal owners, prohibiting them from strip-mining, while allowing owners of other minerals to continue to do so under the right of eminent domain. In short, the coal owners may claim unfair discrimination and denial of equal protection of the law in violation of the federal Constitution.

The threat of such a challenge was recognized by the legislature, which sought to justify this special restriction against coal through extensive findings.[5] Excerpts from some of these are as follows:

(1) Because of the large reserves of . . . coal in eastern Montana, coal development is potentially more destructive to land and watercourses and underground aquifers and potentially more extensive geographically than the foreseeable development of other . . . minerals, and affecting large areas of land and large numbers of people;
(2) . . . to permit the mineral owner to condemn the surface owner is to deprive the surface owner of the right to use his property in a productive manner. . . ;
(3) The magnitude of the potential coal development in eastern Montana will subject landowners to undue harassment by excessive use of eminent domain;
(4) . . . it is the public policy of the State to encourage and foster diversity in land ownership. . . .

These legislative findings will make the task of those challenging the restrictive legislation a formidable one.

DIVIDED-LAND OWNERSHIP

There are two principal methods by which the ownership of the land surface and of the underlying coal become divided. One method is for the owner of both the surface and subsurface to sell only his mineral rights, thus dividing the ownership. The other is for such an owner to sell the land, while reserving or withholding the mineral rights from the sale. This latter pattern was used by the Northern Pacific Railway Co., whose reserved or withheld ownership of coal is now owned by the Burlington Northern Railroad.

The Northern Pacific Railway Co. acquired a vast amount of land in eastern Montana, including the underlying coal, from the federal government under the railroad land-grant acts. Subsequently, the railroad sold large amounts of land to private ranchers but reserved to itself the underlying coal that now belongs to the Burlington Northern Railroad. A Northern Pacific deed, dated 1908, contains this reservation:

> Excepting and reserving unto the party of the first part, its successors and assigns, forever, all coal and iron upon or in all of said lands hereinbefore described and also the use of such surface grounds as may be necessary for exploring for and mining or otherwise extracting and carrying away the same. . . .

Does this reservation not only entitle the railroad to the coal and the right to use so much of the surface as is needed for mining or extracting the coal by deep tunnel and shaft mining but also the right to such surface as is needed for strip-mining the coal?

The answer to that question has not yet been given in Montana, but the question has given rise to litigation and answers in the coal-mining states of the eastern United States. Those eastern decisions will be considered by, and will influence, the Montana Supreme Court. For that reason the case law in Pennsylvania since 1950 has been selected to illustrate the process of decision making and to reveal considerations that may guide Montana courts in deciding whether strip-mining is permissible.

Taking those cases in chronological sequence, the first is *Commonwealth* v. *Fisher,*[6] 1950, in which an 1855 deed conveyed the land, reserving to the seller

> . . . the full entire complete and exclusive ownership . . . as though the present conveyance had not been made, to all metals ores minerals mine-banks and deposits or ores minerals metals or coal . . . [and the right to] excavate . . . any part of said premises.

Some time later the Commonwealth purchased the land surface for recreational purposes, and after that the owner of the coal sought to strip mine the land. The Commonwealth sought an injunction against strip-mining and was successful in the trial court. But the decision was reversed on appeal: Strip-mining was permitted. The appeals court noted that the 1855 deed relinquished common law rights to surface support (i.e., the miner is not responsible for subsidence or collapse of the surface by reason of the mining activity). That could have enabled the court to infer that only deep mining was contemplated; instead, the court found that damage to the surface without liability or responsibility was implied and that the deed contained no restrictions on mining methods. The appeals court also considered the facts that the land was remote, mountainous, and had been logged over. One judge dissented, arguing that the broad, inclusive language reserving ownership of the coal should not be used to confer broad and inclusive means of mining the coal. Thus the language in the 1855 deed quoted above, ". . . as though the present conveyance had not been made. . . ," refers to the quality of ownership reserved and not to mining methods. He also found that strip-mining was inconsistent with the surface owner's use of his land and contrary to the conveyance of that land.

The next case also permitted strip-mining. In *Mount Carmel Railway Co.* v. *Hanna Co.*,[7] 1952, the railway tried to restrain Hanna from strip-mining coal under the railroad right-of-way because (as the court found) such mining would make operation of the railroad impossible until the land had been backfilled after mining was completed. The document in question was an 1891 grant to the railroad of an easement for its right-of-way. The grant reserved for Hanna the minerals "under the surface" and the right to take them "by any method of mining." It "also" reserved the right to use "drifts, tunnels, gangways, airways, breasts, slopes, and other ways through and under the said tracts." The railroad assumed the risk of "the said surface of the ground hereby granted breaking or falling in" by any method of mining. In upholding strip-mining, the court emphasized the language "by any method of mining" and found that the other language, appropriate only to deep mining, followed the word "also" and hence described additional rights rather than a limitation on the generality and breadth of the earlier language.

In *Rochez Bros.* v. *Duricka*,[8] 1953, Rochez had been prevented access for strip-mining and sought to enjoin such interference. The document in question was a 1919 deed that reserved the coal, "Together with the right to mine . . . rights . . . to such mining and removal, draining and ventilating the same, and without being required to provide for support of the overlying strata, and without liability for injury to the said surface . . . [and the] right to enter in, upon, and under the lands." In prohibiting strip-mining, the court noted that the land was agricultural rather than logged over remote mountain land, and it emphasized that the clauses in the 1919 deed were appropriate to deep mining and not to strip-mining. The relinquishment of surface support and rights to damages for injury to the surface were found inapplicable to strip-mining, a method of mining that will necessarily destroy the surface. The "right to enter in, upon, and under the lands" was also found to be language of deep mining. Finally, the court found that the right to destroy the surface must be specifically reserved, because it is so inconsistent with the use of the surface and contrary to the grant of surface ownership. As a general rule for construing such a deed, the court said that if the grantor used language that led to ambiguities or uncertainties regarding his reservations of the coal and mining rights, the doubt should be resolved against him and in favor of the grantee of the land.

In *Commonwealth* v. *Fitzmartin,*[9] 1954, the deeds were executed from 1921 to 1923 and reserved ". . . all the coal . . . and other minerals in and under the surface . . . without any liability whatsoever for damages to said lands. . . ." In allowing strip-mining, the court emphasized the breadth and generality of the quoted language and ignored other language that was in the context of deep mining, such as references to shafts, ventilation, and the like. It declined to follow the 1953 Rochez Bros. case (above) because that case involved rich, useful, agricultural land, whereas in this case, as in the 1950 case of *Commonwealth* v. *Fisher* (above), the state land was cut over, mountainous, and without improvements. Three judges dissented on the basis that the context of the deeds lent itself only to deep mining, that the present utility of the land was irrelevant, and that (following the rule stated in the Rochez Bros. case) any ambiguities or uncertainties should be resolved against the grantor.

In *Wilkes-Barre Township School District* v. *Corgan,*[10] 1961, school land had been strip mined, and the school district was suing for damages, alleging that it had been stripped without right. The document in question was an 1893 deed of the surface, reserving the coal and the right to drive tunnels and passageways under the land without liability or responsibility for injury to the surface, as by subsidence or collapse. In construing this deed, the appeals court stated (as in the 1953 Rochez Bros. case, above) that uncertainties and ambiguities should be resolved against the grantor of the land who reserved to himself only the minerals. The court found that nothing specific permitted the grantor such a broad, destructive power as strip-mining and that strip-mining would not have been contemplated in 1893 when the deed was executed. It also found that the land was valuable for its surface uses, and so it found that the school district had a good case for suing for damages. Two judges filed a brief dissent, saying that the 1954 case of *Commonwealth* v. *Fitzmartin* (above) should be controlling.

In *Heidt* v. *Aughenbaugh Coal Co.,*[11] 1962, the court found that a 1915 mineral lease permitted strip-mining because it provided "The right to mine to include all practical methods now in use, or which may hereafter be used . . . and the right to strip the surface for, excavate, dig, bore, shaft, quarry, and otherwise explore for and mine said minerals."

In *Merrill* v. *Manufacturers Light and Heat Co.,*[12] 1962, Merrill wanted to strip mine and brought an action to prevent interference. The document in question was a 1930 deed that granted the power company an easement for its gas-transmission line but relieved Merrill from responsibility for damages caused "by the removal of surface support thereunder in the mining of coal." The court found that the quoted language referred to weakening of the surface strata by removal of lower supporting strata and had no reference to strip-mining: "Patently, *surface support* is not synonymous with *surface destruction* . . . " (court's emphasis). The court said that since strip-mining was known in 1930 the parties would have expressly provided for it had it been intended. Various other surrounding circumstances were taken into account, such as the fact that in 1930, Merrill did not own all of the mineral and surface rights that he owned by the time of the trial, and he did not have the right to strip mine all of the land when he granted the easement to the power company. Once again, the fact that it was agricultural land affected the court's judgment. It said that the burden is on "him who seeks to assert the right to destroy" and that the conveyance should be interpreted ". . . in the light of the apparent object or purpose of the parties and of the conditions existing when the words were employed." The strip-mining was prohibited.

In *New Charter Coal Co.* v. *McKee,*[13] 1963, the coal in question was granted to New Charter under a 1903 deed, with McKee reserving to himself a seam of coal that lay between the grantee's coal and the surface. New Charter wanted to strip mine its deeper seam, but the court denied it that right, principally because McKee's seam would be torn up by New Charter's stripping.

The most recent case was *Stewart* v. *Chernicky,*[14] 1970, in which Chernicky had strip mined and Stewart sought damages, alleging that his land had been stripped without right. The document in question was a 1902 deed that granted to Chernicky the coal and the right of ". . . mining . . . also the right to drain and ventilate said mines by shaft or otherwise . . . with a full release of land without liability for damages for injury to the surface. . . ." The court found that the deed was not specifically for or against strip-mining, but it placed the burden of proof on him who seeks authority to destroy the surface. It acknowledged the general rule, enunciated in Rochez Bros. in 1953 and in the 1961 Wilkes-Barre School District cases, that ambiguities and uncertainties should be resolved against the grantor, but it didn't find that the deed gave rise to significant ambiguities and uncertainties. Rather, because strip-mining was not common in 1902 when the deed was executed and because it incorporated such language as "ventilate said mines," it found that strip-mining was not intended and, thus, not included in the grant of the mineral rights.

The above cases are almost evenly divided for and against strip-mining. What considerations caused the court to decide one way or the other? In the first place, as would be expected, the principal emphasis in each case was on the language of the grant or reservation of the coal. Broad language, authorizing mining "by any method" or exculpating the mineral owner from liability for any damage, tends toward permitting strip-mining. Language that is particularly applicable to deep mining, such as "ventilating," "tunnels," "shafts," "passageways," and concerning liability for support of "overlying strata" tends toward excluding strip-mining. Factual circumstances also aided the court in interpreting the language, such as whether the land supported a valuable activity (e.g., agriculture), or was merely detimbered eastern mountains or hills, and whether strip-mining was common in the area at the time the language was employed. The release of liability for surface support or damage to the surface has been used by the court to arrive at opposite conclusions, but the more reasonable would seem to be that reached in the Merrill case: Such language applies only to deep mining because *"surface support* is not synonymous with *surface destruction."* Several of the Pennsylvania cases suggest that strip-mining can only be authorized by specific language to that effect, because such a method is inconsistent with and destructive of the ownership of the surface.

Now, with these cases as background, how should the language of the 1907 Northern Pacific deed be handled? That language is repeated here for convenience:

> Excepting and reserving unto the party of the first part, its successors and assigns, forever, all coal and iron upon or in all of said lands hereinbefore described and also the use of such surface grounds as may be necessary for exploring for and mining or otherwise extracting and carrying away the same. . . .

The reservation of all coal "upon or in" the lands conveyed seems neutral, so far as the method of taking it is concerned; that is, addresses itself to ownership rather than to mining methods. Then it speaks of the "use" of such surface as needed for exploration, mining, etc. What is the connotation of "use" in this context in a 1907 deed? It seems unlikely that such a common, general word would be construed as permitting the sort of destruction involved in strip-mining. And what is meant by "mining or otherwise extracting" the coal? The word "mining" is as ambiguous as the word "use"; neither of them aid in carrying the burden of proving a right to strip mine. The words "otherwise extracting" connote a drawing out, as in deep mining.

The Pennsylvania cases tell us that we should look to surrounding circumstances for aid in arriving at the intent of the parties. A very important circumstance is that strip-mining was certainly not common in eastern Montana in 1907, but ranching and other agricultural pursuits were quite common and were expected to be carried on under these grants of railroad land holdings.

The Pennsylvania cases also tell us that uncertainties and ambiguities should be resolved against the grantor who reserved the coal and that the burden of proof is upon him who seeks to destroy the surface. But we look in vain at the Northern Pacific deed for such clear language as "removing," "excavating," "uncovering," or preferably, "strip-mining."

DIVIDING LAND OWNERSHIP BETWEEN SURFACE AND SUBSURFACE OWNERS

Montana was also a participant in the process of dividing land ownership between surface and subsurface ownership, in the same manner as the Northern Pacific company. The state held both the surface and subsurface ownership, but conveyed to homesteaders the land, reserving various minerals, including coal. When public land is conveyed by deed, the conveyance is not called a deed, but rather, a "patent." Montana patents contain this reservation:

> . . . and also excepting and reserving to the State of Montana all title in and to all coal, oil, oil shale, gas, phosphate, sodium and other mineral deposits in the above described land which have not already been reserved by the United States, except sand, gravel, building stone, and brick clay, whether now known or hereafter found to exist therein, together with the right for itself and its lessees to remove such mineral deposits so reserved and to occupy and use so much of the surface of the said lands as may be required for all purposes reasonably extending to the exploring for, mining, and removal of such mineral deposits therefrom, but the lessee shall make just payment to the purchaser for all damage done to

the premises by reason of such entry upon the land and the use and occupancy of the surface thereof.

The operative terms here commence with explore, mine, and remove. If "remove" can be taken as part of the mining operation itself, it could encompass strip-mining, but the word probably was not used in that way. Rather, the whole phrase suggests the progression of a process: Develop the operation, mine the mineral, and remove (transport) it from the premises. The word "mine," then, seems equivalent to the word "mining" in the Northern Pacific deed. Then the state reserves the right to "occupy and use" the necessary surface. Again, wording is neutral and similar to that of the Northern Pacific deed. The clause "required for all purposes reasonably extending to the exploring for, mining, and removal" does not offer much help either, because again there is nothing to indicate that any particular method of mining was contemplated. The clause requiring "payment to the purchaser for all damage done to the premises by reason of such entry upon the land and the use and occupancy of the surface thereof" is not an enabling or authorizing clause; rather, it protects the landowner and restricts the state or the person to whom the state has granted its right to mine the coal. Of course, that clause does imply that damage may result from entry, use, and occupancy, but that would happen whether the land were deep mined or strip mined. So again no words truly describe strip-mining or imply any intention of using such a destructive method.

There is one basis for differentiating this state patent from the Northern Pacific deed. It stems from a doctrine that was developed to protect the public whenever there is a conveyance of public property. That doctrine is that "nothing passes by implication and a public grant will be interpreted in favor of the grantor."[15] This would have the effect of strictly limiting the rights of the homestead patentee to those specifically granted by the state land patent. It would call for shifting the burden of proof from the grantor, as in the Northern Pacific deed, to the purchaser of the land, and it could be used to resolve ambiguities and uncertainties against the purchaser and in favor of the state, once again the reverse of the Northern Pacific situation. Even so, it neither authorizes rewriting a public grant nor avoids the necessity of searching the language of the grant in light of circumstances of the parties at the time of the grant to ascertain what was contemplated and intended.

Certainly, it was intended that the state should have the right to remove "coal, oil, oil shale, gas, phosphate, sodium, and other mineral deposits." But the lack of any differentiation between coal and oil, etc., suggests an absence of any contemplation of strip-mining. And, certainly, it was contemplated that the purchaser would conduct farming and ranching operations on his homestead, and there is nothing to suggest that the state and the homesteader conceived that the homestead might be largely destroyed by strip mining one of the state's reserved minerals.

STRIP-MINING ON HOMESTEADED LAND

The federal government owns most of the coal beneath the ranches in eastern Montana, and the division of ownership of the surface and the minerals parallels the Montana land patents. The land has been homesteaded under the following federal statutes:

> All entries made and patents issued under [stock raising homesteads] shall be subject to and contain a reservation to the United States of all the coal and other minerals in the lands so entered and patented, together with the right to prospect for, mine, and remove the same. . . . Any person qualified to locate and enter the coal or other mineral deposits, or having the right to mine and remove the same under the laws of the United States, shall have the right at all times to enter upon the lands . . . for the purpose of prospecting . . . and shall compensate the entryman or patentee for all damages to the crops on such lands by reason of such prospecting. Any person who has acquired from the United States the coal or other mineral deposits in any such land, or the right to mine and remove the same, may re-enter and occupy so much of the surface thereof as may be required for all purposes reasonably incident to the mining or removal of the coal or other minerals, first, upon securing the written consent or waiver of the homestead entryman or patentee; second, upon payment of the damages to crops or other tangible improvements to the owner thereof, where agreement may be had as to the amount thereof; or, third, in lieu of either of the foregoing provisions, upon the execution of a good and sufficient bond or undertaking to the United States for the use and benefit of the entryman or owner of the land, to secure the payment of such damages to the crops or tangible improvements of the entryman or owner, as may be determined and fixed in an action brought upon the bond or undertaking in a court of competent jurisdiction. . . .[16]

> Upon satisfactory proof of full compliance with the [several homestead, desert land entry, and stock-raising homestead laws] the entryman shall be entitled to a patent . . . which patent shall contain a reservation to the United States of all the coal in the lands so patented, together with the right to prospect for, mine, and remove the same. . . . [The language continues, reading nearly identi-

cally to the 1916 statute quoted above, authorizing licensees of the United States to enter to prospect and to mine, and to occupy so much of the surface as may be required, subject to payment of damages or the giving of a bond to secure damages ascertained by a court.][17]

In 1949 Congress foresaw the probability of strip-mining on homesteaded land and provided that a person seeking the minerals by such a method must, in addition to paying for damages to crops and improvements,

> . . . be liable for any damage that may be caused to the value of the land for grazing by such prospecting for, mining, or removal of mineral.[18]

This law simply determines what the damages will be if federal coal is strip mined under homesteaded land. As it is written, it does not and could not confer the right upon the United States or its licensees to strip mine previously homesteaded land. That is because the rights of the United States and of the homesteaders were established when the land was homesteaded and the United States issued a patent (i.e., deeded the land). Because this statute, subsequently enacted to nearly all the homestead patents in eastern Montana, does not purport to be an exercise of the power of eminent domain (to take private property for a public use on payment of just compensation) the property rights created by the homestead patents are not affected.

There still remains the problem of determining whether the United States, under the quoted laws enacted from 1910 to 1916, reserved not only the coal and the right to mine it but also the right to strip mine it. The process of making this determination is essentially the same as the process used in connection with the Northern Pacific deeds and the Montana land patents. Once again there is no language that authorizes or even refers to strip-mining.

There are some considerations and circumstances that lead toward the conclusion that strip-mining is permissible under these laws. It was certainly a known technology by 1910 and was practiced in states east of the Mississippi; the land patented under the homestead laws was sold to settlers for a nominal price and so the doctrine that in the case of public grants, the grant will be interpreted in favor of the grantor, may obtain the additional force of the appearance of fairness; the laws contain no indication that the United States or its licensees should be precluded from using developing technology in exercising their right of access to the coal; and the homesteaders took the surface land with clear notice that the United States had reserved the coal and the right to mine it.

On the other hand, strip-mining was not being practiced in the West during the period in question, and it scarcely could have been contemplated by the homesteaders. It is doubful that Congress, when it encouraged homesteaders to move West with their families and belongings to settle the public domain, intended that at some time in the future the developed and operating homesteads would be destroyed by ravaging the grazing and farming lands to recover the coal. It is even more doubtful that the settlers came West with that understanding.

These are some of the considerations that will probably be used in making the determination. Undoubtedly, such a determination will be forthcoming, but as of now there is no court case involving federally reserved minerals under homesteaded lands.

Deep mining of coal by shafts and tunnels is, of course, permissible in these lands where the ownership of the surface and of the minerals has been divided. Future court decisions may determine that strip-mining is also permissible on some or all of the lands affected by divided ownership. If the mineral owner is denied by the courts the right to strip mine pursuant to his reservation of mineral rights, he still has the alternative of attempting a contractual solution: trying to purchase easements for strip-mining from the landowner, or offering to purchase the surface ownership.

REFERENCES AND NOTES

1. R.C.M. (1947) sec. 93-9902.
2. Sec. 1, ch. 216, Laws of 1961.
3. R.C.M. (1947) secs. 93-9905(2) and 93-9911(3); Montana Power Co. v. Bokma, 153 Mont. 390, 399-400, 457 P. 2d 769 (1969).
4. H.B. 238, 43d Legisl. Assembly, 1973, sec. 1.
5. H.B. 238, 43d Legisl. Assembly, 1973, sec. 2.
6. 72 Atl. 2d 568 (Pa. 1950).
7. 89 Atl. 2d 508 (Pa. 1952).
8. 97 Atl. 2d 825 (Pa. 1953).
9. 102 Atl. 2d 893 (Pa. 1954).
10. 170 Atl. 2d 97 (Pa. 1961).
11. 176 Atl. 2d 400 (Pa. 1962).
12. 185 Atl. 2d 573 (Pa. 1962).
13. 191 Atl. 2d 830 (Pa. 1963).
14. 266 Atl. 2d 259 (Pa. 1970).
15. 1 Am. Law of Mining, sec. 3.42.
16. 43 U.S.C. sec. 299 (1916).
17. 30 U.S.C. sec. 85 (1910).
18. 30 U.S.C. sec. 54 (1949).

