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Positioning a Metropolitan Area for Global Competition

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Abstract. The contribution of this paper is its conceptual models and related data for identifying appropriate performance measures of an area's infrastructure and using these measures, cognizant of their shortcomings, to estimate the value of this infrastructure in positioning the area for global competition. By focusing on the exports of a metropolitan area's industries, we identify the sources and facilitators of an area's economic growth and development. These include the institutions of higher education for sharpening the area's intellectual resources as inputs for producing the unique outputs of its productive resources, and the air transportation communication facilities and services for moving these outputs to their highest and most worthwhile uses.

1. Introduction

In this work, I address a continuing problem in economic development—accurately measuring the value of an area's infrastructure to its people and communities.[2] Value refers to the performance of the activity and the services it provides its customers and communities. The focus is on the productivity of the activity in question rather than simply its related resource use and expenditures. This counters the currently popular measures of value based on the number of jobs and size of payroll attributed to an activity—measures that rank large, inefficient facilities higher than smaller, efficient ones—although both provide the same value to their customers and communities in performance and services.

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[2] The infrastructure is the basic facilities and services of a community or society. This includes the transportation and communication systems, power plants, waterworks, waste disposal, police and fire protection systems, schools, prisons, and post offices. Some writings extend this definition of infrastructure to include public housing, education, industrial parks, information technology, and various forms of human capital as represented by the total spending of state, local, and federal governments on education, science, and health research (Maki and Lichty 2000, page 158).

The conceptual models, based on detailed breakdowns of industry exports, provide an initial framework for identifying the role and contributions of an area's infrastructure for global competition, like air transportation and higher education, and illustrating their preparation and use. The two types of facilities and services work together as an integrated infrastructure system. With this end in view, we start with the recently completed University of Minnesota study on building a knowledge base for evaluating the competitiveness of the Minneapolis-St. Paul metropolitan area and international airport (Twin Cities Airports Task Force 2001). We extend this study to include measures for estimating and forecasting thevalue of an area's higher education system compared with competing areas. These two series of measures are parts of a knowledge base for positioning the Minneapolis-St. Paul metropolitan area in global competition.

2. Air Transportation Comparison Areas and Transfer Systems

The central theme of the University of Minnesota study is the importance of exports—that is, sales of goods and services to buyers residing outside the metropolitan area--that result in above average returns to local production as a measure of global competitiveness. Central to exports is a transfer system of air, land, and water transportation (with study focus on air transportation), related communication services, and information that moves business travelers and cargo from the local metropolitan area to distant market destinations, and from distant market destinations and supply sources to the local metropolitan area as well as, or better than, the transfer systems of competing areas (Fig. 1). The competing areas selected for the University of Minnesota study include six large inland hub airport areas that are the closest and strongest competitors of the Minneapolis-St. Paul International Airport and the Minneapolis-St. Paul metropolitan area economy. Exports, in dollar values, employment, and value added, serve as measures of the market performance of industries in each of the metropolitan areas. By facilitating the flow of exports to distant markets in each area, the air transportation and communication infrastructures, including the product and market information they generate and transfer, create added value for the industries and areas producing these exports (Maki and Lichty 2000, pages 159-192, 432-459).

The comparison areas provide reference points for measuring and evaluating a target area's economic performance in export markets. Measuring an area's performance against a national average rather than its closest competitors, for example, exaggerates an area's competitive position. The six large air hub (as defined by the Federal Aviation Administration) metropolitan areas—Chicago, Cincinnati, Detroit, Atlanta, Dallas, and Denver—are identified as the closest large inland air hub metropolitan areas competing with the

Minneapolis-St. Paul metropolitan area in air transportation and access to export markets. Each of the six competing areas exceeds the national averages in most performance measures.

The six competing hub areas and also the six additional comparison areas—three with dominant airlines (Pittsburgh, St. Louis, Charlotte) and three with dominant high-tech industry clusters (Boston, San Francisco, and Seattle)—that serve as additional reference areas (Table 1). Minneapolis-St. Paul, with 20 percent population growth from 1985 to 1997, exceeded all other metropolitan areas in the North in population growth. Per capita income in 1997 was the highest in the Minneapolis-St. Paul area, along with Denver, among the seven competing areas. Minneapolis-St. Paul was tied with Dallas, however, for the lowest differential change in per capita income from 1985 to 1997. Differential income change refers to the area income change as a percent above or below the U.S. income change from 1985 to 1997. Per capita income levels are consistently higher than the U.S. averages for each of the reference areas. Population and income growth are among measures used in assessing an area's demand for air transportation and, in turn, capital improvements to handle anticipated increases in airport operations.

