# Railroads, engineers, and the development of spatial economics in France

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## 1 Introduction

The key element in one of the greatest economic revolutions of history, that producing the unparalleled prosperity of the nineteenth and twentieth centuries, was the application of power-technology to transportation. The new technology, especially the advent of the railroad, had the economic effects of reducing transaction costs, lowering product prices, extending the division of labour, and creating an ever-increasing volume of profitable trade. These developments, in turn, stimulated the development of economic theory. The extension of railroads, for example, raised interesting and previously neglected questions regarding the effects of time, location, and distance on economic activity.

Spatial economics is, of course, an analytical abstraction — a notion of how and why economic agents such as sellers and buyers of products and inputs position themselves in the act of exchange. It is a study of how spatial boundaries and/or *in situ* production locales act as decision variables in a market-equilibrating framework. In a mercantile or command style economy, decisions as to where to locate economic activity and constraints on trade are determined chiefly through the political process. Thus it is only in the context of a market economy that the concept of "economic space" finds force. Such was the case in France, where spatial economics was encouraged as part of a general effort to establish the theoretical underpinnings of a market economy. One of the earliest and most efficient incubators of spatial economics was the state's school for the training of civil engineers, the *École des Ponts et Chaussées* in Paris (hereafter, EPC).

This paper focuses on the seminal contributions of two prominent graduates of EPC, Jules Dupuit and Émile Cheysson. Our discus-

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sion showcases their analyses of market-areas, resource movements, time/distance costs, and market "optimality". These two pioneers may be taken as representative of the "French School" of spatial economics, which flourished, albeit without fanfare, in the nineteenth century.

## 2 Spatial economics before the railroads

The list of peak performances in spatial economics before von Thünen is brief, but an appreciation of anticipatory writings in this field is sufficient to disabuse one of the notion that spatial economics was exclusively a German preoccupation.

### 2.1 Pre-classical contributions

One of the earliest and most perceptive pioneers in the field was Richard Cantillon, who anticipated later writers as disparate as von Thünen, Weber, and Hotelling (cf. Popescu [1953]; Ponsard [1958]; Dockès [1969]; Hébert [1981]; Huriot and Perreur [1992]). For example, Cantillon [1755] accentuated the principle of market agglomeration in his analysis of why economic activity radiates inward to a market centre, a phenomenon that he explained on the basis of buyers and sellers seeking to minimise information, transaction, and transport costs. He also analysed and explained spatial patterns of production, recognising that land use is an *economic* decision, and elaborating a pattern of land use that foreshadowed von Thünen's concentric-circle model (Cantillon [1755], pp. 153-55; Hébert [1981]).

Cantillon's influence can be detected in the writings of Sir James Steuart ([1767], pp. 134-35), who generalised Cantillon's basic scheme of land utilisation into a model more nearly approaching von Thünen's system of concentric circles, and who stressed the principles that determine the location of manufactures, the size of market areas, the nature and significance of transport routes, and the division of labour between thinly and densely populated areas. Similar ideas abound in the work of Condillac [1776], who placed the spatial element at the centre of his analysis. Condillac's theory of exchange, whereby goods are traced through the circuit that leads them to the place of highest-valued use, led him to explore the development, location, and boundaries of markets in a way that is evocative of Cantillon's earlier treatment[1].

### 2.2 Classical contributions

Although Cantillon's influence resonated in the works of certain

[1] Ponsard ([1983], p. 3) calls Condillac's performance "a landmark between the contributions of Cantillon and von Thünen".

Continental writers, in matters of space it had little impact on British economics. With the minor exception of Adam Smith [1776], British classical economists were mute on the subject of space. Smith, however, assigned major significance to place and to transportation in his theory of price, allowing "natural" values to vary with alterations in spatial variations of wages, profits and rents. Moreover, Smith recognised transportation costs as a major component of prices, devoting considerable attention to the "carrying trade". Finally, his famous maxim that the division of labour is limited by the extent of the market is replete with suggestions that market areas depend on the portability of products and on the existence and efficiency of transport routes. Despite this general awareness, however, Smith failed to integrate space fully into his analytical system. This minor retreat by Smith turned into a full-fledged rout when Ricardo reduced situational differences to variations in the fertility of land, thereby effectively eliminating spatial considerations from his analytical system. Ricardo made transportation costs indistinguishable from other costs, and in international trade theory, where spatial considerations previously had been prominent, he substituted comparative costs as the crucial factor. The practical effect of Ricardo's methodological and analytical innovations was to dislodge space from mainstream economic theory, so that for a long time thereafter it came to be treated, if at all, *outside* the mainstream deductive models of British classical economics.