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Legal Aspects of Use of the Underground

By definition, the optimum utilization of underground space is a problem in resource allocation. Underground space, although not considered a scarce resource, historically, can now be properly regarded as a potentially scarce resource as competing claims for the space intensify. It does not follow, however, that this competition is a critical problem requiring comprehensive federal or state allocation. Rather, a more precise classification is now needed of the types of underground conflicts so that these can be better assessed in the context of current resource allocation institutions and needed reforms can be more intelligently discussed. For example, protection of underground sources of water is one aspect of the broader problem of regulating urban land development to avoid gross externalities. No single institutional structure or allocation priority seems necessary to promote the optimum use of the underground space. At present, the best policy is a conscious use and selective reform of the full range of allocation mechanisms from a minimally restricted free market to government ownership of the underground. This paper will explore two specific questions of current importance: (1) When should the legal system provide greater incentives than it now does to encourage use of the underground? It will focus on the problem of locating transmission lines underground and the multiple use of utility corridors. (2) When should the legal system restrict or evaluate more carefully the use of the underground? The focus here will be on the problem of deep-well injection.

OWNERSHIP OF THE UNDERGROUND

The underground, as deep as it has been used, has historically been subject to private ownership. Assignment of the surface among various individuals has determined the ownership of the underground. Valuable resources of a fugitive nature in the soil are subject to ownership by the surface owner under the law of capture. However, it has been suggested recently that the underground space should be classified with the historic common property resources, air and water.[1] The consequence of the classification would be that private claims would, in many instances, be subordinated to public rights.[2] Of course, all private ownership is subject to restriction by the exercise of the state's sovereign power (the police power). However, the extent of the constitutionally permissible restriction is greater in the case of water and air, in part, because the owner had long been on notice of the public claims. But, the analogy between underground space and air and water is not, in my opinion, a fruitful one. The technical problems inherent in the division of air and water among competing claimants are not present in the division of underground space. This difference in large part explains the traditional Roman law doctrines that the air and water are not capable of private ownership; these doctrines have formed the basis for the modern principle that air and water are subject to public rights to a greater extent than is the land surface. Beyond the absence of substantial division problems, there is a positive advantage to a system of private ownership of the underground. In many cases underground use should be encouraged to protect amenity values on the surface and a private property regime will encourage the efficient use of resources. Thus, use of the underground should take place within a private property rights regime, unless there is a compelling need for government regulation or ownership.

RATIONALE FOR PUBLIC INTERVENTION

For a property regime to produce an efficient allocation of resources, it must be free of technical defects that economists call market failures. For example, many of these failures result from an inadequate definition of property rights.[3] When property rights are inadequately defined, incentives to overuse a resource may exist because no restraints exist on the power of a user to shift the external costs of a decision to others, or socially desirable uses may be deterred. We shall therefore consider here the major market failures that occur in the use of underground space.

Intervention in the operation of the market can be justified for the following reasons:

1. Resources may be withdrawn because of a collective decision that they have a high but intangible value, and the large number of those who value the resources will prevent the organization of a market to preserve them. This situation would primarily apply to unique natural phenomena such as caverns.

2. Existing users are imposing costs on third parties who are not part of the decision-making calculus; thus it is arguable that resources are being allocated inefficiently. This is, of course, the problem of external diseconomies familiar in the literature of welfare economics. In many cases, existing legal institutions, such as the law of contracts, nuisance, or rights incident to ownership of land such as lateral and subjacent support, are adequate to compel the internalization of diseconomies. However, if the external diseconomies are not likely to become known until some future time, or if the impact on third parties is broadly enough diffused so that it is unrealistic to assume that affected persons will invoke existing legal remedies, there is a case for collective intervention. This will generally take the form of advance scrutiny of the projected impact of a proposed activity such as deep-well injection.

3. The optimum use of a resource may be frustrated if private rights are so inadequately defined that an owner is deterred from making use of a resource because he or she is unable to appropriate the benefits of his or her action. This situation is a reverse of the above; here the individual is deterred from acting because the unappropriable external benefits, as opposed to costs, exceed the appropriable gains. The classic example is the law of abandonment in oil and gas. When gas is injected into a subsurface dome or cavity, it could be argued that since the surface owner has relinquished physical control over the gas, it is proper to infer that there was intent to abandon it. The law of property is initially premised on the assumption that ownership stems from actual or constructive possession of the property. A

Kentucky court once held that the injection of gas for storage constituted an abandonment because dominion was lost.[4] This result flies in the face of the actual intention of the owner and in the face of basic geologic knowledge that allows the limits of the storage area to be defined with reasonable precision. Thus, in fact, the surface owner is in "possession" of the gas. Most courts have so held and statutes allow the storage of gas without fear of abandonment, but this is an example of instances where a rule of property could operate to restrict the operation of the market, and no important social policy is furthered by the rule. Thus, reform is in order.

UNDERGROUND PLACEMENT OF TRANSMISSION LINES

Electric utilities are usually deterred from placing transmission lines underground because of the high cost differential between overhead and underground lines, except perhaps in densely populated urban areas. There is some hope that technological advances will close the cost gap, but for the foreseeable future the cost of undergrounding will exceed overhead transmission lines by a differential of as much as ten times. Despite the high cost of undergrounding, it may still be desirable to place lines underground to preserve amenity and scenic values. The problem is to decide the appropriate constraints that should be placed on utility location decision making, and to find a method of equitably apportioning the cost of undergrounding among the beneficiaries of the undergrounding.

Until very recently, utilities had broad discretion to locate transmission line corridors and to decide whether to place the lines above or below ground. In many states utility transmission lines are exempt from local zoning ordinances on the grounds that the state has preempted the field by the creation of a statewide public utility commission.[5] Judicial review of state public utility decisions approving corridor decisions has been limited. Parties challenging a decision refusing to place lines underground face a double presumption that the decision is reasonable. Public utility commissions presume that the utility's initial decision—usually a simple cost comparison—is reasonable, and a court reviewing the administrative proceeding assumes that the commission acted reasonably.[6] State courts have been reluctant to adopt the reasoning of *Scenic Hudson Preservation Conference* v. *FPC*[7] and impose affirmative planning responsibilities on commissions.[8] The high standard that underground advocates have faced is illustrated by the California Public Utilities Commission, which held that a line need not be placed underground unless the deprivation of aesthetic values was such as to shock the conscience of the community.[9] The standard was derived from an opinion of Justice Frankfurter's announcing a standard to determine if a police body search violated a suspect's constitutional right to due process, but is inappropriate to decide how a legitimate public interest in the preservation of aesthetic values shall be weighed. It must be realized, however, that reluctance of commissions to make aesthetic decisions stems from their understandable conclusion that there are no standards to decide if location A is preferable to location B on aesthetic grounds; alternative route proposals merely shift the burdens of overhead lines to another set of property owners or another area. The major constraint, however, is the existing principle of cost allocation. Utilities are regulated monopolies, but they are still charged with being efficient. They must generally serve all who are willing to pay at reasonable rates, and commissions, with their statutory mandate, have striven to achieve the lowest cost service. Thus, commissions have generally refused to mandate undergrounding when only a class would be benefited, often only those in the line of sight of the projected line, on the grounds it would not be fair to pass the increased costs to nonbenefited users by adding the costs to the rate base.[10] Instead, commissions have suggested that the benefited property owners pay the difference between underground and overhead lines.

Although cost differentials suggest that comparatively few lines will be placed underground in the future, two recent developments indicate that more lines will be placed underground than are now being placed, especially in areas of high scenic value. States are now creating agencies to review power plant siting and transmission line locations or delegating expanded powers to public utilities commissions. The net effect of this new legislation is the creation of a clearer legislative mandate that environmental values be given increased weight in the decision-making process. States are also adopting new land-use planning and control legislation.[11] The legislation varies but the Florida Environmental Land and Water Act,[12] I believe, illustrates a future pattern. The statute, among other things, allows the state to designate areas of critical state concern where development will have a critical impact on the state's environmental resources. This legislation may make undergrounding more justifiable because the designation of an area can be interpreted to mean that it is reasonable for a public utility commission or citing agency to find that the benefits of preserving natural beauty through undergrounding are statewide and thus should properly be borne by all the utilities' customers. Thus, passing the costs through the general rate base will no longer be unfair.

Statewide land-use controls will be stimulated if national land-use planning legislation is enacted. The current proposal, S. 268, will condition planning grants on a state either having a structure that permits direct state land-use planning and regulation or provides for implementation by local units with state administrative review and pre-emption.[13]

JOINT USE OF UNDERGROUND FACILITIES

Joint use is hampered both for technical reasons[14] and because the law seldom requires or even encourages it. The major inducement for joint use is the practical reason that utilities rationally prefer to use existing public rights-of-way because the transaction costs are less when utilities negotiate with public entities, compared with private landowners.[15] At present, there are few constitutional constraints on the use of the power of eminent domain by the major users of the underground public utilities. As a result, each utility can use virtually any corridor it chooses and is not obliged to consult with other users to determine if joint use either at present or in the future would be feasible. The major restraint on the use of eminent domain has been the constitutional requirement that the taking be for a public use or purpose. Delegations of power to public utilities and other public entities that use the underground space are likely to meet the most restrictive standard of the public use doctrine—i.e., use by the public—and thus lack of constitutional authority is not a meaningful constraint on the use of the underground.[16] Moreover, each entity generally has a separate enabling statute that authorizes it to take the property necessary to fulfill its purpose, and legislatures have tended to make broad grants of the power so that the presence of constitutional authority generally equals the right to dig.[17] The legislation authorizing the San Francisco Bay Area rapid transit (BART) district is typical. BART has the power "to take any property necessary or convenient to the exercise of the power . . . whether the property is already devoted to the same use or otherwise."[18]

If property is already devoted to a public use (which generally means the public must have an irrevocable right to use it), a utility may be barred from using it on the grounds that it is already devoted to a high public use. This situation may sometimes constrain the use of the underground, especially if it impairs the amenity or ecological value of the land whose condemnation is sought. New Jersey, for example, has placed a higher duty than normally exists on the utility to show that the use is not arbitrary.

The utility must therefore introduce evidence that less environmentally damaging routes are not feasible.[19] Joint use is, in fact, minimally encouraged by the willingness of courts to accommodate joint uses whenever possible and thus to avoid choosing between two or more public uses. For a court to be required to decide the comparative utility of two or more public uses, there must be a conflict. Courts generally avoid finding a conflict if a joint use is technically feasible. For example, the Iowa Supreme Court recently upheld the location of an interstate pipeline across a state highway because the two uses could be accommodated.[20]

ADVANCE REGULATION OF DEEP-WELL INJECTION

Deep-well injection occurs under conditions of uncertainty as to impact of the distribution and effect of wastes into the injection zone. The most dramatic example of potential adverse impacts is the allegation that the injection of poisonous wastes into a 12,000-foot well near Denver caused the first earthquake in 80 years. The case for advance regulation is that the risks of adverse impact are high but the impacts may be widely dispersed and may not occur until some future date. Further, even if the adverse impacts materialize, it will often be difficult to assign liability to injector because there is insufficient evidence to establish cause in fact. Thus, some regulatory agency must undertake the difficult task of estimating the degree and likelihood of future damage and deciding if this present threat requires that the activity be prohibited or, at least, modified. Generally, it will be possible to allow the injection, subject to monitoring studies. However, it is important to have a regulatory mechanism that requires advance disclosure of the proposed injection and of all available information as to possible impact.

Federal agencies are subject to the National Environmental Policy Act (NEPA) of 1969, which requires that an environmental impact statement be filed for all major federal actions. This requirement will apply to most injections undertaken by agencies such as the Atomic Energy Commission. NEPA is a "full disclosure law"[21] and should make rational public consideration of projects such as salt mine disposal of radioactive wastes possible. However, NEPA requires only a careful balancing of environmental and nonenvironmental factors and, as long as the final balancing is not arbitrary, an agency can undertake an activity in the face of the environmental risks it poses. States are adopting little NEPAs, but most states will continue to rely on permit-granting mechanisms to control injections since substantive conditions can be attached to the permit and the federal government currently maintains only indirect control over nonfederally sponsored deep-well injections; however, this may soon change. Federal involvement in control of the underground environment is currently focused on the control of the disposal of hazardous substances. Federal water pollution control policies and regulations have precluded the use of the ocean as a sink and the current Environmental Protection Agency position is that the disposal of hazardous wastes should be regulated; regulation will result in the mandatory use of underground facilities and the costs of waste management control should be borne by those who generate the hazardous wastes. Proposed legislation would establish federal standards to be regulated by the states.

Most state laws are so general that the state must grant a permit for a deep-well system if the applicant can prove the engineering and geological feasibility of the injection. No states have prohibited deep-well disposal, and there are at best vague legal standards as to what constitutes a sound injection. There is a large variation in state regulations that can be held to apply to deep-well development or maintenance. Most states regulate deep-well injection through their general pollution control laws or through laws pertaining to oil and gas operations. For example, Ohio has amended its gas and oil laws to cover injection disposal; but Texas alone has specific legislation regulating deep-wells, and it is not considered substantial. Disposal by means of injection wells is regulated under the Disposal Well Act of 1971[22] and Statewide Oil and Gas Rule 9. According to the Act, an applicant for permission to operate an oil and gas waste injection well must submit, with his application to the Railroad Commission, a letter from the Texas Water Quality Board stating that "no freshwater sands or strata will be endangered if permission is granted."[23] A similar requirement exists for industrial ana municipal waste injection wells. About 70 percent of the saltwater residue from oil drilling is injected into deep wells in Texas. The increased use of deep wells in Texas for oil–brine disposal has primarily occurred because of a Railroad Commission regulation, Statewide Rule 8, that prohibits oil producers from polluting offshore waters and adjacent estuarine areas, as well as use of saltwater disposal pits. Such regulation of surface water pollution is forcing industries to shift to disposal mechanisms such as deep wells when other treatment facilities, necessitated by law, are more expensive. Thus, the administrative content given to the statute will become increasingly important.

Illinois is one state that has begun to tighten its regulations. The Illinois Environmental Protection Agency has the authority to issue permits for the installation and operation of industrial waste disposal systems, pursuant to standards that it sets.[23] To qualify for the permit under previous legislation, the applicant had to submit an "acceptable engineering report on the project and a demonstration that fresh water will not be adversely affected," and the current administrative practice tracks the former statutory standard. State policy in reviewing such applications provided the following:

> It is the intention of this office that the review of a proposed project be rigorous, with the exercise of conservative judgment. This attitude is taken with the thought that pollution of underground potable and fresh waters will undoubtedly represent a long-term damage to a critical natural resource. An industry that plans to utilize the deep-well injection of wastes should expect that the procedures to be followed to obtain the required Sanitary Water Board permit will be more rigorous than for a surface waste-treatment works, where the necessity for corrective measures is more easily observed and accomplished.[23]

In a DuPage County, Illinois, site the former Sanitary Water Board ruled that fracturing of the basal part of the sandstone injection layer would not be permitted. Fracturing could have increased that permeability, thereby making the project more feasible, but doing so also would have created the danger of possible leakage to potable water sources above the injection zone.[24] This practice of fracturing by pumping wastes into wells under very high pressure is one in which companies frequently engage. Fracturing cracks rocks in the well's storage zone, increasing the well's capacity, but it can also crack the shale above, allowing wastes to seep out of the disposal area. Consistent with this policy, Illinois has prohibited the drilling of wells in a 2,500 square mile area around Chicago to protect an underground supply of slightly salty water that might be a future source of drinking water, thus setting an important precedent for the use of the permit power to reserve underground water for future uses.

CONCLUSION

We have made a rather general suggestion of the proper analytical approach to the study of the relation between the legal system and the optimum use of the underground. We have also surveyed some of the current areas of interaction between the law and existing uses of the underground. Our major conclusion is that the laws governing public utilities—a neglected area of legal scholarship since the courts exited from *de novo* review of rates in the 1940s—need to be more closely examined. The power of eminent domain has been so widely granted with so few standards to structure its use, that the advantages of joint use may not be fully realized. The regulatory mandates of state public utility commissions do not encourage the undergrounding of facilities such as transmission lines. Perhaps some form of pre-exercise review, administered by the public utility commission, to ensure that alternatives such as the minimization of surface disruption and the opportunity for joint use have been studied, is in order. State power-plant-siting legislation provides some useful analogies. In addition, the rules of cost allocation for undergrounding need to be re-examined in light of the current societal preference for the benefits of amenity values.

REFERENCES AND NOTES

1. See R. Wright, The Law of Airspace (1968).
2. See 1 Wiel, Water Rights in the Western States, 1–64 (3d ed. 1911) for an excellent discussion of the influence of Roman law on the development of American public rights and on justrifications for the exercise of the police power.
3. See, generally, DeVany, Eckert, Meyers, O'Hara, and Scott, A Property System for Market Allocation of the Electromagnetic Spectrum: A Legal-Economic Engineering Study, 21 Stan. L. Rev. 1499 (1969).
4. Hammonds v. Central Kentucky Natural Gas Co., 255 Ky. 685, 75 S.W. 2d 204 (1934). See 1 H. Williams and C. Meyers, Oil and Gas Law, para. 222 (1959) for a discussion of state legislation. See Ann. Code Maryland § Art. 66C. § 695B (1973) for an example of a specific statute.
5. See, e.g., Consolidated Edison Co. of New York v. Village of Briarcliff Manor, 208 Misc. 295, 144 NYS 2d 379 (1955). The New York Public Service Law Section 125 (F) (McKinney Supp. 1972–73) now expressly pre-empts local regulation of utility lines where a local regulation is found by the Public Service Commission to be "unreasonably restrictive in view of existing technology, or of factors of cost or economics. . . ."
6. In Re Public Service Electric and Gas Company, 35 N.J. 358, 173 A. 2d 233 (1961).
7. 354 F. 2d 608 (2d cir. 1965), *cert. denied* 384 U.S. 941 (1966).
8. In Re Petition of Public Service Electric and Gas Co., 100 N.J. Super. 1, 241 A. 2d 15 (1968).
9. Ligda v. P.G. & E., 48 P.U.C. 3d 209 (1963). See Kouba, Regulating Electric Transmission Lines in California—Insulation from Aesthetic Shock?, 22 Hastings L.J. 587 (1971).

10. See In Re New Hampshire Electric Cooperative Inc., 71 P.U.R. 3d 414 (New Hampshire PUC 1967) and Virginia State Corporation Commission v. Appalachian Power Company, 65 P.U.R. 3d 283 (1966). Re Southern California Edison Company, 94 P.U.R. 3d 150 (1972), refused to require undergrounding of high voltage transmission lines through residential areas in Los Angeles because the cost differential between overhead and underground lines was 1:16. The basic reason for refusing to allow the increase to be spread through the rate base, at an increased cost of 5¢ per month to all users, was that the cost was prohibitive and air and water pollution abatement had a higher priority than an aesthetically pleasing skyline.
11. The New York Public Service Commission has ordered several partial undergroundings after they were given express authority to consider environmental impact. See Jones, An Example of a Regulatory Alternative to Antitrust: New York Utilities in the Early Seventies, 73 Columbia L. Rev. 462, 526–527 (1973).
12. Fla. Stat. § 380.012 *et seq.* (Supp. 1972).
13. See Note, The Land Use Policy and Planning Assistance Act of 1973: Legislating a National Land Use Policy, 41 Geo. Wash. L. Rev. 604, 610–613 (1973).
14. Energy Policy Staff, Office of Science and Technology, Electric Power and the Environment, 22–23 (1970).
15. See 3 Nichols, Eminent Domain, ch. 10 (1965) for a discussion of the right to use the subsurface of highways held by the public under easements.
16. The general rationale is that the public utilities have the power of eminent domain because they are regulated. See In Re Low, 233 N.Y. 334, 135 N.E. 521 rev'd in part 199 App. Div. 738, 192 N.Y.S. 366 (1922) upholding the constitutionality of a legislative grant of eminent domain to a utility for the construction of a subway. See generally 2A Nichols, Eminent Domain para. 7.1 (1970).
17. New Jersey has, however, conditioned a public utility's right to use eminent domain to tunnel to giving notice to the appropriate local government unit having jurisdiction over the project and the state public utility commission. N.J. S. A. para. 48:3:17.7 and 48:21-5.1 (1940).
18. Cal Public Utilities Code § 28953 (1965).
19. Texas Eastern Transmission Corp. v. Wildlife Preserves, Inc., 89 N.J. Super., 213 A. 2d 193 (1965), *affirmed per curiam*, 49 N.J. 403, 230 A. 2d 505 (1967).
20. Mid-America Pipeline Co. v. Iowa State Commerce Comm., 125 N.W. 2d 801 (Iowa, 1964). See also Re Consolidated Edison Company of New York, Inc., case no. 26100 90 P.U.R. 3d 455 (New York Public Service Comm. 1971). (Utility encouraged to cooperate with local officials to minimize noise level resulting from construction of underground line.)
21. Environmental Defense Fund v. Corps of Engineers, 325 F. Supp. 728 (E. D. Ark, 1972) aff'd 470 F. 2d 289 (8th Cir. 1972).
22. Vernons Texas Water Code § § 22.001-23.004.
23. Comment, Water Pollution Control in Texas, 48 Texas L. Rev. 1029, 1095, N. 3 (1970). Ill. Stat. Ann. ch. III 1/2, § 1039 (Supp. 1973).
24. R. Bergstrom, Feasibility of Subsurface Industrial Wastes in Illinois, Illinois State Geological Survey Circular No. 426, p. 2 (1968).
25. *Idem* at 7.

