Planning the Bell System, 1888-1914: The Cumulative Dynamics of Network and Urban Regional Development

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As regional economies enter the "information era," corporate managers and government officials ponder investment strategies to negotiate the transition. To foster technological and organizational innovation, public debate has focused on building the necessary infrastructure, an "information superhighway," and the potential contribution of the state to such a vast undertaking. Although few would deny the benefits of these investments, their precise impact on long-term economic development, as cause, catalyst, or merely correlate, remains less clear. Perhaps even more controversial is the role, if any, of the state in coordinating and financing this development.

The early history of the U.S. telecommunications industry offers insights into these questions. Between 1888 and 1914, at the dawn of an earlier technological epoch, the Bell System forged a long distance communications network of continental proportions. Over these decades, the interexchange network expanded greatly in its spatial extent and calling capacity (see Figure 1).[1] Moreover, as AT&T president Theodore Vail remarked in 1909, the telephone "had assimilated itself into and in fact become the nervous system" of American business and in particular the complex of wholesale trade.[2] By "<u>annihilating time or distance by use of electrical transmission of intelligence or personal communication,</u>" the network carried the very economic transactions vital to intermediaries and corporate managers located in metropolitan centers, open-ended negotiations and the transmission of non-standardized information.[3]

Vail's observation can be interpreted in two different, but related ways. The simpler and weaker version suggests that the formation of areal telephone networks had followed established patterns of trade and so mirrored the spatial organization of economic activity at the time. This view accords with the far-sighted plan of his trusted deputy, Edward J. Hall. In 1888 Hall envisioned the network as an hierarchical succession of hub-and-spoke systems. "In considering the problem of extension," he remarked, "we strike, all along our lines, new local centres toward which the business ... tends."[4] After two decades of experience, traffic engineers realized Hall's plan and advocated the design of toll or long distance networks that in effect replicated the structure of local and regional urban systems. Subsequent technological innovations and more systematic engineering studies only reinforced this hierarchical organization. By the late 1920s Bell introduced its General Toll Switching Plan, which thoroughly rationalized the design and operation of the long distance network.[5] The schematic representation of the plan, depicted in Figure 2, virtually parallels the structure of a regional and national urban system.

A stronger rendition attaches causal significance to the spread of the telephone network. It sees this innovation in communications technology as an active force, both reinforcing and reconfiguring spatial economic arrangements and hence regional economies and urban systems. As debates over the railroad's place in American history have certainly taught, such claims are notoriously difficult to substantiate, in part because of how they have been construed.[6] In this context, I focus on the synergistic relationship between the telephonic transmission of information and existing networks of transport, communications, and trade. By refining and in some cases transforming ways of transacting over space, the telephone greatly enhanced the value of services offered by these pivotal mercantile sectors and, in turn, created valuable spillover effects, which reverberated throughout the regional economy.

This generation of value has been characterized variously. Geographers speak of agglomeration economies, the advantages derived from the spatial concentration of interrelated economic functions. To economists, it represents an externality, the unintended benefits from enlarging the scale and scope of the communications network.[7] Regardless of the terminology, the long distance telephone network spawned economic forces of increasing returns, which augmented the systemic processes of regional and urban systems development. Although the use of the telephone occasionally altered existing spatial divisions of labor, in most cases it simply elaborated the existing hierarchy of centers. This outcome, as I show, follows directly from the simple models, employed by engineers in planning toll networks in more developed regions. To tap the sources of increasing returns, they designed telephone networks according to the very patterns of economic interaction among urban centers.

Building networks in peripheral areas posed a greater challenge to telephone engineers and entrepreneurs, but also held out the promise of greater returns. The sparse, fragmented array of cities and towns in these regions did not conform to the underlying conditions of their planning model, and so deprived agents of a clear map, which would guide their investments. Drawing on their own experience and the principles derived from more developed regions, telephone entrepreneurs gauged the latent demand for toll service, and advocated building the network ahead of demand in more promising areas. At such critical junctures, these preemptive or developmental investments, like the extension of rail routes, could spur regional development, and decisively shift advantage to a favored site, thereby securing its dominant position in the emerging network and urban system. In this context, expanding the telephone network served as an instrument of city building and hence of the developer capitalist.

1. Systemic Processes and the Sources of Increasing Returns

Bell managers and engineers planned long distance networks to realize the potential increasing returns from toll service. Hall, for one, clearly perceived these systemic processes and their influence. "Developing fully a good system of terminal and branch feeding lines," he observed, "... will not only pay in themselves but will add to the business of the main trunk lines, and every gain in business requiring additional trunk wires means a large gain in profit."[8] Increasing returns, he implies, derived from economies of scale and the interdependence of demand. Scale-dependent processes yielded greater efficiencies (the "gain[s] in profit") from concentrating traffic through larger toll centers and the trunk lines connecting them. At the same, extending the network to encompass interdependent users, those bound by a strong "community of interest," enlarged the demand for toll services, especially the utilization of trunk lines.[9] A properly designed network would tap these complementary forces and generate substantial externalities, the unintended or synergistic benefits from their mutual interaction.

Bell engineers tended to regard these processes mechanistically, that is in terms of technology or other intrinsic properties of the network. Yet, through insight or experience, key officials comprehended the necessary market conditions to realize fully the telephone's economic potential.[10] Harnessing these market forces influenced the design of all facets of the network -- plant technology, operating methods, and spatial structure. Thus, when properly conceived, the processes underlying the development of the toll network are more aptly termed "eco-technic" and exemplify the opposing, but mutually reinforcing tendencies of centralization and dispersion that propel urban systems and regional development.[11]

i) Economies of density

Two examples illustrate the scale-dependent processes in toll networks. The first demonstrates the technological and economic forces, relating the volume of traffic and the efficiency of transmitting messages over space. Building toll lines required large, indivisible investments in transmission capacity. Telephone companies could economize on these outlays in numerous ways, by reducing the number of circuits on a line and increasing the spacing between poles.[12] Still, even the most rudimentary connections imposed truly fixed costs on operating budgets, such as leasing and maintaining rights of way. In turn, the growing volume of traffic increased capacity utilization and lowered unit costs.

On more heavily travelled routes, additional investments in transmission capacity, including the adoption of new technologies, yielded even greater economies and improvements in service quality.[13] Adding more circuits to a line reduced unit overhead charges on each. Moreover, through practice and theoretical analysis, AT&T engineers discovered that larger circuit groups -- trunk lines furnished with multiple circuits -- yielded genuine economies of scale. A 1904 Engineering Department bulletin indicated the actual magnitude of these efficiency gains.[14] Under "ordinary conditions," the transmission capacity of a circuit varied from 30 calls per day on a single-circuit line to 40-45 calls on trunk lines equipped with four or five circuits. In other words, enlarging the circuit group by a factor of four (or five) enhanced the effective capacity or load of each circuit by one-third to -half.

Around the same time, Bell engineers embarked on a program of theoretical research, which explained the source of and limits to these efficiencies. The reasoning is essentially probabilistic, an instance of the law of large numbers. Under "normal" conditions, pooling diverse sources of traffic at a single large center and along larger circuit groups would smooth out random variations in the timing and duration of individual calls.[15] Consequently, plant managers could predict more accurately average loads over time (e.g., a day, week, and year) and plan network capacity accordingly. In turn, because demands would exceed plant capacity on an incidental or irregular basis, individual circuits could carry, on average, higher daily loads without increasing the risk of congestion and so reducing service quality.[16]

Concentrating traffic through larger toll centers also initiated a Smithian process of technological and organizational changes -- a dynamic sequence of innovations in response to market development. More specialized equipment and operating methods typically evolved in tandem and yielded substantial efficiency gains.[17] Denser, more differentiated traffic patterns warranted the construction of switching and transmission facilities tapered to distinct market segments. In turn, Bell engineers refined operating methods that exploited more fully the economic potential of these more specialized facilities.

These innovations required additional outlays of fixed capital and employment of overhead personnel, which increased demand thresholds and so restricted their application to the dense markets within and between large metropolitan areas. Yet, by standardizing and speeding up manual operations, they magnified the productivity of switchboard operators and the rate of "throughput" of the toll plant. The centralization of more specialized equipment and personnel also enabled Bell companies to offer new services, extending the economic scope of its fixed plant and overhead staff.

An important instance was the "call wire system," developed by Joseph Carty of New York Telephone.[18] Carty's innovation was to dedicate a circuit, the "call wire," for transactions between operators. The call circuit placed operators in "instant communication" and so increased their productivity and the average speed of service. Also, by reserving toll circuits exclusively for conversations between paying customers, it substantially increased their carrying capacity and average daily loads. Despite the gains in operator and circuit efficiency, the call wire system was employed only on the routes between Manhattan and Newark and Yonkers, precisely because it devoted a wire circuit on each line to signalling.[19] For other toll calls within the metropolitan area, operators employed the ordinary "ring down" method and communicated with each over toll circuits. As Carty explained, "while this is not such quick service, it is as quick as can be expected where trunks [circuits] are not sufficiently numerous."[20]

Similarly, larger flows of traffic between metropolitan centers justified the construction of direct circuits equipped with loading coils, which improved the quality of voice transmission and toll services. By avoiding intermediate relays, direct circuits enhanced the speed of service and circuit loads. Moreover, the greater clarity of the voice signal enabled Bell engineers to replace the two- with the single-ticket method of recording toll calls.[21] The latter delegated complete control over signalling and accounting to the outward operator at the point of origin, and so reduced the time to complete the connection and the clerical tasks of inward line operators at the destination point.

ii) Interdependence of demand

Alongside the technological and organizational processes fostering centralization, Bell officials and engineers also recognized an opposing tendency to extend the network geographically. Characteristic of other communications and transport networks, this centrifugal force derived from the interdependence of demand for telephone service. According to Thomas Doolittle head of AT&T's Toll Traffic Studies division, a vaster network, connecting more people over a wider area, would enhance the potential use of the telephone and hence its value to customers. Through a series of reports and memorandum, Doolittle elaborated this general principle. He specified the source of these potential externalities as well as their impact on network development.

Demand interdependence, he observed, depended on the geographic range of economic and social relationships. Within urban centers, the highly localized nature of social interactions tended to restrict the systemic benefits from widening telephone networks. Residential customers called frequently within their immediate vicinity, but except for occasional transactions requiring connections to business districts, they rarely contacted subscribers in other neighborhoods. By way of explanation, Doolittle offered a quaint analogy to the impact of urban annexations: "the individual use of the telephone is quite similar to the individual use of the streets; each [person] has his particular route and rarely deviates from it and would not if the city were many times greater."[22] Thus, enlarging exchange networks to incorporate new districts would add subscribers, but not notably increase the demand for service by existing ones.

The toll network, by contrast, mediated more far-flung relationships and therefore was governed by an opposing principle. After a decade's experience, he wrote to Joseph Davis, head of the Engineering Department: "Our records show that the larger the number of places connected, the larger will be the percentage of people interested in the toll lines."[23] Following Hall, he emphasized the complementary demands for toll service within and between metropolitan regions. Simply stated, the volume of long-haul traffic between principal "commercial" centers depended on the density of the short-haul traffic with cities and towns in their immediate hinterland. His schematic model, reproduced in Figure 3, shows this mutual interaction. In the top panel the network, consisting only of a trunk line connecting two large centers, is hardly utilized. In subsequent panels, the increasing number of tributary connections to hinterland cities and towns directly expands the volume of trunk line traffic.

Doolittle intended his simple model to promote local network development by Bell operating companies. Ignoring the systemic benefits from a more extensive network, they often devoted too few resources to building complementary toll lines in their territory. Even if tributary lines were not profitable when reckoned on a stand-alone basis, he showed, they would induce greater utilization of the network, especially trunk lines, and so enhance aggregate earnings. In effect, he advocated subsidizing the construction of tributary connections to smaller centers with the greater earnings on trunk lines between larger cities.[24]

Moreover, as his model implies, these internal transfers of funds are not truly subsidies. Rather, they reflect the spatial separation between the source of the network externality -- investments in tributary connections -- and its realization -- greater profits on more heavily utilized trunk lines. In the absence of a competitive rate structure based on the value of service, accounting for and thus realizing these systemic benefits would demand a more extensive, integrated network. In turn, as explained below, this vital relationship specified the integral components of areal networks and so delineated their spatial boundaries systemically, that is in terms of the geographic scope of these reciprocal demands.

An ambitious program of network development, proposed by New England Telephone, exemplifies Doolittle's model and concretely demonstrates the potential benefits from expanded toll connections.[25] The company would furnish smaller cities and towns with rudimentary exchanges, offering limited local service. These centers, it was acknowledged, would generate few outgoing calls, the basis upon which Bell companies charged customers and so reckoned the revenues and net earnings of toll lines. They would, however, attract a substantial volume of incoming traffic from larger commercial centers and thereby increase the overall utilization of the network and aggregate revenues. To determine prospective sites, then, Doolittle projected their contribution to toll revenues in both directions.