In the nineteenth century, spatial economics flourished on German soil, for reasons discussed by Blaug [1979]. During the high tide of Ricardian economics, von Thünen [1826] invented the "classical" model of location based upon the principles of cost-minimisation and equimarginal resource allocation; and in this regard, he was the catalyst for an increasing stream of analytical extensions by Germanic writers throughout the remainder of the century. For all its "genetic" power, however, von Thünen's analysis antedated the commercial success of the railroad. As powerful and suggestive as it was, von Thünen's spatial economics merely established the classic problem in location theory, namely, the optimal location of producers supplying goods to a central market. The advent of the railroad raised a new set of intricate spatial issues.

## 3 Spatial economics and the transport revolution

The great revolution in transportation, punctuated by the invention of the railroad, was well underway in the United States, France, England, Belgium and other countries by the middle of the nineteenth century; and the expansion of the new transport technology prompted questions of enormous import. What was the nature of the "public interest" in the provision of railroads, and how was "justice" to be preserved among consumers? Should railway operation be based on purely private motives, or should the state take an active role? How was financing to be accomplished, and what was the role of the state in it? Should railway rates be regulated by the state? If so, should they be proportioned to distance or be levied in some other way? How were "railway bubbles" and whole or partial "failures" to be explained and/or prevented?

The answers to these and many other questions were debated among a group of engineers who shared a common core of instruction and who, in France more than anywhere else, became specialists in transport problems. The intellectual incubus of this group of experts was the EPC, which formed part of a bureaucratic network that included a state-sponsored corps of engineers, the Corps des Ingénieurs des Ponts et Chaussées, and an administrative body within the government that held "cabinet" status. By the nineteenth century, French engineers in the service of the state, reflecting the high level of professionalism that had been institutionalised in France, were generally acknowledged as the best in the world(2).

## 4 Early formulations of the law of market areas

French engineers of the *Corps des Ingénieurs des ponts et chaussées* were attracted early on by the problem of spatial competition in transport enterprises, and they made important initial strides in defining problems and devising solutions.

### 4.1 Jules Dupuit (1804-1866)

Dupuit is the acknowledged pioneer of the theory of price discrimination. More than a generation after his death, F. Y. Edgeworth ([1910],

(2) Although threatened by the deconstruction of the Revolution, the EPC and its administrative network survived, due in part to the passionate defence of Mirabeau the younger. Wounded, but basically intact, the *corps* and the *école* successfully regrouped, and subsequently were given new impetus by the new transport technology. Surveying the nature of industrial leadership in France in his *Industry and Trade*, Alfred Marshall ([1919], p. 117) declared: "[...] Frenchmen are specially fitted for certain large enterprises by their talent for engineering. From early times French cathedrals and fortifications, French roads and canals have borne evidence to high creative faculty. Since the Revolution the engineering profession has been held in special honour in France: there is perhaps no other country in which the ablest lads are so generally inclined towards it. The excellent technique of her railways testifies to a high level of engineering ability; and the success of the Suez Canal and other great undertakings indicates largeness of conception on the part of her leading men".

p. 441) called Dupuit "the earliest, and still [...] the highest authority on the theory of price discrimination". As an analytical proposition, however, price discrimination is universally restricted to firms that operate under conditions of monopoly, and Dupuit's pioneer contribution has almost always been cast in this light. But Dupuit was analytically more sophisticated than has customarily been recognised—he conceived of competition as a process whereby entrepreneurs actively seek to differentiate their products in order to curry consumers' favour (Ekelund [1970], Ekelund & Hébert [1991]). For him space was one aspect of product differentiation, and therefore an aspect of competition. Price differentiation (a broader concept than mere discrimination) could be practised, Dupuit asserted, not only by monopolists, but also by *locationally differentiated* competitors. Dupuit's contribution to this issue is contained in an 1849 rejoinder to an attack by fellow-engineer Louis Bordas [1847] on Dupuit's seminal [1844] development of utility-based economic theory. In his reply to Bordas, Dupuit [1849] asserted that certain spatial characteristics of transport goods and services provided strong incentives for the practice of price differentiation and he illuminated this idea in several examples drawn from practical experience.