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Planning the Underground Uses

SOME QUESTIONABLE ASSUMPTIONS

As I read the report on which this conference is based,[1] hereafter referred to as the underground report, I must admit that the problems outlined have a mind-boggling quality, although no modern-day increase in the seriousness of the problem is evident. The report indicates that "Progress in the development of rapid subsurface excavation technology, coupled with increased cost of surface construction, makes a greatly amplified use of underground space economical and feasible." Thinking of examples that come particularly from the urban scene, with which I am more familiar, I doubt that even costless excavation would more than marginally affect the total cost of underground development. For example, would the total cost for underground mass transit be much reduced if costless tunneling were possible?

Further, just because we can use underground space does not mean that we should use it. Persons with an engineering orientation have perceptively been criticized by Ozbekian as practicing the "can" implies "ought"[2] school of planning; namely, since we can do something, we should do it.

Consider the report's assertion of costs. Although it may be true that the cost of above-ground construction has increased despite improved technology, the cost of underground construction has also increased to about the same extent, despite advancement in technology.

It appears only that the costs of excavation are somewhat lower, and if space has already been constructed as a necessary by-product of mining, then it is economical, in some cases, to occupy that space.

It may also be true that land costs have increased, so that market forces dictate a more intensive use of land, either below or above the surface, but the direction of those forces is ambiguous. Land costs have probably increased in direct proportion to greater urbanization; with a leveling off of population size[3] and with some evidence that urbanization in the huge metropolitan areas is abating, land costs may level off. Moreover, despite the case made by Soleri[4] for intense development in his cities-within-large-buildings concept, decentralization and reduction of gross intensities in the use of land seem to be, and probably should be, characteristic of a more dominant national policy. In short, if we had considered planning the underground uses 50 years ago, the problem would have been equally mind-boggling; most of the kinds of underground use mentioned in this report have been with us for some time.

HABITATION USE

Even if the numbers and kinds of underground uses were to increase more than incrementally, the prospect of underground habitation increasing significantly seems remote. Few animate things live very far below the surface, and man seldom has done so. Because national defense no longer seems to require it, at the moment below-surface living seems contrary to natural law and is a fit subject only for science fiction. If construction of underground habitats become very inexpensive, one might have to worry about who would occupy the space. Would underground space become the new place for low-income housing, the new ghetto, the new place to hide social problems that remain because of slow income-redistribution policies? Something would have to change dramatically before the elite would choose underground habitation.

DEEP AND WIDE TUNNELING

Underground mass transit is, however, a more realistic possibility. I am generally against fixed-rail mass transit, surface, elevated, or underground. My main objections are the fixed nature of the system, its lack of alternative uses if it does not work, and the high capital costs. If I were a transit czar, for example, I would use the $3 billion or so that it would cost to construct a fixed-rail mass-transit system in Los Angeles to subsidize instead a free, or nearly free, system of buses or similar vehicles running frequently, running everywhere, and running speedily on existing rights-of-way, partly devoted to their exclusive or semiexclusive use.

Suppose, however, that fixed-rail advocates win, as they have in Atlanta, San Francisco, and Washington in recent years, and the alternatives become fixed rail above, at, or below the surface. Clearly, surface or elevated systems are more objectionable on environmental grounds, relocation costs are higher, and separation of indigenous communities is a great problem unless, of course, the lines are placed to run between natural communities, in which case community reinforcement might be a desirable effect. Moreover, surface and above-surface lines cannot be as direct as underground lines because there is always something on the surface that should not be relocated or overflown.

New tunneling technology could also considerably reduce the cost of undergrounding, but that in itself, as I have explained earlier, may not be a sufficient advantage. The new technology might nevertheless be sufficient to spur a change in law if technological advances made deep tunneling a possibility; the change in law would permit costless or virtually costless rights-of-way.

Except for minimal interference with mineral rights in some places, deep tunneling should result in few opportunity costs and little externalization of costs. Even if deep space were used for storage, a sealed transit tube running through the storage area would not take much space. Even under conventional law, the value taken from a landowner for such a deep underground easement would be minimal, but it could be reduced to nil if deep underground space were in the public domain. Should it be?

Professor Wright is able to speak on the subject with considerably more learning than I can,[5] but the analogy, of course, is with above-ground space. Under the Federal Air Commerce Act of 1926,[6] above-ground airspace property rights were made "subject to a public right of freedom of interstate and foreign air navigation." As Wright explains in his book on airspace,[5(p. 208)] the theory behind this law and others limiting property rights in airspace might be in question, but the practical result is that a landowner has paramount property rights in

> (a) what he actually occupies, plus (b) what he needs, in addition, to ensure the enjoyment of that already occupied, plus (c) any other amount which he could possess or might in the future possess and any further amount of space necessary to ensure the enjoyment of that.

Of course, there are some differences between setting a height limit about which public rights to travel are paramount and setting a depth limit. As indicated previously, if any mineral rights were impaired, compensation would probably have to be paid, but that might be expected to be minimal. If the new tunnel led to ground subsidence, any damages to property would have to be compensated; a deep tunnel through rock or encased tunnels would not be likely to raise large risks in that regard. Except in interstate regions, some difficulty might be encountered basing a federal statute that sets a depth limit on the interstate commerce clause of the United States Constitution, which was the basis for federal regulation of air navigation. There is, however, little that the Congress says to be a matter of interstate commerce that a court would hold not to be.[7,8] Moreover, the states have the power to act, just as many of them adopted the Uniform State Law for Aeronautics,[9] which subjects the right of ownership to the right of flight.

There is one further major difference between right of flight and right of underground transit or other usage. Even under a flight pattern of a busy airport, the air above most privately owned land is occupied only a fraction of the time. When underground space is utilized, occupancy remains. The subway tube is still there when the trains are not running. The right of flight probably does not mean that the United States Army can permanently park a blimp above your property without paying compensation, and frequent, low-level flight constitutes a taking of property for which compensation must be paid.[10]

Should the nation pass a law declaring a public right to subterranean transit? To do so would be consistent with the above-surface right of flight pre-emption, but compensation may be required.

If the right to subterranean transit were declared by the federal government, by the states, or by the states under federal inducements,[11,12] there might be some question as to where the depth line should be drawn. Should Congress or a state legislate a fixed line, e.g., 200 feet below the surface? Should the matter be left to an administrative determination, as was the case with the Air Commerce Act's delegation of authority to the Secretary of Commerce, who fixed the flight line at 1,000 feet in congested areas and 500 feet elsewhere, except when landing or taking off[13]? Or should a statute merely set a standard, e.g., the public right begins at a point below which effective possession is no longer possible? These alternatives and others might be an appropriate subject for research.

One might also consider the need for urgency. Some might think that action should now be taken. If deep-tunneling technology is available to one, it is available to all, and the possibility of effective possession of subterranean space might be increasing rapidly. Perhaps if the public does not act soon, it might only be able to acquire a free right of underground transit at a deeper level than is at present possible.

On the other hand, the situation might not be urgent. General height zoning might be an analogy that would suggest no urgency. Just because it is feasible to build 1,500-foot-high skyscrapers, a city can set height limits far below that under its zoning powers. The height limits make effective possession of space at a higher level impossible. Similarly, under uniform depth limits, enacted for the general health, safety, and welfare, reasonable regulations would be possible, although technology makes deeper utilization feasible. The distinction is in the purpose. If the purpose is to limit depths, generally, and the regulation is reasonable, it is valid.[14,15] So, while we are considering such things as a right to underground transit or indeed, even the nationalization of rights in deep space, both of which will probably require compensation, depth zoning could retain the *status quo,* without compensating landowners.

Deep tunneling may provide another benefit—faster mass transit. I understand that acceleration and deceleration can be much swifter without toppling standing travelers if acceleration is downhill and deceleration is uphill. If so, mass transit subterranean lines, aided by deep-tunneling technology, could look like a roller-coaster line, approaching the surface only at the transit stops. The roller-coaster effect would eliminate the need to transport persons vertically, which I assume takes more energy. Of course, at some point, as the line approaches the surface, private property would be taken, and payment for an easement would be required.

If technology permits not only deep tunneling but large tunneling as well, the new technology might also be applied so that mass transit subterranean lines could double as railroad lines. Certainly, the cost of railroad grade crosssings or railroad impairment of other forms of surface transit are now considerable. Environmental annoyances are great. If railroad lines could be put underground, those costs would be eliminated. In addition, using the underground lines for multiple purposes would somewhat reduce objections to a fixed line, because there would be an alternative or additional use if the glowing predictions of passenger usage by mass transit advocates did not prove correct. Perhaps even Personal Rapid Transit (PRT)–i.e., transit vehicles that have small carrying capacities and can be customer programmed for variable destinations[16,17] –could be included in the large tunnels, which might also carry utilities.

HOW MUCH PUBLIC PLANNING AND CONTROL?

Although the competition for underground space may be increasing, it is not as complex as the competition for surface space. The public planning and control system might therefore be relatively nominal.

Until the second decade of the 1900s, public planning and control of land use was nominal. Control and allocation of uses were primarily effected by the market, by private restrictive covenants, and by laws of public and private nuisance, which appeared to be sufficient to handle the situation. If one assumes that below-surface competition for space is no more complex than that for surface space in the early 1900s, perhaps those precomprehensive planning and control techniques would be adequate.

Essentially, the precomprehensive planning system was an *ad hoc* system in which the first user was able to pre-empt others. For example, under some varieties of the law, if a market made a use feasible, even an offensive one, later users could not "come to the nuisance" and then demand its abatement. First in time was first in right, and restrictions could be placed on subsequent use of property by the persons who first owned it.

Would such a system work to adjust competing underground uses? Perhaps so, because a growing group of respectable academics and practitioners suggest that the old system would be even better than our present omnipresent system of controls.[18–20] Professor Tarlock is an expert on these matters.[21]

The basic thesis of these advocates for decontrolling land-use decision making is that the market can operate far more efficiently than can government. Efficiency does not mean, of course, that the market can provide income redistribution, but these advocates would suggest that other forms of income redistribution, such as a negative income tax, can better provide equity. Moreover, it is clear that the public land-use control system has often been used to discriminate against minorities and the poor,[22] so the public land-use allocation system may not have been any better in practice than the market in reallocating wealth.

Indeed, some of the advocates of the market-model school of land-use allocation would even eliminate nuisance law. They would instead prefer a maximally free opportunity for the users of land to bargain to eliminate land-use conflict. As an example, we can take the typical situation of the smelly, smoky factory and the adjacent residential area. Under present law, the factory is regarded as a "baddie," as making an unreasonable use of its property and, perhaps, as, constituting a nuisance. As a result, the neighbors might force abandonment of the factory or require it to clean up. But it might be very much more efficient if the factory continued to be a baddie and bought out the neighbors. This method brings to mind the philosophical question on whether there is any sound when a tree falls in the forest if no one is there to hear it. The factory may be a baddie only because residences are in the neighborhood. In any cosmic scale, the factory and the neighborhood residential uses are equally good or bad. Consequently, the market-model advocates would allow the owners and users of land, who are externalizing costs on others, to bargain and make transfer payments, and the most efficient allocation of the use of land would result from the bargaining to reduce costs.

Some problems occur in the market system. When there are a number of landowners, the transaction costs—the costs of organizing to bargain—are great. Moreover, there is the "free-rider" problem. For example, it may be more efficient for the neighboring residential users in the illustration to buy out the factory than to move themselves to avoid the pollution. Because there are few or no mechanisms to force all the neighbors to participate, some may benefit from the elimination of the factory without paying any of the cost.

If some of these problems could be eliminated, however, the net result would be an allocation of land identical to that if the land were all in one ownership. To illustrate, consider a new town, owned by a new town development corporation. To maximize its return, it will allocate property to uses that minimize externalities. As a result, a new town may be a very much more pleasant place to live, shop, work, and recreate in than a publicly planned community.

MARKET MODEL PLUS ANTIWINDFALL AND WIPEOUTS MECHANISMS

The problem, as I have indicated, is the cost of bargaining and the absence of mechanisms to reduce these costs. The market-model advocates have not done much work on that, but I hope to. My project is Windfalls and Wipeouts: The Quiet Undoing of Land-Use Controls. I assume the continuance of public land-use controls, although the concept could be applied to a market mechanism, in the unlikely event that the market modelers prevail. My proposed research will lead to a review of all the known and mostly embryonic means of making transfer payments to force payment for externalities or recoupment of benefits. I shall consider those devices that are now being used or have been used in the United States and in several English-speaking countries with legal and social systems similar to ours.

Let me give you some examples. Assume that a neighborhood is planned and zoned for single-family uses. A vacant corner looks appealing to an oil company for a filling station. It is appealing in part because the residential planning-zoning makes the land cheaper. In a titanic battle between neighbors and the oil company, with enormous transaction costs, the oil company is successful. The cheap land costs far outweigh the transaction costs to the oil company, even if these transaction costs include considerable expenditures to influence the political process, to bribe local government officials, and the like. Once successful, of course, the externalities to the neighbors from the filling station can be considerable. But having lost the rezoning case, there is very little the neighbors can do about it. Indeed, proper zoning for an oil company may foreclose a nuisance action.[23]

Public decision makers are very much involved. Indeed, similar titanic struggles between existing and proposed discordant landowners may constitute 90 percent of the business of public decision makers. The political action is where public participation is high, and few matters bring out as many voters as a neighborhood rezoning squabble. The sad part is that the public at large has no real concern over the matter. It is essentially a neighborhood dispute, and the public decision makers, exhausted after resolving neighborhood disputes, have no time, energy, or inclination left to do what they are paid to do—settle larger public policy and planning questions.

Under my system, through a variety of techniques to be examined [such as compensable zoning, unearned-increment taxes, and transfer (purchase and sale) of development rights], the oil company would be required to pay off the neighbors by creating a public institution for making transfer payments. Because the oil company would be forced to pay off, it would be much less inclined to seek the rezoning in the first place. The amount of the payment should at least be sufficient to offset the wipeout of the neighbors; if the oil company is still left with a windfall, it might be appropriate to recapture that for the general public.

Consider some other examples more relevant to undergrounding. The City of Santa Monica, on the shore of the Pacific Ocean, is underlain by a huge reservoir of oil; but that oil pool might as well be a pool of salt water, because oil-well drilling is not permitted in Santa Monica. Oil-well drilling is considered a "baddie," a discordant land use that is not tolerated. Under my system, oil-well drilling would be permitted, even in single-family neighborhoods, perhaps on the condition that the operation look, smell, feel, taste, and sound like a single-family residence. In the City of Long Beach, wells have been erected on man-made offshore islands, with the well structures encased to look like apartment buildings, complete with palm trees. The oil companies might want to comply with such a condition anyway, because any diminishment in value of the neighborhood that resulted from the oil-well operation would have to be paid by the oil company. In short, my system approaches that of the market modelers, because if Santa Monica were in one ownership, the owner would maximize his return by permitting oil wells and residential uses, with the discordances between the two minimized so far as was economically dictated.

Consider an example of benefit recapture. A mass transit system is being considered for Los Angeles. It has been considered ever since a very good mass transit system was abandoned, so do not hold your breath expecting a beginning. During the discussion of the proposal, one company offered to build the system without cost,[24] on these three conditions: (1) that it be given the power of eminent domain; (2) that it be given the power to assess specially for benefits received; and (3) that the market be relatively free to set densities along the route.

Let us assume that for cost and environmental reasons the company decides to use undergrounding, particularly now that it is cheaper. Land values are known to rise enormously around transit stops,[25] because the access makes the land attractive for more intensive development. Unaided, of course, the market may be slow in responding. But if a special assessment is levied to pay the cost of the transit system, measured by the benefit received, the special assessment will have all the development-inducing effects that Henry George noted in advocating his site-value tax. As with the land-value tax, a special assessment is typically only on land; so the market, naturally attracted to intensive development, will be reinforced by the special-assessment burden to cause more intensive development to pay the levy. This series of events is one of the best examples in which concepts from land use and local taxation combine to suggest an attractive idea. Of course, the company being given all this power should have to pay damages, if the transit system causes any, to avoid wipeouts.

ABSENCE OF THE AESTHETICS PROBLEM

In some respects, all land-use control can be reduced to a problem of aesthetics. High-income people do not like to live near low-income people; residential occupants do not like to have to look at factories; architectural controls are used so that the brilliant and garish architectural forms do not upset the owners of conventional dwellings. Isn't it basically a matter of aesthetics, which, of course, may be translated into economic terms, that precludes oil companies from taking the oil out of Santa Monica?

If aesthetic considerations are the major reason for land-use controls, we might argue that the need for such controls underground is much reduced. One cannot see through solid matter. The garbage dump may be offensive when located next to a single-family house, but a sewer line passing unobtrusively overhead on a subway displeases hardly anyone. The comparison may not be fair because the aesthetics problem is keenest with respect to habitation. Let me give a different example, although it is unrealistic because, as I stated earlier, I do not think underground habitation is probable. If you lived in an underground unit, with a common wall separating you from a regional sewage-settling tank, which you couldn't hear, see, smell, taste, or feel, wouldn't you concede that its presence would be much less objectionable than if both uses were on the surface? To the extent you are willing to concede that, you must be willing to concede that the needs for controls of underground uses are far less than for surface uses. You might say, "Ah, but I know it's there, and that displeases me." To you, the law might, and probably should say, "That's too bad, but your displeasure is not sufficient to warrant any remedy."

To the extent that the modern evolution of restrictive covenants is based on aesthetics, as is zoning, the need for complicated restrictions governing underground uses is lessened; and much that is in modern-day restrictive covenants is based on aesthetics.

NATIONAL ENVIRONMENTAL POLICY ACT, AN APOLOGETIC FOR A WEAK SYSTEM

Thus far, I have argued for only modest controls of underground uses. You realize that I am not fanatical about decontrolling—I am not of the Chicago School—but you still suspect that there can be no merit in an argument that would have us dump comprehensive planning and controls for underground uses.

Are the National Environmental Policy Act (NEPA)[26] and similar state acts kin to the simplistic system about which I speak? NEPA, after all, is the darling of the environmentalists, the ecological workhorse, the penultimate in modern control of land uses. Yet, as it is in its concern with nuisance, it is overwhelmingly concerned with physical externalities, not with economic and, surely, not with social impacts. Its basic approach is precomprehensive planning as it is with nuisance; rather than uses being considered in accord with a plan, a use is plunked down at a location and examined in relation to its surroundings. As with nuisance law, the *status quo*, especially if it is in the natural rather than the built environment, comes with a first-in-right presumption. True, under NEPA-like laws, the externalities are more sensitively measured than under nuisance law. Once the adverse effects are found under NEPA, however, development is not precluded, as would be the case if the development constituted a nuisance. NEPA does not use a market system to minimize externalities; rather, it uses an information system,[27] because knowledge is supposed to produce good decision making.

I use NEPA, therefore, not to illustrate the merit of a nuisance-law-like approach, but to indicate that this kind of approach is a modern concept.

WHO SHALL PLAN, CONTROL, AND BUILD THE UNDERGROUND USES?

I might have spoken about some of the trends in planning today and examined how they apply to underground uses. Questions such as the need for plan making, the types of planning, the relation between plans and implementation, whether plans have regulatory effects, whether regulations can be combined, and when compensation should be paid are all of immediate importance. The major current controversy, however, is probably the degree to which planning and control should be decentralized.

Now that you have been half persuaded that my suggestions are heretical, let me make some miscellaneous remarks about planning that will confirm the heresy. My chief targets will be regional and state planning and control. Does, or should, that increasingly strong movement have any application to planning the underground uses?

In the United States, planning and control are at present decentralized and fragmented and are dealt with by local government. They may or may not be rationally decentralized, depending on how rationally the local level is organized. I define fragmented planning and control as that designed for a particular purpose or function.

Whether we are moving in a direction of greater or less centralization and fragmentation is uncertain. General and special revenue sharing is a move toward decentralization. It may mean less fragmentation, because categorical grants often become identified with specialized governments and specialized groups of citizen participants. Categorical grants may have stimulated fragmentation in the United States.

The proposed Land-Use Policy and Planning Assistance Act, with its focus on areas of statewide concern, may promote greater centralization at the state and regional level. The Act also encourages less fragmentation because it gives the generalist planner a large new resource base, as did the "701" program, so that the functional planners will have relatively less power. The Act does not set national land-use policy; it was misnamed when it was called the National Land-Use Policy Act.

The Clean Air Amendments of 1970,[28] requiring the preparation of implementation plans to meet federally established ambient air-quality standards, will lead to greater centralization. This is especially true in those areas that must now have plans for the implementation of transportation and land-use control, because conventional air pollution controls will not be adequate to meet air purity standards. Parochial planning will not be able to accomplish the task. EPA can impose its plan of transportation and land-use controls if the states do not; this ability makes for national centralization and potentially substantial federal inroads into local control. The Act relates in a curious way to fragmentation. Rather than leading to comprehensive planning, it gives priority to air pollution planners, as if air pollution were the only thing that mattered. The essential foolishness of this approach is now manifested by EPA, which is threatening all sorts of remedial actions[29] in the hope that Congress will call its bluff and amend the legislation that gives it the power to plan and control transportation and land use in many of the largest, most complex, metropolitan areas.

Finally, almost all new state legislation proposed for land-use control involves greater centralization in state and regional bodies. Most of it also gives a greater role to general, as distinguished from functional, planning.

