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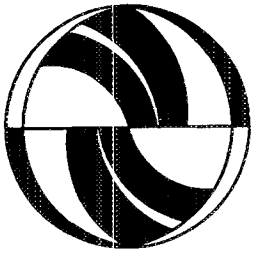
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**The Relationship Between
Transportation and Innovation**

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**The University of California
Transportation Center**
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The Relationship Between Transportation and Innovation

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The Relationship Between Transportation and Innovation

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Our purpose is to highlight an overlooked impact of transportation improvements--the ways improvements stimulate innovation and the development of technologies. Social and economic progress is then achieved through the use of new technologies. Does consideration of technological impacts clarify understandings of transportation improvements?

Using IVHS as a case at point, we will treat that question after providing a classification of impacts and discussing the mechanisms yielding impacts. Although recognizing that there are many factors involved, we will highlight technology as the engine of economic and social progress. We regard technologies as ways of doing things embodied in human skills, products, processes and institutions.

The topic seems timely. Such recent initiatives as the Oresund bridge in Malmo-Copenhagen, high speed rail and Intelligent Vehicle Highway Systems (IVHS) all beg impact questions. Transportation's close cousin, communications, is undergoing remarkable improvements. The Clinton

administration and others are promoting information superhighways, and many proponents claim that such superhighways will spawn technological improvements. Might transportation experiences illuminate those claims?

Interconnections

Transportation, technological, and economic and social developments are interconnected in various ways, as recollection of fragments of history reminds us. The first railroad, the Stockton and Darlington, used early products of the industrial revolution, in particular, the steam engine and iron. Its task was to haul coal for steam generation. George Stephenson's Liverpool and Manchester Railroad connected the mills of Manchester with the ships at Liverpool. Railroad transportation was both a user of newly developed technologies and a responder to markets created as industries based on new technologies emerged.

But that is a one way street -- the industrial revolution and its technological advances drove transportation development. Did influences run the other way? Did

transportation improvements stimulate technology development? J. M. Fenster's discussion of the innovation of the sewing machine comments on that question.¹ She is mainly concerned with innovative actors and the plight of displaced hand sewers.

Transportation only gets part of one sentence (p. 41) in which Fenster remarks that the hand sewers could not keep up with power looms pouring out cloth and railroad cars ready to take away garments. Market access via railroad service asked for more efficient production, and the sewing machine was the answer.

Bits of information such as these do no more than say that everything is related to everything else. Can we sort out relations in sensible ways? We can think of three cuts.

Transportation Advances

Transportation is a big activity. It's a market for the products of innovators, and employs technologies that may be adopted by other activities. That's a first category or cut. Call it within-transportation technologies. Examples are provided by the development of electronic data interchange (EDI) for use by the railroads, the refinement of mass assembly methods by automobile manufacturers, and the development of various construction technologies. Developed (or refined) to meet the needs of transportation, technologies such as these were spun-off to other activities.

One might reason that any activity, large or small, creates technologies, improves them, and spins them off. Considering this from a cost benefit point of view, it could be said that any alternative has technological impacts of some value.

Countering that reasoning is the certainty that the impacts produced by some choices may be more desirable than those from others.

That might be an argument, say, in support of IVHS versus existing methods of increasing highway capacity. Perhaps investment in IVHS will accelerate technology advances more than existing approaches simply because the technology advances from previous approaches have already been captured.

Widening the view, a lively debate might result when comparing the technology advances from IVHS with those from space transportation.

Having introduced this within-transportation class of technology development and said it should not be set aside lightly, it will not be emphasized in further discussion because we suspect some other impact categories are intrinsic to transportation and are more important.

Latent Technologies

Some thoughts about innovation and technology are needed before proceeding. We think of an innovation as a *useful* combination of prior arts, putting things together for a purpose. "Useful" is the key word, and the market provides a test of useful. Put another way, there are many techniques for doing almost anything. An innovation is a superior technique when the useful criterion is applied. Fulton's steamboat provides an example. Fulton wasn't the first person to apply steam to boat propulsion, yet he is recognized as an innovator because he found an appropriate market niche on the Hudson River.