The planned extension of the network by New England Telephone, as in Doolittle's diagram, clearly hinged on the interdependence of demand for toll service within urban regions. Yet, the expected pattern of traffic did not follow its representation of large centers as mere relay stations mediating connections between smaller ones. Rather, the net flux of traffic within urban regions, it implies, would radiate from large to small centers along feeder lines. This trend suggests that users in the former, not the latter, valued more highly the greater range of toll connections and, in turn, more strongly advocated the extension of the network. A later report by AT&T engineers stressed this very point. "Unless ... complete facilities [are] provided in towns of all kinds and characteristics, the value of telephone service in places of higher commercial activity will be materially lessened because of the absence of exchanges in towns of smaller activity."[26] Significantly, the predicted asymmetric flow of traffic from centers of "higher" to "lower" commercial activity corresponds to the spatial range of their mercantile functions and hierarchical order in the urban system.[27]

Doolittle's very analysis of demand interdependence hinged on these spatial economic relationships, even though his own formulations often obscured the connection. In his analogy to pedestrian traffic, for example, he incorrectly attributed demand interdependence to a particular geographic network. In fact, it only showed how the use of the telephone by residential subscribers paralleled the highly circumscribed fields of personal economic and social interactions. By contrast, businesses customers, especially intermediaries in larger commercial centers, demanded the most extensive range of telephone connections both within and beyond city limits. In competitive markets with dual service, these "core" users typically purchased both. Additionally, to obtain toll connections to nearby cities and towns, they willingly accepted hefty rate increases for extended Bell service, and, if necessary, even committed resources to establish their own independent companies.[28]

In other words, interdependent demands characterized both exchange and toll networks, but were more visible in the latter, whose use was dominated by "core" business customers. Through the telephone, merchants and other intermediaries could maintain closer contact with clients in their trade area. Substituting more frequent telephone calls for costly, time-consuming business trips, they could offer more prompt, responsive service. Additionally, by lowering transactions costs and amplifying the channels along which information flowed, telephone service potentially deepened and widened trade areas and so enabled merchants in one center to encroach on the markets of another. Consequently, the telephone became a potent weapon in recurrent urban rivalries.[29]

Similarly, Doolittle often insisted on a simple, almost linear relationship between city size and effective demand for toll service, despite his own evidence which showed a weak, empirical regularity at best.[30] In a different context, Bell engineers vehemently denied this correlation, and instead focused on the "the class and general prosperity of the population" and "business conditions" as more fundamental determinants of demand.[31] Like urban geographers, it seems, Doolittle used population as a shorthand to gauge the economic functions of a center and in turn its potential commercial relations with other centers. Significantly, in his comprehensive reviews of territorial networks, he consulted "Dun's Reference Book," and not simply the census of population, to identify "the most promising places" to extend the network.[32] From this source, he gleaned information on their economic structure: the number, size, and type of banks; "rated" manufacturing and mercantile establishments; and the size distribution of firms by net worth.

These data identified the likely sources of demand for toll service in each city, as well as the likely recipients of toll calls from other centers. Unlike population aggregates, they measured more accurately a center's total contribution to the growth of the regional toll market. From this perspective, Doolittle's suggestion of building marginal lines, when they "round out a system," acquires a decidedly spatial-economic meaning.[33] It implies completing the nexus of interdependent economic relationships within urban regions, that is the "urban system," and not simply filling in the physical connections between geographically proximate centers.

2. The "Natural" Bounds of Territorial Networks

According to Hall and Doolittle, when properly designed and operated, long distance networks would generate increasing returns and expand cumulatively. Through investments widening and deepening the network, operating companies tapped reciprocal demands for toll service. By funnelling these larger flows of traffic through nodal points and trunk lines, they realized scale economies, compounding their net earnings. The greater stream of retained profits, in turn, would finance further network expansion, the extension of existing feeder lines and the construction of new ones.

This "virtuous" cycle only explains how momentum builds within the system and so poses two fundamental questions. First, it does not specify the constraints or countervailing impulses that restricted network development economically and spatially. Were there, in other words, natural bounds to territorial networks? Second, by its very nature, this cumulative process cannot account for its origins or initial conditions -- the thresholds of capital investment and demand and the supporting infrastructure necessary to realize increasing returns.[34] What, then, engendered this initial momentum or critical mass? This question constitutes the proper domain of history, the indefinite consequences of human agency and collective action, and not of deterministic, systemic forces.

Bell managers and engineers clearly perceived the geographic limits to network development, but from rather different perspectives. At the very outset, Hall emphasized technological constraints on voice transmission, which would confine networks to the regional level.[35] Although major advances in transmission technology eventually erased these physical barriers, engineers postulated new sources of diminishing returns due to the exogenous influence of technology and geography. Increasing distance and congestion costs, they argued, would eventually offset the benefits of extending feeder lines to more remote, marginal places and of relaying the additional traffic through a single, large center.[36]

Yet, in relating his vision of a national network, Hall also implied that the binding and therefore relevant constraints on territorial networks were determined systemically, that is by the very spatial-economic processes generating increasing returns. In the ascending progression of hub-and-spoke systems, technology restricted the dimensions of only the largest, regional networks. "Included in each of these two great circles," he remarked, "would be a host of smaller ones centering at the various large cities from which the business of a state or section radiates."[37]

Through "careful analysis" of traffic patterns, Doolittle formulated a set of "principles and methods" for the design of territorial networks that corroborated Hall's vision.[38] Although never formalized into a systematic model, its essential outlines can be gleaned from his comprehensive studies of the Buffalo and New England Telephone Companies, conducted in the 1890s.[39] Both companies operated in developed urban regions and were distinguished by their almost ideal toll networks. Doolittle's task amounted to identifying the few remaining gaps in each territory that warranted additional investments in toll lines and urban exchanges.

In deciding where to build toll lines, Doolittle employed a simple benefit-cost analysis. As he explained to AT&T president Frederick Fish in 1904, "Experience has taught that the gross earnings of a toll line should equal at least 20% of its [construction] costs in order to cover the interest upon investment and the cost of maintenance."[40] Using linear approximations, he projected outward toll revenues on the basis of city size, and construction costs by the length of the line. To capture the induced revenues from inward traffic, he merely doubled the former. Formally, his analysis can be expressed:

$$2\cdot(R\cdot P) \geq (0.2)\cdot(C\cdot L),$$

where R = expected per capita receipts from outward calls, usually the average for the territory or a comparable group of centers; P = the center's population; C = average per mile construction costs, and L = the length of the line.[41]

This criterion determined the intensive and extensive margins of network development, the minimal size of a center or its maximal distance from others to obtain a connection. For a given geographic range, a city would be integrated into the network, only if its population exceeded the following threshold:

$$P^{*} = (0.1)\cdot(C\cdot L/R).$$

This formula simply restates the central conclusion of his schematic model (see Figure 3). Building feeder lines to

> more and more places ... was found to advance the per [capita] earning of all places connected to the extent that from time to time we found it safe to base our expectations on a higher and yet higher figure. This in turn enabled us to recommend the extension of toll line systems to smaller and yet smaller towns.[42]

Translated into the terms of the above equation, the fruits of past investments, in the form of higher realized and hence expected per capita revenues (or R), lowered population thresholds (or lengthened those of distance). Thus, widening and deepening territorial networks created new investment opportunities for operating companies, as well as furnished them with the internal funds to finance these projects.[43]

Taken to its logical conclusion, the analysis delimits territorial networks systemically by the reciprocal demands for toll service. By tapping places bound by relations of economic interdependence or economically "rounding out a system," new lines would not only augment traffic on adjacent routes, but also enhance the "earning power of ... the entire system of lines," i.e., the critical variable R.[44] These investments, therefore, would eventually yield profits and sustain cumulative growth. In contrast, building toll lines to places not joined by a strong community of interest would enlarge the population connected, but not induce a proportionate increase in the demand for toll services. Along with diminished net earnings, such investments would deflate average revenues per capita (i.e., R), and so reverse the trends in population and distance thresholds that had propelled network expansion.

In a telling instance, Doolittle explicitly invoked this more general principle to resolve an investment decision. He questioned the construction of a relatively short line (of 9 miles), even though his method returned a favorable benefit-cost ratio (of 1.6).[45] With "very little capital invested in business," he figured, the town would neither generate nor attract many toll calls, and so would not realize the expected level of revenues, derived solely on the basis of population.

Almost a decade later, Hall reasoned along similar lines and delineated the geographical boundaries of territorial networks by "natural" breaks in the spatial patterns of traffic. The "logical" design of territorial networks, he observed, "will result in a system of lines tapering out in all directions [from business centers] towards the borders and this tapering will represent very closely the resultant of traffic pressure and available capital."[46] The density of toll line circuits radiating from a center, he implies, reflects the spatial gradient of its traffic, which diminishes at an increasing rate with the distance travelled.

Borrowing an obvious physical analogy, Frank Fowle, an engineering consultant to independent companies, explicitly applied the gravity model to predict the volume of calls between centers and, in turn, to plan toll networks.[47] By way of illustration, he plotted the relationship between the density of toll traffic and distance for a typical center (see Figure 4). The cumulative percentage of outward calls, measured on the vertical axis, declines almost exponentially with the air-line distance, measured on the horizontal one. Fowle's formulation also accounts for the greater density of traffic and hence trunk line circuits between larger centers.

Yet, as Doolittle's more qualitative formulation suggests, the pull that a commercial center exerted over cities and towns in its hinterland reflected the strength of their reciprocal economic ties, and not simply the interaction of population size and distance. The geographic scope of territorial networks, in other words, depended on the dimensions of the local spatial division of labor and, in turn, the nodality or hierarchy of the center anchoring the local urban system. Accordingly, Doolittle drew narrow boundaries around the toll networks of several lower order centers in upstate New York, commensurate with their limited economic functions and toll traffic. As detailed traffic studies demonstrated, 40 percent of their outward calls were "local," reaching destinations less than 15 miles away.[48] Moreover, only 10 percent of all calls travelled distances exceeding 40 miles.

In the national metropolises of New York and Chicago, toll traffic and local networks extended over a wider area, but still did not approach the technological limits of voice transmission. A study of the Chicago market in 1907 found that 90 percent of all toll calls were confined to an area within 100 miles of the central business district.[49] In fact, toll traffic within the city borders proper generated 50 percent of Chicago Telephone's toll revenues. More generally, calls between regional centers rarely transcended the boundaries of contiguous territories. In 1898, for example, almost 90 percent of the traffic on AT&T long distance lines travelled less 224 miles (see Table 1). Although the spatial range of traffic steadily increased, by 1902 only a small fraction of calls exceeded a radial distance of 400 miles.

Viewed alternatively, these systemic limits correspond to the geographic range of a commercial center -- the spatial dimensions of its trade area or hinterland. Doolittle explicitly stated this principle in his criticisms of and remedies for the often myopic and inconsistent policies of AT&T and its operating companies. As he discovered, commercial centers and the cities and towns in their hinterland often fell under different jurisdictions of the Bell System. They were either located in the territory of different operating companies or came under the domain of the operating and parent company. The absence of compatible pricing and routing policies to coordinate traffic flows between divisions, which Hall termed the "border problem," fragmented urban regions and squandered the systemic benefits of an integrated network.[50]

In the peak of the competitive period, for example, Doolittle decried the very existence of the Central Union Company which operated in the Midwest.[51] Determined almost residually, its territory excluded the region's principal commercial centers -- Chicago, St. Louis, Cleveland, and Cincinnati. Without these vital connections, the company had inadequately supplied toll service to customers in the "vicinity of each large city" and was facing stiff competition from independent companies, which stepped in to fill the void. To resolve the problem, he concluded, "it would have been much better ... if [the territory] had been divided into three or four companies, in order that the natural trend of business could have been cared for in a natural way toward the great cities."[52]

Southern Bell Telephone, by contrast, confronted barriers created by AT&T's policies regulating access to its long distance lines. Ignoring local market conditions, AT&T imposed excessive demand thresholds on tributary connections and offered inadequate commissions on feeder traffic. These policies restricted the access of adjacent areas to larger cities in the territory and so thwarted investments in the local network. Consequently, Doolittle observed, "the territory along the [AT&T] lines has become a sort of telephone desert."[53] To remedy the problem, he proposed some form of joint control over these pivotal routes. By leasing or acquiring circuits on AT&T poles, Southern Bell could provide the region's commercial centers with valuable short-haul connections to the cities and towns in their trade area.

Bell's marketing strategies also assimilated these salient economic relationships, as they adapted toll service to the hierarchy of commercial centers and the circuits of wholesale trade, which they mediated. For example, its Key Town Sales Plan designated key towns or calling points, where sales agents could readily contact customers in the adjacent territory by telephone. Primary calling points served manufacturers' agents and jobbers, selling non-perishable, more specialized commodities, such as drugs and hardware, to "more widely separated customers."[54] Smaller, secondary centers catered to less specialized intermediaries, such as merchants in the wholesale grocery trade, who covered narrower regions more intensively.[55]

The maps of toll centers and their domain, not surprisingly, replicated the successive systems of metropolitan centers and trade areas (see Figure 5). Primary calling points were naturally sited in larger metropolises because of their economic and geographic centrality. In particular, their more efficient toll plant and operating methods offered direct connections to larger, more distant centers and so furnished specialized wholesalers with access to a wider area, paralleling the greater geographic range of their trade. Secondary points, by contrast, were drawn from an intermediate tier of cities. Their toll centers formed local nodes in a finer mesh of tributary connections that reached retail merchants in nearby towns and rural market centers.