In-migration of population into each of the areas is an additional measure of area growth and viability. The U.S. Bureau of the Census estimates population in-migration of 17.9 thousand and 900, respectively, for the Minneapolis-St. Paul MSA and the Cincinnati CMSA and out-migration of 8.9 thousand and 17.8 thousand, respectively, for the Chicago and Detroit CMSAs in 1999. In-migration estimates for Atlanta, Dallas, and Denver are, respectively, 73.3 thousand, 37.8 thousand, and 23.8 thousand. The old Rust Belt cities, exemplified by Chicago and Detroit, experienced lagging population growth compared with the large cities in the South and West.

3. Forecasts of Area Employment, Population, and Airport Activity

I also address a host of interrelated measures that are important to the preparation and use of area activity forecasts and this work. The area forecasts serve a two-fold purpose: first, to provide public agencies with the required information for their infrastructure planning and, second, to provide individuals with readily accessible information on each airport's prospective capital expansion activities.

The Federal Aviation Administration periodically prepares and publishes its forecasts of passenger enplanements and airport operations for each of the hub airports.[3] The Metropolitan Council also prepares and publishes its

[3] The Federal Aviation Administration (FAA) prepares forecasts of passenger enplanements and airport operations based on its independent, objective, econometric modeling systems. In addi-

forecasts for the Minneapolis-St. Paul International Airport (MSP) and its regional airports (Metropolitan Council 1996 and 2001). Both sets of forecasts are based on aggregate measures of economic activity ostensibly affecting air travel and airport operations. They do not include individual forecasts for each of the markets for air travel and cargo. The MSP passenger forecasts, for example, “are dependent on projections of employment and income, the cost of flying, and airline hubbing activity,” according to the Metropolitan Council description of its forecasts. Airline “hubbing activity” relates to various supply-side variables.

Table 1: Population and Per Capita Income, 1985, 1997, and Annual Change 1985-1997.

	Population			Per Capita Income		
Large Hub Area	Total 1985 (thou.)	1997 (thou.)	Annual C hg. (pct.)	Total 1985 (thou.)	1997 (thou.)	Annual Chg. (pct.)
United States	237,924	267,744	1.0	14.4	25.3	0.0
North:						
Chicago CMSA*	8,130	8,751	0.6	16.3	30.0	0.4
Boston NECMA#	5,524	5,827	0.4	17.1	31.8	0.5
Detroit CMSA*	5,108	5,443	0.5	16.1	27.4	-0.3
Mnpls-St. Paul MSA*	2,334	2,795	1.5	17.1	30.1	0.0
St. Louis MSA#	2,444	2,559	0.4	15.6	27.2	-0.1
Pittsburgh MSA#	2,466	2,360	-0.4	15.6	27.2	-0.1
Cincinnati CMSA*	1,755	1,934	0.8	14.1	26.2	0.5
South:						
Wash.-Baltimore CMSA	6,181	7,213	1.3	17.7	31.3	0.1
Dallas CMSA*	3,641	4,678	2.1	17.0	28.7	-0.3
Atlanta MSA*	2,577	3,634	2.9	15.7	28.3	0.2
Charlotte MSA#	1,058	1,352	2.1	13.8	26.5	0.8
West:						
San Francisco CMSA#	5,821	6,718	1.2	19.5	34.6	0.1
Seattle CMSA#	2,609	3,378	2.2	15.8	29.8	0.6
Denver CMSA*	1,943	2,319	1.5	16.7	30.1	0.2

*Designated competing airport area
#Comparison Areas
Source: U.S. Department of Commerce, BEA, REIS, 1969-1997.

