Our analysis of marketing and prices in Chapter 4 proceeded on the assumption that producers and consumers are located at a single point. Within such a point market, of course, there are no costs of moving products through space! We first assumed in Chapter 5 that transfer costs were zero and, hence, concluded that product prices would equalize completely and perfectly in the several regions connected through trade. We then developed a more realistic model which included the costs associated with the spatial distribution and segregation of production and consumption. Now we turn to a more detailed consideration of transfer costs and the impact of these costs on economic specialization and trade.

**6.1 COMPONENTS OF TRANSFER COST**

With production and consumption carried on at spatially separated locations, the transfer of products—raw materials and semifinished and finished goods—provides a necessary and essential connection. These transfer services may include activities such as the assembly or collection from small producing sites, loading and other terminal activities, the transportation to major market centers, and the distribution to wholesalers, retailers, and final consumers. Some of these activities are not directly related to space or length of haul, but the costs of performing other services are clearly a function of the distance involved. The com-

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plex of all of these costs of movement we call transfer cost. The costs that are directly related to length of haul are usually called transportation costs, but the fixed or constant costs we shall call terminal costs.

6.2 DISTANCE-COST RELATIONSHIPS

The relationship between length of haul and cost of transfer services is called a transfer cost function. Several commonly observed types of distance-transfer cost relationships are illustrated in Figure 6.1. Type A is a horizontal line suggesting that transfer charges are a constant $T_a$ regardless of distance. An example is the structure of first-class postal rates in the United States where the entire country is blanketed by a single zone within which charges are constant regardless of the distance involved. Type B is a more conventional zone-rate system where charges increase with distance but through a series of discontinuous steps. The familiar zone charges for parcel post illustrate this type. Many rail freight tariff schedules are also based on this scheme. Notice that we have drawn this function with a relatively high initial charge $T_b$; this “intercept” value covers terminal and other costs not associated with distance. Type C is a continuous function with an initial charge $T_c$ to cover nondistance factors plus a straight-line relationship to cover transportation costs which are a linear function of distance. Such a linear function is frequently encountered when all factors other than distance (including size and type of equipment) are held constant.

![Figure 6.1 Alternative transfer cost-distance relationships.](image)
Type D is also a continuous function but one which describes a situation where costs or charges increase at a decreasing rate with distance. Such a less-than-proportional schedule commonly describes commercial transportation rates. It may also be expected when transfer conditions or the type of carrier used changes with distance. For example, the transportation of milk to a large metropolitan center may be performed (1) with direct delivery from farms to market by small trucks from nearby zones, (2) with initial assembly from farms by small trucks for concentration at country receiving stations and transportation to the city in large trucks from intermediate zones, and (3) with the operation of country stations and rail transport from distant zones. In each location, the most economical transfer arrangement tends to dominate, with the result that the complex of transfer costs will usually be found to increase with distance at a decreasing rate.

Moreover, transfer costs and charges are influenced by many factors. Certainly conditions such as terrain and topography are important, as are the type of carrier and the total amount of traffic. In fact, transport facilities are themselves subject to change over time and, in the long run, reflect changes in both the demand for and the techniques for providing transport services. The characteristics of the product are important (bulkiness, value, perishability, type of container, and size of lot).

The institutional setting will have an important effect on charges (if not on costs) through the type of competition that is permitted among carriers and the decisions of public rate-establishing agencies. The type A flat charge for first-class mail is a good example of this institutional influence. Early mail rates were steeply graduated with distance, but with improvements in transportation this influence was reduced. Finally, and certainly on an arbitrary basis in relation to real costs, the federal government established a single rate for all except local mail, and eventually this single rate was expanded to cover all domestic first-class mail service. No doubt, terminal costs are more important than transportation costs in the modern mail service, and possibly a system of zoned rates would even increase these terminal costs; but the flat-rate system generally involves some subsidization of distant shippers by nearby shippers. The same is true of any zone system. Shippers near the inner boundary of a given zone subsidize shippers near the outer boundary, but this may be slight relative to the gain in simplicity in applying a zoned rather than a point-to-point rate schedule.
6.3 TRANSFER COST SURFACE

Suppose that transfer cost for a given product can be expressed as a linear or curvilinear function of airline distance. Consider one localized market with product supplies situated at points scattered over a completely uniform and flat geographic area. Let us assume further that, as far as transport distances and costs are concerned, this plain is appropriately surfaced (with concrete or asphalt connections) so as to make travel in any direction equally feasible. The resulting spatial pattern of transfer costs from every point on this plain to the market is called a transfer cost surface.