3. Systemic forces and human agency in planning toll networks

The "development" of an existing network, Fowle observed, follows the same principles that govern the "projection of an entirely new plant."[56] Accordingly, Doolittle's analysis delineates not only the systemic limits to territorial networks, but a simple model for planning them. The design of local and regional networks, it implies, should trace out the reciprocal demands for toll service between principal centers and their hinterland cities and towns and so replicate the structure of local and regional urban systems.

Although conceptually simple, the insights of this model were readily applied only in developed regional economies, like the territories of the Buffalo and New England Telephone Companies, which already satisfied its initial conditions. Their highly articulated spatial divisions of labor, dense patterning of cities and towns, and complementary transport and communications networks furnished entrepreneurs and engineers with a detailed, reliable road map guiding investments in toll lines. In territories "evenly populated with towns and cities and ... continuously settled and developed," telephone managers could expect higher revenues per circuit mile and so greater potential investment opportunities. As important, under these conditions traffic levels tended to vary more continuously with the size of and distance between centers and so were predicted accurately by simple empirical generalizations, such as the gravity model.[57]

Building networks in more rural, peripheral regions, by contrast, posed greater challenges to telephone entrepreneurs and engineers. Dispatched to the Northwestern Company, which spanned the territory from Minnesota to the Dakotas, Doolittle diagnosed its poor toll service by the delayed, "unbalanced" development of its toll network. These problems, he acknowledged, were practically endemic to such regions.[58] Hall also confronted this dilemma first-hand in his dual role as president of Southern Bell Telephone Company, which operated in the southeastern states. According to his depiction, the company's "partially developed" network simply mirrored its fragmented urban system. Toll lines radiated from commercial centers, but were punctuated by large gaps because of "traffic demands and available capital."[59]

When viewed in terms of Doolittle's model, the constraints to network development singled out by Hall -- inadequate levels of demand and sources of finance -- reflected the limited scope of the cumulative processes generating increasing returns, and not simply external factors. Peripheral regions, the logic implies, did not furnish the initial conditions necessary to sustain ongoing expansion. Their sparse, almost enclave patterns of economic development, skewed size and spatial distributions of cities, and skeletal transport and communications networks curtailed the interdependent demands for toll service and so short-circuited the reciprocal interactions that increased per capita revenues (or the variable R in the above equation). Unable to generate sufficient momentum, network development was trapped in a "vicious" cycle and stalled.

These structural impediments formed a recurrent theme in reports on toll development in the Southern Bell territory, for example. The company's presidents repeatedly emphasized the wide gaps between commercial centers, which tipped benefit-cost calculations against building lines connecting them.[60] What the region lacked, they implied, was a dense layer of small and medium sized cities to fill in its urban system. The sketchy rail network only compounded these problems. The company's toll lines followed indirect, lengthier rail routes to more marginal centers. Rates, based on circuit mileage not air-line distance, inflated the cost of connections to these centers, further isolating them and stifling valuable short-haul traffic. Yet, the alternatives, either building direct lines or adopting uniform prices, diminished net earnings on these lines by increasing capital outlays or reducing profit margins.[61]

To surmount these obstacles and realize the potential benefits of an integrated network, telephone companies had to extend their lines into unchartered territory and so to formulate a more comprehensive and costly long range strategy of investment. Such ambitious undertakings amounted to an "original accumulation" or "building ahead of demand," and so required greater initiative on the part of telephone entrepreneurs among others.[62] Unlike investments in planned excess capacity, managers could not readily project demand growth and faced longer gestation periods. Consequently, these projects required large initial investments and were plagued by greater uncertainty over the future stream of returns.

At the same time, these ventures were not simply the speculative schemes of urban boosters. In fact, telephone engineers and planners cautioned against the excesses of the "promoter." Referring to them as the "brown tail moth of the telephone business," Doolittle, for one, considered their influence to be almost noxious.[63] S. Levings, a former Bell employee and contributor to Telephony, had a less extreme reaction. He urged managers to consult with "older inhabitants" about the future prospects of their communities, but cautioned them to discount the information appropriately. "It is only natural," he observed, "that a resident of a town for a long period of time, and who has perhaps made his fortune in the town, should be optimistic, and be in that class know as 'boosters'."[64]

Through experience, Bell engineers and managers groped towards solutions that fell in between the extremes of rigid determinism, based on calculable risks, and mere fortune, that is sheer speculation or chance. Their strategies consisted of two, complementary components. To supplement their company's meager retained earnings, they relied on external sources of finance within and outside of the region. In turn, they drew on the cumulative know-how within the Bell System to identify the actual or proximate sources of effective demand for toll services. In particular, the "planning model" of Hall and Doolittle informed their investment decisions and instructed operating companies in the proper design and operation of territorial networks.

To be sure, Bell companies wielded these financial resources and key competences strategically.[65] Both Hall and Doolittle recognized the potency of Bell's long distance network as a foil against competition, and were instrumental in formulating and executing Bell's mature and successful strategy to stifle actual and potential entry. Yet, as this history shows, their planning model was not simply a reaction to competition. They had formulated is essential outlines prior to and independent of its strategic application. If anything, the experience of the competitive period vindicated and elaborated their insights. They not only explained the effective challenges mounted by the independents, but also inspired key organizational innovations, such as strategic acquisitions and sublicensing, which were equally effective in subduing them.

Telephone companies raised funds from varied sources, depending on the magnitude of the investment and its place in the network. At one level, AT&T assumed greater financial responsibility for building the principal nodes and trunk lines that would integrate local networks into larger regional and national ones.[66] Its long distance division directly underwrote and constructed the trunk lines between larger centers. Additionally, as Vail plainly admitted, AT&T functioned as a "holding company" and assisted operating companies in financing their long term investment strategies.[67] In both cases, these financial flows originated in the higher order centers of core regions, either through the profits earned on toll and exchange service in Bell's largest urban markets in the north or through the sale of AT&T's stocks and bonds in national and international financial markets.

Filling in the network -- extending feeder lines from commercial centers to hinterland cities and towns and building rural lines to develop the markets of the latter -- fell under the jurisdiction of operating companies. To finance these investments, they drew more heavily on their own resources and those of local capitalists. They devised various plans, which distributed capital costs according to the systemic and strategic value of the investment among other factors.

At the lowest tier in the hierarchy, Bell companies operated and even constructed less remunerative rural or "farmers'" lines in response to the demands of mercantile customers in smaller cities and towns. Under the threat of actual or potential entry from independent companies, they were more willing to underwrite these investments directly. For example, Nebraska Telephone provided equipment and connections at rates barely covering costs, as long as farm households built and maintained the lines to nearby exchanges. Such investments were preemptive, not predatory, accelerating construction in areas with potential demand. "There is no money at these rates," its president admitted, "but it [the policy] protects our small exchange and prevents building opposition toll lines."[68] Still, he anticipated a growing volume of toll traffic in the reverse direction, as merchants utilized the telephone more frequently to contact their rural customers. "Toll line receipts," he concluded, "will be our salvation."

Similarly, where competition dictated, Southwestern Bell actually built "cheap" rural lines extending 5 to 6 miles from its exchanges. The lines would connect a maximum of 10 to 12 customers and provide them with inexpensive party-line service.[69] Yet, before undertaking these investments, it too sought evidence of potential demand and canvassed the countryside to enlist a minimum of 5 customers.

Where entry posed a less immediate or serious threat, Bell companies sought to shift the financial burden to local capitalists. In reaction to the threat of mail order companies, Bell promoted rural lines and service to country stores. They insisted, however, that merchants bear a portion of these costs, either by investing in line construction or subsidizing rates for farm customers.[70] In another example from the south, a company combined elements of the Nebraska and Southwestern Bell policies and built rural lines serving nearby "truck" farmers, only if merchants paid for all calls, regardless of who originated them. As an agent for Telephony reported, "the business men receive many orders over the telephone, which would be less frequent if the farmers had to pay toll, and are quite reconciled to paying for all ... calls."[71]

Eventually, Bell operating companies adopted more systematic policies, formalizing their relations with local business interests in cities of all sizes. Southern Bell promoted the "Sparta, Ga. plan" to forge joint ventures with its business customers.[72] The company informed its urban exchange managers about the successful efforts of merchants in this small Georgia city, who raised $500 to finance the construction of rural lines. The company's special agent on rural development was especially enthusiastic about an initiative, devised by the commercial superintendent of its Charlotte, North Carolina division, which adapted the plan "with equal success to a larger city."[73] As he explained to Bell officials, by garnering "the financial and moral support" of the Charlotte business community, "our plan is expected to produce results, which could not be otherwise obtained in such short time and at such small cost to this Company." He also circulated a memorandum promoting this version of the plan to the commercial superintendents of its other divisions, headquartered in the largest cities of the territory.

Southern and Southwestern Bell also reached accommodations with independent companies to solve "the farmers line question" and to provide their larger centers with more extensive hinterland connections. By relaxing the parent company's technical standards, Southwestern Bell simply sublicensed rural lines and exchanges built and operated by local merchants.[74] Beginning in 1900 Southern Bell embarked on an ambitious program of consolidation, which filled in the gaps of its toll network. It acquired or sublicensed independent companies, especially those which formed local toll systems around the largest centers in the territory, Atlanta, Birmingham, Charlotte, Jacksonville, and Raleigh.[75]

These arrangements, but especially sublicensing, institutionalized a division of labor between Bell companies and local capitalists. Under sublicense contracts, the latter assumed responsibility for exchanges and feeder lines in peripheral areas, while the former furnished longer distance toll connections, joining them into local and regional networks. Independent companies, Bell officials acknowledged, often enjoyed decisive cost advantages in these sparser markets. Additionally, the policy drew on the financial resources and goodwill of local elites. As Hall observed, "This [sublicensing] will relieve us from the burden of furnishing large amounts of capital and thereby enable us to thoroughly develop and protect strategic points."[76]

Bell companies gained the "co-operation" of independents, where they effectively controlled the long distance market and so could wield access to their network strategically. Thus, consolidation both exploited and reinforced Bell's initial advantage in this area. Sublicensing extended the scope of Bell's network and so greatly enhanced the value of its toll services to key business customers. At the same time, by fragmenting the independents, the policy prevented them from forming a rival network.

Mobilizing local and distant sources of finance was a necessary aspect of this entrepreneurial activity. To realize their investments and form viable toll networks, Bell officials had to decide where and when to channel these funds. A sufficient condition, in other words, demanded a set of guidelines to assess the latent market for toll service. In practice, these two sets of conditions often overlapped. As in the case of railroad construction, telephone companies determined the location and timing of many investments based on the funds subscribed by local merchants and other capitalists.[77] Although the willingness of local businesses to contribute financially frequently reflected their booster spirit or the keenness of town rivalries, it also indicated their accumulated wealth and so the extent of local economic development. Similarly, the actual or potential threat of entry directly indicated the effective demand for telephone service by local intermediaries and their customers, especially those residing in larger cities and their trade areas.

Based on past experience, Bell managers also developed simple rules of thumb or formulas to predict the demand for toll services. Hall, for one, applied his and Doolittle's "model" to determine the location of the pivotal nodes that would anchor the regional network in the south. In 1901 correspondence to AT&T's acting president Alexander Cochrane, he urged the company to finance the acquisition of Southern Bell's rival in Charlotte. Although unprecedented, the investment would convey exclusive control over a potentially vital site, which, he predicted, would become "an important centre for all toll development" in the textile region of North and South Carolina. As evidence, he referred to the city's size and rapid growth, but especially to its vital commercial position as "central supply point" for the burgeoning textile industry.[78] Consulting a map of the region, he might also have mentioned Charlotte's central position in one of the most densely urbanized regions of southeast and at the juncture of intra- and interregional rail routes.

Locating a divisional headquarters in Charlotte was the culmination of considerable economic development within the city and its trade area. At the opposite extreme, managers and agents prospected for fertile economic terrain that would spawn the very kind of urban, commercial development conducive to the demand for toll service. In rural, mainly farming regions, they assigned significant weight to agrarian institutions or social structures. Officials of Southwestern Bell, for example, blamed the plantation system for the uneven regional diffusion of the telephone among farm households in Texas and Arkansas.[79] The concentration of landholdings and centralization of economic decisions on tenant plantations weakened the market for telephone service for two reasons. The skewed distribution of wealth and income deprived most households of the means "to keep body and soul together," let alone to purchase a convenience, like telephone service.