Forecasts of passenger enplanements and airport operations at each of the competing metropolitan areas are more restricted measures of economic growth than population and employment. These forecasts are based on econometric and regression models with highly aggregated indicators of area economic change, along with “what if” simulations of airport engineering models based on assumed airport capacities. The models incorporate both demand-side variables, like personal income, and supply-side variables, like

tion, the FAA assembles the forecasts prepared by individual airports in support of their capital enhancement plans and programs.

hubbing activity. Expert evaluations of these models are needed to reveal clearly their demand-side and supply-side biases.

Minneapolis-St. Paul, Detroit, and Cincinnati have large differences in the comparisons of projected annual change in population and the projected annual change in passenger enplanements and airport operations. The employment and export projections from the University of Minnesota study are demand driven. If the below-average growth in passenger enplanements and airports operations were viewed as supply constrained in any way, the difference between the two sets of projections could represent and "exports potential gap" for the Minneapolis-St. Paul International Airport. Clarification of forecast model bias and constraints is an important part of any review and evaluation of airport activity forecasts.

Table 2: Total Passenger Enplanements and Area Population Change, 1997-2010

Originating Airport	Enplanements Total 1997 (mil.)	2010 (mil.)	AnnChg 1997-10 (pct.)	Population Change Annual 1997-10 (pct.)	EnpPop Diff. (pct.)
North:					
Chicago O'Hare	32.6	43.6	2.7	0.8	1.9
Boston Logan	12.7	16.9	2.2	0.3	1.9
Detroit Wayne County	15.9	27.4	4.3	0.7	3.6
Minneapolis-St. Paul	4.1	22.9	3.8	1.3	2.5
St. Louis	14.1	22.4	3.6	0.4	3.2
Pittsburgh	10.3	15.6	3.2	-02	3.4
Cincinnati/North KY	9.5	19.2	5.5	0.9	4.6
South:					
Dallas/Ft. Worth	28.9	48.2	4.0	2.1	1.9
Atlanta	31.6	44.3	2.6	2.9	-0.3
Charlotte/Douglas	11.2	16.9	3.3	2.1	1.2
West:					
San Francisco	19.4	30.3	3.5	0.9	2.6
Seattle-Tacoma	12.3	19.0	3.4	1.7	1.7
Denver	15.7	22.0	2.6	2.2	0.4

Source: Terminal Area Forecast Fiscal Years 1997-2010, FAS, U.S. DOT, 1999.

The Federal Aviation Administration has projected enplanement levels for 2002 and 2010 in its Terminal Areas Forecast report (Table 2).[4] The projected annual increases in passenger enplanements extend the relatively high growth rates (relative to population) of the 1990s to 2010 for a majority of the selected airports, including Minneapolis-St. Paul. Large differences occur, however, in the population and enplanements growth rates. Minneapolis-St.

[4] The enplanements include all passengers, both business and leisure travelers. These are not separated in any of the tabulations because of the lack of data. Air transportation exports, with reference to business or leisure travel, represents the purchases of local air transportation services by non-local sources.

Paul shares with Boston the two smallest growth rate differences between population and enplanements among the seven competing and comparison areas in the North.

Growth in airport operations exceeds population growth in all but two of the 13 metropolitan areas (Table 3). The FAA projections of airport operations show annual change rates below those for enplanements because of a larger number of enplanements per operation anticipated in future years. The Minneapolis-St. Paul airport, with an annual change rate of 2.2 percent, ranks fourth among the seven competing areas and fifth among the 13 selected airports. These are the estimates and projections presumably underlying current expansion plans and programs at each of the competing areas. They are based on regression models of aggregate measures of area economic activity, or, alternatively, "what if" simulations of airport engineering models, rather than detailed industry-specific measures of employment, output, and exports of the sort cited in the University of Minnesota study. The latter allows for a pinpointing of industry changes accounting for differences in forecast and actual levels of business travel and cargo shipments and an assessment of these changes with the help of the U. S. Bureau of Labor Statistics and related industry projections cited earlier.