A transfer cost surface can be described in either cross-section or plan view. Given a linear transfer function like type C in Figure 6.1, the cost of moving a product to market will increase at a constant rate as distance to market increases. This case, illustrated for the cross section along the line $RS$ in Figure 6.2, has a very simple interpretation. A shipment originating at $D_1$ will incur a transfer cost of $T_1$ per unit of product, at $D_2$ a cost of $T_2$ per unit of product, etc. Alternatively, we may represent the transfer cost surface in plan view by connecting those sites where a given outlay is required to transport a unit of product to market. In our simplified model these equal-transfer-cost contours consist of a series of concentric circles. An isocost contour represents the locus of points on a plain where equal transfer costs will be incurred when shipping a given product to a given market center.

If the transfer cost function takes the shape of type D in Figure 6.1, the resulting isocost contours are concentric circles but with radii that increase at an increasing rate rather than at a constant rate, as is the case with a type C function. To illustrate, the isocost contours in Figure 6.2 are drawn to represent equal increments to transfer cost from one contour to the next; that is, $T_1 - T_0 = T_2 - T_1$, etc., for each pair of contour lines. With a linear transfer cost function, these contours are equally spaced on the plain and distances $D_1, D_2$, etc., represent equal increments in terms of miles to market. However, with a type D cost function the distance between $D_1$ and $D_2$, $D_2$ and $D_3$, etc., becomes greater and greater because the cost surface rises at a decreasing rate.

In much of the material that follows, we utilize a transfer cost function of type D. Furthermore, we usually express transfer costs as a simple and regular function of airline distance. These assumptions simplify the presentation and permit emphasis on the major influences of location on price. They are admittedly unrealistic assumptions, however, as will be shown. Bear in mind that any application to a real-world situation will involve the use of actual rates and rate structures appropriate to that
situation. Such actual rate structures typically result in final solutions that are less smooth and symmetrical than the ones suggested here, but the underlying principles and generalizations will not be affected.

6.4 EFFECT OF TRANSPORT NETWORK ON COST

Any real geographic area will be characterized by a complex of non-uniform topography—hills and valleys, mountain ranges, rivers, and streams. These topographic influences, interacting with nonuniform spatial distributions of resources, will give rise to particular spatial distributions of human populations—a complex of major cities and suburban areas, secondary cities, towns, villages, and rural districts. Interconnecting these population distributions, and developing simultaneously with them, will be particular networks of transportation routes—the grid of major and secondary highways, rural roads, trunk-line and feeder railroad routes, water transport by major rivers, canals, lakes, and coastal ocean routes, plus the complex of scheduled and chartered airline routes.

The obvious impact of the real-world rail and road networks is to distort the relationship between transfer costs and airline distances.
Under many circumstances, this distortion may be slight. In Connecticut, for example, comparison of airline and highway mileages for selected points indicates that highway mileage \( H \) may be represented as a function of airline mileage \( A \) with a correlation of 0.99: \( H = 2.4 + 1.02A \). In other circumstances where natural barriers are more formidable, the location of mountain passes and bridges over major rivers will represent "gateways" that may seriously affect point-to-point transport distances and costs. This suggests that equal-cost contours will be irregular instead of forming concentric circles.

Even when the relation between airline and highway distance is not greatly affected, topographic features may significantly change cost relations. Thus, we expect that the near-level topography of Iowa or of the Central Valley of California will result in lower trucking costs per ton-mile than the rugged terrain through the Rocky Mountains west of Denver or the mountain passes between Nevada and California.

These distance and cost distortions can be expected to destroy the smoothness and symmetry of locational solutions suggested by our theoretical discussions, but not the basic concepts. Given any irregular pattern of transport costs, it will still be possible to define appropriate transport cost contours for materials and products. Population and production densities will also affect transfer costs, since they determine the aggregate volume of products shipped and the availability of "backhaul" loads and, hence, influence the utilization of the available capacity of existing transport systems.

