Transport Network Planning

Patrick O'Sullivan,
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1 TRANSPORT INVESTMENT AND DEVELOPMENT

The Geography of Growth

The control or promotion of the expansion of transport facilities is perhaps the most powerful geographically-specific instrument that government can use to guide economic development. That transport is not only important but fundamental in structuring our material existence is suggested by the role which MacKinnon (1978) has attributed to the solution of logistic problems in the evolution of man's adaptability and greater brain capacity. He postulates that it was the need to conserve effort in seeking food which triggered the development of this calculating, pliant creature, man. Similarly the means man has devised to move himself and things from place to place have a profound bearing on the evolution of his institutional and economic arrangements. In examining the history of how man has satisfied his diverse needs and attained his goals through scarce means, it is clear that, whatever the ends, the means are limited by man's political and mechanical capability to manage space. These limits on control over the physical environment have been reduced through time but at an uneven pace. This we can see in the very different levels of material well-being throughout the world. The process of geographical change is visible in the spread of innovations and development. These processes in their turn are accomplished by the permissive provision of means of movement and communication.

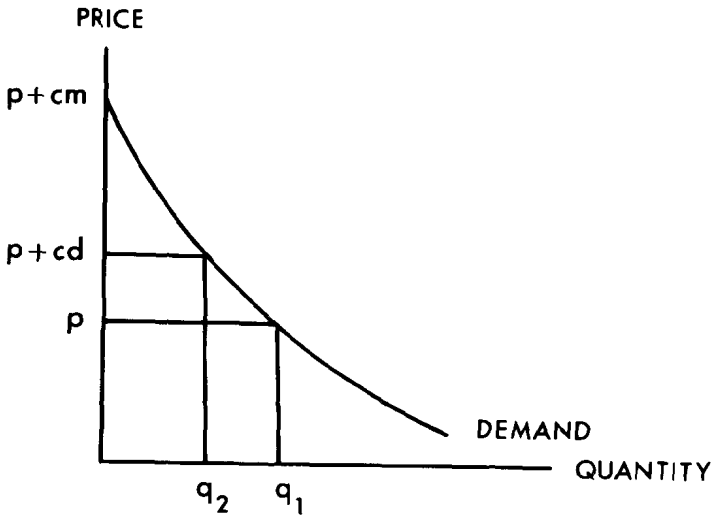
Musgrave (1959) has partitioned government's purpose in guiding the economy into three components, a trichotomy of function which may be seen readily in the transport investment process. The elements are:

1. *Resource Allocation Function* The provision of social goods or the process by which the mix of social goods is chosen and by which social and private goods are distributed.
2. *Distribution Function.* The adjustment of the distribution of wealth in conformance with societal notions of fairness and justice.
3. *Stabilisation Function.* The use of budgetary policies to maintain high employment, relative price stability and appropriate rates of economic growth.

The transport sector's share of resources is determined by the necessity of overcoming distance in meeting society's needs. A major determinant of the shape of the economic landscape as it evolves then, is the manner in which distance is conquered. A society at a given state of technology will attempt to develop a transport network to minimise the total disutility of distance. Activities will competitively locate in relation to the network in such a way as to maximise the total utility of the system. Differing needs and abilities to move goods and services will result in arrays of central places and market areas, geographical specialisation in production and the varying scopes of political, cultural and social territories. This differential response to the friction of distance changes over time with technical improvements in transport. Reductions in transport costs enable the drawing of larger markets and resource bases into an integrated economy.

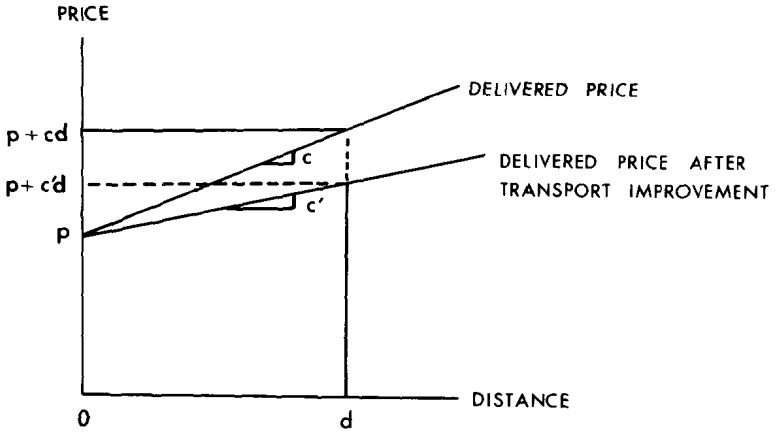
To clarify this contention consider the sale of a single good in an abstract geographical setting. A producer located at 0, sells his product at an ex-works price p, representing the cost of production and normal profit. The demand for the good decreases with price with consumers taking quantity q_1 at price p as in Figure 1.1.

Figure 1.1.