These developments relating to decentralization and fragmentation of planning and control include little of importance that relates to planning the underground uses. I see no great difference in underground uses that suggests that they should be treated in a more or less centralized manner. I certainly do not think that a specialized, fragmented-planning institution should be created to deal with them.

These new planning developments are not entirely what is needed to deal with the problem at hand; I shall conclude, therefore, by describing a model for planning, which I think should be applied to all uses, including those of the underground.

The first step is to identify socioeconomic-geographic regions in the United States. The second step is to abolish all local governments within those regions. The third step is to recreate counties with boundary lines coincident with the regions. The fourth step is to create boroughs coincident with the urbanized neighborhoods within the region. These neighborhoods may range from 50,000 to 200,000 in population. On completion of these four steps, the nation would be rationally organized for planning.

A business of government is planning; a business of planning is to create a system of governments that can govern. It is inefficient to give stronger planning powers to, and share revenues with, governments that are so irrationally decentralized and fragmented that they cannot govern.

I should point out that for regions within states, there is ample power in the states to reorganize. For interstate regions, powerful federal inducements to encourage interstate compacts will no doubt be needed.

When the reorganization is complete, three things will have been accomplished: regionalization, rational decentralization, and the virtual elimination of fragmentation. Both the county and the borough governments are general purpose entities. In the county area that is not organized into boroughs, although such boroughs should be easy to organize when requested by residents of the area, the county has total power. The boroughs have almost total power within their boundaries, except that the county sets minimum performance standards, raises revenues and distributes them on an equalized basis, and has the power to provide services by contract.

Total power to the boroughs also implies the power to contract among themselves. Funding of borough services will be based on the amount the county would have to spend to perform the services efficiently at the basic minimum standard the county sets. If that standard is met, the borough can use excess funds for higher priority services; the borough will provide for services by contract with the county, with other boroughs, or by itself. Essentially, there will be three competitive purveyors of services, and the most efficient will be utilized. The original definition of the region makes it large enough to handle problems that are truly regional in scope, but several subregional solutions (contracts among boroughs) may be more efficient for other services. The borough will provide its own services where that is most efficient, or where, despite inefficiencies, the neighborhood feels strongly that neighborhood control is more important than efficiency, e.g., in community police services. Note that the responsibility is placed on the borough, regardless of which level provides the services. Note also that the borough is funded at the level needed to provide these services.

Besides constructing the system to encourage regionalism, where that is appropriate, there is one regionalizing concept to be used—the "Golden Rule" that borough officials represent not only those who elect them and who live within borough boundaries but also all those affected by their actions. Unless an action has a favorable impact on all those affected by the action, the borough has no power to act. Under present systems of local government, local government officials act only for the benefit of their own constituents, externalizing costs to and internalizing benefits from the region as they are able. We now sometimes have regional policemen to prevent such acts, but such a system does little to encourage responsibility. The proposed Golden Rule, however, forces local government officials to act in a regionally responsible manner, if they are to act at all.

This Golden Rule concept, policed by standards set by the county to ensure local access to, from, and through each borough, is reinforced by a system of financing that not only encourages regionalism but provides equity. It is responsive to the principle of local or regional wealth distribution set fourth in the *Serrano* and *Hawkins* cases,[30-32] that taxation and services should be equalized within socioeconomic-geographic regions. The wealthy elite could no longer internalize regional benefits and shield themselves from (externalize) regional costs by the simple expedient of walling themselves within a municipal boundary.

Once an area is organized for governance, including planning, control, and public development, it is still necessary to adopt a planning and control system. I have previously suggested[33] a planning system that is a detailed, readable, information system to support *ad hoc* decision making. The control system should be essentially as it now is, modified to include the regional concerns before mentioned and with unitary (one-stop) rather than multiple regulation, on which the anti-windfall-and-wipeout system is overlaid.

REFERENCES AND NOTES

1. National Academy of Sciences, Study Group on the Uses of Underground Space, Report on the Feasibility of a More Coherent National Policy for the Governance of Underground Space (June 1972).
2. Ozbekian, "Can" Implies "Ought," in Planning for Diversity and Choice, S. Anderson ed. 208 (1968).
3. See, generally, the reports of the Commission on Population Growth and the American Future (1972).
4. P. Soleri, The Bridge between Matter and Spirit Is Matter Becoming Spirit (1973).
5. R. Wright, The Law of Airspace (1968).
6. 44 Stat. 568 (1926).
7. For example, loan sharks can be controlled by federal regulations, since Congress found that the sharks are controlled by organized crime, which affects interstate commerce. Perez v. U.S., 402 U.S. 146 (1971).
8. The Civil Rights Act can be applied to restaurants if a substantial portion of the food they serve has moved in commerce, Katzenbach v. McClung, 379 U.S. 294 (1964).
9. 32 Handbook, National Conference of Commissioners on Uniform State Laws 106 (1932) discussed in R. Wright, *supra,* 108, *et seq.*
10. U.S. v. Causby, 328 U.S. 256 (1946).
11. The inducements might be financial; e.g., if the states did not act in a certain way they would lose federal funds. See, e.g., 49 U.S.C. § 1110 (4) requiring localities to restrict the heights of uses near airports to secure federal airport funds.

12. See Federal Highway Beautification Act of 1965, 23 U.S.C. § 131, requiring control of advertising signs on federal aid highways, with loss of aid if not controlled as directed.
13. Currently, the height limit is found in regulations of the Administrator, Federal Aviation Agency, 14 C.F.R. § 91.79. The minimum flight level in congested areas is 1,000 feet above the highest obstacle within a horizontal radius of 2,000 feet.
14. General height zoning around airports is valid. Morse v. San Luis Obispo, 247 Cal. App. 2d 600, 55 Cal. Rep. 710 (1967); Smith v. Santa Barbara, 243 Cal. App. 2d 126, 52 Cal. Rep. 202 (1966).
15. Sneed v. Riverside, 219 Cal. App. 2d 205, Rep. 318 (1963), flight-plan zoning creates a "highway in the sky."
16. Elias, Ward, and Wilson, Personal Rapid Transit, Computerized, in Morgantown, West Virginia, Pt. II, The Computer as the Heart or Personal Rapid Transit, Computers and Automation, June 1972, at 11.
17. Paul S. Gurski and Darwin G. Stuart, Dual-Mode Transportation: A Case Study of Milwaukee, Highway Research Record No. 415, at 4 (1972).
18. Coase, The Problem of Social Cost, 3 J. Law & Econ. 1 (1960).
19. Ellickson, An Alternative to Zoning: Covenants, Nuisance Rules and Fines as Land Use Controls, 40 U. Chi. L. Rev. 681 (1973).
20. B. Seigan, Land-Use Control without Zoning (1971).
21. A.D. Tarlock, Toward a Revised Theory of Zoning, 1972 Land-Use Controls Annual.
22. See, e. g., D. Hagman, Urban Planning and Land Development Control Law, ch. 18 (1971).
23. Robinson Brick Co. v. Luthi, 115 Colo. 196, 169 P. 2d 171 (1946).
24. Cf. Olcott, Innovative Approaches to Urban Transportation Planning, 33 Pub. Adm. Rev. 215, 220 (1973). "Without much question, this problem [financing] is the prime roadblock [to mass transit]."
25. See, e.g., Lee, Analysis of BART Impacts on Bay Area Land Use, Transportation Engineering Journal (May 1972).
26. 42 U.S.C. para. 4321 *et seq.*
27. I hesitate to use the term "system." The NEPA approach is essentially *ad hoc* and not very cost-effective, since each development requires its own environmental impact statement. My preferred approach to planning is *ad hoc* decision making, based on comprehensive information systems, as distinguished from either a master (comprehensive) plan or environmental impact statements. See Muddling Through II, in D. Hagman, Public Planning and Control of Urban and Land Development (1973).
28. 42 U.S.C. § 1857 (1970). On transportation and land-use plans, see 42 U.S.C. § 1857c–5(a) (2) (B).
29. "Life without Cars?" *Time,* June 25, 1973, at 54.
30. The principle, extracted by combining the two cases, is that the quality of public services within a unified socioeconomic-geographic area should not be dependent on wealth (income) of the subareas. Serrano v. Priest, 5 Cal. 3d 584, 96 Cal. Rep. 601, 487 P. 2d. 1241 (1971).
31. See Hagman, Property Tax Reform: Speculations on the Impact of the Serrano Equalization Principle, 1 Real Estate Law J. 115 (1972).
32. Hawkins v. Town of Shaw, 461 F. 2d 1171 (5th Cir. 1972).
33. See *supra,* note 27.

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Economic Trends and Demand for the Development of Underground Space

In making forecasts of the consumption of a particular product, an economist will usually focus on price, income, and population as key explanatory variables. He asks such questions as the following: Do consumers show a considerable, or only a small response as price changes? If price declines by 10 percent, does quantity purchased increase 1 percent, 10 percent, 100 percent? What can we predict about the trend of future prices? If we assume that per capita income increases over time, will there be a corresponding increase in per capita consumption of the product of interest? What can we predict about the rate of increase in per capita income? Finally, a forecast of total output is obtained by multiplying per capita consumption by the forecast level of total population; hence, what are the forecast levels of future population? Employing this framework, an economist musing about underground space use might see little, or at best, only moderate growth in such use.

Because much of the demand for underground space comes from the public sector, it may be somewhat unresponsive to price changes; it is possible that public officials make investment decisions in terms of political impact, without too much concern about price per unit. (But getting more bang for the buck generally has good political impact, so that *some* response to price change can be expected.)

On casual reflection, it seems that many uses of underground space are likely to be income inelastic and show little or no per capita increase with increased income; such a situation is likely for water supply tunnels and sewers. Further, per capita demand for subway tunnels declines as income increases and people switch from mass transit to the automobile.

Finally, increased demand because of population growth is likely to be considerably lower than would have been forecast only a few years ago, as the rate of growth of population continues its precipitous decline.

A first estimate might thus yield a forecast of moderate or even limited growth in underground space use. But a number of countervailing trends are plausible, perhaps even likely, so that a second estimate, which accounted for these trends, would yield a considerably higher forecast.

The countervailing trends include possible marked price declines, the growth in concern about the environment, and some possible changes in the distribution of the urban population. I shall consider each in turn.

PRICE CHANGES

There have been few published analyses of underground construction prices over time. One of the few is a RAND Corporation study by George Hoffman that arrived at some optimistic conclusions about declines in tunneling costs.[1] Hoffman may have been overoptimistic because of some questionable assumptions, but his study might point the way to some useful work.

Hoffman compared costs per mile of urban expressways and underground automobile tunnels over time, using data from *Engineering News-Record.* He found a rise in the former and a fall in the latter and expected these cost trends to continue, with tunnel costs falling below expressway costs in the not-too-distant future. Hence, he suggested the possible construction of a vast subterranean transportation system, consisting of a large number of freeway tunnels and a very large number of underground parking spaces and/or a series of multistory parking garages.

The argument is open to question because the data on expressways included a large number of New York City cases in the later years of the time series, whereas the data on tunnels included New York City cases in the early years of the time series. Because New York City values are probably above average in both applications, results are likely to be biased, i.e., the early period tunnel price and the later period expressway price were both above the United States average, so trend lines would be pulled down for tunnels, up for expressways. In any event, experience in the 10 years since Hoffman published his paper suggests that there was a fair amount of overoptimism in his forecast.

IMPACT OF THE ENVIRONMENT

One of the consequences of the concern with the environment and the effects to improve it should be a considerable increase in the use of underground space. The impact is likely to be quite important over the next 5–10 years and may well extend further into the future. Environmental quality appears to have a high income elasticity, that is, with increasing per capita income, there appears to be increased concern about the environment and an increased willingness to spend money on cleaning it up. Hence, if we assume increased per capita income over time, the environmental movement will possibly have substantial impact for many years to come, although presumably many of the problems will have been considerably ameliorated.

Increased use of underground space will be generated by some likely increases in subway construction associated with action against air pollution, increased sewer construction associated with action against water pollution, and the placing of utility lines underground for aesthetic reasons.

Of course, many environmentalists have an animus against growth and high-population density, and this can lead to constraints on underground space use, as well as to some contradictions in policy. Thus, in many metropolitan areas, concern about suburban growth has led to a moratorium on sewer permits.[2] The Environmental Protection Agency (EPA) developed a sewer grid plan for a prospective grant in Delaware, anticipating future growth; but because the state wants to keep the land in open space, EPA has dropped the plan.[3] A Bureau of Reclamation water diversion tunnel in Colorado for the Frying Pan–Arkansas Project was opposed by environmentalists because it increased the salinity in the Colorado River system.[4] Certainly, the viability of mass transit is reduced if density is restricted; and in view of a simultaneous process from the reverse direction, transportation systems generate high-density development near system nodes (i.e., highway intersections or stations for subway systems). Considerable increases in density near stations have been generated by the subway systems in Montreal, San Francisco, and Washington, D.C.

Despite the occasional contradiction and conflict, a number of recent developments support the inference that environmental cleanup will have substantial impact on underground use. The efforts to allocate Highway Trust Fund money to mass transit use is a case in point. Los Angeles mayor-elect Bradley has pledged a rapid-transit rail system within 4 years.[5] EPA has approved a Dade County, Florida, program for underground sewage disposal and proposed three similar programs in Florida; however, the United States Geological Survey has expressed concern about risks that may be involved in such deep wells.[6] New York City has recently set up a 10-year master program for citywide storm sewer and sanitary sewer construction, with a price tag of $1.5 billion[7]; and the courts have ordered that EPA make available to state and local water pollution programs $11 billion appropriated by Congress for fiscal years 1973 and 1974. Much of the money, of course, will go to sewage-treatment plants, but a considerable portion should be allotted to sewer construction, including some spending on separation of combined storm and sanitary sewers.[8,9]

Spending on separation of combined sewers could be a very large component of tunneling expenditures during the next 10 years or so. Estimated costs for handling the task range from $15 billion for partial separation, to anywhere from $30 to $100 billion for complete separation.[10–12]

In 1970 the National League of Cities and the United States Conference of Mayors conducted a survey of sewage-treatment facility "needs" in 1,105 cities. On the basis of the survey, total urban needs of $33 billion to $37 billion were projected to 1976, with interceptor and storm sewer improvements amounting to about half that total.[13,14] Some estimates based on the survey data appear here as Table 1. Of course, needs are likely to be well above what people would pay for if they bore the cost themselves, but the thrust of water pollution legislation suggests that much of the cost will be borne by the federal government.

As a final item on the impact of the protection of the environment, it may be noted that a number of states and localities now require that electric and telephone lines for new housing be placed underground.[15] Conservationists have long attacked overhead lines as unsightly. The heightened interest in aesthetics coincides with some apparent decline in the cost of underground utility lines relative to that of overhead lines.[16]

TABLE 1 Cost per Capita of Sewage-Treatment Needs, by Region and City Size, 1971-1976[a]

Region and City Size (population in thousands)	Number of Cities in Sample	Average per Capita Costs (dollars)			
		Treatment		Interceptor and Storm Sewer Improvements	Total
		Primary and Secondary	Tertiary		
South					
10-< 50	19	76.01	40.29	128.56	244.86
50-< 100	15	45.34	38.44	57.83	141.61
100-< 250	14	65.91	28.44	35.60	129.95
250-< 1000	9	58.26	22.87	60.06	141.19
Northeast					
10-< 50	29	209.86	29.67	167.72	407.25
50-< 100	22	124.36	23.68	122.24	270.28
100-< 250	9	230.19	52.23	170.03	452.45
250-< 1000	2	167.33	201.58	296.44	665.35
New York City	1	165.23	241.49	38.13	444.85
North central					
10-< 50	36	98.02	42.54	170.82	311.38
50-< 100	16	97.40	32.52	174.50	304.42
100-< 250	17	55.22	16.76	171.40	243.38
West					
10-< 50	23	79.94	10.82	14.30	105.06
50-< 100	20	45.10	58.56	83.21	186.87
100-< 250	8	28.64	25.06	94.26	147.96
250-< 1000	2	95.87	6.18	205.44	307.49

[a]Calculated from data appearing in National League of Cities, statement of Donald G. Alexander before the House Appropriations Committee, May 5, 1971, Appendix A, 1971.

Reproduced from Irving Hoch, *Urban Scale and Environmental Quality*, Commission on Population Growth and the American Future, research reports, Vol. III, Ronald G. Ridker, ed. (1973), Table 26, p. 263.

URBAN POPULATION DISTRIBUTION

A major factor affecting the use of underground space is the distribution of urban population in terms of both population size and density of urban areas.

When cities grow large, they sometimes outgrow their local water supplies and have to import water from distant points, as happened in Los Angeles and in New York City. This importation can entail a considerable amount of tunneling for the conveyance systems.

Population density is an important factor in the economic viability of underground utilities, sewer systems, and underground rail transit. In 1966, the Department of the Interior estimated that for high-voltage transmission lines, undergrounding in congested areas was advantageous. The cost of undergrounding relative to overhead lines was 15 : 1 in rural areas but was approximately equal in congested urban areas. (The rural cost differential has persisted through time, so that some authorities on the subject feel high-voltage lines will have to remain above ground.[17-19])

Paul Downing[20] has estimated sewer costs per capita as a function of population density. In Table 2, a sewer depth of 10 feet, a pipe life of 50 years, and a 5 percent interest rate are assumed. Reductions in cost per capita with density occur because costs per gallon flow per 100 feet decrease as sewer pipe diameter increases and length of sewer pipe per capita decreases.

Costs in Table 2 include all per capita costs of collecting the sewage of a 160-acre area and transporting it to a point on the edge of the area. The additional cost of transporting sewage from this point to the treatment plant also declines as density increases; and, of course, it increases as the distance to the treatment plant increases. The marginal cost of a septic tank is $13.42 per capita per year. Hence, as density increases, there will be a shift from septic tank to sewer, with the changeover point determined where the sum of sewer and treatment cost falls below septic tank costs. Because septic tank effluent may pollute groundwater used as a source for drinking water, an earlier point of changeover to sewers may be warranted. Downing indicates that the actual switch from septic tanks to sewers is most likely to occur at a density of around 16 persons to the acre.[20] Hence, sewers are most liable to be developed where small places,

TABLE 2 Sanitary Sewer Costs at Various Densities of Development (dollars)

Density (people/acre)	Total Sewer Cost for 160-Acre Area	Total Sewer Cost (per capita)	Annual Sewer Costs (per capita/year)
0.4	36,914	576.00	33.60
1.0	40,064	250.40	14.59
4.0	70,920	110.81	6.46
16.0	213,598	83.40	4.86
64.0	215,267	21.02	1.22
128.0	219,370	10.71	0.62
256.0	193,123	4.71	0.27
512.0	222,874	2.72	0.16

Source: Paul B. Downing, *The Economics of Urban Sewage Disposal,* New York, Praeger (1969), Table 13, p. 53.

with concurrent low densities, increase in size, and attendant higher densities make sewers economic.

This inference is supported by estimates of the percent of the population that is served with sewers. As of 1968, 70 percent of the population was connected to sewers,[21] with essentially complete coverage in communities of over 50,000 in population (Table 3).

Estimates of percentage of total U.S. population connected to sewers, by decade, appear in Table 4. A freehand extension of the trend of the data suggests an upper bound of 90 percent around the middle of the next century, consistent with the long-run urbanization of the U.S. population. As suggested earlier, however, we may be moving more quickly to the asymptote as a consequence of anti-pollution activities.

Turning to underground rail transit, for a number of years, transit in general and subways in particular have usually been uneconomical in terms of covering all the costs involved. Most municipal systems operate with a considerable public subsidy. In 1964, Meyer, Kain, and Wohl developed careful estimates of costs per passenger trip for alternative modes, covering the complete trip between home and downtown. Costs are a function of urban density, but even in high-density areas, rail rapid transit is the most economical mode only with very high passenger volumes. Their estimates are exhibited in Figure 1. On the basis of this figure, Meyer, Kain, and Wohl concluded that automobile commutation is as economical as any urban mode

TABLE 3 Estimated Percentage of Population Connected to Sewers, by Population Group, 1968

Community Size	Percentage Connected to Sewers
> 100,000	100
50,000–100,000	100
25,000– 50,000	95
10,000– 25,000	93
5,000– 10,000	90
5,000	50
Rural population not in communities	0[a]

[a]Presumptive estimate.

Estimate from data in U.S. Federal Water Quality Administration, *Municipal Waste Facilities in the United States,* 1968 Inventory, Table 18, p. 34; and U.S. Bureau of the Census, *Census of Population: 1970, Number of Inhabitants,* PC(1)-A1 (1971), Table 7, p. 1-46.

TABLE 4 Percentage of U.S. Population Connected to Sewers, by Decade

Year	Percentage	Year	Percentage
1880	18.9	1930	49.9
1890	25.6	1940	53.3
1900	32.2	1950	53.7
1910	37.4	1960	61.6
1920	44.7	1970	71.2

Sources: U.S. Federal Water Quality Administration, *Municipal Waste Facilities in the United States*, 1968 Inventory, Table 17, p. 34; and U.S. Bureau of the Census, *Census of the Population: 1970, Number of Inhabitants*, PC(1)-A1 (1971), Table 2, p. 1-42.

available when hourly maximum volumes per corridor are below 10,000 trips. From that point on, bus rapid transit is generally cheaper than rail rapid transit until very high traffic volumes are attained.

Rail rapid transit remains economically attractive . . . only where population densities are extremely high, facilities are to be constructed underground, or rail roadbed structures are already on hand and can be regarded as sunk costs. It is therefore significant that most American cities with enough population density to support a rail-transit operation, *or even with prospects of having enough*, usually possess rail transit already.[22] [Italics added for emphasis.]