The square or rectangular network of transport routes is common enough to justify specific comment here; these regular networks are approximated by the section and township roads in many parts of the United States as well as by the street patterns in many cities. Such a grid is suggested in Figure 6.3; equal-distance contours will now be a
system of squares centered on the point in question, with these squares rotated 45 degrees in relation to the underlying transport grid. Price surfaces will also reflect this pattern of concentric squares.

6.5 ALTERNATIVE MODES OF TRANSPORTATION

Not only are transport cost contours distorted from circular form by topography and transport grids but also by alternative transport systems or technologies. We have mentioned the complex of roads, railroads, waterways, and air routes as examples of four major forms of transportation. Each will be characterized by its own particular grid of routes and, also, by appropriately different cost functions. Without attempting a detailed treatment, we point out that more "sophisticated" transport systems frequently involve relatively large investments and high fixed or terminal costs per ton but much lower operating costs per ton-mile for actual transportation. This very general situation is illustrated in Figure 6.4 where line $ab$ represents the costs for the relatively simple system $T_1$ and line $cd$ represents the costs for the more complex or sophisticated system $T_2$. Such a comparison should be appropriate for various pairs of systems—wagon versus truck, small truck versus large truck, large truck versus rail, and so on.

One consequence of these alternative transport technologies is that there may be zones within which each will have the advantage of lowest cost. In Figure 6.4 it is clear that the simple system will be most advantageous for transportation within the zone $oe$—for short hauls near the market—while the more complex system will show lower costs for long hauls. In general, we may expect a progression from small trucks to large

![FIGURE 6.4 Transfer costs with two alternative transportation systems.](image-url)
trucks to rail, as transport distance increases. Correspondingly, the appropriate aggregate transfer cost function will show a general tendency to increase with distance but at a decreasing rate; the discontinuous function $afd$ illustrates this for the two-technology case.

Let us consider the alternatives represented by trucks of varying size and capacity. As truck size increases, both fixed and variable truck costs will increase. At least within limits, however, these cost increases will not be in direct proportion to the increases in capacity; that is, fixed truck costs per ton and variable truck costs per ton-mile will decrease. With larger trucks, however, the costs per customer associated with direct loading and unloading services will usually increase. Considering all elements, we can expect to find that average route costs per unit of product will show higher “intercepts” and lower “slopes” as truck size increases. This is indicated graphically in Figure 6.5. It is immediately apparent that there will be zones around the market within which a particular technology or size of truck will be optimum. Notice that this does not mean that every possible technology will be utilized; we have illustrated one case where the combination of high intercept and high slope results in costs that are never as low as the costs possible with other organizations.

We have observed that increasing truck size will often be associated with decreasing unit truck costs—fixed costs per ton and variable costs per ton-mile—but that these advantages tend to be offset by increasing costs of direct customer service. In plain words, this means that very large equipment, for example, the truck-and-trailer combination, is quite economical for over-the-highway transportation involving long distances but is very costly for the stop-and-go operations characteristic of collection or delivery routes. In fact, it may be physically impossible for this

[Figure 6.5: The cost-distance relationships for various transport technologies and the determination of zones within which a particular technology is optimum.]
large equipment to perform collection or delivery services. At-farm collection will often involve driving through narrow roads or lanes, off the main highway to farmsteads, and delivery operations also may involve narrow streets that would be difficult or impossible to negotiate with large-scale equipment. Moreover, the time required to make individual collection or delivery stops places an outside limit on the total volume that can be handled on any route—a volume often far short of physical truck capacity.

6.6 COMBINED MODES OF TRANSPORTATION

The availability of a railway (waterway or major highway) along a particular route through a region will affect transport costs by elongating the isocost contours along the axis of the low-cost route. Moreover, this will usually permit the economical combination of two transport systems. A farm located off a main highway may be most economically served by a small truck on a "stub" or "feeder" route. With such a system of feeder or stub routes, at-farm collection will be made by small trucks that deliver their volume, not to the market but to main highways where it is loaded on large trucks for transport to market. This has the effect of lowering the fixed cost for large-truck operation and, thus, permitting lower combined costs that would be possible with any system based on single trucks. This is suggested in Figure 6.5 by the relationship labeled feeder technology.