Table 3: Total Airport Operations and Exports Change, 1997-2010

Originating Airport	Airport Operations Total 1997 (thou.)	2010 (thou.)	AnnChg 1997-10 (pct.)	Exports Change Annual 1997-10 (pct.)	Diff. (pct.)
North:					
Chicago O'Hare	892	1,081	1.5	3.6	-2.1
Detroit Wayne County	547	758	2.5	1.9	0.6
Minneapolis-St. Paul	496	658	2.2	4.4	-2.2
Cincinnati / Northern KY	413	674	3.8	3.5	0.3
South:					
Dallas / Ft. Worth	903	1,334	3.0	4.8	-1.8
Atlanta	785	958	1.5	5.4	-3.9
West:					
Denver	463	580	1.7	5.7	-4.0

Source: Terminal Area Forecast Fiscal Years 1997-2010, FAA, 1999.

The correlation between total enplanements with total population and total employment, for example, will vary from area to area because of differences in the mix of business and leisure travelers and cargo, whether originating or passing through, and in the level and intensity of price competition among airlines serving that area. More importantly, total airport operations will limit the level of total enplanements, depending on airport capacity, size and type of aircraft, and market share strategies of individual airlines.

The recently published Benchmark Report projected capacity improvements for 31 airports, including the seven competing airports, adds more complexity to any review and evaluation of airport activity forecasts (Federal

Aviation Administration, 2001). The capacity benchmarks are defined as "the maximum number of flights an airport can routinely handle in an hour." The projected growth in exports—an indicator of demand growth—exceeds the Benchmark Report demand growth for all but Detroit and Cincinnati. The Benchmark Report projected less demand growth for Detroit and Cincinnati than the projected growth in airport operations. The FAA developed the capacity benchmarks "to understand the relationship between airline demand and airport runway capacity and what we in the aviation community can do about it." They are estimates that vary widely with weather conditions, runway configurations, and the mix of aircraft types. They assume there are no constraints in the en route system or the terminal area.

Several new data sources were used in the preparation of the capacity benchmarks, namely, the Operations Network (OPSNE) that is designed to measure the performance of the FAA flight control system, the Aviation System Performance Metrics (ASPM)—originally a cooperative venture between 10 air carriers and the FAA to supply detailed flight data for flights to and from 21 major airports, and the Airline Service Quality Performance (ASQP) with flight data reported from the 31 major airports to measure carrier flight performance.

The new data sources still lack the modeling capabilities for the next step beyond the preparation of capacity benchmarks, namely, the preparation of the detailed demand forecasts and the capital improvements to handle the corresponding increases in airport operations. Data are lacking for each airport that take into account the individual demand components—business travelers, leisure travelers, and cargo, with further breakdown of each of these categories, at least by origin and destination of travel and cargo. Data on commodity exports and imports currently include aggregations of revenues from business travel and air cargo shipments. The detailed data breakdowns are neither available nor required for current forecasting models. These models generate forecasts that actually are simulations of airport engineering models based on various assumptions about local operating conditions, airport capacities, and originating air traveler and cargo requirements. The Metropolitan Airports Commission, for example, manages the Minneapolis-St. Paul International Airport. The Commission lacks adequate oversight of, and accountability for, the forecast system and process—a condition that may exist elsewhere among competing airports. Serious miscalculations of future airport space and facility requirements are likely to occur that will adversely affect air transportation-dependent businesses, like those in the high-tech cluster, and involve costly measures to correct.

A large air transportation hub is an essential infrastructure of a technology-intensive economy with markets world wide and dispersed input sources that require much face-to-face communication. Such communication is increasingly important in a technology-intensive economy as a means of transmitting non-standardized information that must be discussed, interpreted, and analyzed before it can be used (Maki and Lichty 2000, page 459).

4. From Current to Long-term Performance Indicators

The export market cycle of product and money flows builds on the critical role of intellectual (i.e., information and know-how) resources for supporting and directing an area's production systems to their most profitable products and markets. Large metropolitan areas specialize in various services—from transportation and communication to financial, personal, and business services, and health care (Maki and Lichty 2000, pages 120-158). They bring "new dollars" to purchase the agricultural and manufactured products originating elsewhere as intermediate products for local industries and as final products for local consumption. This conceptual model of long-term change applies to each of the competing areas.