For the same reason farm households on tenant plantations created weak markets for rural merchants, who therefore did not have the incentive to invest in rural lines. High rates of geographic mobility frustrated efforts of merchants to cultivate customer loyalty by building lines or subsidizing telephone service. Many plantations also directly provisioned their tenants, and so preempted the relationship between rural merchants and their customers, which the telephone mediated. Unlike independent merchants, plantation commissaries could exploit their bound or protected market and conduct their trade in consumption goods along the same wholesale lines used to purchase agricultural supplies and to market staple crops. Despite the economies of scope and lower transactions costs, these practices generated more limited demands for local transport and communications services and so impeded local commercial development. Telephone engineers, as might be expected, found comparable market conditions in company manufacturing towns.[80]

By contrast, rural telephony spread more rapidly to prosperous, yeoman farming regions in these two states and for that matter in similar rural settings throughout the country.[81] These areas were more densely settled and developed, and independent proprietors tended to cultivate larger, more valuable tracts of land. In turn, these middling sorts generated denser markets for local intermediaries and so supported a more extensive network of cities and towns and transport routes. Extrapolating from their experience, Southwestern Bell officials hoped that the impending dissolution of large estates into "farms of more moderate size" would spur the growth of telephone demand.[82]

Building networks in peripheral regions, these examples illustrate, followed familiar economic and spatial processes. The alternative methods of financing these investments initiated financial flows that proceeded almost sequentially down the urban system at every level. This hierarchical chain of finance typically occurred during the "frontier" or formative stage of development in peripheral regions.[83] Lacking a solid economic foundation to spark cumulative growth, these areas depended heavily on external sources of finance from the more developed core. In turn, because of the sparse, uneven spread of development, external funds, including those raised in the region, were channelled narrowly through scattered "outposts," the gateway cities or entrepots and smaller commercial centers that linked regional producers to national and world markets.

From a broader perspective, these financial relationships fueled the spatial expansion of the urban system from core to peripheral regions or the "colonization" of new territory through the direct and indirect investments by capitalists in the core. Unlike other colonizing ventures, however, building telephone networks was a systemic process. As the experience of Bell companies attests, their seed capital took root, only where it engaged local forces of economic development, and not simply conveyed economic or political control over local resources.[84] In other words, these ventures can be regarded as "developmental" investments. They fostered the growth of latent markets, which evidenced the proximate and more fundamental sources of demand for toll services. By interacting with these local conditions, improved toll facilities would in hothouse fashion compress the time required to achieve the critical thresholds triggering the systemic processes of network expansion. Thus, they functioned like catalysts; they did not initiate, but accelerated ongoing development at the local level.

4. Whither the State?

Through this excursion into the early history of long distance telephony, I have explicated the planning model for areal toll networks, implicit in the insights and practices of Bell and other telephone engineers and entrepreneurs. Simply stated, the analysis implies that an efficient toll would replicate the structure of the region's economy and urban system, and augment the systemic processes of urban-regional development. "The whole thing sums up," a Bell representative observed, "in the statement that the telephone is a potent factor in permitting each economic function to be performed where it can be done to best advantage."[85]

Viewed less statically, the telephone potentially furthered technological and organizational changes throughout the regional economy and contributed to the formation of new mercantile complexes within core and peripheral regions. In the former the telephone followed the well trodden paths defined by complex, highly developed systems of economic interdependence and the dense networks of transport and communications that mediated them. Within this context it reinforced relationships of nodality and hierarchy in local urban systems. In the latter, by contrast, the telephone entered less developed, more pliable space and through strategic placement could decisively shift initial advantage and so crystallize new urban systems.[86]

Notably absent in this account is the explicit contribution of the state at any level -- federal, state, and municipal. Unlike in other political economic contexts, private enterprises, not state agencies, financed and operated this vital communications infrastructure. Moreover, market forces -- that is competition between Bell and independent companies -- spurred this development. In response to entry, Bell accelerated the construction of its toll network, especially in regions experiencing intense competition (see Figure 1).[87] It also poured resources into the development of key inventions such as the loading coil, vacuum-tube repeater, and carrier circuits that would extend the geographic range and reduce the cost of long distance calls.[88] Independent companies also grasped the competitive value of long distance service and attempted to build rival systems at the local, regional and even national level.

Despite the apparent anomaly of the U.S. experience, a closer inspection affirms the fundamental message of those advocating state intervention. The formation of such a complex economic and technological system as the telecommunications network, they argue, demands some kind of conscious authority to plan and coordinate its myriad, interdependent components.[89] This critical locus of control would finance those integral elements of the network, which yield their benefits indirectly or only over a long time horizon. Moreover, it would also develop and enforce technical and operating standards to insure the compatibility of all components and so to integrate them seamlessly into a truly national system.

Direct state intervention was unnecessary during this period, precisely because the centralized administration of the Bell System assumed these very functions. From its inception, the parent company justified the Bell monopoly on these grounds. Under Vail, of course, this position gained a prominent place as expressed by the corporate motto: "One System, One Policy, Universal Service."[90] Although Vail did not conceive the goal of providing nation-wide "universal service," he ingeniously identified it with the unified governance structure of the Bell System. Moreover, in 1913, when postal officials contemplated taking over telephone service, Vail deflected their arguments by insisting on the priority of the Bell System. The company's policy of "one telephone system -- under one control," he remarked, "has been appropriated ... by the advocates of government ownership."[91] Bell's "natural" monopoly, in other words, had supplanted the state.

Vail's public relations were persuasive, precisely because his organizational reforms harmonized the company's actual practices with its official rhetoric.[92] As a holding company, AT&T channelled finance to its operating divisions and orchestrated their investment decisions to advance the goal of "universal service." In particular, Vail emphasized the unique capacity of the Bell System, as compared to smaller independent companies, to underwrite a national long-distance network by building lines in marginal areas and, when necessary, ahead of demand. At the same time, through vertical integration into manufacturing and research and development, AT&T achieved economies of scope, and regulated "the quality and style of apparatus, [and]... improvements" in equipment to preserve and enlarge the domain of interconnection.[93]

The interplay of these economic and technical functions, Vail further reasoned, spawned an inexorable or cumulative process, which would culminate in Bell's monopoly over the industry. Through a simple, compelling syllogism, he rationalized the company's recent success in acquiring or sublicensing its competitors:

> With the extension of the speaking limits of the telephone over connecting lines came also the necessity for the extension of the territorial limits of the exchange systems, the necessity of standardization, uniformity of apparatus and operating methods, and an effective common control over all.[94]

This trend of consolidation, he predicted, would continue until all telephone facilities were acquired by or "closely associated under the control of one central organization." Of course, he conveniently failed to mention that AT&T had deployed its capacities strategically to achieve this goal.

Yet, the core competences of AT&T's central administration were not sufficient to restore Bell's monopoly and hence to realize Vail's vision of a unified national telephone network. The company also relied on the support -- often unwitting -- of the state at every level of government.[95] First and foremost, Bell enjoyed a significant initial advantage over its competitors, which it acquired during the period of its patent monopoly. The parent company possessed sufficient resources to tap national and international financial markets, and through the internal transfer of funds, boosted the prospects of its weaker operating companies. Also, under patent protection, the company acquired a decisive technological lead in long distance transmission through its cumulative learning and strategic acquisition of patents.

Second, municipal and state authorities instituted Bell control over key local and regional markets. Most important, Bell companies enjoyed exclusive franchises in New York, Chicago, and Boston. These pivotal markets generated the vast majority of the Bell System's profits and so helped to finance its strategic investments in more vulnerable territory, as well as its ongoing research and development. Also, denied access to these centers, independents could not match Bell's long distance network and so gradually lost the vital support -- financial and political -- of the business community.

In turn, with the aid of business customers, Bell companies successfully lobbied regulatory authorities to extend their control. In larger cities with "dual" or competitive service, municipal officials increasingly accepted Bell's claim of a natural monopoly and compelled independents to consolidate. At less critical sites, state regulators mandated Bell's technical and operating standards to insure the integration of independents into Bell's long distance network. In exchange for state support, Bell companies typically acceded to some form of state-wide regulation. Vail, in fact, embraced state regulation, which would further his own goal of standardizing technology and rates. Rate regulation would also shield Bell companies "from aggressive competition" over their most "profitable" markets.[96]

Finally, lax state and federal oversight enabled Bell companies to leverage their market power in long distance service into a virtual monopoly over the entire industry. Despite various concessions to independents and regulators, AT&T under Vail insisted on exclusive access to its long distance network and aggressively challenged state laws mandating physical interconnection. Only when prompted by AT&T's acquisition of Western Union did the U.S. attorney general investigate the company's strategic consolidations.[97] Although the Kingsbury Commitment offered independents a temporary respite, Bell by this time controlled directly and indirectly over 80 percent of the telephone market. Ironically, the courts were less favorably disposed to the exclusive toll associations, organized by independent companies. Their dubious legal standing dealt the independent associations another severe blow. They lost the financial support of wary investors, and were unable to prevent the defection of key companies to the Bell System.

As Alan Stone observes, the prevailing ideology of "public service liberalism" warranted these various forms of state intervention.[98] To furnish public goods like universal telephone service, state and federal governments frequently resorted to market regulation and, if necessary, bestowed private monopolies. Yet, in echoing Vail's defense of a Bell monopoly, Stone simply ignores the alternative policies to achieve this goal, including mandatory interconnection and direct subsidies for telephone service in marginal areas.

In turn, the formation of the Bell monopoly has skewed the political-economic lessons of more recent history. Deregulation of various telecommunications services, I maintain, does not undermine the case for state intervention. Rather, it only shows that Vail's grand vision of the Bell System exceeded the much narrower scope of the "natural" monopoly in providing universal telecommunications, services.

END NOTES

1. The data come from the Annual Reports of the American Bell Telephone Co. for the period 1882-89 and of the AT&T Co. for the period 1900-15. Poll miles measure the spatial extent of the network; toll wires gauge the circuit capacity.

2. Annual Report of the AT&T Co., 1908, 22. Vail actually refers to the Bell System, not the entire telephone network. Not surprisingly, observers during the period commonly related electric communications technology to the human nervous system; see, for example, Joel A. Tarr, et al, "The City and the Telegraph: Urban Telecommunications in the Pre-Telephone Era," Journal of Urban History, 14 (November 1987), 54.

3. Annual Report of the AT&T Co., 1910, 23 (emphasis in the original).

4. AT&T Archives, Box 1011, AT&T Co., Building of Early Long Distance Lines, 1885, 1887-1888, 1908, Hall-Hudson, 21 January 1888.

5. H.C. Osborne, "A General Switching Plan for Telephone Toll Service," Bell System Technical Journal, 9 (July 1930), 429-47; "Technical Developments Underlying the Toll Services of the Bell System," Bell System Technical Journal, 15 (July 1936, Supplement), 58-65; and Bancroft Gherardi and F.B. Jewett, "Telephone Communication System of the United States," Bell System Technical Journal, 9 (January 1930), 61-62.

6. The classic references on the debate over the railroad are Leland H. Jenks, "Railroads as an Economic Force in American Development," Journal of Economic History, 4 (May 1944), 1-20; Robert W. Fogel, Railroads and American Economic Growth: Essays in Econometric History (Baltimore: Johns Hopkins University Press, 1964); Albert Fishlow, American Railroads and the Transformation of the Ante-Bellum Economy (Cambridge, MA: Harvard University Press, 1965). See also Paul David, "Transport Innovations and Economic Growth: Professor Fogel on and off of the Rails," in his Technical Choice, Innovation, and Economic Growth (New York: Cambridge University Press, 1975), 291-314; and Peter McCellland, "Social Rates of Return on American Railroads in the 19th Century," Economic History Review, 25 (August 1972), ???.

7. For a general discussion incorporating both notions, see W. Brian Arthur, "Urban Systems and Historical Path Dependence," in Jesse H. Ausubel and Robert Herman, eds., Cities and Their Vital Systems: Infrastructure Past, Present, and Future (Washington, D.C.: National Academy Press, 1988), 85-97; and "'Silicon Valley' Locational Clusters: When Do Increasing Returns Imply Monopoly?" Mathematical Social Sciences, 19 (June 1990), 235-51.

8. AT&T Archives, box 1011, AT&T Co., Building of Early Long Distance Lines, Hall-Hudson, 21 January 1888.

9. Jeffrey Rohlfs, "A Theory of Interdependent Demand for a Communications Service," Bell Journal of Economics and Management Science, 5 (Spring 1975), 30-31, uses the term "community of interest groups" to characterize interdependent demands for telephone service.

10. In 1887, Edward Hall, then general manager of the newly formed AT&T Company, offered a, if not the, critical insight by distinguishing the "field of usefulness" of the telephone and telegraph. "If the long-distance telephone competes with anything," he observed, "it is with the railroad. ... When the nature of the business requires personal communication, question and answer, the railroad or telephone line must be used, and this is our field: quick communication with instantaneous replies and prolonged personal

interviews." AT&T Archives, box 1259, AT&T Co., E.J. Hall, Long Distance Telephone Work, 1887; and box 1011, AT&T Co., Building of Early Long Distance Lines, 1887-1888, Hall-Hudson, 21 January 1888.

11. I have borrowed the term "eco-technic" from Ross Thomson, "The Eco-Technic Process and the Development of the Sewing Machine," in Gavin Wright and Gary Saxanhouse, eds., Technique, Spirit, and Form in the Making of Modern Economies: Essays in Honor of William N. Parker (Greenwich, CT: JAI Press,), 243-69, who emphasizes the dialectic between technology and the market in the process of innovation. For similar notions, see Thomas P. Hughes, "The Evolution of Large Technological Systems," in Wiebe E. Bijker, Thomas P. Hughes, and Tevor J. Pinch, eds., The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology (Cambridge, MA: MIT Press: 1987), 51-82; and William Lazonick, Business Organization and the Myth of the Market (New York: Cambridge University Press, 1991). I am grateful to Kenneth Lipartito, who cautioned against reifying the economic relationships embodied in complex technological systems, like the telephone network, into the very instruments or "artifacts" themselves.