Because much air pollution is generated by the automobile, it is often argued that the least-cost solution indicated by the market (as well as by Meyer, Kain, and Wohl), ought to be replaced by a modal mix more favorable to mass transit generally and to underground rail transit in particular. It is not at all obvious, however, that subsidy to transit is a particularly good way to respond to automobile air pollution. For example, if one were unhappy about football because its rules led to antisocial behavior, why not change those rules, rather than subsidize baseball? But normative issues aside, it can be predicted that a good deal of subsidized underground transit development will occur in the near future, presumably at densities well below the break-even point.

It is plausible that besides utilities, sewers, and transit, demand for other uses of underground space also increases with urban density, e.g., demand for underground parking, underground concourses, and shopping centers such as those at Rockefeller Center in New York, L'Enfant Plaza in Washington, D.C., and the Place Ville-Marie in Montreal. As density increases, land becomes more valuable and hence will be used more intensively. This will involve utilization of

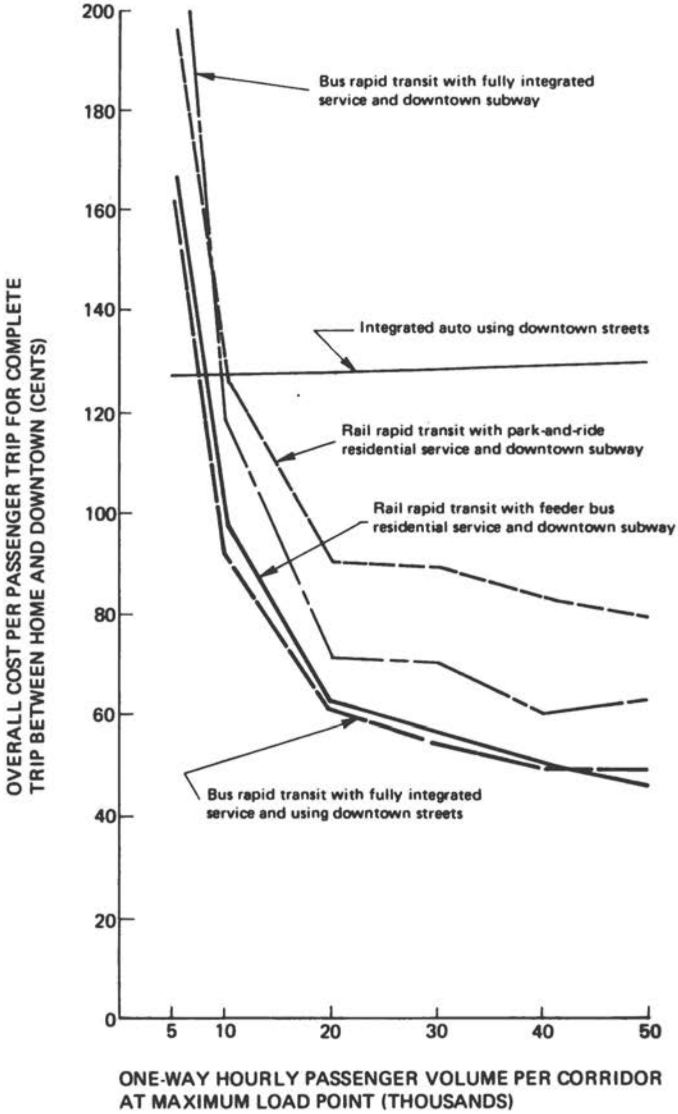

FIGURE 1 Cost comparisons for alternate modes of urban transportation. Overall home–downtown passenger-trip costs for high residential density along corridor, hourly downtown passenger-trip originations of 10 per block at the home end, 10-mile line-haul facility, and 4-mile downtown distribution-system route length. [Source: J. R. Meyer, J. F. Kain, M. Wohl, *The Urban Transportation Problem*, Cambridge, Harvard University Press (1965), Figure 55, p. 304.]

space both above and below ground: high-rise buildings and underground space use. It should be possible to relate expenditures on or quantity of underground space per capita to population density and to derive forecasts based on forecasts of population density. Population density within an urban area tends to decline with distance from the central business district (CBD), as shown in Figure 2.

The relationship has been approximated by the function $D = Ae^{-bk}$, where D is density, k is distance from the center, and A and b, are constants (e is the base of the natural log). In natural logs we have $\log D = a - bk$, where $\log A = a$, a linear relation graphed in Figure 3. As cities increase in size, density tends to increase at every point, as exemplified by Chicago, Detroit, and Pittsburgh (Figure 4).

There is evidence, however, that the increase is inhibited somewhat at the center and intensified at the fringe, explainable as a crowding-pollution effect. With increased crowding and pollution, there is some inhibition of population increase: that is, people tend to avoid the center. Hence, I see the pattern of Figure 5 as a consequence of population growth. This pattern has been obscured by shifts occurring in the basic relation as a consequence of improvements in urban transportation–specifically, the mass use of automobiles and the building of urban freeways and beltways. Because access has been improved to points further out, there has been a relative shift of location outward, as shown in Figure 6.

If we combine growth and shift in the relation,[23] we obtain the results shown in Figure 7. Say density has to be above a certain level, D_1, before underground space use is economic. In Figure 7, such use is no longer economic in time period 2. But what of time period 3? That is, what of the future? It is my impression that much of the impact of the automobile has played itself out, resulting in less

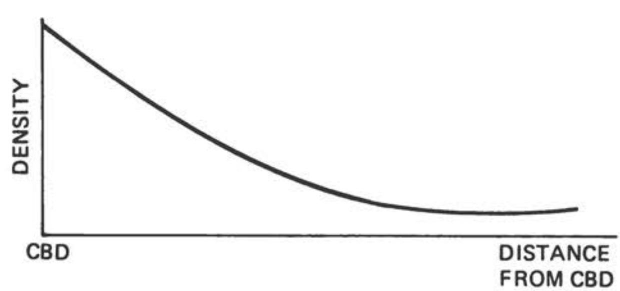

FIGURE 2 Typical urban density relation.

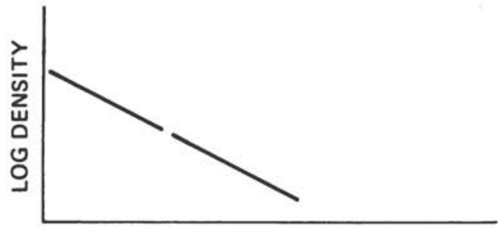

FIGURE 3 Log form of density relation.

shift and more direct growth effect in the future; the changes of Figure 5 will dominate those of Figure 6, perhaps moving many areas back above the hypothesized D_1 level. As noted here at many points, antipollution activity is likely to increase the demand for underground space use, lowering the level of D_1 in the diagram.

Some detailed documentation of these density relations seems worthwhile because of their importance in projecting future urban form and hence underground space use.

A general decline in urban density in the 1960–1970 decade is shown in the lefthand portion of Table 5, which exhibits average urban density for the United States, for major regions of the country, and for population groupings within each major region in 1960 and 1970. The table also shows density changes for suburban fringe areas, and in these areas density generally increased during the decade. The amount of increase will typically be understated, because a number of cities annexed some of their closein, relatively high-density suburbs. Hence, the evidence supports the argument embodied in Figure 6. The regional differences shown in Table 5 can be viewed as a corollary of the argument. Northeastern cities are the oldest, southwestern and western cities the newest, and those in other regions are in between. We can expect the impact of the automobile to be a function of age of city, with newer cities much more auto-oriented than older cities. Investment in roads and buildings is rather long term; it is much more expensive to insert freeways in builtup areas than in sparsely settled areas. Hence, average density will be lowest in the newest areas (southwestern and western) and highest in the oldest (northeastern).

The lower part of Table 5 shows that density generally increases with population size, lending some support to the argument embodied in Figure 5.

Some additional evidence is available on the specific argument of Figure 5, which is that the upward shift of the density relation with increased size is dampened at the center, interpreted as reflecting pollution-crowding effects.

Richard Muth estimated the density function, $D = Ae^{-bk}$, for each of 46 United States cities for 1950.[23] Using Muth's estimates

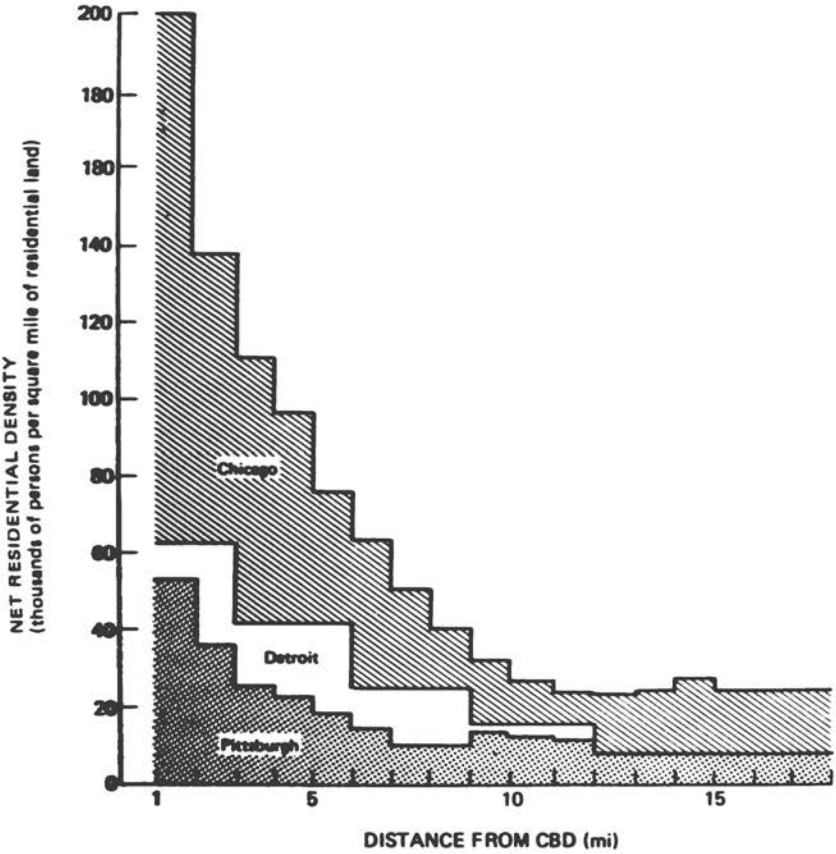

FIGURE 4 Net residential density, by distance from the CBD for Chicago, Detroit, and Pittsburgh. [Source: J. Meyer, J. Kain, and M. Wohl, *The Urban Transportation Problem*, Cambridge, Harvard University Press (1965), Figure 33, p. 207. Their sources were: Chicago–Chicago Area Transportation Study, final report, vol. 2, data projections (July 1960), Table 29, p. 112; Detroit–computed from Detroit Metropolitan Area Traffic Study, Report on the Detroit Area Traffic Study, part 1, *Data Summary and Interpretation*, Lansing, Michigan, Table 8, p. 30, and Table 36, p. 123; Pittsburgh–Pittsburgh Area Transportation Study, final report, vol. 2, *Forecasts and Plans*, Pittsburgh (February 1963).]

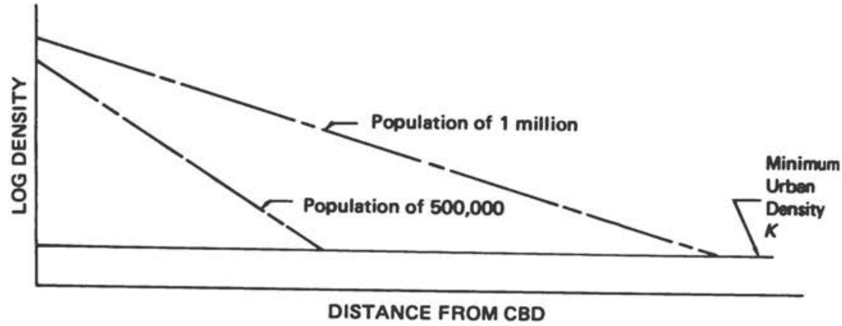

FIGURE 5 Presumed effect of pollution and crowding, given population growth.

as data, I related A and b to urbanized area population size by means of regressions using log values of the variables, plus regional dummy variables. In antilog form, these were the results obtained:

$$A = 6.03\,(1.71^{*} \mid NE)\,(0.73 \mid W)\,P^{0.208^{**}};\ R^2 = 0.26,$$
$$b = 4.54\,(1.49^{**} \mid NE)\,(0.90 \mid W)\,P^{-0.424^{*}};\ R^2 = 0.34,$$

*significant at 0.05 level; **significant at 0.10 level; | indicates a conditional relation.

The A equation is of the form $A = CP^{0.208}$, where $C = 6.03 \times 1.71$ given the northeast region, $C = 6.03 \times 0.73$ given the west, and $C = 6.03 \times 1.00$ given cities in the remainder of the country (the north central and southern regions). The regional effect parallels that noted earlier in Table 5. In the equations for A and b, P refers to urbanized area population in thousands. The hypothesis of equal-

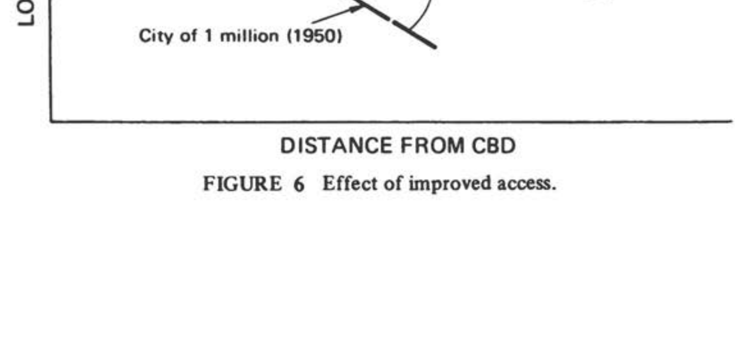

FIGURE 6 Effect of improved access.

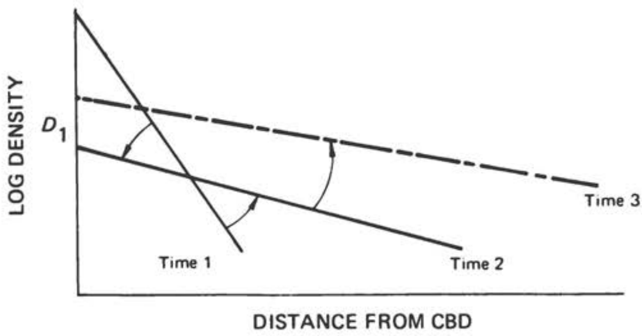

FIGURE 7 Combined effects of access improvement and growth.

ity to one is rejected for the *P* coefficient in the *A* equation, i.e., *A* does *not* increase proportionately with population. In conjunction with the negative coefficient for *P* in the *b* equation, we have algebraic results corresponding to the geometry of Figure 5. The results indicate a less than proportionate increase of density near the center, a greater than proportionate increase at the periphery, as population size increases.

James Barr obtained individual city estimates of *A* and *b* for 1960, using essentially the same sample of Census tracts that Muth had employed for 1950. However, estimates for only 30 cities were obtained because of massive redefinition of Census tracts in the remaining cases.[25] Between 1950 and 1960 there was generally substantial reduction in both *A* and *b*, presumably reflecting the growth in intraurban highways and attendant surburbanization in the period. Comparing Barr's estimates with Muth's, the 1960 value of *A* declined to 0.65 and that of *b* declined to 0.63 of the corresponding 1950 value, on average. These changes correspond to the shift of Figure 6. Regression results using the Barr estimates as data show considerable similarity to the 1950 cases:

$$A = 2.89\,(1.92^{**}\,|\,\mathrm{NE})\,(0.63\,|\,\mathrm{W})\,P^{0.236}\,;\; R^2 = 0.21,$$
$$b = 11.80\,(1.41\,|\,\mathrm{NE})\,(0.69\,|\,\mathrm{W})\,P^{0.616^{*}};\; R^2 = 0.34.$$

The hypothesis that the coefficient of *P* equals one in the *A* equation is again rejected. The coefficient of *P* is again negative and statistically significant in the *b* equation, so that a flattening out of the density relation again emerges.

Figure 8 exhibits intraurban density patterns for six cities in

TABLE 5 Average Density for Urbanized Areas, Their Major Central Cities, and Their Suburban Fringe Areas, 1960 and 1970

Region and Population Size of Urbanized Areas (thousands)[a]	Average Density (population per square mile): Urbanized Areas 1970	Urbanized Areas 1960	Major Central Cities[b] 1970	Major Central Cities[b] 1960	Surburban Fringe Areas 1970	Surburban Fringe Areas 1960	Number of Cases[c]
Regional Averages							
United States	2815.6	3306.1	4555.4	5301.8	1967.4	1963.0	206[d]
Northeast	3316.4	3620.8	7563.0	8096.0	2216.2	2212.0	44
Southeast and north central	2722.5	3345.1	3986.3	4929.2	1786.1	1910.6	111
Southwest and west	2586.4	2949.9	3199.3	3738.3	2150.5	1860.2	51[d]
Regional and Population Size Averages							
United States							
New York City	6683.0	7512.0	26,343.0	25,966.0	3580.0	3541.0	1
2,500–10,000	4808.5	5117.2	12,836.0	13,435.0	3514.8	3383.0	6
1,000–2,500	3445.0	3852.1	7,045.1	7,654.5	2679.1	2660.9	18
250–1,000	2829.1	3210.6	4,410.8	5,184.4	2263.1	1984.3	56
0–250	2592.4	3164.7	3,689.9	4,474.7	1630.6	1756.4	125
Northeast							
New York City	6683.0	7512.0	26,343.0	25,966.0	3580.0	3541.0	1
2,500–10,000	4670.5	5387.0	14,550.0	15,370.0	3289.0	3572.5	2
1,000–2,500	4575.3	5425.3	11,129.0	12,063.0	3241.3	3501.0	4
250–1,000	3412.9	3488.8	[illegible]	[illegible]	[illegible]		

Southeast and north central							
2,500–10,000	4905.0	5541.5	13,039.5	14,058.0	3220.5	3142.5	2
1,000–2,500	3148.4	3592.8	7,147.5	7,956.4	2425.8	2494.8	8
250–1,000	2705.8	3266.3	3,928.1	4,867.7	1893.7	1983.1	29
0–250	2621.2	3288.3	3,407.0	4,364.0	1631.8	1782.3	72
Southwest and west							
2,500–10,000	4850.0	4423.0	10,918.5	10,877.0	4035.0	3434.0	2
1,000–2,500	3087.0	3149.0	4,185.8	4,313.0	2642.2	2322.5	6
250–1,000	2651.3	2918.2	2,958.1	3,469.3	2800.3	1851.2	16
0–250	2269.1	2815.3	2,551.2	3,241.1	1492.9	1637.9	27[d]

Source: Averages based on data appearing in U.S. Bureau of the Census, *U.S. Census of Population: 1970, Number of Inhabitants*, final report PC(1)-A1, United States Summary (1971), Table 20.

[a] Regions based on Department of Commerce Classification. East includes New England and Mideast. West includes Rocky Mountain, Far West, and Hawaii. See *Survey of Current Business* (May 1971) p. 20–24.

[b] "Major Central City" consists of *one* city for each urbanized area and is that city having the greatest population if more than one city appears.

[c] Cases limited to urbanized areas with observations in both 1960 and 1970 and with non-zero population in the surburban fringe.

[d] Beaumont, Texas, suburban fringe excluded because 1960 population consisted of three persons, and density of one person per square mile. Hence, one less case was used in obtaining both the 1960 and the 1970 average for the suburban fringe, with 205, 50, and 26 cases, respectively, appearing for the U.S. average, regional average, and regional-population size average.

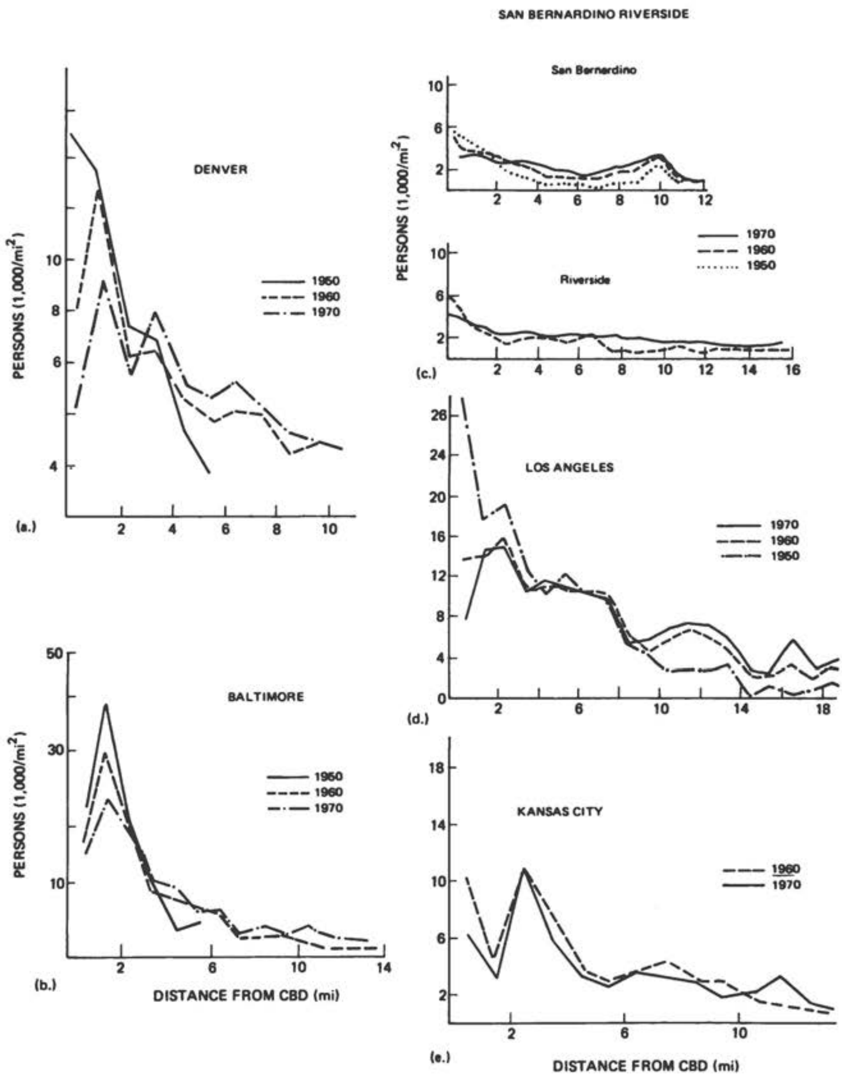

FIGURE 8 Population density profiles: (a) Denver; (b) Baltimore; (c) San Bernardino–Riverside; (d) Los Angeles; (e) Kansas City. [Source: Earth Satellite Corporation, *Land-Use Change and Environmental Quality in Urban Areas,* prepared for the Council on Environmental Quality (1973), pp. 35, 83, 98, 111, 130.]