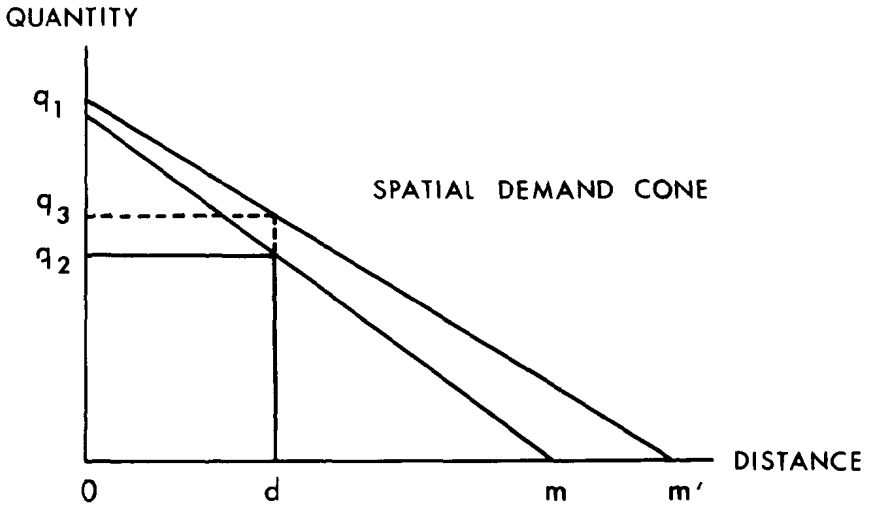
The consumers are located at a uniform density around 0 on an unbounded plain with transport costs increasing equally as a function of distance in all directions. The consumer pays a delivered price of p + cd, where c is the unit cost of transport per mile and d is the distance they are removed from 0. Assuming no scale economies or terminal costs in transport, delivered price will increase linearly with distance from the factory as in Figure 1.2.

Figure 1.2



The consumer located at the factory gate will pay p and consume q_1, while the consumer at distance d from the factory will pay p + cd and consume q_2. The quantity consumed will diminish geographically as delivered price increases with distance from the site of production. In the abstract space we have specified we can describe a geographical demand cone centred on the factory at 0 as in Figure 1.3. The quantity consumed decreases from a maximum at distance zero to zero at the margin of the market m where demand vanishes at prices p + cm on the demand curve of Figure 1.1. If investment in the transport system reduces the unit cost of transport from c to c' and all else remains equal, the delivered price function will rotate down as in Figure 1.2. Delivered prices will be reduced to p + c'd and p + c'm and by c – c' at every location at some remove from the production site. This will induce an increase in demand at every distance from the source and rotate the spatial demand cone upwards and outwards in Figure 1.3. This will extend the margin of the market from m to m' bringing new participants

Figure 1.3

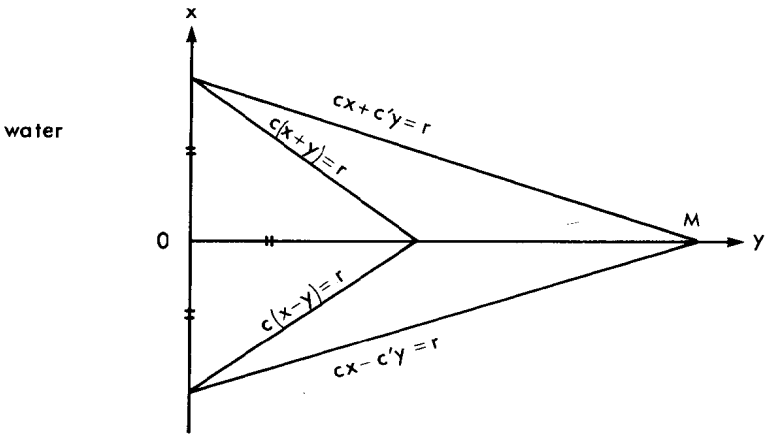


into the economy, as well as expanding the consumption of previous customers, from q_2 to q_3 at radius d in Figure 1.3, for example.

This analysis can readily be modified to treat the supply of geographically dispersed factors of production, resources or products to a central market or processing point, with similar results in terms of reduced transport costs extending commerce and increasing material well-being. As an illustration we can adapt Walters' (1968) Ellet model from the developing agricultural scene in which he set it to urban industrial circumstances. Consider a city with one employment focus at 0 on a straight coastline, as in Figure 1.4. The circumstances of Chicago on Lake Michigan or Toronto on Lake Ontario are not far removed from this.