Unlike von Thünen's "stationary production" approach to space, Dupuit's analysis of spatial pricing involved competition between two pre-existing carriers on the basis of railway rates and transport costs. Dupuit employed an arithmetic example, and illustrated it with a figure (see Figure 1), in order to establish the theoretical basis for the fact that location serves as a parameter of railway rates charged. Using passenger traffic as an example, Dupuit ([1849], p. 28) posited:

> "[...] a town $V$ is situated 30 km. from a railway station $S$ and 50 km. from another station $U$, which is 40 km. from $S$. The unit rate by rail or road is 0 fr. 08. The cost of the various trips the passenger can take is as follows:

| | | |
|---|---|---|
| $SU$, by rail | 40 km. | 3.20 fr. |
| $VS$, by road | 30 km. | 2.40 fr. |
| $VU$, by road | 50 km. | 4.00 fr. |
| $VSU$, by road and rail | 70 km. | 5.60 fr." |

In this instance Dupuit found that

> "all travellers from $V$ to a place $X$ on the railway beyond $S$ and $U$ will follow the route $VUX$ which saves them 1.60 fr. and consequently the proportional tariff deprives the section $SU$ of the railway of considerable traffic" (Dupuit [1849], p. 8).

However, the railroad

> "might, for instance, let the people of $V$ book a through ticket to $U$ for 4 francs, which means that the railway trip costs 1.60 fr. instead of 3.20 fr. As a result, two kinds of passengers will travel on the line $VS$, some paying

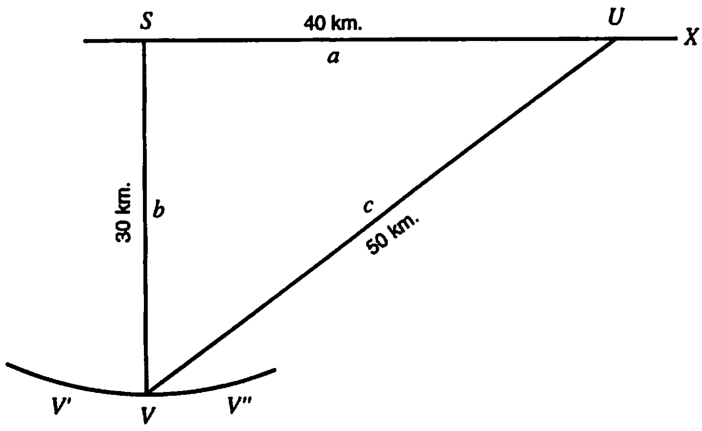


**Figure 1:** Illustration of Dupuit's arithmetic rxample

3.20 fr. and some 1.60 fr. This may seem odd at first sight, but in truth is no more odd than the sight of one train carrying two tons of merchandise of the same volume at a completely different freight rate" (Dupuit [1849], p. 29).

Dupuit's finding may be illustrated algebraically by letting

- $SU = a$, $VS = b$, $VU = c$,
- $T$ = the rate per person per kilometre on the highway (or any other competing mode), and
- $t$ = the rate for travel per person per kilometre on the railway.

The condition under which passengers will be indifferent to the route chosen because the transport cost of passengers along $VU$ is the same as along $VSU$ is expressed as: $Tc = at + Tb$. Inasmuch as Dupuit assumed that location is a parameter, $a$, $b$, and $c$, are given and $T$ is known. Rearranging the former equation, then, the fare for passenger traffic can be derived as: $t = T[(c - b)/a]$. Since $c - b < a$, $t$ must be less than $T$ in order to attract traffic. In Dupuit's example (Figure 1), $c = 50$ km, $b = 30$ km, $a = 40$ km and $T = 0.08$ fr., so that the railroad must set $t$ less than or equal to 0.04 fr. in order to attract the passenger traffic.

As can be seen from the formula above, the value of $t$ crucially depends upon $a$, $b$, $c$ and $T$; hence,

> "the locations, distances and prices [. . . ] can give rise to infinitely many tariff combinations" (Dupuit [1849], p. 30).

If $T$ and $a$ are given, locational differentiation of buyers represented by different combinations of $b$ and $c$ generate different values of $t$.

Obviously, therefore, locational differentiation of buyers makes price differentiation more feasible.