The general influence of a low-cost transport route, such as a waterway, was first pointed out by von Thünen in 1826, but the feeder route-main route case was given formal mathematical treatment by Launhardt in 1882.¹ The Launhardt analysis is illustrated in Figure 6.6 where the localized material is at point A, the market at point B, and where the main-line, low-cost transport route is represented by the line CB. The shortest distance from point A to the market at point B is a straight line representing the use of feeder route transportation only. However, with main line transportation costs \( r_2 \) lower than feeder route costs \( r_1 \), it is clear that this would not represent the minimum cost method for all material sources. Instead, the minimum cost arrangement will involve transportation from A by feeder route to some point D with final transport to market from D to B along the main route.

¹This section draws heavily on R. O. Been, "A Reconstruction of the Classical Theory of Location" (unpublished Ph.D. dissertation, Department of Agricultural Economics, University of California, Berkeley, 1965).
Assume that two modes of transport are available, truck and rail, at rates of $r_1$ and $r_2$ dollars per ton-mile. In Figure 6.6 we let the line $CB$ represent the rail line, $a$ the distance from point $A$ to the line $CB$, and $b$ the distance between the intersection of the perpendicular drawn from $A$ to $CB$ and the point $B$. The distance traveled by truck is represented by $y$ and the distance traveled by rail is represented by $z$. In the event that the two modes are used, special costs of transferring cargo from one mode to the other, amounting to $C$ dollars per ton, are incurred.

We may write out these conditions as follows.

**Direct (Mode 1)**
\[
TC_t = r_1 \sqrt{a^2 + b^2}. \tag{6.1}
\]

**Combined (Modes 1 and 2)**
\[
TC_c = r_1 y + r_2 z + C. \tag{6.2}
\]

The minimum cost route from $A$ to $B$ by combined modes involves travel by truck along the line $AD$, transhipment to rail at point $D$, and rail shipment from $D$ to $B$. It will be shown that the lines $AD$ and $CB$ form the angle $\alpha$ such that $\cos \alpha = r_2/r_1$. We let $z = b - x$ and rewrite Equation 6.2 as
\[
TC_c = r_1 \sqrt{a^2 + x^2} + r_2 (b - x) + C. \tag{6.3}
\]

Since all the terms in Equation 6.3 except $x$ are fixed, we can find that value for $x$ that will minimize total cost by taking the derivative of Equation 6.3 with respect to $x$ and setting this equal to zero:
\[
\frac{dTC_c}{dx} = r_1 \frac{x}{\sqrt{a^2 + x^2}} - r_2 = 0
\]
\[= r_1 \cos \alpha - r_2 = 0
\]

or
\[
\cos \alpha = \frac{r_2}{r_1} \tag{6.4}
\]
The cost-minimizing location for changing transport modes is that point $D$ where the cosine of angle $\alpha$ is equal to the ratio of the transport rates.

It is possible to generalize concerning the choice of direct or combined modes by using the relationships developed above. By using relation (6.4), we may write

$$\frac{x}{y} = \frac{r_2}{r_1} \quad \text{or} \quad x = \frac{r_2}{r_1} y. \tag{6.5}$$

Since

$$\sin \alpha = \frac{a}{y} \quad \text{or} \quad y = \frac{a}{\sin \alpha} \tag{6.6}$$

we rewrite Equation 6.2, by using relations (6.5) and (6.6), as

$$\min TC_c = r_1 \frac{a}{\sin \alpha} + r_2 b - \frac{r_2^2}{r_1} \frac{a}{\sin \alpha} + C \tag{6.7}$$

We may now write the equation for the curve representing locations where the costs of truck and combined modes are identical by using relations (6.1) and (6.7) as

$$\begin{align*}
TC_t &= \min TC_c \\
&= r_1 \sqrt{a^2 + b^2} = r_1 \frac{a}{\sin \alpha} + r_2 b - \frac{r_2^2}{r_1} \frac{a}{\sin \alpha} + C \tag{6.8}
\end{align*}$$