Listing the high-tech industries among long-term economic indicators serves the double purpose of identifying an industry cluster, in this case, a group of industries that make use of a common pool of skilled workers, transportation infrastructure, and technical know how, and that accounts for a high proportion of total output in exports. The Minneapolis-St. Paul MSA ranked third in high-tech employment as a percent of total employment (at 7.9 percent), following Dallas and Denver (each at 9.8 percent). More than 55 percent of total high-tech manufacturing employment in the Minneapolis-St. Paul MSA was in Surgical, Dental, and Medical Instruments and Supplies Group. This major group included the three high-ranking medical devices industries (381, 382, and 384) and was the largest among the competing areas.

Communication services that are closely related to the high-tech sector constitute another critical resource for global competition. Production of communication services in the U.S. amounted to $1,126 per person in 1997, including foreign exports. Local spending for communication services was less in the North, but higher in the South and West, with Denver leading the competing areas. Exports of communication services, that is, purchase of communication services by non-residents, was the second lowest for the Minneapolis-St. Paul MSA, next to Cincinnati. Dallas had the highest exports and next to highest growth rate.

5. Measuring Trends in Industry Employment and Exports

Besides population and income change, trends in industry employment and exports associated with changes in industry location and concentration provide additional measures of change in the demand for area infrastructure. The Location Quotient is introduced as a simple measure of industry location.[5] A Location Quotient (LQ) of more than one indicates an above-average level of commodity output in the given area—that is, a geographic concentration of an export-producing industry. Three-digit and four-digit Standard Industrial Classification (SIC) of industries provide maximum industry detail for showing important differences in industry composition among the seven competing metropolitan areas.[6]

Top ranking industry concentrations are parts of top ranking industry clusters in the Minneapolis-St. Paul metropolitan area (Porter, 1998). The phenomenon of industry and commodity clustering is readily illustrated by the industry composition of the high-technology industry cluster in the Minneapolis-St. Paul MSA.[7] The high-technology industries with above-average concentration, that is, with Location Quotients greater than one are provided in Table 4. Also listed are the same measures for the top 80 LQ ranking and all industries.

The 19 high-technology industries have the highest ratio of foreign to domestic exports, that is, air travel and shipments to destinations outside the given metropolitan area. The high-tech industries are followed by the remaining industries among the top 80 and, finally, all other sectors. The higher concentration .of an industry in an area correlates with a higher level of local production and, hence, a larger excess supply of industry output for export. The high-tech industries generate a proportionately higher level of exports from their total commodity supply and, hence, they account for a proportionately larger share of an area's economic base than other export-producing industries. They also have higher earnings per worker. The higher value foreign exports are the most air transportation dependent among the three industry groups. The technology-intensive industry clus-

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[5] Defined as the ratio of the percentage that the total output of a given commodity in the area is of total area output divided by the corresponding commodity percentage for the region or nation.

[6] The IMPLAN model, available from the Minnesota IMPLAN Group, provides a 528-sector breakdown of inter-industry transactions—purchases and sales of industries, households, and governments, by county and year for 1990s. It also includes estimates of exports—domestic and foreign—for each industry producing in excess of local sales. It also provides a detailed industry breakdown of imports.

[7] Industry and commodity clusters are the groups of industries that are interrelated in production and product utilization.

ters thus serve as important long-term indicators of the adequacy and suitability of an area's infrastructure, particularly higher education, for sustaining its viability and growth.

Table 4: Clustering of High-tech Industries with LQ Greater Than 1.00, MSP MSA, 1997*

Industry	Code	LQ (thou.)	Employ ment (mil.$)	Exports (mil.$)	Foreign (thou.$)	LabEarn per-Work
Electromedical Apparatus	3845	11.1	6.2	217	375	72
Automatic Temp. Controls	3822	9.5	5	432	56	68
Computer Storage Devices	3572	7.4	4.3	0	267	64
Surgical and Med. Instrument	3841	4.7	6.5	223	322	55
Mech. Measuring Devices	3823	4.6	6.9	66	487	55
Surgical Appliances & Supplies	3842	4.0	4.8	368	184	50
Printed Circuit Boards	3672	3.6	6.3	0	132	42
Computer Peripheral Equip.	3577	2.7	2.6	362	120	59
Lab. Apparatus & Furniture	3821	2.4	0.3	0	0	48
Electronic Computers	3571	2.3	5.8	156	814	85
Commic. Equip. N.E.C.	3669	2.3	0.9	0	25	47
Computer & Data Process.	7370	1.9	44.1	2,092	88	54
Search & Navigation Equip.	3812	1.7	3.4	238	64	55
Telephone & Telegraph	3661	1.6	2.4	32	118	65
Optical Instruments & Lenses	3827	1.4	0.4	0	32	59
Dental Equipment & Supplies	3843	1.3	0.2	2	15	50
Engineering, Architectural	8710	1.1	19.8	496	52	30
Analytical Instruments	3826	1.0	0.4	26	50	60
Motion Pictures	7800	1.0	8.8	0	55	16
Total, high-tech			129	4,710	3,257	51
Top 80, LQ rankings			335	26,958	7,790	56
Total, all sectors			1,991	57,456	13,648	33