A generalised model of "market boundaries" may be readily developed with these tools, and Dupuit in fact investigated the effects of a change in location on railway rates. Continuing the above analysis, assume that $a$, $b$ and $t$ are given. Dupuit used a change in $c$ to indicate the change of location. Differentiating $t = T[(c - b)/a]$ with respect to $c$, we obtain: $(t/c) = (T/a) > 0$. This result is consistent with Dupuit's proposition that,

> "if we varied the location of the point of departure $V$, we would discover, according as we move it further away from $U$ [*e.g.*, $V'$ in figure 1] or closer to it [*e.g.*, $V''$], that the fare will become higher or lower" (Dupuit [1849], p. 29).

Since $V$, $V'$ and $V''$ are in circumference[(3)], the radius, $b$, will be the same.

## 4.2 Émile Cheysson (1836-1910)

After a hiatus of several decades, the hyperbolic nature of market boundaries was elaborated and generalised by Émile Cheysson, who published a remarkable *conférence* in 1887 entitled *La Statistique géometrique*[(4)]. Acknowledging the priority of Dupuit and Launhardt[(5)], but elaborating a problem broached earlier by Foville ([1880], pp. 116-118), a fellow *polytechnicien*, Cheysson formalised the derivation of market boundaries in a geometric model employing *rate indifference curves*. Cheysson's formal model yielded solutions to the following important issues that Dupuit anticipated, but did not formally resolve: (1) how the individual seller located in space determines the optimum route over which his goods are shipped to a fixed destination, and (2) how, within limits each carrier can enlarge its own market area at the expense of other carriers. The first of several spatial models invented by Cheysson is reproduced here as Figure 2.

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(3) For further elaboration on these points and on the consequences of Dupuit's location theory for contemporary arguments about economic regulation and deregulation, see Ekelund and Shieh [1986]; [1989].

(4) Jean-Jacques Émile Cheysson (1836-1910) was a graduate of the École Polytechnique and EPC, a member of the Société de Statistique de Paris and a follower of LePlay, who advocated social reforms based on the statistical analysis of working-family budgets. *La statistique géometrique* espouses a program that in its fundamentals employs an embryonic form of econometrics. Cheysson [1887] sought to marry statistics and economic theory in order to derive solutions to practical problems (cf., Hébert [1986]).

(5) On various aspects of Launhardt's contributions to spatial economics, see the respective articles in this issue by Perreur and Dos Santos Ferreira.

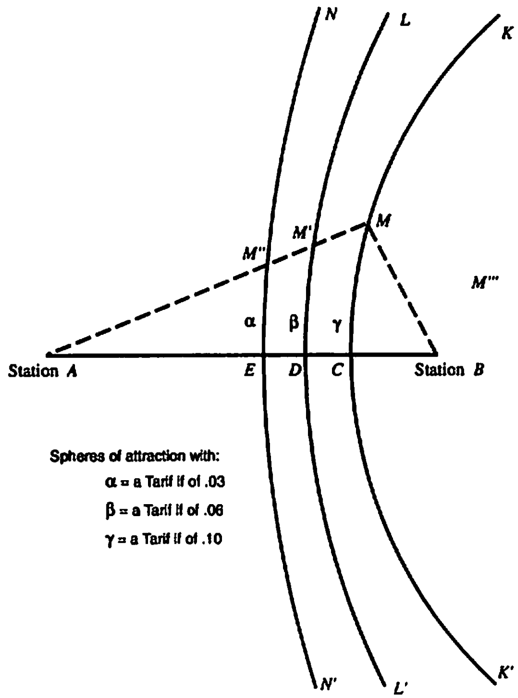


**Figure 2:** First spatial model of Cheysson

Cheysson posed the problem in terms of a shipper at point $M$ seeking to transport goods to destination $A$. The broken lines in Figure 2 represent existing highways over which goods may be shipped from point $M$. The railway traverses the distance between $A$ and $B$ along the solid line segment $AB$. Cheysson ([1887], p. 210) noted that

> "merchandise situated at point $M$ will not adopt route $MBA$ in place of continuing to take the more direct route, $AM$, unless there is a reasonable difference in the rates for the two routes".