To find the point on the line $CB$ where truck and combined modes are equally costly, we let $a = 0$ and rewrite Equation 6.8 as

$$r_1 b = r_2 b + C$$

That is, the distance from point $B$ in miles is equal to the special cost $C$ divided by the difference in the two rates. If $C = 0$, the equal cost boundary is the straight line through $B$, forming angle $\alpha$ with $CB$. If $C \neq 0$, the boundary described by Equation 6.8 will not be a straight line. Notice that isocost contours for truck transport will be arcs of circles as shown in Equation 6.1. Isocost contours for combined modes are readily constructed from relation (6.7). The reader can verify for himself that these isocost contours are straight lines having the same slope as line $AD$ but opposite sign.
6.7 Collection and Delivery Routes

When the outputs of individual firms (or the purchases of individual households) are small relative to the available capacities of transportation units and when transportation costs per unit of product decrease with increases in capacity, local transportation will be most advantageously organized in collection (or delivery) routes. Rather than point-to-point transportation, then, we will have routes that serve a number of producers and that haul the combined loads to market. The general principle that governs route organization resembles that for the allocation of market areas. The collection section of each route should be a concentrated and exclusive territory, for this will eliminate route duplication and thus permit minimum transfer costs.

That these nonduplicating collection or delivery areas will minimize transportation costs can be demonstrated by a simple example. Consider a number of producers evenly spaced along a single road extending from market. Assume that these farms are located every mile along the road in the pattern suggested below:

\[ M(\text{o o o o o}) (\text{o o o o o}) (\text{o o o} \ldots) \]

Route 1  Route 2  Route . . .

Here, \( M \) represents the location of the market and \( o \) the location of the farms, spaced one mile apart along the road from market. Suppose that transportation to market is performed by truck and that collection trucks have a capacity equal to the output of five farms. Following the principle of exclusive collection areas, we organize routes as indicated: Route 1 collects from the first five farms; Route 2 collects from the second five farms; and so on. Consider any two routes, for example, Routes 1 and 2. Route 1 involves a total round-trip travel of 10 miles; Route 2 travels a total of 20 miles; thus, the combined travel is 30 miles.

We now inquire as to the effects on total mileage (and, hence, on total transfer costs) of compensating shifts of farms between these two routes since, if it is possible to reduce distance by these changes, then the exclusive areas will not represent the cost-minimizing solution. Suppose we exchange Farms 5 and 6. This will leave travel for Route 2 unchanged at 20 miles, increase Route 1 to 12 miles, and so increase the total from 30 to 32 miles. We can only reduce the travel for Route 2 by substituting nearby farms for the most distant farms on the route. If we exchange Farm 5 for Farm 10, travel by Route 2 will be reduced to 18 miles; but now Route 1 must collect from Farm 10, and so its travel is increased to 20 miles; the total mileage is thus increased to 38. In this way, we discover that no alternate route assignment of farms that maintains each
route at capacity load will permit total mileage or total transportation cost lower than the one that is involved with the exclusive collection areas.

Although the structure of competition and of joint costs poses problems in this situation, it is informative to explore the geographic structure of hauling charges that might evolve with this system of route organization. The costs of operating a truck route with fixed volume and number of customers can be represented quite realistically by a linear function where the "fixed" component represents overhead costs plus the fixed costs associated with direct customer services (such as the actual loading and unloading operations at each farmstead) and the "slope" component represents the variable operating costs per mile traveled. We ignore the fact that cost per mile will increase somewhat as the load on the truck increases from zero to capacity. Insofar as this is important, the minimum-cost organization of the route will require that the truck start its collection at the most distant producer and that it accumulate the full load on the return trip to market. With this understanding, the simplification of using a single, average cost per mile is not serious. For any route, then, the average cost per unit of product hauled will be represented by

\[ C = a + 2bD \]

where

- \( a \) = the nonvariable costs divided by route volume
- \( b \) = the variable cost per mile divided by route volume
- \( 2D \) = the round-trip mileage between the market and the most distant customer.