12. They could also reduce circuit quality by using lower gauge copper wire or even by substituting iron for copper; see, for example, Annual Report of the Southern Bell Telephone and Telegraph Co. (SBT&T), 1907, Pickernell-Hall, 21 February 1908. Circuits made of lower gauge copper and iron were effective only on low density, short haul routes; Osborne, "General Switching Plan," 443-44; M.D. Fagen, ed., A History of Engineering and Science in the Bell System, The Early Years (1875-1925) (Bell Telephone Laboratories, 1975), 343.

13. AT&T Archives, box 1309, Relation between Population and Rates, 1906, Ford-Fish, 24 May 1906; Frank F. Fowle, "Economical Development of Toll Territory," Telephony, 17 (January 9, 1909), 41. For example, increasing the number of circuits from 4 to 5 reduced the "average annual charges" per circuit mile from $36.2 to $30.2 or by 16.6%.

14. AT&T Archives, box 1057, AT&T Co., T.B. Doolittle, Toll Lines, 1904; and R.I. Wilkinson, "Beginnings of Switching Theory in the United States," Electrical Engineering, 75 (Sept. 1956), 796-98. According to Wilkinson, Bell engineers drafted "the first 'comprehensive' traffic engineering" study in 1903, which demonstrated these "objective efficiencies" empirically. "Ordinary" methods refer to both technology and operating procedures and, as note below, reduced the capacity of toll circuits. For other contemporary evidence, see Frank F. Fowle, "Economical Development of Toll Territory," Telephony, 17 (January 2 1909), 9; and George K. Gann, "Handling Long Distance Traffic," Telephony, 18 (August 28, 1909), 206. For more contemporary estimates, see Leonard Waverman, "The Regulation of Intercity Telecommunications," in Almarin Phillips, ed., Promoting Competition in Regulated Markets (Washington, D.C.: The Brookings Institution, 1975), 213-14.

15. Wilkinson, "The Beginnings of Switching Theory," 796-801; and Edward C. Molina, "Application of the Theory of Probability to Telephone Trunking Problems," Bell System Technical Journal, 6 (July 1927), 461-94. The same principles apply to wholesale trade and explain the rationale for bulk transactions -- the accumulation of orders and shipments over time and space.

16. A simple example, taken from William Feller, An Introduction to Probability Theory and Its Applications, vol. 1 (New York: John Wiley, 1968), 191-92, illustrates the point. A city is divided into two equal districts, each served by separate toll centers furnished with same number of circuits, k. The likelihood that a caller will encounter a busy signal depends on whether demand at either center exceeds circuit capacity, or Prob(X_1>k or X_2>k), where X_i = the demand for toll calls at center i over the interval. If the demand for calls in the two districts are essentially uncorrelated, then

it is far less likely that both centers would encounter capacity constraints at the same time, or Prob(X_1>k and X_2>k) << Prob(X_1>k or X_2>k). Therefore, when one center experienced excess demand, the other, most likely, would have excess capacity -- unutilized circuits that could handle the overflow traffic. By consolidating the two centers into one or enlarging the circuit group to 2k, the company could either improve the grade of service (i.e., reduce the risk of congestion delays) or increase average circuit loads.

17. As Osborne, "Technical Developments," 47, observed, "In nearly all cases some changes in equipment design or arrangement is desirable to permit the best service and the most economical operation of method." The reference to "throughput" is intended to relate the organizational and operational innovations developed by Bell to similar processes adopted by other large-scale enterprises in production and distribution during the period; see Alfred D. Chandler, Jr., Scale and Scope: The Dynamics of Industrial Capitalism (Cambridge, MA: Harvard University Press, 1990), 21-31.

18. AT&T Archives, box 1285, Toll Line Service, 1896-1898, Doolittle-Hudson, 25 May 1898. I am grateful to David Gabel for bringing this document to my attention.

19. When operated by a common power source, the method yielded even greater savings. With this technology, "supervising signals or lamps" on switchboards would indicate when circuits were busy and in turn the completion of a connection. Toll operators could account more precisely for toll calls and rapidly "clear the trunk instantly for the next call, thus making possible the handling of a larger number of calls per trunk than at present." The application of the common battery system to the toll plant depended on improvements in line quality and in traffic density and so was also limited to larger markets. See also Osborne, "Technical Developments," 48-49; Fagen, ed., History of Engineering and Science, 488-502; and Milton L. Mueller, "The Switchboard Problem: Scale, Signaling, and Organization in Manual Telephone Switching, 1877-1897," Technology and Culture, 30 (July 1989), 534-60.

20. AT&T Archives, box 1285, Toll Line Service, 1896-1898, Doolittle-Hudson, 24 May 1898. According to Wilkinson, "The Beginnings of Switching Theory," 797, "ringdown" methods reduced the capacity of trunks by 25 percent.

21. See also Bancroft Gherardi and F.B. Jewett, "Telephone Communication System of the United States," Bell System Technical Journal, 9 (Jan. 1930), 35-36; H.S. Osborne, "Technical Developments Underlying the Toll Services of the Bell System," Bell System Technical Journal, 15 (July 1936), 35-40; Fagen, ed., History of Engineering and Science, 618-24.

22. AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1892-1896, Doolittle-Davis, 4 June 1896.

23. AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1892-1896, Doolittle-Davis, 4 June 1896 (diagram); box 1330, AT&T Co., Toll Line Service, 1900, Doolittle-Hudson, 20 June 1900; AT&T Co., Toll Line Service, 1903-1904, Doolittle-Hudson, 22 March 1904; and box 2020, AT&T Co., Thomas B. Doolittle, Annual Reports, 1903, 1906-1908, Doolittle-Fish, 7 March 1904.

24. AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1892-1896, Doolittle-Davis, 4 June 1896; Doolittle-Davis, 7 July 1896; box 1309, AT&T Co., Relation Between Population and Rates, 1906, Ford-Fish, 24 May 1906; and box 1330, AT&T Co., Toll Line Service, 1903-1904, Doolittle-Hudson, 22 March 1904.

25. AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1897-1898, Doolittle-Hudson, 14 June 1898.

26. AT&T Archives, box 1309, Relation between Population and Rates, Ford-Fish, 24 May 1906 (emphasis added).

27. In fact, geographers use this very evidence to delineate urban systems and the trade areas of higher order centers; John R. Borchert and Russell B. Adams, "Trade Centers and Trade Areas of the Upper Midwest," Upper Midwest Economic Study, Urban Report No. 3 (September 1963); and Ronald Abler, "The Telephone and the Evolution of the American Urban System," in Ithiel de Sola Pool, ed., The Social Impact of the Telephone (Cambridge, MA: MIT Press, 1977), 318-41. According to Ronald Abler et al, Spatial Organization: The Geographer's View of the World (Englewood Cliffs: Prentice-Hall, 1971), 265-66, a more nodal or dominant center sends its greatest flow of traffic to a smaller city, where size is measured by population.

28. David F. Weiman and Richard C. Levin, "Preying for Monopoly? The Case of Southern Bell Telephone, 1894-1912," Journal of Political Economy, 102 (Feb. 1994), 120-25; see also John V. Langdale, "The Growth of Long-Distance Telephony in the Bell System, 1875-1907," Journal of Historical Geography, 4 (April 1978), 145-59; Kenneth Lipartito, The Bell System and Regional Business: The Telephone in the South, 1877-1920 (Baltimore: Johns Hopkins University Press, 1987), 82-100; Milton L. Mueller, "The Telephone War: Interconnection, Competition, and Monopoly in the Making of Universal Telephone Service, 1894-1920" (Ph.D. dissertation, University of Pennsylvania, 1989), 177-81; and David Gabel, "Competition in a Network Industry: The Telephone Industry, 1894-1917" (Unpublished mss., Queens College, 1992), 7-9.

29. The threat of competition from merchants in nearby towns frequently prompted merchants to demand greater toll connections; see AT&T Archives, box 1214, AT&T Co., Rural Telephone Service, 1899-1902, President of Nebraska Telephone-Fish, 14 April 1902.

30. To be fair, Doolittle was making a different point; toll traffic depended more on the total population of a center than the number of exchange subscribers. Managers, he worried, myopically focused on the latter, and so underestimated the potential toll traffic in their territory, especially where competition was strong. Still, his empirical evidence shows that toll receipts per capita varied from a minimum of $0.262 in a city of 4703 people to $1.610 in a town of 1342; AT&T Archives, box 1057, T.B. Doolittle, Toll Lines, 1904. Also, in an earlier document, he offered an important qualification: "it is fair to presume that there should be some relation in the amount of receipts per inhabitant, provided that the toll facilities are of like character, and adequate;" AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1897-1898, Doolittle-Hudson, 3 June 1898.

31. AT&T Archives, box 1309, AT&T Co., Relation between Population and Rates, 1906, Wray-Hubbard, 14 May 1906 (quotation); Ford-Fish, 24 May 1906.

32. AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1892-1896, Doolittle-Davis, 8 July 1896; AT&T Co., Toll Line Service, 1897-1898, Doolittle-Hudson, 14 June 1898; box 2020, AT&T Co., Thomas B. Doolittle, Annual Reports, 1903, 1906-1908, Doolittle-Fish, 4 January 1907; box 2026, SBT&T Co., Toll Traffic Matters, 1909, Doolittle-Carty, 14 July 1909. Geographers define the hierarchical order of a center by the number and geographic range of its economic functions; it is often highly correlated with population. See, for example, Brian J.L. Berry, Geography of Market Centers and Retail Distribution (Englewood Cliffs: Prentice-Hall, 1967), 14-18, 35-40.

33. AT&T Archives, box 1057, AT&T Co., Thomas B. Doolittle, Toll Lines, 1904, p. 2; box 2020, AT&T Co., Thomas B. Doolittle, Annual Reports, 1903, 1906-1908, Doolittle-Fish, 7 March 1904.

34. In his analysis of the capitalist economy, for example, Karl Marx, Capital: A Critique of Political Economy, vol. 1 (New York: Vintage Books, 1977), Part 8, conceived the problem in terms of an "original" or "primitive" accumulation, non-capitalist forms of amassing wealth such as the forcible expropriation of property by the state. On the role of external spheres in capitalist development, see Rosa Luxemburg, The Accumulation of Capital (New York: Monthly Review Press, 1972), chs. 6-9 and Section 3; and Carol Heim, "External Spheres and the Theory of Capitalist Development," Social Concept, 3 (December 1986), 3-42. More recently, Brian Arthur and Paul David have heralded these lacunae as the proper domain of "history," by which they mean "small events," which are outside of the scope of deterministic processes; W. Brian Arthur, "Competing Technologies, Increasing Returns, and Lock-In by Historical Events," Economic Journal, 99 (March 1989), 116-31, and "Urban Systems and Historical Path Dependence;" Paul A. David, "Understanding the Economics of QWERTY: The Necessity of History," in William N. Parker, ed., Economics History and the Modern Economist (Oxford: Basil Blackwell, 1986), ???, and "Path Dependence: Putting the Past into the Future of Economics," Institute for Mathematical Studies in the Social Sciences Technical Report, No. 533 (Stanford University, 1988).

35. AT&T Archives, box 1011, AT&T Co., Building of Early Long Distance Lines, Hall-Hudson, 21 January 1888.

36. Frank F. Fowle, "Economical Development of Toll Territory," Telephony, 18 (January 9, 1909), 39; Osborne, "General Switching Plan," 445-46; and Fagen, ed., History of Engineering and Science, 233-34, 542. Longer feeder lines had to be equipped with more costly, higher grade wires, and calls from outlying centers required more intermediate switches and circuitous routes, which increased the cost of and delays in completing connections. The concentration of traffic through toll centers, Moreover, created "unbalanced" peak load demands, which strained the capacity of central office equipment.

37. AT&T Archives, box 1011, AT&T Co., Building of Early Long Distance Lines, Hall-Hudson, 21 January 1888.

38. AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1892-1896, Doolittle-Davis, 7 July 1896.

39. AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1892-1896, Doolittle-Davis, 8 July 1896; and AT&T Co., Toll Line Service, 1897-1898, Doolittle-Hudson, 14 June 1898.

40. AT&T Archives, box 2020, AT&T Co., Thomas B. Doolittle, Annual Reports, 1903, 1906-1908, Doolittle-Fish, 3/7/1904; box 1057, AT&T Co., T.B. Doolittle, Toll Lines, 1904.

41. He used a similar exercise to determine other investment decisions: adding circuits to an existing line and building or expanding an urban exchange and toll center. These latter calculations include additional arguments to determine projected costs and revenues from exchange service. See AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1892-1896, Doolittle-Davis, 8 July 1896; AT&T Co., Toll Line Service, 1897-1898, Doolittle-Hudson, 14 June 1898; and S.D. Levings, "The Development Study," Telephony, 17 (February 20, February 27, March 6, March 27, 1909), 217-18, 244-45, 275-76, 372-74.