When the cost of shipping merchandise along $MA$ is the same as shipping it along $MBA$, the shipper will be indifferent as to the route taken. The locus of points along which shippers at different locations will be indifferent for any given rate relationship between carriers forms the hyperbolic curves in Figure 2. Cheysson pointed out, for example, that all points such as $M'''$, situated to the right of $KCK'$ and within the hyperbolic surface, fall within the "sphere of attraction" for the railroad at station $B$; whereas points outside of this boundary will ship by highway directly to $A$[6]. The conclusion, which may be derived from

(6) Following Cheysson, let $T$ represent the transport rate per ton-mile on high-

Dupuit's model (*supra*), is that the important factors in determining market boundaries between competing carriers is the relative tariff, or the ratio, $t/T$. The larger the ratio $t/T$, the greater the curvature of the territorial boundary and the closer its zenith to $B$.

The Dupuit-Cheysson invention of spatial divisions between competing transport firms became a staple of twentieth century developments in spatial theory, although the founders of the theory have been curiously neglected(7). In Cheysson's case, the neglect is even more surprising because he took spatial analysis beyond the simple case involving differences in transport rates, extending his hyperbolic surfaces to the case involving commodity price differences as well.

## 5 Competing firms in economic space

Cheysson's foray into spatial economics led him to the discovery of the dimensions of spatial competition when sellers of products compete on the basis of delivered prices to (homogeneous) demanders.

### 5.1 Transport costs and hypercircles

Cheysson assumed that producers are situated at linear distances from each other, and that commodities traded are homogeneous and have identical base prices, so that differences in selling price at various points within the market area are attributable solely to differences in transport costs. Figure 3 is a replication of Cheysson's graphic model.

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ways and $t$, the railway rate. Point $M$ and all other points along $KCK'$ are drawn so that the total transport costs for a given consignment of goods shipped from that point to destination $A$ are identical, regardless of carrier. Therefore, the equation that describes $KCK'$ is $AMT = MBT + Abt$. This equation assumes the form of a hyperbola: $AM - MB = ABt/T$. (A hyperbola is the locus of a point that moves in a plane so that the difference of its distances from two fixed points is a constant. In Figure 2, points $A$ and $B$ are the foci for hyperbolas $KCK'$, $LDL'$, and $NEN'$). The rail line could improve its competitive position by lowering rates. According to Cheysson ([1887], p. 210), "[;] in order to bring in such points as $M'$ the railroad must lower its rates; for example from ten centimes to six. The boundary of the corresponding sphere of attraction will then be moved to $LDL'$. Finally, to bring in points such as $M$" the railroad must agree to a new rate reduction which will extend the market boundary to $NEN'''$".

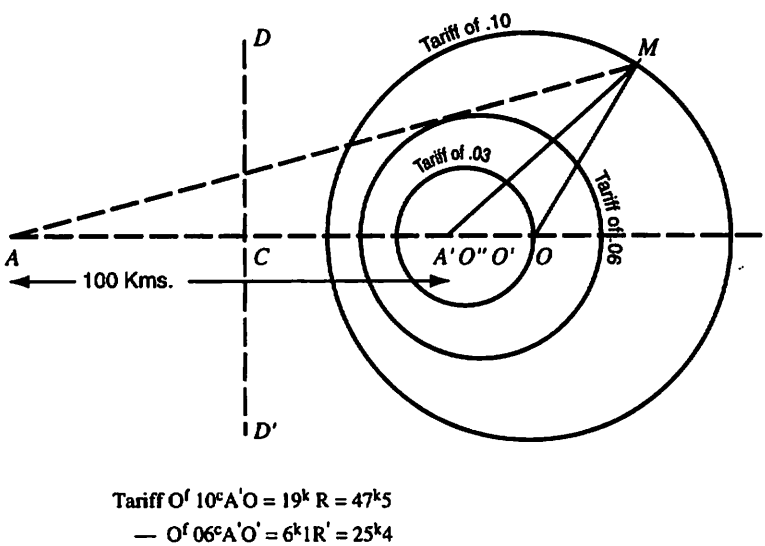
(7) Until recently, Cheysson, and to a lesser extent Dupuit, were relegated to a curious state of neglect by most students of spatial economics. Even in his own country, Cheysson has been regarded mainly as an innovator who combined geometry with statistics in economic analysis (Divisia [1950], p. 16). In his survey of the historical development of spatial economics, Claude Ponsard [1958] does not even mention Dupuit or Cheysson, although he cites Alfred Marshall for a lesser contribution.