Often the words innovation and technology are used to mean the same thing. We would say that the desktop computer bundles innovations (chips, programs, etc.) to form a technology, while others might say the same thing using different wording. In any event, as long as something is useful, whether it is called an innovation or a technology doesn't matter.

Techniques for doing things abound, they are latent, and transportation improvements may allow a technique to become a technology in the sense just described. An example should help transmit the idea. The Virginia reaper was available and in modest use for a time, but it didn't bloom as the predominant technology for harvesting small grains until railroad service spread in the Great Lake states.

Several conditions were created. Grain production increased as markets extended beyond those available for grain into such areas as transportable whisky. With the build up of grain shipments, clearing houses, grain futures markets and other innovations emerged. Emphasizing industry development in Chicago, Cronon describes these developments.²

John Ringwalt's list of railroad impacts refers to the application of scientific principles.³ Writing in 1888, Ringwalt was referring to the techniques of the time and the ways they bloomed when rail service became available.

Opportunities

Our example brings us to another type of innovation, opportunity innovations. The increases in grain production and

shipments created an opportunity. Instead of farmers accompanying shipments of grain to markets and making sales, institutions and firms grasped the opportunity and innovated ways to manage grain transactions. Transportation improvements change the situation, and change yields opportunities (necessities) to do old things in new ways and to do new things.

Some Relationships

Having identified categories of transportation-induced innovations and given some examples from rather distant yesterdays, we need to examine the ways transportation, innovations, and social and economic progress are related before addressing today's situations.

Specialization

In most of today's cost benefit analyses, transportation improvements are seen to decrease the cost of moving people and goods and/or improve the quality of service. Going beyond that, generalizations made by geographers and regional economists include phrases such as increased labor sheds and raw material supply areas, as well as market areas.

Choices for production and distribution are increased. Individuals may have enriched choices for employment, shopping, recreation and other activities. The words increased specialization and spatial scale catch how improved transportation opens opportunities for innovation.

Writing in 1776, Adam Smith emphasized the opportunities for specialization (but not technology development) derived from the water

and highway transport services of his day.⁴ His chapter, "The Division of Labor is Limited by the Extent of the Market," pointed out that as markets increased in size, opportunities for the specialization of labor increased.

What does specialization do for technology development? Specialization results in repetitive work, and repetitive work opens opportunities for innovation and technology development. The task of making many holes in wood, for instance, invites the innovation of a drill, a product innovation. There is not much need for a drill if just one hole is needed, just as there isn't much need to invent a hammer to drive one nail. With an enlarged market, many copies of a product become feasible, and producing many copies invites the innovation of a process for efficient production.

***Big markets spur
specialization and
innovation***

Adam Smith referred to labor specialization in the production of products of his day, yet larger and more variegated market areas open options for producing variations on existing products or new products. Put another way, market niches for new things may be found among diversities of environments and markets. At the same time, access to new raw materials open options for producing new things.

To sum up, specialization seems to offer opportunities for technologies embodied in skilled labor, products and services, and processes of production. The increased market sizes that permit specialization also

are permissive of the innovation of new products and services. As a simple example, increased market size provided an opportunity for the innovation of scissors for left-handed users.

Smoothing the Flow

Recall that wooden ships made seasonal ocean voyages timed to favorable sailing weather and the pattern of the harvesting of crops. Service on canals in Europe and the U.S. also responded to the seasons. Services were often limited by low water in the fall and by ice in the winter. Rail and steam ship services began to relax the seasonal grip on production and other activities -- excepting, of course, agriculture. They smoothed the flow of goods and people. Today, products of agriculture flow year round from worldwide sources.

To translate that observation into opportunities for innovation, think of smoothing the flow as creating opportunities for continuous flow production. Referring to continuous production, Beniger emphasizes the importance of continuous flow in his analysis of the evolution of the information society.⁵

In the past, that notion could be interpreted as permitting the transition from batch production to continuous production, and thus opening opportunities for innovations in iron and steel production. Two ingredients not yet mentioned include the capability of improved transportation to handle larger quantities of goods and the emergence of the telegraph, which aided the coupling of production and markets, as well as the synchronized control of production among plants and between plants and markets.

Extending the smoothing notion, it has volume, precision, robustness, and other dimensions.