42. AT&T Archives, box 1330, AT&T Co., Toll Line Service, 1903-1904, Doolittle-Fish, 22 March 1904; and box 2020, Thomas B. Doolittle, Annual Reports, 1903, 1906-1908, Doolittle-Fish, 7 March 1904.

43. Formally, Doolittle's insight locates the influence of demand interdependence in the variable R, whose magnitude depends on the size and scope of the network, measured say by the total population of centers with toll connections. In making these calculations, Doolittle suggested alternative estimates of R: the average for the entire Bell System or operating company or the average for comparable cities in the region. The choice of estimate, in fact, exploited different manifestations of the network externality. The former implied the "subsidization" of new lines by the additional profits earned on other lines nationally or regionally. The latter represented the direct realization of demand interdependence through the greater density of traffic on the spokes of local systems.

44. AT&T Archives, box 1057, T.B. Doolittle, Toll Lines, 1904; and box 2020, AT&T Co., Thomas B. Doolittle, Annual Reports, 1903, 1906-1908, Doolittle-Fish, 7 March 1904.

45. AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1892-1896, Doolittle-Davis, 8 July 1896.

46. AT&T Archives, box 1377, AT&T Co., Operating Companies -- Building Lines, 1906, Hall-Fish, 5 July 1906.

47. Fowle, "Economical Development of Toll Territory," Telephony, 17 (December 19, 1908), 638-39. Based on an admittedly crude methodology, he derived the following relationship:

$$T = 0.00022\ (P_1 \cdot P_2)/D^2$$

where T = the volume of traffic; P_1, P_2 = the size of each center, and D = the distance between them. Fowled restricted his analysis to calls travelling at least 40 miles. The estimate of short-haul traffic is based on data from Chicago; see the discussion below.

Fowle's model implies that the toll line development would follow the contours of urban population potential; see also Borchert and Adams, "Trade Centers and Trade Areas of the Upper Midwest," 5; Abler et al, Spatial Organization, 216-24; and J.W. Simmons, "Interaction among the Cities of Ontario and Quebec," in L.S. Bourne and R.D. McKinnon, eds., Urban Systems Development in Central Canada: Selected Papers (Toronto: University of Toronto Press, 1972), 203-05. Whether accurate or not, Fowle credited himself with this original contribution.

48. AT&T Archives, box 1330, Toll Line Service, 1900, Doolittle-Hudson, 20 June 1900; Toll Line Service, 1901, Doolittle-Cochrane, 18 January 1901. "Local" calls fell within the exchange district and were not carried on "extra-territorial" lines of the operating company or AT&T long lines.

49. Chicago Special Telephone Commission, Report on the Telephone Situation in the City of Chicago (Chicago: Gunthorp-Warren Printing, 1907), 50-51, 75. A survey of Chicago's toll revenues in 1910 yields similar results; "Details of Chicago Telephone Company's Toll Business Covered in Recent Report," Telephony, 60 (February 25, 1911), 243. In such densely populated regions, technological constraints, such as switchboard capacity, limited the size of a central office, not the areal network. Local networks consisted of multiple central offices, connected by direct trunk lines or indirectly through tandem offices. The configuration of central offices determined the number of intermediate switches to complete a connection and so affected the cost and quality of service. Like the geographic scope of the network, however, it depended primarily on calling patterns.

50. AT&T Archives, box 1377, AT&T Co., Operating Companies -- Building Lines, 1906, Hall-Fish, 5 July 1906; and box 2020, AT&T Co., Thomas B. Doolittle, Annual Reports, 1903, 1906-1908, Doolittle-Fish, 14 January 1907.

51. AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1897-1898, Doolittle-Hudson, 1 November 1898; Doolittle-Hudson, 23 November 1898.

52. AT&T Archives, box 1285, AT&T Co., Toll Line Service, 1897-1898, Doolittle-Hudson, 1 November 1898.

53. AT&T Archives, box 2026, SBT&T Co., Toll Traffic Matters, 1909, Doolittle-Carty, 14 July 1909.

54. Richard Whitcomb, "The Key Town Plan of Selling by Telephone," Bell System Quarterly, 8 (January 1929), 53.

55. Wholesale grocers, for example, operated within a more limited geographic range because of the greater density of retailers and perishability of their products.

56. Fowle, "Economical Development," 612.

57. AT&T Archives, Box 1057, AT&T Co., T.B. Doolittle, Toll Lines, 1904; Box 2020, AT&T Co., Thomas B. Doolittle, Annual Reports, 1903, 1906-1908, Doolittle-Fish, 7 March 1904; and Fowle, "Economical Development," 639 (quotation). These conditions would also yield an almost linear rank-size relationship -- the relationship between the logarithm of city size and the logarithm of their rank according to population; Brian J.L. Berry, "City Size Distribution and Economic Development," in John Friedmann and William Alonso, eds., Regional Development and Planning: A Reader (Cambridge, MA: MIT Press, 1964), 140-47; Salah El-Shakhs, "Development, Primacy, and Systems of Cities," Journal of Developing Areas, 7 (October 1972), 12-16; G. William Skinner, "Cities and the Hierarchy of Local Systems," in G. William Skinner, ed., The City in Late Imperial China (Stanford: Stanford University Press, 1977), 237-38; and Carol A. Smith, "Modern and Premodern Primacy," Comparative Urban Research, 9 (1982), 80-82.

58. AT&T Archives, box 2020, AT&T Co., Thomas B. Doolittle, Annual Reports, 1903, 1906-1908, Doolittle-Fish, 14 January 1907.

59. "An examination of the toll line maps," he observed in 1906, "will show ... development from commercial centres in radial lines with enclosed gaps, between the groups, bridged partially by main lines;" AT&T Archives, box 1377, AT&T Co., Operating Companies -- Building Lines, 1906, Hall-Fish, 5 July 1906.

60. AT&T Archives, box 1340, SBT&T Co., Exchanges Report, 1900, Hall-Cochrane, 2 November 1900. The problem was noted earlier in SBT&T Co., Annual Report, 1882. The sparse distribution of cities in the territory increased the distances, which had to be bridged by toll lines. Consequently, building the network entailed greater cost and higher demand thresholds than in a territory, where cities were more densely packed; see also AT&T Archives, box 1057, AT&T Co., T.B. Doolittle, Toll Lines, 1904.

61. AT&T Archives, box 2026, Toll Traffic Matters, 1909, Doolittle-Carty, 14 July 1909; see also box 2020, Thomas B. Doolittle, Annual Reports, 1903, 1906-1908, Doolittle-Fish, 14 January 1907. Building direct lines that did not follow rail routes entailed greater capital outlays in clearing and leveling rights of way, whereas more circuitous routes required more relays in routing traffic and higher operating costs. Either way, connections to marginal centers entailed higher unit costs.

62. This formulation of the problem draws on the classic cases of nineteenth-century transport improvements; see Roger Ransom, "Social Returns from Public Transport Investment: A Case Study of the Ohio Canal," Journal of Political Economy, 78 (September-October 1970), 1041-60; Fishlow, American Railroads, 165-203; and Lloyd Mercer, "Building Ahead of Demand: Some Evidence for the Land Grant Railroads," Journal of Economic History, 34 (June 1974), 492-500.

63. AT&T Archives, box 2020, Thomas B. Doolittle, Annual Reports, 1903, 1906-1908, Doolittle-Fish, 14 January 1907.

64. Levings, "The Development Study," 275. Of course, local boosters were at times equally frustrated by Bell officials, who attempted to install the parent company's technological system in their region regardless of local conditions; see Lipartito, The Bell System, 40-44, 69-76.

65. See note ?? above for references on Bell's strategic use of its long distance network during the competitive period.

66. In other political economic contexts, the state, either national or provincial governments, furnished the finance for these infrastructural investments; see, for example, Claude S. Fischer, America Calling: A Social History of the Telephone to 1940 (Berkeley: University of California Press, 1992), 54-56. As I suggest below, the extremes of private versus public investments are not as great as they might seem.

67. AT&T, Vail stated, "is primarily a holding company, holding stocks of the associated operating and manufacturing companies;" AT&T Co., Annual Report, 1908, 15. In subsequent reports, AT&T Co., Annual Report, 1910, 26, he qualified this statement and emphasized the economic benefits from centralized control. On the evolution of Bell's organizational structure, see Robert W. Garnet, The Telephone Enterprise: The Evolution of the Bell System's Horizontal Structure, 1876-1909 (Baltimore: Johns Hopkins University Press, 1985); George D. Smith, The Evolution of a Business Strategy: Bell, Western Electric, and the Origins of the American Telephone Industry (Baltimore: Johns Hopkins University Press, 1985); and Lipartito, The Bell System, esp. ch. 7.

68. AT&T Archives, box 1214, Rural Telephone Service, 1899-1902, President of Nebraska Telephone-Fish, 14 April 1902.

69. AT&T Archives, box 1342, Rural Telephone Service, 1903-1904, Farnsworth-Fish, 27 April 1903. For earlier efforts, see AT&T Co., box 1330, Toll Line Service, 1892-1896, Doolittle-Davis, 7 July 1896.

70. AT&T Archives, box 1342, Rural Telephone Service, 1903-1904, Allen-Fish, 12 August 1903; Allen-Carleton, 12 August 1903; and Richardson-Allen, 5 September 1903.

71. "Handling Farm Telephone Lines in Southern Territory," Telephony, 19 (May 14, 1910), 619. By providing a precursor to "800 service," this policy offered an alternative solution to the problem, noted by Doolittle, of reaping the systemic benefits of network development.

72. AT&T Archives, box 1342, Rural Telephone Service, 1903-1904, Harris-Ellsworth, 17 February 1909, and Harris Circular Letter, 3 May 1909. See also Georgia, Railroad Commission, Annual Report of the Railroad Commission, 1908 (Atlanta: State Printer, 1909), 32-35.

73. AT&T Archives, box 1342, Rural Telephone Service, 1907-1910, Harris-Ellsworth, 30 June 1909.

74. AT&T Archives, box 1342, Rural Telephone Service, 1903-1904, Farnsworth-Fish, 27 April 1903. Doolittle had earlier proposed the formation of such strategic alliances with independent companies, but Bell officials rejected it; box 1285, AT&T Co., Toll Line Service, 1897-1898, Doolittle-Hudson, 1 November 1898 and 23 November 1898.

75. AT&T Archives, box 1340, SBT&T Co., Acquisition of Independent Companies, 1902-1911, Gentry-Hall, 13 October 1909; "Southern Bell Eliminates Prospect of Competition in Jacksonville, Fla., and Advances Rates," *Telephony* 16 (December 26, 1908), 677; see also Weiman and Levin, "Preying for Monopoly," 10-15.

76. AT&T Archives, box 1348, AT&T Co., Sub-Licensee - Advantages to Operating Company, Memo, 1903, Hall-Fish, 31 July 1903; box 66, AT&T Co., Sub-Licensing Policy, 1907-08, Hall-French, 16 May 1908; and box 1340, SBT&T Co., Petersburg Telephone Company, Virginia, Organization, 1902, Hall-Fish, 24 July 1902.

77. In the context of railroad construction, Fishlow, *American Railroads*, 191, observes that "the very fact of contributions by towns and counties along the route gives lie to the existence of an unsettled wilderness." Still he acknowledges that local subscriptions "could on occasion be catalytic and even crucial" in securing the necessary external funds to complete these projects; Albert Fishlow, "Internal Transportation," in Lance Davis et al, *American Economic Growth: An Economists' History of the United States* (New York: Harper and Row, 1972), 495.

78. AT&T Archives, box 1340, SBT&T Co., Acquisition of Independent Companies, 1897-1901, Hall-Cochrane, 6 March 1901. A telling index is the relative increase in the population potential of Charlotte from 47% to 60% between 1880 and 1900. In the same year, AT&T would make a more consequential decision, when it relocated the headquarters of Southern Bell from New York to its largest, most profitable exchange in the territory, Atlanta. The factors entering into the timing of the decision and its final outcome are considered more thoroughly in David F. Weiman, *Locating the New South: Reconstruction, National Market Formation, and Metropolitan Development in the Southern Upcountry, 1860-1914* (New York: Cambridge University Press, forthcoming).

79. AT&T Archives, box 1342, AT&T Co., Rural Telephone Service, 1903-1904, Farnsworth-Fish, 27 April 1903; and box 1363, AT&T Co., Rural Telephone Service, 1907-1910, Ellsworth-Fish, 12 March 1907; Pettengill-Pickernell, 25 November 1908.

80. AT&T Archives, box 1309, AT&T Co., Relation between Population and Rates, 1906, Hibbard-Wray, 14 May 1906 and Ford-Fish, 24 May 1906; and Fowle, "Economical Development," 638.