He reasoned as follows:

"[...] let us assume that $A$ and $A'$ are supply centres which are 100 kilometres apart. If both points are equipped with the same means of transport, which travels both directions between $A$ and $A'$ where price per ton-kilometre is 25 centimes, they will be (*ceteris paribus*) in exact equilibrium from a transportation point of view. Their respective market areas will be defined by the vertical line $DD'$, which crosses the middle of $AA'$. But if centre $A$ was served by a railroad which subsequently reduced the price per ton to 10 centimes, the market area of $A'$ would be restricted and enclosed within a curve upon which each point, such as $M$, represents equal transport cost for distances $AM$ and $A'M$. This curve is a circle, whose centre, 0, is situated 19 kilometres beyond $A'$, having a radius of 47.5 kilometres.

[...] If, to increase its gains, the company which serves $A$ diminishes its tariff of 10 centimes to 6 centimes, it will restrict the circle which encloses $A'$ such that the radius of the smaller circle is only 25.4 kilometres.

[...] Finally, let us assume the tariff falls to 3 centimes: centre $A'$ is reduced to a smaller circle whose radius is 12.5 kilometres. While $A'$ starves to death, centre $A$ is enriched at the formers expense" (Cheysson [1887], pp. 209-10).




Tariff $O^f$ $10^c A'O = 19^k$ $R = 47^k5$

— $O^f$ $06^c A'O' = 6^k1$ $R' = 25^k4$

— $O^f$ $03^c A'O'' = 1^k5$ $R'' = 12^k5$

**Figure 3:** Transport costs and hypercircles: Cheysson's graphic model

In this manner Cheysson introduced the *hypercircle* to spatial economics, a concept that subsequently became a standard tool of many locational models. While Laundhardt deserves priority on this invention, Cheysson nevertheless refined certain points of the model and explicated its mathematical foundations in a lucid manner[8].

Although it is unclear whether the lower freight rates extended to point $A$ are the result of the emergence of a new and different means of transport or the result of preferential rates extended by the same carrier serving both $A$ and $A'$, analytically it makes no difference. Cheysson had clearly demonstrated the effects of differential rates upon the sales territories of sellers competing at fixed locations. The point that needs to be stressed here (but which can only be partially explicated due to space constraints) is that the leading French engineer-economists understood the many different margins of competition (*e.g.*, space, time, quality) and did not embrace the mechanistic model of "pure competition" that eventually insinuated itself into neoclassical economic theory. Time and again, they stressed that time saved (*i.e.*, speed of transport) is an important element of utility in the shipment of goods[9].

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[8] Cheysson provides the equation for the circles in Figure 3 as $Amp = A'Mp'$, since at any point on the boundary, the condition holds that the total transport charges are the same for distance $AM$ as for $A'M$. In this equation, $p$ and $p'$ represent the freight rates per ton-mile from shipping points $A$ and $A'$, respectively. Now rewrite $p$ and $p'$ as $p_1$ and $p_2$. Cheysson also established that $AA' = d$; $A'O = a$; $OM = R$; and $n = p_1/p_2$. The variable $n$ expresses the ratio of freight rates, and "the distance from shipping point $A'$ to the centre of the circular market area". From this Cheysson ([1887], p. 210) concluded that: (1) $OM = R = na$, and that (2) $a = d/(n^2 - 1)$. Equation (1) gives the radius of the circular market area, but equation (2) is a crucial part of the analysis, since it gives the distance from $A'$ to the centre of the circle that describes the market area of $A'$ This is the so-called "midpoint problem" which Cheysson fully understood both in economic and mathematical terms. Launhardt's earlier [1882] analysis anticipated Cheysson's hypercircle analysis on some points, but not on the latter one. Schneider [1935] later expanded Launhardt's discussion and R.G.D. Allen ([1938], pp. 80-82) first provided a complete modern mathematical solution to the "midpoint problem" which has been demonstrated to be equivalent to Cheysson's conclusion that $R = na$ (Hébert [1972], pp. 570-71).

[9] Favier [1824] and Brisson [1830], for example, used the durability of public works to devise a choice rule for alternate public works constructions; Girard [1827] and Minard [1850] treated time saved in transport as part of the notion of utility derived from public works; Courtois [1833] related time to the opportunity cost of capital in measuring transport costs; and Nadault de Buffon [1829] made a general plea for the centrality of time in all economic calculations of commercial application. But it was Dupuit who explicated all of this best in the general context of a theory of competitive markets. For elaboration on these points, see Hébert [1996].