Today's just-in-time production catches part of the smoothing flow notion, but only part of it. It focuses on the inputs to production and draws attention away from the coupling of production with markets and the ability to modify production processes in timely ways.

Consumer Innovations

The language of innovation and technology largely deals with the creation and production of physical products, such as televisions, drugs, automobiles, and TV dinners. This discussion has already gone beyond that in mentioning process technologies and the embodiment of technologies in human skills. We need to go an important step further and identify consumer (or consumption) technologies.

Just as society has innovated ways to produce, it has innovated ways to live: ways to acquire education, engage in recreation and work, organize home life, and such. This is what we term consumer innovations.

The concept of consumer innovation is useful when thinking of the impact of automobilization. Automobiles were rich men's toys in their early days. They substituted for the horse and buggy for Sunday recreation, touring, and trips to visit friends.

By the 1920s, families had begun to innovate new uses, and there were innovations of products and services supportive of those uses. In short, ways of life began a transition to today's auto based commuting, shopping, residential locations and endless lists of other things. The

provision of mass transit in the late 1800s was the basis for a prior economic and social transition. In both cases, of course, there were both production and consumption innovations.

The path from transportation improvements to social and economic development passes through innovation and technology development processes: the opportunities created by transportation improvements are grasped and products and services are matched with markets. The adoption of innovations enhances development. Social and economic developments affect the demand for transportation improvements, of course. Also, there is interaction between the offerings of producers and the demands of consumers.

People and Economics

Transportation's innovation-technology relations have been discussed as if they are free of any social and economic context. That is obviously not the case, so we will touch briefly on social and economic topics.

Social Issues.

There are human aspects of technological change that go beyond how consumer innovations touch the lives of individuals. For one thing, people are innovators, and much has been written about the creative process of innovation.

Some innovators sense a need and possible ways to meet it and engage in systematic search -- an educated trial-and-error sort of thing. That was Edison's style and the style in which pharmaceutical companies searched for new drugs until recently.

Sometimes innovators are mavericks who reject conventional ways of thinking, as McLean did when he put containers on ships. There are other styles.

In addition to considerations at the level of innovative persons, there are institutional, reward structure and social context considerations.

Innovations and new technologies change things, and change may affect individuals differently. There are winners as persons gain when production and consumption are specialized. At the same time, there are losers. Specialization may make old forms of production and consumption obsolete, and people with ties to old ways of doing things may not be in a position to take advantage of new options.

The policy analyst might observe that change is ever present. Without claiming that the situation is handled perfectly, it might be observed that the costs of change are managed through unemployment insurance, welfare, and job retraining. This reasoning seems to say that change has a random, dispersed character that's best treated by the broad policies such as those in place.

***New technologies
bring winners...
but also losers***

We might be able to anticipate winners and losers and craft better policies to manage the costs of change. To do this, we must consider the spatial market-supply area changes that accompany transportation improvements, as well as the specialization opportunities that accompany these changes.

Again using an example from the past, the resource base and production methods of New England farmers became obsolete as the Erie Canal opened opportunities for uses of new resources and methods of production in the Great Lakes. One can speculate about how the impacts of those changes might have been managed if understandings of net gains and winners and losers had been available.

Economic Forces.

In addition to the social context of innovation, innovation and technology development take place in an economic system context. Although some economists have paid attention to the economic determinates of innovation and the consequences, innovation and technology development lie outside of mainstream economics. Innovation is seen as stochastic, a sometime thing that just happens. It's exogenous, something that goes on external to the main economic forces that steer economies.

Even so, it is recognized that technology improvements that yield increased productivity are primary factors responsible for economic development. There has been recent interest in how transportation infrastructure investment increases productivity, with "some, but not much" the result of investigations.⁶ These results are derived from aggregate production function analyses applied mainly to data series for recent decades.

To speculate, perhaps data series that cover periods of rapid transportation improvements or are desegregated to examination of particular industry sectors might tell a different story. In the case of the

housing industry, that's strongly suggested by a remark made in 1921 that the use of motorized vehicles increased contractor productivity by 51% by, for instance, enabling foremen to visit more jobsites on a daily basis.⁷

Souleyrette's study of the evolution of the use of wallboard in the same industry indicates savings of about \$4 billion per year that can be associated with truck services and the ways those services accelerated the diffusion of the substitution of wallboard for plaster.⁸

IVHS Brainstorming

Transportation improvements surely have an impact on technology development. But is that observation useful? To address that question, we will examine some aspects of IVHS using innovation-technology concepts.