81. Rural development, measured by the number of telephones per 100 farms, averaged between 2.5 to 2.8 in the counties around Dallas and Fort Worth, but only 0.2 and 0.4 in the Houston and Little Rock divisions; AT&T Archives, box 1363, Rural Telephone Service, 1907-1910, Ellsworth-Fish, 12 March 1907. The former regions had higher levels of agricultural and urban development; U.S. Bureau of the Census Office, *Statistical Atlas of the United States* (Washington, D.C.: Government Printing Office, 1914), plates 140, 239, 242, and 258. These same factors explain the uneven diffusion of the telephone across states; see Claude S. Fischer, "The Revolution in Rural Telephony, 1900-1920," *Journal of Social History*, 21 (Fall 1987), 13-15; Claude S. Fischer and Glen Carroll, "Telephone and Automobile Diffusion in the United States, 1902-1937," *American Journal of Sociology*, 93 (March 1988), 1163-65; and Fischer, *America Calling*, 92-107, 277-86.

82. AT&T Co., box 1363, AT&T Co., Rural Telephone Service, Ellsworth-Fish, 12 March 1907.

83. Michael P. Conzen, "Capital Flows and the Developing Urban Hierarchy: State Bank Capital in Wisconsin, 1854-1895," Economic Geography, 51 (October 1975), 321-38. See also David R. Meyer, "A Dynamic Model of the Integration of Frontier Urban Places into the United States System of Cities," Economic Geography, 56 (January 1980), 126; James E. Vance, Jr., The Merchant's World: The Geography of Wholesaling (Englewood Cliffs: Prentice-Hall, 1970), 87-90; and A.F. Burghardt, "A Hypothesis about Gateway Cities," Annals of the Association of American Geographers, 61 (June 1971), 270.

84. As the example of Southern Bell shows, AT&T succeeded in developing the southern market, only when the company relented in its policy of securing absolute control over every tier of the telephone network and forged strategic alliances with local businesses, including other telephone companies; see Weiman and Levin, "Preying for Monopoly."

85. F.E. Richter, "The Telephone as an Economic Instrument," Bell System Quarterly, 4 (October 1925), 285.

86. John R. Borchert, "American Metropolitan Evolution," Geographical Review, 57 (July 1967), 301-32, makes a similar point about the impact of transport innovations.

87. See, for example, Weiman and Levin, "Preying for Monopoly?" 115-20; Langdale, "The Growth of Long-Distance Telephony;" and Lipartito, The Bell System, ch. 6; and Gabel, "Competition in a Network Industry," 20-22.

88. Fagen, ed., History of Engineering and Science, 235-90; Neil H. Wasserman, From Invention to Innovation: Long-Distance Telephone Transmission at the Turn of the Century (Baltimore: Johns Hopkins University Press, 1985); and Kenneth Lipartito, "America's Success with Long Distance Telephony, 1890-1930," 5-20.

89. A recent statement of this position can be found in The New York Telephone Exchange, Connecting the Future: Greater Access, Services, and Competition Telecommunications (New York, n.p., 1993), 17-25.

90. Annual Report of the AT&T Co., 1909, pp. 18-19. For similar claims by Vail's predecessors, see Annual Report of the American Bell Telephone Co., 1885, 24-25; and Annual Report of the AT&T Co., 1904, 11.

91. Annual Report of the AT&T Co, 1913, p. 60.

92. Garnet, The Telephone Enterprise, 128-54; and Galambos, "Theodore N. Vail and the Role of Innovation," 108-17.

93. Annual Report of the AT&T Co., 1908, 16-18; 1909, 22-23; 1910, 14 (quotation), 26, 41-44; and 1911, 30.

94. Annual Report of the AT&T Co., 1910, 24-25.

95. On the role of state policies in assisting Bell, see Gerald W. Brock, The Telecommunications Industry: The Dynamics of Market Structure (Cambridge, MA: Harvard University Press, 1981), 99-122, 149-76; Kenneth Lipartito, "System Building on the Margin: The Problem of Public Choice in the Telephone Industry," Journal of Economic History, 49 (June 1989), 332-36; Gabel, "Competition in a Network Industry;" and Weiman and Levin, "Preying for

Monopoly?"

96. Annual Report of the AT&T Co., 1910, 33.

97. For the case against the Bell System, see U.S. Federal Communications Commission, Proposed Report: Telephone Investigation (Washington, D.C.: Government Printing Office, 1938), esp. ch. 5. Given its common law origins, the Sherman Act may not have enjoined these actions; see Martin J. Sklar, The Corporate Reconstruction of American Capitalism, 1890-1916 (New York: Cambridge University Press, 1988), ch. 3; Herbert Hovenkamp, Enterprise and American Law, 1836-1937 (Cambridge, MA: Harvard University Press, 1991), pt. VI; and Christopher Grandy, "Original Intent and the Sherman Anti-Trust Act: A Re-examination of the Consumer-Welfare Hypothesis," Journal of Economic History, 53 (June 1993), 359-76.

98. Alan Stone, Public Service Liberalism: Telecommunications and Transitions in Public Policy (Princeton: Princeton University Press, 1991), 12-22.

TABLE 1
Geographic Range of Messages on AT&T Long Lines, 1891-1902

Distance (miles)	10/1891	3/1898	Distance (miles)	7/1902
	% of Calls	% of Calls		% of Calls
104	77.3	63.6	187	83.3
224	98.1	89.8	362	96.7
324	99.3	94.5	512	98.8
424	99.9	97.2	662	99.5
624	100.0	98.7	1037	99.9
824		99.2	1437	100.0

Notes: % of calls measures the fraction of total traffic that travels less than the corresponding distance.
Sources: AT&T Archives, box 1345, AT&T Co., Long and Short Haul Messages, Statistics, 1896-1902, Davis-Fish, 19 November 1902.

Figure 1: Toll Network of the Bell System, 1882-1915

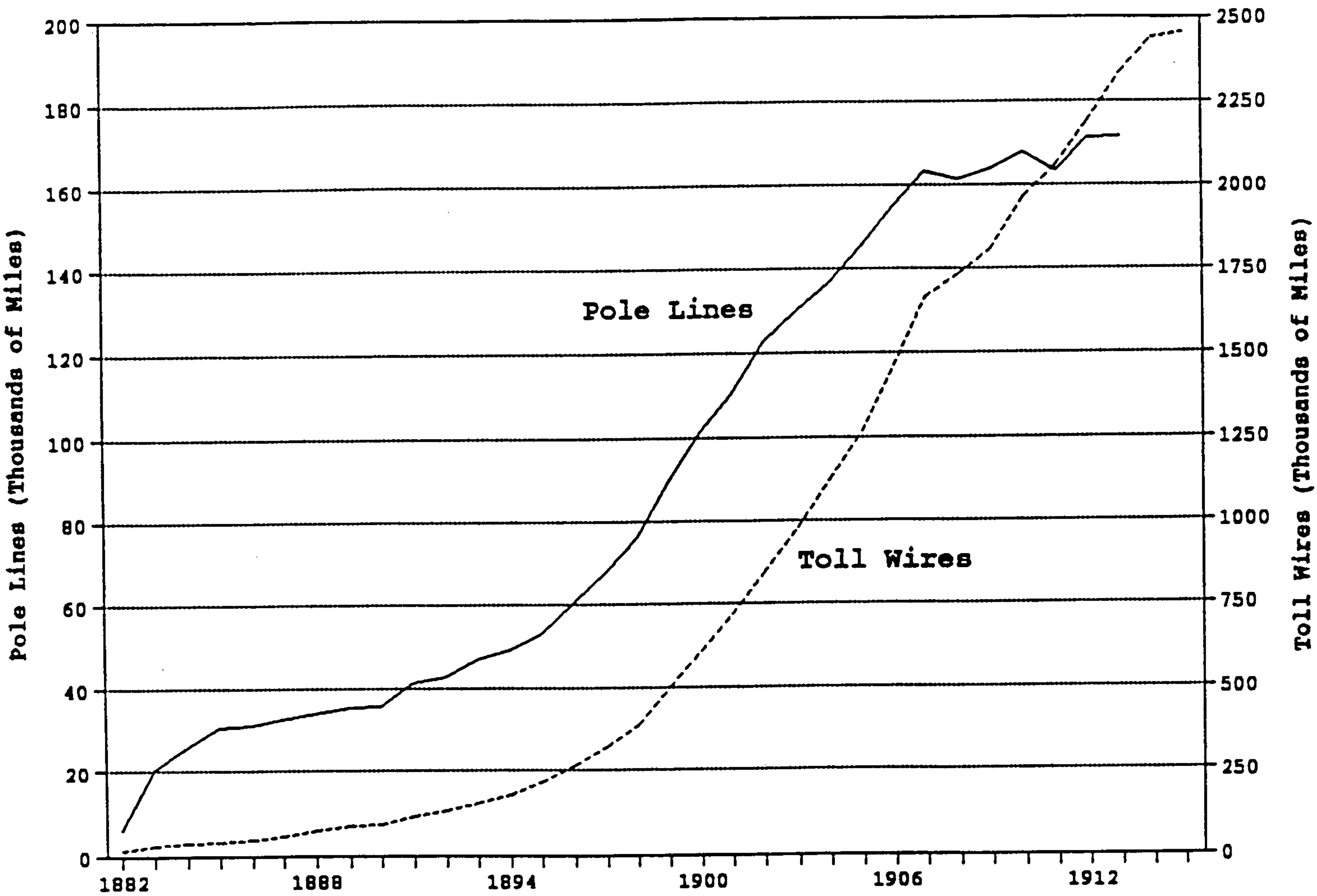
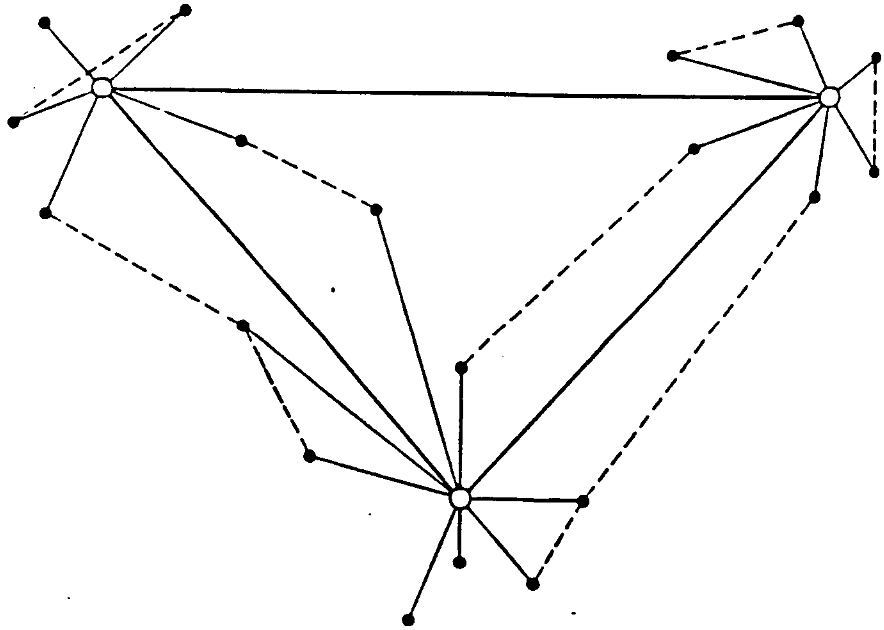


Figure 2
AT&T'S General Switching Plan ca. 1930

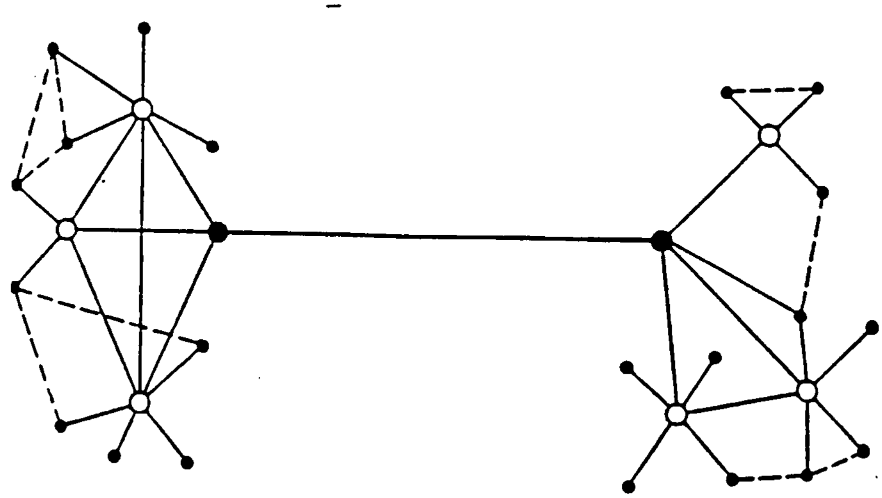


SOLID LINES - FUNDAMENTAL ROUTES OF GENERAL PLAN

DASHED LINES - SUPPLEMENTARY DIRECT CIRCUIT GROUPS

O PRIMARY OUTLET
• TOLL CENTER

Fig. 5—General toll switching plan—application in local company area.



SOLID LINES - FUNDAMENTAL ROUTES OF GENERAL PLAN

DASHED LINES - SUPPLEMENTARY DIRECT CIRCUIT GROUPS

● REGIONAL CENTER
O PRIMARY OUTLET
• TOLL CENTER

Fig. 6—General toll switching plan—illustration of interconnection of important switching offices throughout Bell system.