### 5.2 Quality variation

One of Cheysson's innovations in particular, shows how product quality and location interact in profit-maximising decisions about resource use. Figure 4 is a replication of Cheysson's model of quality variation in a locational context. This particular example examines the choice of road-paving materials (stones) of different durability (quality) and different costs. One type of stone, designated "domestic," is of lesser quality as a road surface, but is readily available at constant cost, $AP$, from fields adjacent to the proposed highway (see Figure 4). The other type of stone, designated "foreign", is more durable as a road surface but it is also more costly at the road construction site, primarily because of transport costs which are assumed to increase in proportion to the distance transported and in proportion to the length of time in transit.

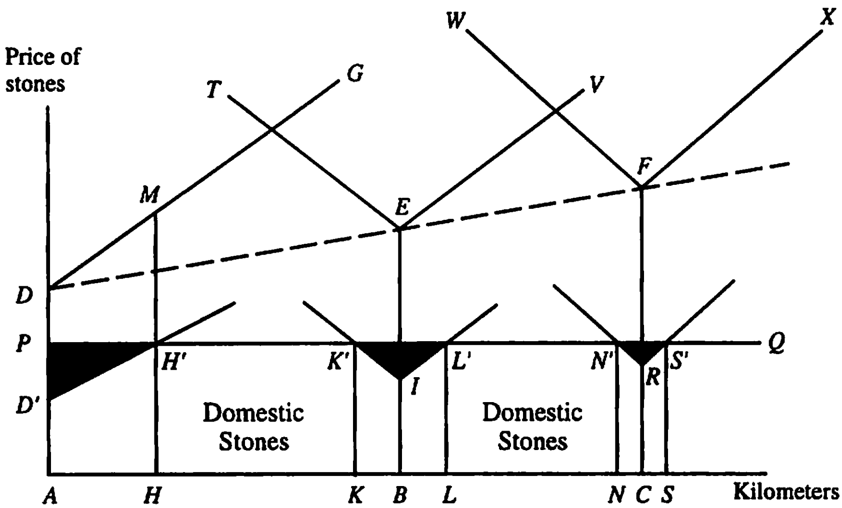


**Figure 4:** Cheysson's model of quality variation in a locational context

In Figure 4, points $A$, $B$, and $C$ represent railway stations (supply centres) along rail line $AS$; while $AD$, $BE$, and $CF$ represent delivered prices of the foreign stones at points $A$, $B$, and $C$, respectively. These prices are assumed to increase in proportion to the linear distance from point $A$, so that $CF > BE > AD$. According to Cheysson ([1887], p. 226):

> "The [higher quality] stones are transported by dumpcart from these stations to the road site so that the cost of the stones increases very rapidly in proportion to the distance from the nearest station, and finally reaches $MH$ [for example] for the distance $AH$. On the other hand, stones found in the neighbouring fields are procured at a constant cost shown by the line $PQ$".

Line $DG$ is a total cost function, including transport costs, for "foreign" stones shipped from station $A$. Separate but similar functions (*e.g.*, $ET$, $EV$, $FW$, $FX$) are presumed to exist for the same stones shipped east and west from points $B$ and $C$ [(10)]. These "space cost curves" are usually expressed in nominal-cost terms, but consider Cheysson's argument:

> "In order to compare these two types of stone we must consider the unit price of each for the same quality and take into account the supplementary costs of the labour employed in breaking them up.... If we acknowledge, for example, that [the higher quality] stones wear twice as well as the others, we shall find the [full] cost of using the better stones reduced by one-half. This is expressed [in Figure 4] by the line $D'H'$, which cuts line $PQ$ at $H'$. Thus we find that for the portion of the highway $AH$ is would be advantageous to use the more durable materials, while along $HK$ the advantage is on the side of the local materials. Proceeding in the same fashion, we are able to determine the different zones tributary to each supply source, in regard to that input's respective purchase price, quality, and transport cost" (Cheysson [1887], p. 226).

The *space cost curves*, $D'H'$, $IK'$, $IL'$, $RN'$ and $RS'$ are thus expressed in real or full cost terms. They are used, moreover, to demonstrate a least-cost solution to the problem of determining appropriate supply areas with the shaded areas (in Figure 4) reflecting the relative real cost advantages of the higher quality inputs. In effect the two qualities are substitutes in production by the fixed physical coefficient, one-half. Although Cheysson's solution to this problem proceeds on a fairly simple level of abstraction, it is perfectly general in nature[(11)].