*From America's High-tech Economy, Ross C. DeVol, Milkan Institute, 1999.
Source: Minnesota IMPLAN Group, 1999 IMPLAN Model and 1997 IMPLAN Database.

6. Comparing Long Term Education Indicators

A commonly used measure of higher education and its performance compared with the selected states identified earlier relates to a state's ranking in Research and Development (R&D) expenditures. The total R&D expenditures of Science and Engineering doctorate degree granting institutions in selected states are compared, in Table 5, with total R&D expenditures and total Gross State Product. The last three columns refer to (1) the annual change in the R&D expenditures of S&E doctorate degree granting colleges and universities during the seven-year period from 1992 to 1999, (2) the colleges and universities share of total R&D expenditures, and (3) the colleges and universities R&D expenditures per $1,000 of Gross State Product (GSP). The college and university R&D share for Minnesota was 10 percent compared to six percent for Michigan and 28 percent for Missouri. Its GSP share was $2.49 per $1,000 GSP compared to $3.41 for Missouri and $3.27 for Michigan. The University of Minnesota is the only S&E doctorate degree granting institution in Minnesota among the top 200 (compared with 12 each for Texas, Massachusetts, and California).

Minnesota's support of its higher education systems ranks second to Illinois among the six competing states. Performance, as measured by Science and Engineering doctorates and graduates per 10,000 population, does not always rank second for Minnesota. Rather, Colorado and Texas, which rank sixth and seventh in funding of higher education, vie with each other in ranking first in each of the Science and Engineering measures cited in Table 6. Graduate students and doctoral engineers, for example, rank below the U.S. average and well below Texas. Minnesota, however, ranks second on patents issued, following Texas.

Table 5: Comparing R&D Expenditures and GSP, 1999 and Annual Change, 1992-99

State and Region	R&D Expend. (bil.$)	GSP (bil.$)	Higher Ed Institutions Total (no.)	R&Dexp (bil.$)	AnnChg (pct.)	R&D Share (pct.)	GSP Share (dol.)
North:							
Massachusetts#	11.1	221	12	1.4	4.3	13	6.46
Pennsylvania**	8.2	339.9	8	1.4	5.7	16	3.97
Illinois*	8.0	393.5	7	1.1	6.0	13	2.68
Michigan*	14	272.6	4	0.9	5.0	6	3.27
Ohio*	7.1	320.5	6	0.7	6.2	10	2.31
Missouri**	1.8	152.1	4	0.5	6.9	28	3.41
Minnesota*	3.6	149.4	1	0.4	2.3	10	2.49
South:							
Texas*	9.5	601.6	12	1.7	4.9	18	2.83
North Carolina**	4.7	218.9	4	1.0	8.4	20	4.36
Georgia*	2.3	229.5	7	0.8	7.0	35	3.51
West:							
California#	41.7	1,033.0	16	3.5	23	8	3.41
Colorado*	3.2	126.1	3	0.5	7.5	15	3.89
Washington#	7.5	172.3	2	0.6	5.5	8	3.36

*Competing areas, ** Second tier comparison areas; #High-tech comparison areas

Source: National Science Foundation, Science and Engineering Indicators 2000, Table 2-21 Total R&D and GSP by state, 1997; Academic Research and Development Expenditures: Fiscal Year 1999, Table B-21 R&D Expenditures at Universities and Colleges, by Geographic Division and State, Fiscal Year 1999.