Figure 3
Doolittle's Model of Demand Interdependence

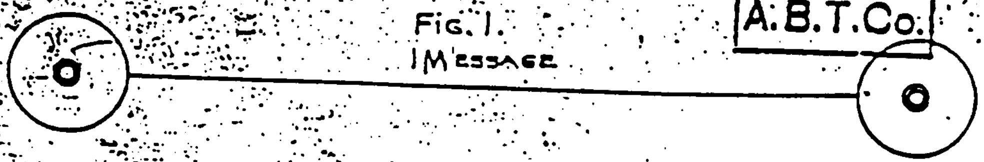


Fig. 1.
1 Message

Diagram showing the increase of business over long trunk lines, by connecting groups of tributary places and assuming one message between each two points.

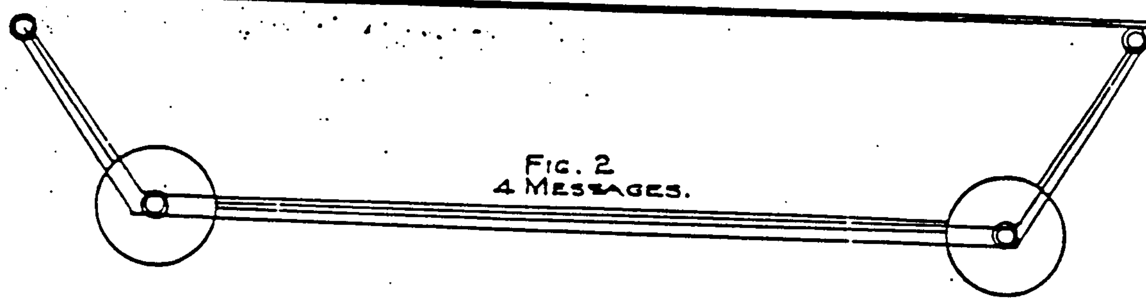


Fig. 2
4 Messages.

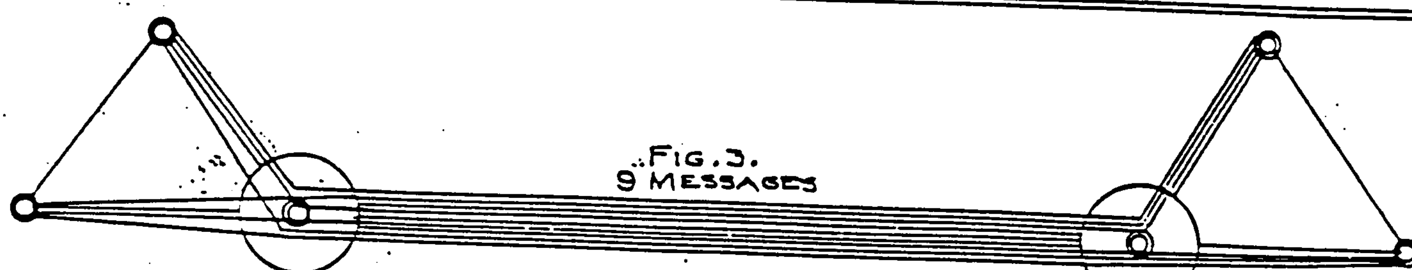


Fig. 3.
9 Messages

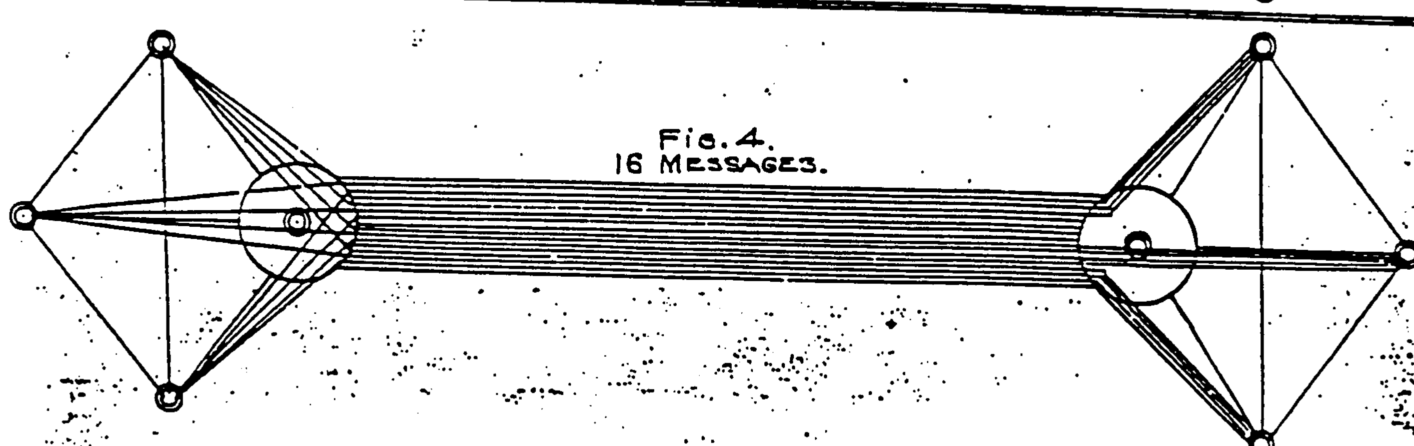
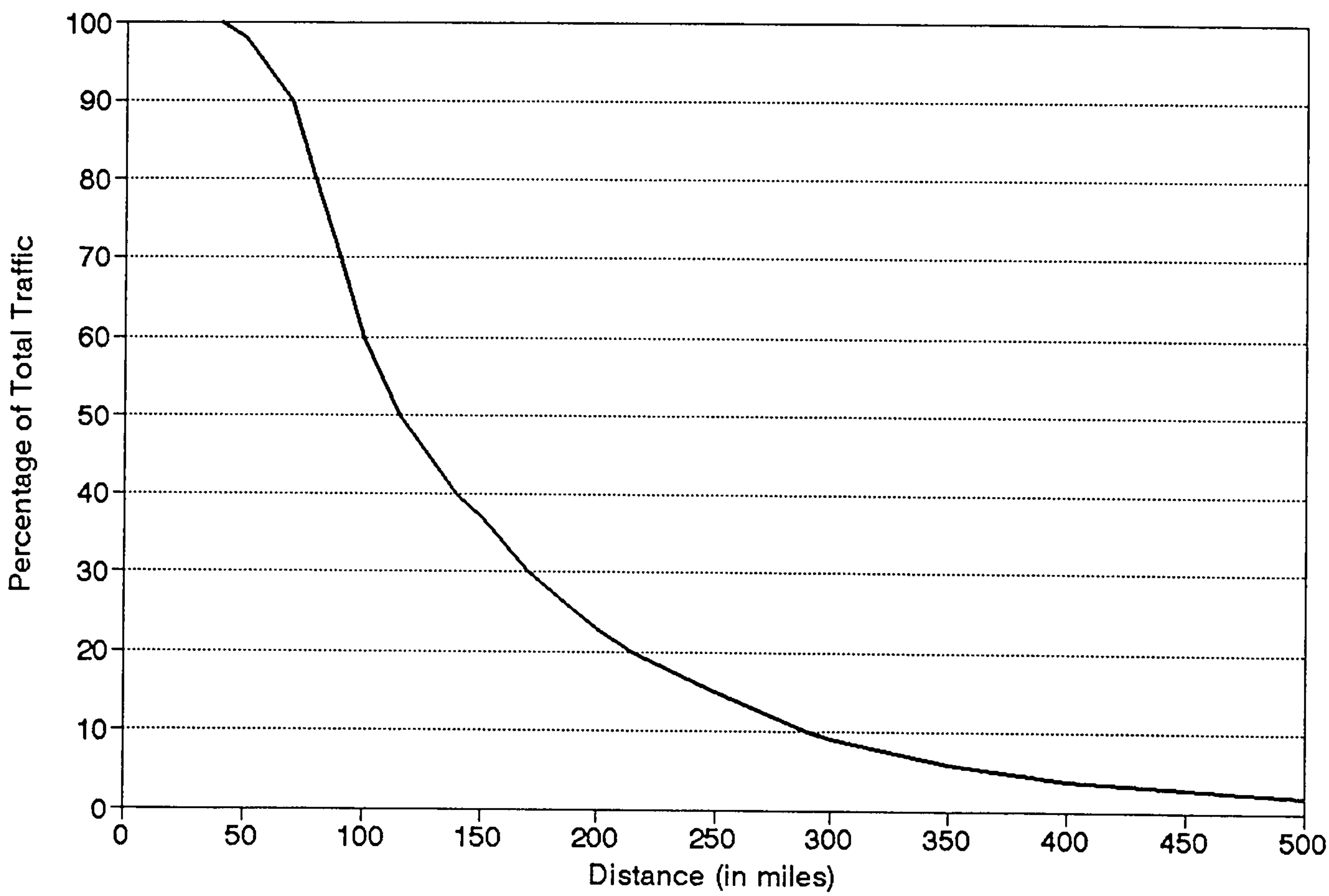
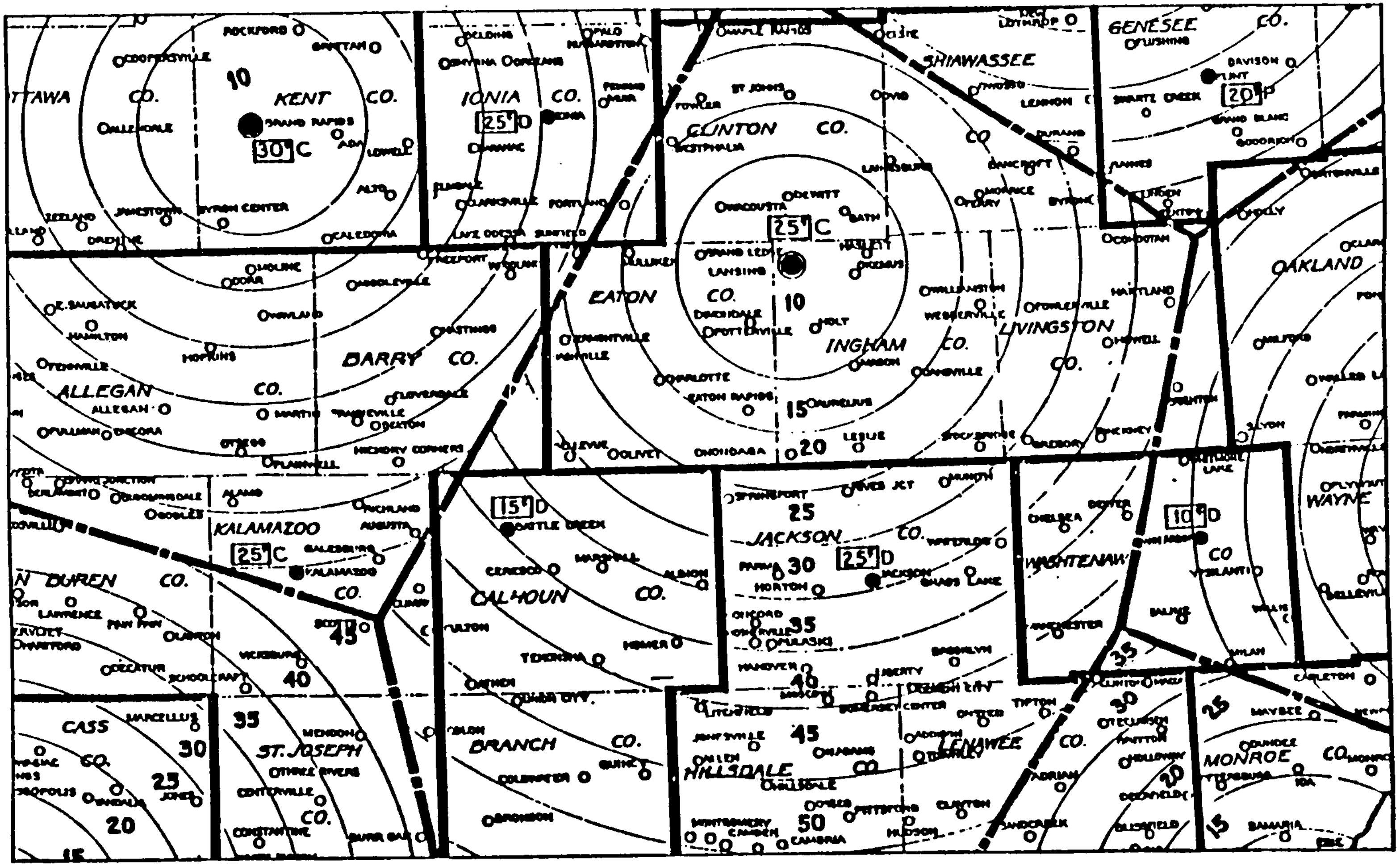


Fig. 4.
16 Messages.

Figure 4: Relationship between Traffic Levels and Distance





LAYOUT OF KEY TOWN TELEPHONE SALES AREAS.

Showing Primary and Secondary Calling Points and Associated Calling Areas.

◉ Primary Calling Point. ● Secondary Calling Point. ▬ ▪ ▬ Primary Calling Point Area. ▬▬ Secondary Calling Point Area.

Customers Facilities

C—Customers Room. P—Use of Private Office. D—Use of Desk Space.