Cheysson thus introduced full price considerations into a particular problem, but the conception of quality as an element in the competitive process was clearly manifest in Dupuit's earlier work, and was

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(10) In location models, these lines are commonly referred to as transport gradients, or as Smith ([1966], p. 97) has more appropriately termed them, space cost curves.

(11) In emphasising full cost Cheysson displayed more originality than later investigators of supply-area problems who either abstracted from the consideration of input quality altogether, or discussed the theoretical significance of quality variation but failed to make it an explicit part of their analyses (cf., Hoover [1948] or Isard [1956]). On the positive side, Cheysson's supply-area analysis reappeared in the literature on location economics (cf., Smykay [1961], pp. 153-54; Smithies [1941]; and Greenhut [1956], p. 254). Greenhut's treatment, which actually adapts von Thünen's "linear model," calls to mind Mark Blaug's dictum, that the use of subsequent contributions to economic theory to explain and interpret earlier ones affords an excellent illustration of what is meant by "progress" in economic analysis.

demonstrably part of the econo-engineering tradition at EPC. The entrepreneurial function of seeking to maximise utility by altering product quality was a primary theme in Dupuit's work. He understood perfectly well that quality modifications were constantly introduced (thereby altering the *foundation* and the *form* of competition) in the production of transportation and *all* goods. As he asserted,

> "[...] it does not often happen that a modification of the productive process which reduces costs does not also modify the quality of the product; the latter becomes better or worse, larger or smaller, lighter or heavier, quicker or slower, and so on. Now all these qualities have a value which must be taken into account in the calculation of utility" (Dupuit [1844], p. 100).

Space, time, quality, and the ensuing product variations they occasioned, occupied the centre of the economic analysis enriched by the French engineers who walked with Dupuit.

# 6 Conclusion

The microeconomic analysis of space, conceived of as both location theory and market-area analysis, was launched in the nineteenth century. This development was encouraged by the advent of the railroad, and it was nurtured in France by an educational institution and milieu that catered to state engineers. Dupuit was a prominent, but by no means the only, participant in an ongoing econo-engineering tradition of investigation at the École des Ponts et Chaussées throughout the nineteenth century. Despite a parallel German tradition in spatial economics in which engineers also played a prominent role, the French engineers constituted an identifiable and separate tradition in this branch of economic theory and policy. With the exceptions of von Thünen [1826] and Launhardt [1882], moreover, the great thrust forward in spatial economics by German writers has been a twentieth-century development (*e.g.*, Weber [1909]; Palander [1935]; Schneider [1935]; Lösch [1940])(12).

In France, spatial questions were not raised in a mere academic setting. Virtually all of the engineering contributors to location theory were driven by an attempt to show that "regulated" or uniform pricing schemes worked to the detriment of aggregate economic welfare. This was especially so where state leasing contracts and regulations led to uniform tariffs, a problem particularly acute in France. The French

(12) The impression, certainly among American economists, that the tradition is Germanic in origin rests, at least partially, on the influence of Schneider [1935]. American contributions prior to 1935 were relatively few. Fetter [1924], for example, developed a market area analysis very close to the Dupuit-Cheysson approach, although he was unaware of the French contributions. Also see Hyson and Hyson [1950], who reinvented Cheysson's "hypercircles" much later.

government built railroads on the advice of the Corps des Ponts et Chaussées — sometimes significantly in advance of actually leasing them to private enterprise. It served as tenant to the French railway companies. Sealed bid contracts containing maximum lease stipulations were received by the government. Often the bid with the expressed willingness to accept the *shortest* lease was granted, although other factors were considered. By 1850, according to Lardner ([1850], p. 378), leases had become far shorter than the traditional 99 years, owing to the frenzy in railway stock speculation. In return for state support, the companies had to submit to price regulation. It is against this institutional backdrop that the contributions to location theory of Dupuit and his cohorts must be evaluated.

Apart from the "splendid isolationism" of von Thünen early in the nineteenth century, and the brilliant theoretical animadversions of Launhardt near the end of the century, vital elements of the core of spatial economics were pioneered by French engineers who had been trained at the École des Ponts et Chaussées. The collective nature and significance of this contribution, which has been partially illuminated in this paper, has been underappreciated in the history of economic thought. As spatial economic theory evolved into a "specialised" branch of economics in the twentieth century, it was forgotten that the econo-engineers attempted to make space and location theory an inextricable part of *general* economic theory in order to reach a basic understanding of the factors that can create or destroy economic wealth and welfare.

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