IVHS is a vast undertaking. We will assume that the transportation improvements it may provide will have the effect of either maintaining the level of present services in the face of increased demand and constraints on physical facility investment or improving services.

We will not examine the full scope of IVHS. Rather, we will narrow the discussion to urban highway automobile passenger transportation, with a brief mention of trucks. We assume that IVHS technologies will mainly be crafted to enhance existing services. The potential for developing new services will not be completely ruled out, although it does not now appear to have priority in IVHS programs.

The Urban Context.

If you consider urban morphology from a technological viewpoint, land

use patterns may be viewed as physical results of production and consumer technologies, with land use arrangement and character subject to zoning, resource availability, historic path dependence, and other factors.

The transportation system plays the role of a connecting technology. It enables interactivities among production and consumption processes. If the capacity of the transportation facilities is too low, there is congestion. That comes about when transportation improvements have energized technology developments and the realization of these in land use patterns, yet have not been able to keep up with the connectivity requirements of the technology developments. It's an out-of-phase problem.

But considering the role transportation plays in energizing technology development, we need to put the problem in a different way. Without transportation improvements similar to those in the past, the pace of social and economic advances resulting from technology development must be constrained. Opportunities for progress based on innovations are reduced, and the problem is that of dampened technology-based advances.

One can directly experience the congestion (development out-of-phase) statement of the problem. The dampening of technology-based advances is out-of-sight and out-of-mind, but that is not saying it is unimportant.

About IVHS.

If IVHS improvements enable keeping the status quo, then the present gulf between what-might-be and what-is will be unchanged. Modifying that a bit, suppose that

IVHS developments enable keeping the status quo in large, congested cities but enhance services in medium-size and small cities. Then the spatial balance of development would shift toward those places where technology developments may continue to advance.

Suppose that in addition to enhancing present services, IVHS enables the discovery of new services and related functions. It is now a new ball game, for this should lead to the emergence of latent and opportunity technologies, that is, new functions to be served.

In this scenario, social and economic development would be energized as specialization and flow improvements run their course. This is not so speculative. The trucking industry already is applying computers, information systems and communications in ways that provide new services, and service users are changing the ways in which they do business.⁹

The joint nature of discovery needs to be emphasized. The discovery of new transportation services *and* functions happen together; new functions turn on the emergence of latent or opportunity technologies in society generally. In today's world, of course, discovery is limited by energy and ecological constraints not present in the past. Discovery might provide a "stop doing what we are doing and do new things" route to managing energy and ecological problems.

What about communications?

Transportation and communications do the same sorts of things. They connect activities; they are coupling technologies. Many of the comments above could have just

as well been made for communications--larger market areas, opportunities to specialize, control of flows, etc.

Similar stories could be written for transportation and communications. Complementary relations exist, as demonstrated by the above illustration of how both the railroad *and* the telegraph enabled continuous production. Competitive or substitute relations, such as telecommuting, also exist.

Much is said about the computer and communications paradox, which was recently explored by a National Research Council (NRC) committee.¹⁰ Major investments have been made in information technologies (IT), yet when productivity gains are measured, they are generally not found. Productivity gains are found when the inputs (such as hours of labor or dollars) for a unit of output decrease. Such gains are expected from innovation and improved technology -- doing things more efficiently.

The NRC committee speculated that the economist's specification and measurement of productivity gains may not measure service improvements well, that new technologies take a while to emerge, and that the impact of IT may appear in production activities. This seems reasonable, yet we would further speculate that IT impacts would be found if they were sought using the organizing ideas that apply to transportation.

Conclusions

Using the word communication to mean transportation, the famous engineer-economist Jules DuPuit said in 1844, "(t)he ultimate aim of a means of communication must be to

reduce not the costs of transport, but the costs of production."¹¹

We agree, but think that much more is involved than reducing production costs. Transportation improvements enable people to do new things, as well as doing old things in new ways. So we have proposed a route through innovation

and technology development that yields social and economic progress from transportation improvements.

Acknowledgement

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