Comparisons of academic research and development (R&D) expenditures and the funding of Science and Engineering (S&E) research provide additional measures of the performance of a state's higher education system. In Fiscal Year 1999, the University of Minnesota ranked 15th nationally in total R&D expenditures and 18th in federal R&D expenditures among the top 200 S&E doctorate degree-granting institutions of higher education (Table 7).

Ranked ahead of the University of Minnesota in total expenditures among the seven competing states are University of Michigan and Texas A&M University. Important differences occur, also, in the distribution of R&D expenditures by S&E field and the proportion of total expenditures attributed to federal sources. Total expenditures for Life Sciences (i.e., Medical, Agricultural, and Biological), ranked 11th, while Engineering ranked 30th and Physical Sciences ranked 41st among the top 200.

Table 6: Total Spending for Higher Education and Related Indicators, 1995

		Science and Engineering Items Per 10,000 Population					
State	PerCap HighEd Expend* (dol.)	Doctorate Awarded	Post Doctoral (no.)	Graduate Students (no.)	Doctoral Scientists (no.)	Doctoral Engineers (no.)	Patents Issued (no.)
U.S. **	673	1.0	1.4	16.4	17.3	3.3	2.3
Minnesota	743	1.2	1.7	13.8	19.0	2.9	4.2
Illinois	790	1.3	1.0	18.6	16.5	2.8	2.6
Michigan	640	1.2	1.3	18.2	13.7	3.6	3.1
Ohio	609	1.0	1.0	19.0	14.5	3.6	2.5
Georgia	605	0.8	0.8	12.3	12.9	1.6	1.3
Colorad0	566	1.0	1.3	15.9	14.4	3.6	0.7
Texas	503	1.5	2.2	23.8	24.7	5.2	11.0

**Total for 50 states, District of C olumbia, and Puerto Rico.
*Total current fund expenditures for higher education from all sources.
Source: Division of Science Resources Studies, National Science Foundation.

Except for math and computer science, the doctorate research program rankings are higher (in numerical value) than the corresponding expenditure rankings among the top S&E sub-fields at the University of Minnesota (Table 8). The top-ranking program--Chemical Engineering--ranks third in expenditures and first in doctorate research.[8]

Performance rankings of colleges and universities for prospective students have wide circulation in the U. S. media. For example, U.S. News rankings of the best graduate schools are based on performance measures, like reputation, placement success, and student selectivity.[9] The current rankings of accredited master's degree programs in business administration

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[8] These rankings are based on a 1993 survey of over 88,000 faculty members in 41 fields at 274 universities and over 1 million publication, citation, and research grant records of the faculty members.

[9] In the ranking of accredited master's programs in business administration, reputation (weighted by 0.4) is measured by the ratings of business deans and directors of accredited programs and corporate recruiter, placement success (weighted by 0.35) is measured by the mean starting salary and bonus (40 percent) and employment rates computed at time of graduation (20 percent) and three months after graduation (40 percent), and student selectivity (weighted by 0.25) is measured by the mean GMAT (65 percent) of fulltime students entering in the fall of the past year, the mean undergraduate GPA (30 percent), and the proportion of applicants accepted by the school (5 percent). See 2002 Graduate School Rankings on usnews.com education website.

show 18 universities in ten of the 12 states listed earlier (excluding Minnesota), above the University of Minnesota. The Financial Times uses performance measures in its global business school rankings. These include salary of graduates (20 percent), salary percentage increase (20 percent), and numerous individually less valued measures, some based on resource input measures (60 percent).[10] The Financial Times rankings show 22 universities in ten of the 12 states listed earlier above the University of Minnesota. States with the larger number of research universities, relative to population, also have the larger number of high business school rankings in both the U.S. News and the Financial Times surveys.

Table 7: R&D Expenditures at U of MN, by Science and Engineering Field, 1999

S & E Field	Total Rank	Total Amount (thou.$)	Federal Rank	Federal Amount (thou.$)	Federal Relative (pct.)	Non-federal* Amount (thou.$)	Non-federal* Relative (pct.)
Engineering	30	38,564	29	24,055	62	14,509	9
Physical sciences	41	17,382	31	14,357	83	3,025	2
Environmental	37	12,986	46	6,120	47	6,866	4
Math & computer	19	12,294	20	8,838	72	3,456	2
Life sciences	11	269,055	14	147,648	55	121,407	74
Psychology	13	7,095	7	5,068	71	2,027	1
Social sciences	24	14,008	58	2,127	15	11,881	7
Total or average	15	371,384	17	207,761	56	163,623	100

*Non-federal total includes $23,933 thousand industry sponsored research.
Source: NSF, Division of Science Research Studies, Academic R&D Expenditures.