The original transport system consists of an infinitely dense square lattice of streets with a uniform cost of travel of c per trip mile. The residents are located in this plan at a uniform density with one worker per residential site. Workers are faced with the choice of subsisting at home at a cost of s per family, just covered by the dole, or travelling to work in 0 at a cost of c per mile for a fixed wage w. The demand for labour at 0 is infinitely elastic at wage w. We can view $w - s + r$ as a location surplus. The margin of the labour shed in these circumstances will be given by:

Figure 1.4



$$c(x+y) \leqslant r, \quad y \geqslant 0, x \geqslant 0$$

and

$$c(x-y) < r, \quad y < 0, x \geqslant 0$$

(From now on we may drop the mirror image expression, remember its existence and operate in the positive quadrant). The rent associated with a location is given by $r - c(x+y)$. This is at a maximum of r at 0, is zero at the margin of the labour shed and totals $r^3/3c^2$. The total number of round trips to the employment site in any day is $(r/c)^2$. It is proposed to build a new motorway straight east from 0 to a distant city. What are the benefits of this improvement? How can they be measured? The investment is beneficial in that it reduces travel times along its alignment reducing the cost per mile from c to c'. This makes greater incomes from employment at 0 available to more people and increases the locational surplus of present travellers. The new limit of its labour market will be given by $cx + c'y \leqslant r$. This is more far flung than the original limit. The new labour shed will stretch out furthest along the new road while not extending at all along the coast where no cost reduction for travel is available. At every position away from the coast some advantage can be taken of the new road up to the limit at M. The total number of trips to and from work will increase to r^2/cc' and total rent will increase to $r^3/3cc'$. The total benefits arising from the investment can be measured by the difference between the two

rent volumes: $r^3/3cc' - r^3/3rc^2$. The response of travel demand to the reduced cost will be given by:

$$\epsilon = \frac{c}{(r/c)^2} \cdot \frac{r^2/cc' - (r/c)^2}{c' - c}$$

$$= \frac{c^2}{r^2} \cdot \frac{(r^2/c)(c/cc' - c'/cc')}{c' - c}$$

$$= \frac{c[(c - c')/c']}{c' - c}$$

$$= -c/c'$$

and as the difference between $c' - c$ goes to zero so the elasticity of demand for trips with respect to transport costs goes to -1. The unitary value for elasticity of this model is obviously an upper limit and relaxation of the various assumptions about the elasticity of demand for labour, the length of the road, the uniformity of transport costs, etc. will squeeze the extent of the margin, reduce the elasticity value and curtail the benefits to be expected.

Devised as a theoretical basis for an operational rule of thumb in the evaluation of agricultural penetration roads in colonial economies, this model can hardly be applied directly to urban problems. The structural device of a single focus of demand to generate neat analytics would obviously be lost in the multiplicity of employment and activity nucleii of a real city. The model does, however, isolate the components of the benefits of transport improvements insightfully, albeit, statically.

With the increase in the potential market for any good, resource or factor resulting from the above process, the possibility exists of an increase in productivity due to the increase of trade, and specialisation of production according to the comparative cost advantages of different areas. This results in the growth of service and manufacturing industries. The expansion of markets may induce the application of improved mechanical methods to production, leading to further increases in productivity and wealth. Increases in the range of markets call for geographical adjustment in the location of production to reap the most from a new set of opportunities. Activities compete for locations according to the advantages they derive from nearness to other activities, markets and resources. Broadly, those enterprises

whose viability requires a greater amount of exchange with the rest of the economy will pre-empt more generally accessible locations. Service and manufacturing activities emerge as nodes of localisation at strategic junctures of the network with their geographical frequency governed by their market threshold levels. The concentration of population involved in factor-intensive activites leads to urbanisation of a sector of the population.

The concentration of non-agricultural production to avoid movement costs, generates further growth. Multiplicative effects of development are usually stimulated at existing towns and cities. The economies of agglomeration, which are to a major extent savings on communication and transport, and investment in urban infrastructure induce further growth at urban foci. Traffic is heaviest and increasing most rapidly at these concentrations. Cost savings from investment will be greatest in these sections, encouraging their improvement and further increasing their attractiveness.

Further reductions in the cost of distance with investment and technical advance can again expand the scale of social and economic interaction, extending development into the periphery of the nation. The process of geographical integration involves a gradual penetration of commerce into tradition, with duality reflecting the vestiges of impermeable older ways and inhospitable terrain. The dual face of the landscape negates any simple notion of geographical equilibrium of location patterns. However, the political attachment and intercourse of traditional with commercial regions leads to adjustment through migration, spillover and the continual shrinkage of social and economic distance.

Transport and Government

The transport system provides the channels for the trade which sustains growth and an efficient growth path for an economy's geographical structure must be supported by the provision of sufficient transport capacity at efficient prices. The theory of prices and trade between geographically separated markets postulates a set of prices for a good such that inter-area differences do not exceed the marginal cost of transport. This can be demonstrated using Cournot's (1838) two region trade model and the device of back-to-back supply and demand graphs, as modified by Samuelson (1952). Consider trade in a single good which is produced and consumed in two geographically separated markets, regions 1 and 2. We may analyse traffic between them and price adjustments by swinging the quantity axis of region 2 through