We assume that competition among routes or potential competition from operators willing to enter this market will be such as to keep rates charged for transport service in line with costs: for every route, the sum of the charges levied for the service will exactly equal total operating costs including necessary profits. Although many irregular patterns of charges within a given route might satisfy this requirement, we consider only linear rate structures. The rate for any location \( i \) within the collection area of a given route, then, may be represented by

\[ R_i = a + 2bD + e\left( D_i - \frac{D_n + D_m}{2} \right) \]

where

- \( D_i \) = the distance from market to the customer in question
- \( D_n \) and \( D_m \) = the distances to the nearest and most distant customers served by the route
- \( e \) = the slope or inclination of the rate structure in cents per mile; if \( e = 0 \), all customers served by the route will be charged a flat rate equal to the average route costs.
If this rate equation is applied to the two routes in our earlier example, the specific rate structures would be as follows.

\[
\text{Route 1. } R_i = a + 10b + (D_i - 3)e \\
\text{Route 2. } R_j = a + 20b + (D_j - 8)e
\]

By construction, these rate systems will equate total route revenue to total route cost for either route. There remains the question, however, of the possibility of increased profits by an exchange of customers. The operator of Route 2 might drop the customer located 10 miles from market and add the customer from Route 1, located 5 miles from market. Changes in net revenue for Route 2, then, would be

\[
\Delta Y_2 = + R_5 - R_{10} + 10b
\]

where the last term represents the reduction in route travel costs associated with the dropping of the most distant customer. Substituting the above specific rate equations gives the change in net revenue as

\[
\Delta Y_2 = a + 10b + 2e - a - 20b - 2e + 10b = 0.
\]

For this possible exchange, therefore, there would be no gain for Route 2. If Route 2 dropped customer 6 and added customer 5, however, the change in net revenue would be

\[
\Delta Y_2 = a + 10b + 2e - a - 20b + 2e = 4e - 10b.
\]

This exchange would be profitable for the operator of Route 2, apparently, if \(e\) is positive and greater than 2.5b.

By making other calculations of this type, we can arrive at the following general conclusions.

1. If \(e\) is negative, the rate structures will provide profitable opportunities for interroute customer exchanges. The resulting competitive scramble will make these rate structures unstable and force it to a flat-rate structure where \(e = 0\).

2. If \(e\) is positive and falls within the range from 0 to 2.5, operators will not be able to improve net revenue by shifting customers, and the rate structures will be stable.

3. If \(e\) is positive and greater than 2.5, possibilities for increased net revenue through customer shifts will exist, the rate structures and route organization will be unstable, and competition will force the structures back to positions where \(e\) is not greater than 2.5.

These limits are illustrated in Figure 6.7. Apparently, the efficient organization of collection routes will be stable as long as the transportation rates or charges fall within the limits indicated above. Observe that
a smooth and continuous system of rates, extending across all routes and increasing in line with the increases in average costs \( (e = 2.0) \), falls within these limits. This may seem to be the most reasonable and equitable system and, if instituted, it should be stable; but there is no reason to expect that this particular system will result automatically from free competition. Notice also that, although our discussion has assumed linear and continuous rate structures within routes, individual charges may vary erratically as long as they fall within limits where between-route shifts are unprofitable.

A logical extension of the feeder-route system involves the use of shipping stations or plants where volume is concentrated from a number of local collection routes and held for large-volume shipment to market. In addition to the advantages inherent in feeder routes, this type of organization may permit the consolidation of volumes from a number of shippers and, thus, gain advantages from bulk instead of individual shipment. The addition of plant operations adds a new element of cost—an element that tends to increase the “intercept” or fixed component in the cost-distance relationship. If such a system is economical, however, the added cost is more than offset by lower direct collection costs and by lower cost per ton-mile for transport from plant to market.

It is not our intention to suggest here that any particular form or type of transport is economical for a particular situation; that is, after all, a matter of empirical fact. Instead, the above theoretical treatment suggests how the problem of the selection of least-cost transport technology should be approached under various circumstances. The theory can be used, as
indicated, to outline the approach to such problems, but the final solution must rest on the real facts of cost relationships for alternative systems of collection and transportation.

SELECTED READINGS

Transfer Costs