Tracking changes in the funding and performance of an area's higher-education system provides measures of an area's long-term competitiveness—the ability of its educational institutions to better serve its people and economy, especially the technology-intensive sectors, than the educational institutions of competing areas. Funding, of course, is an input measure. Even more important as measures of long term competitiveness are the various indicators of output and performance--Science and Engineering graduate students, doctorates awarded, patents issued (and commercialized), and the level and degree of competition among Science and Engineering graduate schools and research centers in each of the competing metropolitan areas. Missing are the additional performance indicators that would show, for example, the numbers of graduates of a state's institutions of higher education

[10] The individually less valued measures include a mix of performance (output) and resource (input) measures like value for money (i.e., rate of return for each dollar spent), career progress, aims achieved, placement success, employed at three months, alumni recommendation, women faculty, women students, women board, international faculty, international students, international board, international mobility, international experience, language, faculty with doctorates, Financial Times (FT) doctoral rating, and Financial Times research rating. See Financial Times, January 19, 2001 and FT.com career point/business education website.

who find employment within the state, by industry and earnings, and the taxes these industries and their employment generate for the support of the next cycle of investments in higher education. The additional information would provide additional measures of university performance for assessing the returns to the state on its long-term investments in higher education.

Table 8: R&D Expenditures at University of Minnesota, by S&E Sub-field, 1999

	Total Expend (1999)		Doc. Res (1993)	
S & E Field	Ranking	Amount (thou.$)	Ranking	Score (no.)
Engineering:				
Aeronautical	23	3,561	12	3.40
Bioengineering / Biomedical	30	766	17.5	3.48
Chemical	3	11,419	1	4.86
Civil	18	7,016	13	3.76
Electrical	33	6,694	18	3.73
Mechanical	24	6,532	8	4.07
Other	59	2,576	na	na
Physical sciences:				
Astronomy	25	2,516	24	2.89
Chemistry	46	7,241	21	3.89
Physics	38	7,025	22.5	3.75
Math & computer science:				
Math	13	5,069	14	4.08
Computer science	27	7,225	47	2.67

Source: (1) NSF, Division of Science Research Studies, Academic Research and Development Expenditures, fiscal year 1999 (estimated); (2) National Academy of Science, National Research Council, Research Doctorate Programs in the U.S.

7. Building and Using an Area's Knowledge Base: Summary

Building and using a knowledge base for assessing the value of an area's air transportation and higher education systems remain continuing challenges to their communities. Forecasts of the demand for and supply of air transportation for the Minneapolis-St. Paul and competing area airports often times are simply engineering model simulations of anticipated airport operations based on alternative capital expansion programs. Moreover, the forecasts are distorted by airport management biases, whether towards the dominant airline with a corporate interest to limit the supply of airport slots, the downtown businesses favoring a nearby airport to reduce travel time to the airport, or nearby residents affected by airport noise and roadway congestion. Much depends, of course, on the information itself—its content and purpose—and the information sources, providers, and recipients. In Minnesota, much of this information is internal to the dominant airline or higher education institution, where the airline is one of the state's largest employers and the state university is the largest and also the only S&E doctorate degree granting institution in the state.

Total R&D funding, including state, federal, and private sources, correlates with the total number of S&E doctorate degree granting institutions in a state, even when adjusting for population. The available performance indicators suggest an attendant value in splitting the one university, as in Minnesota, into two or more independently competitive S&E doctorate degree granting institutions. Still lacking, are the second round performance measures based on the contributions of the completed research to a favorable economic environment for businesses or the contributions of the graduate studies completed to a favorable cultural environment for top-rated symphony orchestras, writers, and artists. This view of public infrastructure investments counters the view of public works proponents who emphasize the immediate payoff in local jobs and payroll, often justified by economic "multiplier" findings of local impact studies.

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