1960 and 1970 and for three of the cities in 1950. One must exercise care in interpreting these patterns. Thus, relatively low density sometimes occurs near the center, because nonresidential commercial use of land has outbid residential use; if we measured total person hours of activity, rather than persons in residences, per square mile, peaking at the center would be considerably more pronounced. With this caveat, Figure 8 affords some basis for the argument that in the future the growth effect of Figure 5 will dominate the auto-induced shift of Figure 6. For example, compare Los Angeles with Baltimore, noting that the density scale for the latter is on a log basis. In both cases, peak density occurs at 2 miles from the center (reflecting the shift into non-residential land use near the center). Between 1960 and 1970, however, there was little change in this peak for Los Angeles, whereas there was a considerable drop in the peak for Baltimore. Now, Los Angeles is much closer to an asymptotic limit to auto ownership than is Baltimore; that is, the impact of the automobile on density is much closer to completion in the western than in the eastern city. Again, in the case of Riverside, note the general increase in density that occurs between 1960 and 1970 at every distance beyond a mile from the center.

SUMMARY

An increase in future urban density can be predicted because much of the impact of the automobile in reducing density has already had its effect. Further evidence ties the observed flattening of the density relationship (Figure 5) to the effects of air pollution and noise.[26] Environmental cleanup will tend to reverse this effect. Finally, some direct actions taken in support of the environmental cleanup will tend to increase density, e.g., investment in mass transit.

We should be able to incorporate these changes into forecasts of future population levels and densities. Given these forecasts, we should be able to develop derived forecasts of underground space use. The evidence suggests that such forecasts will show relatively pronounced increases in demand for underground space use, in both the short and long term.

REFERENCES AND NOTES

1. George A. Hoffman, Urban Underground Highways and Parking Facilities. Memorandum RM-3680-RC, RAND Corporation (1963).
2. David Broder, *Washington Post*, p. C6 (April 15, 1973).

3. Richard Liroff, Brookings Institution, seminar presentation, A History and Assessment of the National Environmental Protection Act, Resources for the Future (June 20, 1973).
4. Anthony Ripley, Water Diversion Tunnel Is Dedicated in Colorado as Its Opponents Protest, *New York Times*, p. 62 (July 5, 1972).
5. *Wall Street Journal*, p. 1 (May 31, 1973).
6. *Air and Water News*, p. 1 (June 4, 1973).
7. Edward Ranzall, Mayor Offers $1.5 Billion Plan To Correct City Sewer "Failures," *New York Times*, p. 43 (March 1, 1972).
8. *Washington Post*, p. A1 (May 9, 1973).
9. *New York Times*, sec. 4, p. 5 (May 13, 1973).
10. Some general discussion of the combined sewer problem appears in National Academy of Sciences Publication 1400, Waste Management and Control, pp. 155–157, 169–170 (1966).
11. Roger Starr and James Carlson, Pollution and Poverty: The Strategy of Cross-Commitment, *The Public Interest*, pp. 116–122, in particular (Winter, 1968).
12. U.S. Public Health Service Division of Water Supply and Pollution Control, Pollutional Effects of Stormwater Overflows from Combined Sewer Systems (November 1964).
13. *Nation's Cities*, pp. 6, 8–9 (August 1970).
14. National League of Cities, statement of Donald G. Alexander before the House of Representatives Appropriations Committee, May 5, 1971, Appendix A.
15. A regulation states that, from September 1971 on, any new service for a Maryland subdivision must be installed underground, but there are no undergrounding regulations for transmission lines over 33,000 V because of cost and engineering problems. In New York, all utility lines must be underground in new subdivisions, but regulations do not yet apply to new service in old subdivisions. High-voltage transmission lines are not covered. Information from personal communication with the Maryland Public Service Commission, Baltimore, and New York Public Service Commission, Albany (September 1973).
16. L. P. Di Matteo and Mathew W. Stewart, Prepare To Go 100% Underground, *American City*, p. 62 (October 1967).
17. U.S. Department of the Interior, report to the President, Program for Advancing Underground Electric Power Transmission Technology, Washington, p. 13 (1966).
18. Federal Power Commission, The 1970 National Power Survey, Part II, Washington, II-2–64 (1971).
19. Arthur D. Little Corp., Energy Policy Issues for the U.S. during the Seventies, Arlington, Virginia, p. 25 (1971).
20. Paul B. Downing, The Economics of Urban Sewage Disposal, New York, Praeger, pp. 49–54, 100–106 (1969).
21. U.S. Federal Water Quality Administration, Municipal Waste Facilities in the United States, 1968 Inventory, p. 9.
22. J. R. Meyer, J. F. Kain, M. Wohl, The Urban Transportation Problem, Cambridge, Harvard University Press, pp. 303, 364 (1965).
23. This is a modified version of Figure 1 in Richard Muth, Cities and Housing, Chicago, University of Chicago Press, p. 96 (1969).
24. *Ibid.*, Table 1, p. 142.
25. J. L. Barr, Transportation Costs, Rent and Intra Urban Location, Department of Economics, Washington University, pp. 44–45 (1970).
26. For example, see my review of the literature in Urban Scale and Environmental Quality, Commission of Population Growth and the American Future, research reports, Vol. III, Population, Resources and the Environment, Ronald G. Ridker, ed., pp. 251–255, 268–269, in particular (1972).

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Dynamic Analyses of Demands for Underground Construction

In the absence of accounting data that would permit the direct calculation of tunneling expenditures, one must employ economic analysis,[1] cost-engineering techniques,[2] and surveys[3] to estimate indirectly the current level of underground construction. To date, such estimation attempts have followed the lead of the National Academies of Sciences and Engineering, which divide expenditures into two categories: civil and mineral engineering projects.

As can be seen in Table 1, by far the larger share of underground construction takes place in the mineral sector, which accounts for two thirds or more of the perhaps $3.5 billion annual expenditures. Of the civil construction activities, which are largely public, about half involve transportation systems. The remainder involve water and waste disposal facilities, utilities, and a plethora of less extensive but more exotic uses.

The difficulties in obtaining reliable estimates of demands are well documented.[4] In general, they are of two kinds. First, the actual level of activities and the mechanism by which decision makers select an underground alternative in preference to a surface facility are difficult to determine. To get a more precise idea of the amount and cost of current activities by category and the sensitivities of current con-

TABLE 1 Cumulative Estimated Basic and Priority Tunneling Demands in the United States and Associated Probabilities or Realization, 1970-1979 (in $ billions)[a]

Category of User	Lower Bound: OECD-U.S. Demand[b]		Upper Bound: Basic Plus Priority Activities		Realization Probability	Total Demand Estimates	
Construction sector							
Transportation	4.45	(13.3)[c]	24.8	(20.7)	0.5	12.4	(15.9)
Utilities	5.32	(15.8)	43.5	(36.6)	0.75	32.6	(41.6)
Water	1.91	(5.9)	4.0	(3.4)	1.0	4.0	(5.1)
Novel and other	0.12	(0.3)	25.0	(21.0)	0.3	7.5	(9.6)
Total construction	11.8	(35.2)	97.3	(81.7)		56.5	(72.2)
Mineral sector	21.8	(64.8)	21.8	(18.3)	1.0	21.8	(27.8)
Grand total (U.S.)	33.6		119.1			78.3	
Grand total (OECD)	54		262			163	

[a]Assuming current technology, costs, and prices, except for novel categories.
[b]OECD Organization for Economic Cooperation and Development, *Report on Tunneling Demand 1960-1980*, Table 141, p. C-25; reproduced in Newcomb.
[c]All values in parentheses are percentages.

struction decisions to important variables, the U.S. National Committee on Tunneling Technology is attempting to collect benchmark data from key cities and to evaluate construction choices. The Underground Construction Research Council of the American Society of Civil Engineers has considered the problem of accurately accounting for all the costs and benefits of alternative methods when these are options on a given project. This kind of estimation problem involves the assessment of current and static market conditions for the demand and supply of underground facilities.

Although the accounting problems are formidable, a framework for analysis exists in the ordinary economic analysis of capital goods markets. Because the demand for underground space is derived from the demand for some final good, such as energy, or service, such as transportation, current levels of activity are determined at any given time and place by the output of the using industry or the user's budget and the price of tunneling per cubic yard relative to the price of surface facilities. Other things being equal, the quantity of tunneling demanded will increase as price falls. Similarly, the cost per cubic yard of supplying underground construction can be considered a function of the size and number of projects undertaken. For instance, the amount of underground excavation demanded in ferrous or nonferrous ore production, given the demand schedule for steel and durable goods from which it is derived, will be related to the price of underground excavation relative to the price of open pit mining. Yards of earth removed will also be on the schedule relating supply to price based on the engineering costs of firms producing ores for the market. Actual excavation "requirements," i.e., the actual quantity of ore demanded and supplied *at the market price*, represent an equilibrium of these demand and supply schedules. The "going" rate for new metal will be the highest price required to bring out the last increment supplied, i.e., the industry's "marginal cost" of metal ore. The difference between value added in the industry and average costs on all projects will be profits to the sector. Thus the market will integrate needs and preferences of buyers, including their spatial and environmental concerns, into the demand equation and the engineering considerations and constraints of sellers into the supply equation. Finally, it will simultaneously determine quantities taken and the price of ore, i.e., "requirements."

Although we are far from determining the best way to estimate the level of such current construction activities and the mechanism by which buyers and sellers contract for the "right" amount of underground space, we have an acceptable static framework for the task, and we hope that present studies will give good indications of the levels of activity for major categories. In any case, I assume that good results can be obtained and turn to the second, more serious, problem of estimating future demands on the basis of known current information.

The usual way to forecast demands is to project trends by comparing static levels of activity at different points in time and projecting the differences. This method, however, will not explain any shifts in the rate of change. Will there be large upward shifts in the demand for underground space in the near future? If so, what are the variables important for major categories of demand? How are these variables related in the systems generating given mineral or civil construction projects? Answers to these questions require a more dynamic framework for forecasting.

An effective dynamic framework is one that from initial levels of demand can describe how feedbacks and longer range factors affecting demand and supply equations may change trends significantly over time. The problem of dynamic formulation is not unrelated to the problems of data collection, because statistics collected without regard to the mechanisms and variables that cause significant changes in the rate of growth for given categories of demand will not provide a reliable basis for estimates of future demands.

The urban construction sector offers a number of good examples of projects for which demands are sensitive to a host of variables other than the cost of tunneling or the budgets of users. How can one be content to project present rates of growth from sample surveys without wondering about the variables and systems that can produce large changes in usage trends? Certainly, environmental controls, changes in population densities, and national policies on energy conservation will affect future urban tunneling requirements. An adequate answer to questions about future urban tunnel demands involves more than static comparisons of current demands and the projection of past trends. If appropriate dynamic frameworks can be constructed, factors affecting future growth rates can be explicitly modeled and the sensitivity of forecasts subjected to some testing.

This paper explores some important variables for each category of excavation demands and describes the role of dynamic frameworks in the construction of forecasts. The second section gives some examples of how simple dynamic models can be used to test hypotheses about the growth of urban areas. Finally, implications are drawn for those interested in overall tunneling forecasts and in partial studies of individual categories of demand. In the examples the demands for urban transportation and services are emphasized because of the importance of civil engineering projects dealing with urban needs.

DYNAMIC VARIABLES AND MECHANISMS IN THE IMPORTANT CONSTRUCTION MARKETS

Mineral Sector

Underground excavation demands in hard-rock and soft-rock tunneling are directly related to the demand for ores in the basic mineral and energy industries. The final demands from which they are derived are generally well forecast. The comparative static frameworks of these forecasts have not offered serious problems to analysts until recently because the ordinary economic variables (ore price and the level of buyers' outputs) have been sufficient to explain most changes in demand over time. As Pfleider[5] has shown the long-term trends in mining technology away from the use of underground excavation techniques have been so marked that virtually all ferrous and nonferrous metals in the United States today are mined by surface methods. Nonetheless, important strategic reserves of nickel, molybdenum, copper, and zinc within the Unites States must be mined underground if they are to be exploited.

Forecasts of particular energy mineral requirements, on the basis of conventional trend analysis, have been satisfactory for many years. More recently, however, the facts have proved so at variance with these forecasts that it is obvious even to the inexpert that we need more dynamic frameworks for the estimation of how rival fuels will share the market and at what prices. Few experts foresaw the sensitivity of coal production to the changes in safety regulations or in producer and user technologies. Many of these changes have been required by new environmental and social concerns. A few mineral engineers recognized early the problems of underground excavation technology, but their concerns went unheeded. If adequate and more general frameworks for modeling the dynamics of energy markets had existed, their forecast requirements for underground mining would have been better appreciated.

The construction of dynamic models to predict future underground coal mining levels through 1990 can serve to illustrate how long-term future requirements of one energy source might be estimated in competition with other energy sources for the market. Assume first that one can define explicitly all important variables, how they influence usage rates for fuels over time, and how these relations come together in a complete market supply system.

Consider then the static coal market, with demand and supply equations as depicted above. Economic studies of the past behavior of this market permit reasonable values to be set for the static state variables. These are the elasticity of coal demand, the elasticity of coal supply, and total energy demands for each of the next 15 years.

Similar static market equations can be written for each of the rival fuels. Important additional bits of information are required for a dynamic general market system analysis. These include data on reserves of domestic oil and gas, siting schedules for nonfossil plants and of fossil fuel conversion facilities, including power stations. The manner in which a fuel supply adjusts to shifts in its demand in each case must also be made explicit. The forecasts for overall energy demands generally agree on annual demands through 1990. The supplies of domestic natural gas and oil are limited, so that setting reserve to production ratios will determine the annual increments of these fuels in given years. The number of nuclear plants sited and the expansions of hydroelectric capacity, possibly through 1990, are known. A long gestation period is required for siting. With these constraints, one can define as an arithmetic residual a fossil fuel gap of about 50–60 quadrillion Btu annually by 1990. This gap must be made up by either imported oil or domestic coal. Thus the upper and lower bounds for both fuels can be set.

To carry the dynamic modeling further in this example, we must define explicitly how the coal market will adjust to certain constraints on the supply of imported oil. For every choice of adjustment mechanism, there will be another model that we can define within the same framework. Each model is a reasonable predictor, depending on assumptions made. The amount of coal mining forecast is therefore not a single-point estimate, but a set of possible points, each with some probability of occurrence. The average or expected value of these possible coal shipments is computable as a statistic. Another such statistic is the variance of possible coal shipments, indicating to some extent how risky is the choice of a given "scenario" in preference to another. Simulation techniques can often narrow these possibilities down to a tractable few. Thus statistics can help one to assess the robustness of his coal-requirements estimate in a given case, and simulation can serve as a means of correcting and revising his estimates.

When simple dynamic models such as this are used to establish statistical estimates for mineral requirements, the most likely shift factors on the demand side are seen to be changes in user technology and changes in mineral trade. Mechanisms that shift the supply relation are primarily changes in producer and transportation technology, discovery, and other factors that influence reserves, their accessibility, or production.

Finally, the amount of underground coal mined must be determined. A submodel comparing underground with surface mining productivities, and knowledge of the costs of safety and environmental control for both technologies, must be determined. Productivities vary for the methods of mining, and safety laws affect surface operators less than underground operators. The spatial characteristics of the fuel markets will determine which United States reserves are the feasible ones. In the West, surface mining will almost always be the only technique available. Sulfur and the other characteristics of coal seams will influence costs and availabilities, and these must be factored into the dynamic model.

On the oil supply side, balance-of-payments restrictions, given world market requirements (quantities and prices), impose constraints. From the scenarios for coal and for various productivity estimates the possible timepaths of underground mineral excavation requirements through 1990 can be generated.

In this dynamic modeling, statistical theory can play several obvious roles. Many of the model parameters may be set statistically. Probability and decision theory play a part in the interpretation of results. Finally, the questions of parameter stability and the property of the estimates derived empirically, compared with those produced by simulation techniques, must be faced.

Civil Construction Sector

For convenience and accuracy it is best to divide public civil construction into urban and exurban construction, including utilities' requirements for underground lines. The exurban demands for highway and water tunnels are major categories of interest. Each is the concern of governmental agencies whose estimates of what public works have a chance of being constructed over the next decade are often useful.

Although demand shifts and many delays can affect these requirements the political process assures a reasonable time for discussion. Thus *ad hoc* adjustments to the annual projects' forecast of agencies appear to be as good a basis as any for the estimation of exurban civil demands.

The same cannot be said of urban demands for transportation, water, waste disposal, or public utilities. For one thing, there are no urban counterparts to the federal agencies concerned about large-diameter hard-rock tunneling common in the exurban sector. Instead, a great variety of offices and commissions participate in the planning or selecting of particular transportation and water systems in the typical city or suburb. Urban plans are notoriously deferrable and free from reports or survey. Finally, the variables and systems generating demands are complex, compared with those in mineral and energy-utilization systems or in transportation between cities.

Nevertheless, urban civil projects offer excellent opportunities for dynamic modeling because of the greater sensitivity of these demands to the future spatial distribution of the city and the city's mode of survival. Although the task is more difficult, it is also more rewarding.

In the search for dynamic models and mechanisms that might adequately represent the viable alternatives for urban transit and waste disposal, a great many variables appear to be influential shift factors for the demand or supply of underground space. In general, these variables will relate to the growth of suburban areas and their spatial restructuring over time. In addition, special variables will be seen to affect demands for alternative transportation modes and the types of water-utilities improvement people will require. Obviously, environmental restrictions are greatly influencing all these demands.

The future spatial distribution of the city is the subject of considerable controversy among experts. The field has yet to be surveyed adequately; however, one summary of the synergism of urban blight good enough to repeat is that of Eli Goldston,[8] who describes how attempts to solve particular problems on a piecemeal basis have encouraged urban blight.

One congressional reaction to the difficulties of establishing governmental policies that are not synergistically counterproductive has been to require broad technology assessments[9] before social legislation. In other cases, congressional reaction has been to favor benign neglect. Dynamic modeling of urban growth is a form of economic and technical assessment that offers an attractive analytical alternative to either descriptive impact statements or neglect.

The variables of importance in such social systems analysis are only now beginning to be recognized. Certainly, the density of urban population and changes in the ratio of central city to total urban population are important measures in estimating the requirements for subways and utilities. The densities of population by income class and the percentage of poor spatially appear to be critically connected with blight. Age of housing in the central city and the total urban stock of old housing are indicators of potential blight. Expenditures on urban services, especially those available to the central population, and city taxes relative to suburban tax rates are important factors in the rate of migration outward.

From the treatment accorded the problem of predicting urban sprawl, it is apparent that different political scientists or geographers will employ these variables differently in their analysis of the city's viability or of its future form. Some will interpret the data to argue for more intervention, others for less. Both answers might be used widely, depending on the city's commercial position or on those responsible for its planning. In any case, there are obviously a number of plausible dynamic frameworks that can be used to model the city's growth, especially its spatial redistribution of population and activities over time.

EXAMPLES OF DYNAMIC MODELS OF URBAN GROWTH

Literary descriptions of urban blight are of interest because they are not bound to explicit formulations and quantitative terms and so can give free reign to describe the complex mechanisms at work over time that determine current urban crises. In "social audit,"[8] Eli Goldston contrasts the pre-World War II ability of United States cities to grow with some logical relation between economic forces, population, and the form of government decision making, with their failure to cope since. Three successive immigrations were well absorbed by growing United States urban centers. The fourth immigration, largely domestic minority groups as opposed to foreign, has not been successfully accommodated:

> Even though this fourth migrant flow is less than 20 percent of the total, it was directed by discriminatory housing practices almost entirely into the central city areas at a time when jobs in private industry were moving to the suburbs. Although the previous urban poor had been different and unskilled, now they also were color-coded. The unskilled jobs were vanishing to the suburbs, and mass transportation didn't connect the ghetto and the jobs.

We experienced something quite unlike that earlier city growth when both new jobs and new homes were found in the city proper. At that time the municipal tax base expanded with new factories, new stores, and new apartment houses. After World War II the cities increasingly were filling up with the disadvantaged and the discriminated against. Municipal growth had, indeed, become cancerous rather than benign. Thus the urban crisis came upon us.

Unfortunately, as a society, we had no apparatus to measure and to analyze this crisis as it developed. Therefore we had no national policy against which individual programs, whether of government or of business, could be tested. Of course, we can look at it the other way—because we had no policy we therefore had no statistics. We measure what we care about. And we do something about things whose dimenisions are understood. As a matter of fact, as we now are beginning to realize, most of our government programs made the growing crisis worse. We gave FHA mortgages mostly in the suburbs. We built highways to facilitate commuting from the suburbs. We permitted welfare differences that encouraged the poor to migrate from the countryside to the cities. Business as well as the other sectors of our society participated as citizens in ignoring the growing problem and tolerating the unsound programs which pushed our central cities into crisis. And business moved plants from the central city to the suburbs, which meant that white residents moved out to follow their jobs, and white, but not black, migrants from the countryside could find homes with easy transportation to work. But it is an exaggeration to say that business was the primary villain. No one in government or in the universities was predicting the coming crisis, and government programs such as urban renewal encouraged what business did by offering incentives to move and by condemning old central-city plants. Our cities may indeed be a pretty awful mess today, but the free enterprise system in itself did not make them what they are; it took a whole series of small and medium-size decisions by government agencies and business firms which did not add up to a big overall wise social decision. Most of the incentives fed into the market by the government induced just the wrong sort of private firm response.[8]

Goldston hypothesizes that the disintegration of the city is really a synergistic effect of many private sector economic decisions and public efforts to ameliorate particular urban conditions. In each public sector program the agents believe they administer a specific treatment for a social ill. But second-order effects may be counterproductive. For instance, the displacement of poor from rural areas is accelerated by the many specific programs subsidizing the urban poor. Programs aimed at assisting the middle-class consumer to purchase durables, and so stimulate new industry investments, subsidizes groups with rising incomes in a way that hastens their outmigration to the suburbs. Urban-renewal programs tend to replace residential buildings and blue-collar industry with office buildings and white-collar services, accelerating unemployment and removing housing in the central city. In this holistic view, the net effects of a specific program are not always clear.

Although urban geographers and economists have been justifiably cautious about modeling of the dynamic mechanisms leading to urban decay, they have recently begun to apply the simple dynamics of macroeconomic models to the problems of blight in interesting ways. Underground services, such as water or mass transit lines, can hardly be unaffected by the redistribution of urban population and the changing character of activities in central places relative to those on the fringe. As population densities change, all utilities' systems are affected.

Those analysts who have long urged governmental agencies to undertake dynamic analyses of rapid excavation demands will be gratified to see social studies undertaken to explain urban change. Two recent economic examples are worthy of note, both supported by the Ford Foundation and the Urban Economics Group at Princeton University and both interdisciplinary.

The first study is reported in a 1971 paper by Professor W. J. Baumol and W. E. Oates of Princeton and E. P. Howrey of the University of Pennsylvania.[10] It employs two simple relations between income and blight that reduce to a single difference equation similar to that of early dynamic macroeconomic models for the economy described by Samuelson.[11] The Baumol group estimates multipliers and depicts an uneasy equilibrium in central city growth. In it, deterioration (D_t) is a function of current income (Y_t) and future income (Y_{t+1}). Blight is measured by the proportion of housing in the core that is considered sub-standard (A_t). Blight increases as urban income falls. Under parameter values reflecting a Keynesian stagnation condition, when current income exceeds equilibrium income, blight increases until average city income falls to some sustainable level. At this level, city revenues and services are unacceptably low. The policy implications drawn depend critically on the assumption that wealthier citizens are motivated toward suburban living more by relative costs than the presence of the poor. Given this assumption, the multipliers for target variables capable of attacking urban blight directly, such as the increase in public-housing expenditures, are offset by the impact of variables that speed the flight of the rich indirectly, such as an increase in urban taxes. The higher the initial level of city income and wealth, the more likely it is that the decision to finance improvements for the poor by progressive taxation will result in immiserizing stagnation or growth in which the population density levels off or rises as average city income falls. In a statistical "test of hypothesis" the authors try to estimate the multiplier parameters empirically from United States data on median future family income (1960 is $t + 1$) as a function of the current proportion of substandard housing units (t is 1950), where the latter is obtained by relating it in turn to current-period family income. "Substandard" housing is defined as 30 years old. The results are:

$$Y_{t+1} = \underset{(58.0)}{4041} - \underset{(10.1)}{2764}\, D_t \qquad R^2 = 0.55$$

$$D_t = \underset{(13.7)}{0.531} - \underset{(8.9)}{60^{-5}}\, Y_t + \underset{(2.4)}{0.053}\, A_t \qquad R^2 = 0.49$$

Solving the system for Y yields:

$$Y_{t+1} = 2573 + 0.2\, Y_t - 146\, A_t.$$

The multipliers are written in terms of the equation parameters and indicate the elasticities of future city income with respect to the fiscal target variables, expenditures on public housing, and changes in taxation. These elasticities show that a small reduction in taxes of $3.50 per capita results in the same increase in median family income of $15.00 as an investment in public housing of $751 per capita.

The results are too fragile to take seriously (see below). However, the logic of the model suggests strongly that outmigration of the richer groups is a key mechanism in blight and that attempts to correlate urban decline statistically with measures of the population's living standard or civic fiscal policies should prove useful.

In 1973, the Princeton group, supported by the Ford Foundation and the National Science Foundation, published the results of a larger modeling effort, by David Bradford and Harry Kelejian, to determine the nature of the outmigration relation hypothesized. In "An Econometric Model of the Flight to the Suburbs,"[12] the investigators tried to test statistically the relation between the rate of outmigration of richer groups to worsening central city income, measures of net fiscal advantage to residents, and measures of cost differentials between city and suburb. Using data from 87 metropolitan areas and from past studies, they base their measure of fiscal advantage on summary statistics of central city budgets for 1957. Their estimate of advantage to the middle and poorer percentiles is a measure of total city expenditures, revenues, and transfers. Their estimate of cost differentials is housing built before 1940 in the central city and suburbs, and median-family-income measures for the urban area and central city are used.

In this case the dynamics of the model are represented simply by fitting a log ratio as a distribution function, $G(F)$:

$$G_i(F) = F_t^a,$$

where F is the fraction of the central city area to total urban area, as defined in the Census, and $G_i(F)$ is the percentage of central city to total urban population for a given income class, i. Thus, the distribution function relates historical concentration in the central city, for each income group from poor to wealthy, to the spatial division of the city between central and fringe places. For each income group, this function is approximated by the exponential in which a_{it} is the parameter of dispersion for the ith income group.

In the empirical portion of the study, regression is used to obtain the coefficients ($C_0, C_1, \ldots, C_n$) associating the fiscal and cost-differential variables mentioned above to the degree of dispersion found in the data, a_{it}, for each income group i:

$$a_{it} = C_{i0} + C_{i1}X_{1t} + C_{i2}X_{2t} + C_{i3}X_{3t-10} + C_{i4}X_{4t-3} + C_{i5}X_{5t}.$$

Here X_1 = the percentage of all housing units in the central city built before 1940

X_2 = the percentage of all housing units in the urbanized area built before 1940

X_3 = the measure of the concentration of the population in the urbanized area in 1950

X_4 = the net fiscal surplus received by a poor family residing in the central city

X_5 = the change in F between 1950 and 1960.

The results for the middle-class population (where the ith interval cumulates the upper half of the income distribution) are given in the study.

For the urban poor, the dispersion parameter coefficients are:

$$a_t = \underset{(5.88)}{0.921} + \underset{(2.64)}{0.553}\, X_{1t} - \underset{(4.43)}{1.085}\, X_{2t} + \underset{(5.33)}{1534}\, X_{3t-10}$$

$$+ \underset{(2.50)}{0.308}\, X_{4t-3} + \underset{(6.37)}{0.911}\, X_{5t}.$$

The signs support well the hypothesis of the authors and confirm a heavy influence on outmigration of the trend in population concentration (X_3) recorded by the previous census. Fair correlation is incidenced by an R^2 of 0.74.

IMPLICATIONS FOR ESTIMATION OF TUNNELING DEMANDS

If the estimates of these studies were more robust, the implications of results for those interested in the statistical estimation of tunneling demands would seem clear. The two studies sampled identify one hypothesis concerning the factors influencing the historical spatial distribution of the city. If the future is consistent with past trends in the change of urban densities, the use of past data can help to forecast one possible scenario for future urban sprawl.

When transportation studies are made on a given city where the hypothesis is thought to hold, the rate of sprawl might be "predicted." A spatial model of city transit systems might then be used to note the effect of sprawl on transit system efficiency. The identification of other hypotheses consistent with the data will yield other scenarios, and these, also through simulation, can yield representative forecasts of efficiency. Two things should be brought to the notice of those concerned with the financing of projects or the design of transit tunnels. If such models are used, the sensitivity of tunnel cost or location parameters to the rate of urban sprawl or of central city contraction can be predicted. In some cities, such as San Francisco, the optimal mass transit routes would not vary much, no matter how the density of the fringe areas changes compared with the urban core. In others, such as Los Angeles, the effect on the optimal routes may be larger as density changes. Revenues and costs may similarly be less sensitive to failures to predict sprawl rates in some cases than in others, and so on. In all these cases one would be in a better position to determine the riskiness of establishing the sort of fixed transportation system implied by an extensive use of underground transit.

Second, the focal agency attempting to forecast tunnel demands could survey cities periodically on the basis of statistical models. They could use census data more analytically to predict the sensitivity of their demand estimates, for major urban categories, to changes in their assumptions about which of the several identified models actually obtains. It may happen that simulation of mass transit systems indicates that, under a wide number of different assumptions, the estimates of passenger miles and demand patterns generated are insensitive under quite contradictory assumptions, and the value of a project can be considered "robust" to criticism. When demand estimates prove very sensitive, however, the probability that projects will go forward might be modified for cities for which the critical assumptions seem realistic.

Successful private sector realty investors have long estimated the sensitivity of large capital investments in central cities. Currently, many of their rules of investment are being disturbed by the rate of change in urban densities, the spatial distribution of income, and so on. Similarly, public urban projects have today come under scrutiny that would have been unquestioned 10 years ago, because it is thought that their values might also be sensitive to urban blight. The fact that such a generalization may be most unfair to the public planner may be lost sight of without explicit modeling of the dynamic sort suggested here. There are several reasons suggesting that this may be the case at least for urban transit.

New urban mass-transportation projects, by providing once and for all a cheap and efficient solution to intracity movement, may restimulate the investment in residential housing and job-creating construction that fortifies rather than depreciates the value forecast for the project. Thus, because the transit system is a major determining factor in the economics of location, it may once again increase the densities of the central city and so determine a change in rate of sprawl forecast. More important, it may be found by modeling alternative views that, even when the hypotheses of declining densities are accepted, the value of a project remains suprisingly high. For instance, because increased flight of middle-class families contracts the area of the central city, lowers densities, and changes the mix of available jobs, it may create enough demand for cross transit from suburbs daily to more than offset the decreases implied by the falling densities of urban areas that initially encouraged the project. If the design of the project and its value were found "robust" under all hypotheses, then the confidence of forecast tunnel mileage would increase accordingly.

Although the first results of pioneering model builders do not satisfy critics, some qualified confidence may be given to estimates when the size of the test statistics given in parentheses under the coefficient estimates indicate, as they do in the Bradford–Kelejian case, that standard errors of forecast are low. A great deal more must, of course, be done in the collection of data by survey and sample. However, even at the present level of model crudity, a considerable amount of speculation about the future of tunneling demands can be intelligently examined by means of simulation techniques. For statistical tests of hypothesis, it is too early to declare whether by this method one can improve the guesses that experts will be asked to make.

REFERENCES AND NOTES

1. NAS–NAE, Rapid Excavation: Significance, Needs, Opportunities, National Academy of Sciences Publication No. 1690, Washington, D.C. (1968).
2. Robert Baker *et al.*, The Use of Underground Space To Achieve National Goals, a report of the Underground Construction Research Council of the ASCE, American Society of Engineers, N.Y. (1972).
3. OECD, Report on Tunneling Demand, Organization for Economic Cooperation and Development, Advisory Conference on Tunneling, Washington, D.C. (1970).
4. Richard Newcomb, Realism in Statistical Demand Forecasting: The Econometric Challenge, Rapid Excavation Tunneling Conference Proceedings, Chicago (1972).
5. E. P. Pfleider, An Overview: NAS–NAE Study on Rapid Excavation, Proceedings of the Tunnel and Shaft Conference of the Society of Mining Engineers, Minneapolis (1968); SME (1970).
6. T. E. Howard, Rapid Excavation, Problems and Progress, Proceedings of the Tunnel and Shaft Conference of the Society of Mining Engineers (1968); SME (1970).
7. Howard L. Hartman ed., Proceedings of the symposium on R/D in Rapid Excavation, Sacramento State College, California (October 1968).
8. Eli Goldston, The Quantification of Concern: Some Aspects of Social Accounting, Carnegie–Mellon University, Pittsburgh, Pa. (1971).
9. V. T. Coates, Examples of Technology Assessments for the Federal Government, discussion paper 208, Program of Policy Studies in Science and Technology, George Washington University, Washington, D.C. (1970).
10. W. E. Oates, I. P. Howrey, and W. J. Baumol, The Analysis of Public Policy in Dynamic Urban Models, *Journal of Political Economy* (January–February 1971).
11. P. A. Samuelson, A Synthesis of the Principle of Acceleration and the Multiplier, reprinted in the Collected Scientific Papers of Paul A. Samuelson, MIT Press (1966).
12. D. Bradford, and H. Kelejian, An Econometric Model of the Flight to the Suburbs, *Journal of Political Economy* (May–June 1973).

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Conservation of Energy by Use of Underground Space

Occasional statements in the technical literature indicate that placing some human activities below ground may result in appreciable savings in energy consumption. Some writers express the opinion that other cost savings also would result, such as less overhead and maintenance, lower insurance rates, a better environment for some activities, and for some an improvement in health.[1-3] On this basis, a preliminary investigation, therefore, was undertaken to identify the policy issues bearing on such use and to collect data to establish the extent to which energy could be conserved.

POLICY CONSIDERATIONS

Public Policy

As a broad generality, public policies are formulations of goals that guide societal decisions. In practice, public policies also constitute a final arbitration and statement of competing value judgments. These individual judgments or policies vary in time and space and with interest groups. Public policies are enunciated in legislative action (statutes), court decisions on competing claims, through administrative procedures, or by the conscious decision of legislators to let precedent stand.[4] Although such policies ordinarily reflect compromise between conflicting value judgments, it is well to remember that public policies stated at different times and on separate, but related subjects, frequently conflict at their interfaces, requiring further arbitration, clarification, and enunciation. Thus, we have a cyclical, dynamic system—democratic, pluralistic, and free enterprise or market dominated—into which to search for existing policies and alternatives that would guide beneficial use of underground space.*

When public policies on use of underground space are developed, they should be developed in a manner to minimize conflicts. For instance, these policies should not be viewed as separable from other major public policies.

ASSUMPTIONS

It is well to remember that assumptions underlie value judgments that guide formation of public policies. Thus it is essential, if we are to suggest a public policy on this matter, that we start by re-examining and questioning our assumptions.

Competent people working in the same field may have different basic assumptions. Since it often is difficult to isolate the assumptions of one's own field, we shall illustrate the fundamental role of assumptions by an example in another area. Here are the basic assumptions given in two recent publications on ecology, both by people of recognized stature; since it is not our field, we shall not attempt to decide which assumption is better. The first is, "We approach this set of problems with an ecologist's basic assumption that it is advantageous to man to keep the environment stable. . . . Stability is an objective because the alternative, progressive degradation of the environment, is unacceptable. . . . Human influences on the total amount of life cause a systemic and predictable degradation of structure."[5] Compare that assumption with this from another recent publication: "Man's bondage to nature does not imply, however, that the quality of human life is linked inexorably to an unchangeable order of things. Human nature and external nature possess multiple potentialities that man can discover and use according to his fancy. . . . The surface of the earth can be profoundly altered without desecrating it or de-

* We acknowledge the assistance of William L. Oakley, U.S. Atomic Energy Commission, in the development of this statement on policy.

creasing its fitness for life. . . ."[6] It is obvious, to us at least, that policies based on these two assumptions would not be similar.

We can start by making explicit some of the conference's assumptions:

1. Technologic improvements will make underground usage more attractive in the future than it is now and will narrow the cost differential significantly between underground construction and surface construction.
2. It is in the national interest to use the underground dimension for societal purposes.
3. Policy guidelines at national levels can be formulated to optimize use of underground space and to reduce to a minimum disputes among claimants for this space.

In this paper we simply note these assumptions without analyzing their validity.

Our assumptions should be set side by side with available data to see if they are supported by facts. If our assumptions are supported by facts, two further policy aspects must be considered. How do the proposed policies interface with other policies? How best to implement them?

Policy Interfaces

One of the "national policy" decisions sometimes used as an example of effective public policy is the Air Commerce Act of 1926, which stated that the United States has "complete and exclusive national sovereignty in the air space" over this country.[7] This policy is diametrically opposed to the older doctrine of common law, that ownership of land carries with it ownership of the overlying airspace to the periphery of our universe. It has been suggested that a similar, sweeping policy could be transferred to use of underground space. Courts have held, however, that even under the Air Commerce Act, the landowner owns at least as much of the airspace above his ground as he can occupy or use in connection with the land.[8] Jack can grow his beanstalk to any height he desires. This is not a severe limitation when we consider the usual dimensions of buildings, even including television towers and skyscrapers, but in the context of usage of subsurface space, the analogy leaves us exactly where we are today.

As noted, public policy that developed at different times and places may result in conflicting policy interfaces. Future policy decisions, such as guidelines for use of subsurface space, should be formulated to reinforce good existing policies and not to create new conflicts. Such formulation would make each policy supportive of the other. Development of such supportive policies may be more effective than starting out anew to develop broad, general guidelines.

As an example, there is a federal policy on conservation of energy, that has been enunciated in the President's Energy Message of April 18, 1973, directing the establishment of an Office of Energy Conservation within the Department of the Interior. Policies for governance of underground space that would encourage its use to conserve energy would support this policy. The objective of this paper is to show that the potential to conserve energy, by greater use of underground space, exists.

Policy Implementation

National policy, even if enunciated at a federal level, can be implemented at state or local levels, as well as at the federal level. Implementation consists of structuring the instruments of governments toward stated policy objectives (in this case, conservation of energy). At all levels this can be done by legislation, economic incentives, standards and codes, zoning regulations, planning, and education.

Economic controls can discourage some uses and encourage others. One familiar form of economic incentive is the use of tax structures. Taxes related to human shelter are structured so as to make home ownership more economically advantageous than renting for many people.[9] This policy of tax subsidy to homeowners is derived from an older tax policy, originally devised "to meet the conditions of organized business, such as merchants and manufacturers. . . ."[10,11] The present tax subsidy to homeowners represents a conscious decision to let it stand.[4]

Other examples of economic incentives to implement public policy involve low-interest loans and depreciation allowances. If use of underground space to conserve energy is to be encouraged, similar allowances could be made to eliminate the difference between underground and surface construction costs. As Charles H. Jacoby has suggested,[12] there might be an "appreciation allowance" for every cubic yard of underground space preserved for use (to cover extra cost). Investment credit allowances have been proposed to encourage exploratory drilling for oil and gas; i.e., the use of underground space to obtain fossil fuel energy. Other more direct government participation to encourage the development of underground space could be a commitment by the government to buy and utilize excavated material in those instances where it is shown that use of such space would conserve energy.

Zoning, similarly, may be used to implement such a national policy. Some shopping centers at present are constructed underground. Others are so fully enclosed that, for all practical purposes, they might as well be underground. One can visualize that local zoning authorities might allow, for example, a shopping center to be constructed in an area advantageous to merchants, if this were done underground with the surface area dedicated to "the highest and best use" for civic purposes, such as a public park in the town or the maintenance of open space or farmland close to urban centers. A cornfield on top of a shopping center could be a valuable asset to the urban area individuals, and merchants.

Long-range planning also can be used in conjunction with other tools of governance, to encourage use of subsurface space for conservation of energy. For instance, in conjunction with construction of subways in urban areas, exits could be planned to make access to below-ground areas attractive to merchants or manufacturers.

ENERGY CONSIDERATIONS*

In this section, three main questions are discussed:

1. Is there a potential for conserving energy by using subsurface space rather than above-ground space?
2. Is there a good data base from which to design heating, cooling, and air-conditioning facilities for underground construction?
3. How much energy could be saved by building underground?

Before people will seriously consider subsurface construction as a viable option, good data must be available in which engineers, architects, and planners have confidence. Furthermore, before time, effort, and inevitably dollars are expended to produce data in an acceptable form, the potential of recovering these costs should be demonstrated; this we hope to do, however tentatively.

*We acknowledge the assistance of Dr. Charles R. Nelson, University of Minnesota, in compiling the data on underground space.

Is there a potential for conserving energy by using subsurface space? The affirmative answer to this question will be illustrated by a number of examples. Energy is required to heat and cool buildings and to control the relative humidity of air, both for comfort and for dry storage of materials. Less energy is required to achieve the same result in an underground facility as in an equivalent facility above ground.

Underground Storage and Refrigeration

Energy can be saved because the temperature underground varies only slightly from the yearly average temperature–mother earth is a marvelous integrator. Hence, less heating in winter and less cooling in summer are required. Subsurface construction avoids direct sun radiation, which, in summer, can contribute significantly to the cooling load.

The surrounding mass acts as a heat sink, making standby refrigeration equipment unnecessary. Cooling plants can be shut down for many days for maintenance and repair, or due to local power failures, without adverse effects to frozen goods. It is reported that in underground cold-storage facilities in Kansas City, for example, the temperature rises typically 1 °F per day after plant shutdown. Similar aboveground facilities rise 1 °F per hour, making standby equipment imperative. The experience of Spacecenter, Inc., which operates similar facilities underground in Kansas City and above ground in St. Paul, Minnesota, is listed in Table 1.[13]

TABLE 1 Cost Comparison of above- and below-Ground Storage and Refrigeration (dollars per foot^2)

Kind of Storage	Installation Costs[a,b]		Operating Costs	
	Above Ground	Underground	Above Ground	Underground
Dry storage	10	2.50	0.03	0.003
Refrigeration	30	8-10	0.12	0.010

[a]Excluding cost of land or underground space.
[b]No standby equipment required underground.

Underground Space in Kansas City (millions of feet^2)

	Total in Kansas City	Spacecenter, Inc.
Already mined	120	7
Mining rate/year	5	0.25
Dry storage and refrigeration	3	1

The operating costs underground, which reflect the energy consumption, are typically one tenth of those for above-ground facilities. In addition, capital outlay is reduced considerably. Energy is required to produce raw materials for the cooling equipment and to manufacture it, so that the smaller plant requirement actually contributes to the conservation of national energy.

Underground Manufacturing

The experience of Brunson Instrument Company,[14] a precision instrument manufacturer, is cited to illustrate many advantages of underground location in addition to the energy saved. These advantages are as follows:

1. *Maintenance* Everything underground is protected from wear and tear of weather extremes–wind, moisture, heat, freezing; no roof or exterior walls to maintain.
2. *Utility savings* Electrical utilities, pipes, sewers, and drains can be either hung from the ceiling or put in shallow ditches; there is no problem of freezing.
3. *Insurance* Fireproofing construction costs are less, and windstorm hazard is nonexistent, making excellent insurance rates available.
4. *Strength* Floor loads are almost unlimited. Heavy machinery does not require elaborate foundation support; e.g., in Kansas City the shale can be loaded to 200 tons per foot^2.
5. *Stability* There is no vibration. Delicate machines and instruments need not be isolated, thus avoiding an expensive and difficult task.
6. *Operating savings* Machines remain accurate for much longer without realignment, due to very stable temperature and humidity conditions.

The greatly reduced energy requirements for an underground plant are illustrated in Table 2.

At full capacity the Brunson Instrument Company will employ 500 people and install more machines. It has been estimated that under these conditions, no more heating equipment will be needed[14] due to the added heat input from people and machines and only two-thirds more air-conditioning plant will be required.

TABLE 2 Cost and Energy Comparisons for a Precision Manufacturing Plant above and below Ground[a]

Item Compared	Above Ground[b] (Estimate)	Underground (Brunson Instrument)
Heating units (Btu/h)	~ 2,000,000	750,000
Refrigeration (tons) for dehumidification	~ 500–700	57
Operating costs (dollars/year)	~50,000–70,000	3,200[c]
Fire insurance (dollars/$1,000)	2.85	0.10

[a]Brunson Instrument Co., conditions: 140,000 ft^2; 125 employees; 77 ft below surface; 54 °F initial rock temperature.
[b]From Faber.[15]
[c]This figure is particularly low since the air-conditioning plant is operated only at night to bring temperature and humidity below that required. Because of the heat capacity of the rock, temperature and relative humidity of the air then slowly rise during the day. This technique reduces the electrical demand factor.

Underground Commerce and Habitation

Neanderthal man lived in caves, not because he was too stupid or too lazy to build a shelter, but for far subtler reasons that only now, as man reaches out beyond the moon, are beginning to dawn on us. A subsurface home is defended easily and can be kept at a pleasant temperature with little expenditure of energy.

Substantial amounts of energy could be saved by greater use of subsurface space for commerce and habitation. Technical changes, however, must be economically and socially sound and must be implemented widely if they are to have a significant impact on energy consumption.

At a recent energy conservation conference, K. J. Saulter[16] stated, "In particular, potential technical developments which reduce the use of fuels in residential and commercial space heating and cooling, and the transportation section are regarded as those with the largest potential payoffs." Of the total United States energy consumption for 1972,[16] 20.4 percent was used for residential and commercial heating and cooling, and 25.1 percent on all transportation. It is interesting to note that at the conference not one mention was made of the potential use of underground space to conserve energy.

What can be done? Where does the energy go? Energy is wasted by unwanted heating or cooling of the surroundings. By reducing heat transferred to and from surroundings, less energy is consumed to maintain the desired conditions. Architects and engineers alike often affirm that it is more economical and as effective to use better insulation than to build underground. The following example will demonstrate that underground structures are far superior from an energy-conservation standpoint.

The equation for heat flow rate is

$$q = UA(t_1 - t_2)$$

or

$$Q = q/A = U(t_1 - t_2),$$

where q = heat flow rate, Btu/h
Q = heat flow rate per unit area, Btu/h/ft^2
U = thermal transmission coefficient, Btu/h/ft^2/°F
A = area through which heat is transferred, ft^2
t_1 = inside temperature, °F
t_2 = outside temperature, °F.

(Note that when t_2 is greater than t_1, i.e., during summer, q is negative; thus heat flowing into a building is considered negative.)

In a given region the temperature difference is determined by weather extremes for above-ground structures. Underground, however, as noted, the temperature remains almost constant at the yearly mean temperature. For example, the temperature 10 feet underground in the Minneapolis area varies from 47 to 51 °F, whereas the daily temperature varies from –30 to 95 °F. Table 3 lists typical thermal-transmission coefficients (U values).[17]

Table 4 gives Q, the heat flow rate per unit area, above and below ground in Minneapolis, for the mean, maximum, and minimum daily temperatures in winter and summer. This shows, for example, that on a cold winter day the heat flow rate per unit will be 5.5 times greater above ground for a wall with 8 inches of insulation (wall 3), and 8.4 times greater for a wall with 4 inches of insulation (wall 2),

TABLE 3 Typical Thermal-Transmission Coefficient *U* Values

Material	*U*
Roof, asphalt plus 1-in. timber	0.45–0.53
Windows, double glazed, 70 percent glass	0.45–0.55
Wall 1, no insulation	0.30–0.45
Wall 2, 4-in. insulation	0.20
Wall 3, 8-in. insulation	0.13
Basement, in contact with soil, no insulation	0.10

TABLE 4 Heat Flow Rate per Unit Area, Q, for Buildings above and below Ground[a]

	Above Ground				Below Ground[b]
	Roof	Wall 1	Wall 2	Wall 3	(t_2 = 50 °F)
Winter (January) mean,[b,c] t_1 = 75°F		t_2 = 10 °F ($t_1 - t_2$) = 65 °F			($t_1 - t_2$) = 25 °F
Q, Btu/h/ft²	29-35	19-29	13.0	8.5	2.5
Ratio Q above/Q below	12-14	8-12	5.2	3.4	
Winter (January) minimum,[d] t_1 = 75 °F		t_2 = −30 °F ($t_1 - t_2$) = 105 °F			($t_1 - t_2$) = 25 °F
Q, Btu/h/ft²	47-56	32-47	21.0	13.7	2.5
Ratio Q above/Q below	19-22	13-19	8.4	5.5	
Summer (July) mean,[e] t_1 = 75 °F		t_2 = 80 °F ($t_1 - t_2$) = −10°F			($t_1 - t_2$) = 25 °F
Q, Btu/h/ft²	−4.5to −5.3	−3.0 to −4.5	− 2.0	− 1.3	2.5
Ratio[f]					
Summer (July) maximum,[e] t_1 = 75 °F		t_2 = 95 °F ($t_1 - t_2$) = −20 °F			($t_1 - t_2$) = 25 °F
Q, Btu/h/ft²	−9.0 to −11.6	−6.0 to −9.0	− 4.0	− 2.6	2.5
Ratio[f]					

[a] Negative sign indicates heat gained.
[b] An inside temperature of t_1 = 75 °F and an underground temperature of t_2 = 50 °F were used throughout.
[c] In the winter or heating cycle, the mean temperature for the full 24-h period averaged over the month was used since buildings must be heated continuously; here t_2 = 10 °F.
[d] A minimum winter temperature of t_2 = −30 °F and a maximum summer temperature of t_2 = 95 °F were used as an example of the maximum heat flow rate conditions. The heating and cooling plant size must be sufficient for these extremes.
[e] During summer the mean temperature during the day was used since buildings need cooling only when the outside temperature exceeds 75 °F; here t_2 = 85 °F.
[f] A ratio Q above/Q below is not listed for summer since above-ground heat flows into a building, while underground heat flows out of it (see text).

compared with an uninsulated wall underground, and *Q* can be 19 to 22 times greater through a roof than underground.

During summer a large amount of heat that must be removed flows into a building above ground, whereas heat flows out of an underground structure, lowering the cooling load. The ratio *Q* above/*Q* below is not given in summer because heat flow underground is out of a building, which is desirable since heat is produced by lights, cooking, machines, and people, whereas heat flow above ground is into a building, which is undesirable as it adds heat to the internal heat load. On a hot summer's day, for example, to maintain an above-ground building (of wall 2 construction) at the same temperature as a similar underground building, (4.0 + 2.5) Btu/h/ft^2 of wall area, plus (9.0 + 2.5) Btu/h/ft^2 of roof area would have to be removed by an air-conditioning plant, assuming the heat loss through the floor to be comparable to that in the underground building.

In no way can improved insulation on an above-ground building begin to compete with subsurface structures from the viewpoint of energy conservation.

IS THERE A GOOD DATA BASE?

There is no good data base. A preliminary search indicated data little better than that available to Neanderthal man. Most engineers and architects confronted with the problem of heating and cooling immediately turn to the American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE)[17] volumes. The 1972 edition of this work consists of four large volumes comprising 2478 pages in all. One half page is devoted to basements, the nearest approach to subsurface space, and begins, "Unfortunately, complete data on ground temperature adjacent to buildings are not available. . . ." Certainly, there are a few reports spread throughout the country that do give some useful information; these should be collected and critically evaluated.

HOW MUCH ENERGY COULD BE SAVED?

If the living quarters of residential units were placed above ground with the accustomed windows and view, with bedrooms and bathrooms along with rooms usually associated with a basement semi-underground, that is, underground but with greater access landscaped into window enclaves, considerable energy could be conserved.

Achenbach,[18] of the National Bureau of Standards, Building Environment Division, has reported the calculated potential cost savings over the next 25 years, if thermal transmission characteristics of new and existing housing units are upgraded. The Bureau predicts that the present 60 million dwelling units will increase to about 100 million if, of the existing dwellings, 3 percent are built and 1 percent are retired each year for 25 years.

If heat transmission characteristics could be reduced by 50 percent in all new buildings and by 10 percent in all existing buildings, savings in energy and cost for the next 25 years would be those shown in Figures 1 and 2. Savings in energy would be in excess of 70×10^{15} Btu, almost equal to the total energy consumed for all purposes in the United States in 1972 (the actual total for 1972 was 71.9×10^{15} Btu).[16] Cost savings totaling $100 billion would accrue at May 1973 fuel prices. Most predictions are that the relative cost of energy will increase substantially in the future so that actual savings could amount to considerably more.

These savings are for dwelling units only and do not include those from subsurface manufacturing and commerce, which also could be very substantial.

As shown in Table 4, heat transmission is reduced most effectively by placing the structure underground; in so doing, reductions by factors of 3 to 8 are easily obtained.

Since energy is required to manufacture goods, the smaller air-conditioning and heating units and vastly reduced amounts of insulation needed in underground buildings represent an additional energy saving. The extra energy required for underground construction, however, must be subtracted from these potential savings. If we assume that technological improvements will significantly narrow the difference in costs between underground and surface construction, the energy conservation becomes proportionately larger.

A well-landscaped residential area, with possibly only one-third the normal above-ground volume of houses visible, would be less cluttered with buildings, creating a feeling of greater outdoor space. Some rooms could extend below the garden or outdoor patio. With imaginative architecture this could be most attractive.

PSYCHOLOGICAL AND HEALTH EFFECTS

The first completely underground elementary school in the United States, which can be used as a fallout shelter, was opened in Artesia,

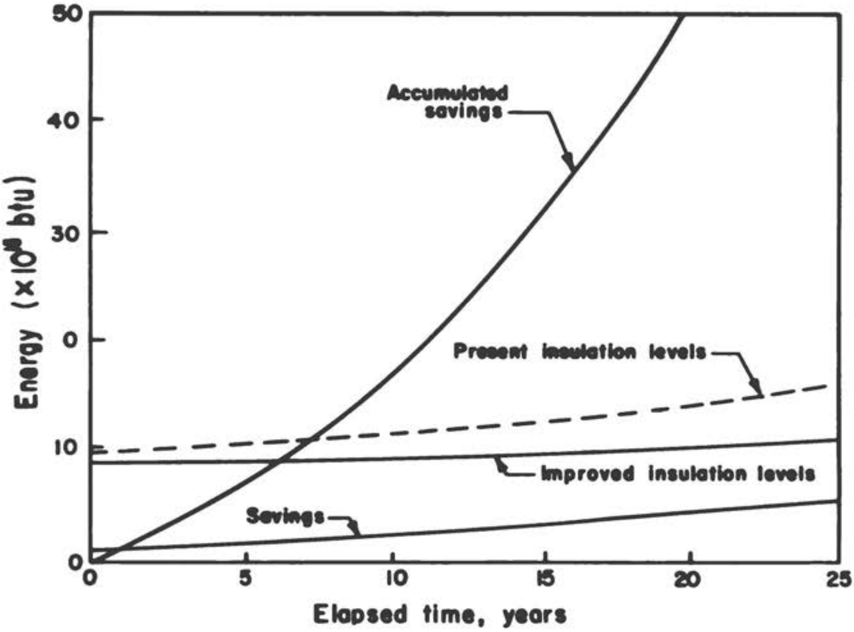

FIGURE 1 Energy usage and energy savings achievable by improved thermal design of dwelling units. From Achenbach.[18]

New Mexico, in September 1962. An evaluation of the Abo Elementary School, in which a detailed study of pupil achievement, anxiety and mental health, opinions about the school, psychological effects, and general health, was made in 1972.[1] The authors concluded that

> It seems that after ten years of experience with children attending an underground and windowless elementary school, the professionals concerned with the health care of children in Artesia, N.M., the location of the Abo school, are generally convinced that not only is the school not detrimental to the physical and mental health of their pateints, but it is actually a benefit to some.
>
> Although not as supportive of the school/fallout shelter facility as the parents of pupils who attended, the sample of the public clearly favored the school. Nine out of ten recommended that other schools be built like Abo, if such schools cost no more to build than other schools.

Manufacturing and consulting engineering firms sited underground in Kansas City found[19] that, in general, their employees "are ex-

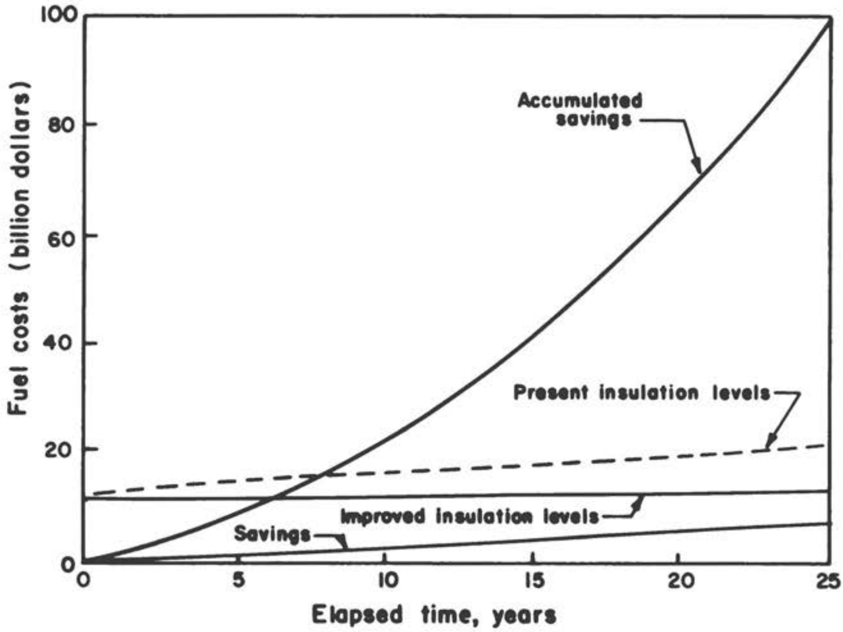

FIGURE 2 Cumulative cost savings at current (1973) fuel prices from improved thermal design of present and future residential buildings. From Achenbach.[18]

tremely pleased with the working conditions. . . . We have found efficiency to be better than that of offices above ground, probably because our people are not distracted by what is going on out in the street."

CONCLUSION

Building design, we believe, should be directed toward more advanced conservational systems, of which underground construction is one. Sufficient thought has not yet been given to the energy conservation aspect of the use of underground space to formulate appropriate policies. The data base is too thin and too particularized. Nevertheless, such use appears to have sufficient promise to warrant further investigations. We conclude that:

- There is a considerable potential for conserving energy through greater use of subsurface space.

- Energy can be saved by placing storage, refrigeration, and manufacturing plants underground and dwellings semiunderground.
- In no way can improved insulation for above-ground construction begin to compete with underground buildings in the conservation of energy.
- There appear to be no adverse psychological effects of working in properly designed underground buildings.

We recommend that several areas be examined in greater detail before sensible new policies can be suggested:

- Existing data on initial construction costs, operating costs, and all reports concerning heating and cooling of subsurface space should be collected. Research should be supported to generate new reliable data where needed. The data must be analyzed in the context of the total energy input and output, i.e., construction, manufacture, and use.
- All data, design procedures, and conclusions then should be consolidated in a well-known source, such as ASHRAE,[17] to ascertain whether there are sufficient societal savings to warrant formulation of a national policy on the subject, or to pursue studies of the subject in connection with supporting another policy.
- Current policy and legislation should be reviewed to identify where it might conflict or support a proposed policy in regard to fire rules, lighting requirements, insurance practices, and health and safety regulations.
- Special interest groups that might be affected positively or adversely should be identified.
- Potential sociological and psychological implications should be studied.
- It should be determined what new institutional arrangements can be made.
- The role and responsibilities of the government should be defined.
- It should be determined if there are other options that accomplish the same purpose that might be simpler to implement.

Thought might be given to developing a comprehensive and integrated set of policies for the use of underground space. At present, policies concerning this use seem to be *ad hoc* and not part of a rationalized scheme. Until such a scheme can be formulated, wise and beneficial use of subsurface space can best be directed by developing reinforcing policies that support good existing public policies such as the conservation of energy.

REFERENCES AND NOTES

1. Frank W. Lutz, Patrick D. Lynch, and Susan B. Lutz, Abo Revisited, Defense Civil Preparedness Agency (1972).
2. Robert F. Baker *et al.*, The Use of Underground Space To Achieve National Goals, Underground Construction Research Council (1972).
3. Truman Stauffer, Sr., Guide Book to the Occupancy and Use of Underground Space in the Greater Kansas City Area, Geographic Publication No. 1, Kansas City, University of Missouri (1972).
4. John F. Burby, Economic Report/Capital-Gains Laws Looms as Prime Target of New Ways and Means Hearings on Tax Reform, *National Journal,* pp. 1835–1844 (December 12, 1972).
5. G. M. Woodwell and C. A. S. Hall, The Ecological Effects of Energy: A Basis for Policy in Regional Planning, Energy, Environment, and Planning, Brookhaven National Laboratory, pp. 50–51 (1971).
6. René Dubos, A God Within. Charles Scribner's Sons, New York, p. 14 (1972).
7. 49 U.S.C., para. 176 (a).
8. United States v. Causby *ex ux.* United States Report, Vol. 328, pp. 256–275.
9. Henry J. Aaron, Shelter and Subsidies, Washington, D.C., The Brookings Institution, pp. 53–54 (1972).
10. C. Harry Kahn, Personal Deductions in the Federal Income Tax, Princeton, Princeton University Press, p. 124 (1960).
11. Joseph A. Pechman, Federal Tax Policy, Washington, D.C., The Brookings Institution, pp. 76–77 (1966).
12. Charles H. Jacoby, Underground Mining, Mine Storage, and Other Uses. Engineering Foundation Conference on Need for National Policy for the Use of Underground Space (1973).
13. C. W. Arend, Vice President, Spacecenter, Inc., 444 Lafayette Rd., St. Paul, Minnesota 55101, personal communication (1973).
14. A. N. Brunson, President, Brunson Instrument Co., 8000 East 23rd Street, Kansas City, Missouri, personal communication (1973).
15. K. Faber, Mechanical Engineer for Setter, Leach, and Lindstrom, Inc., Architects, Foshay Tower, Minneapolis, Minn., personal communication (1973).
16. K. J. Saulter, U.S. Fuel Consumption, Supply, and Prices: Past, Present, Future, Energy Conservation Conference, University of Minnesota, Minneapolis (1973).
17. American Society of Heating, Refrigeration, and Air-Conditioning Engineers (1972).
18. P. R. Achenbach, Energy Conservation in Buildings; Its Foundation, Cost, and Acceptance, Energy Conservation Conference, University of Minnesota, Minneapolis (1973).
19. N. Chryssafopoulos, Employee Attitudes, Corporate Officers Symposium on Underground Facilities, Kansas City (1962).

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