Evaluating the Economic Benefits to Michigan of Alternative Road-Bridge Investment Mixes

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16. Abstract

A well-maintained and efficient transportation system provides the backbone for all economic activity within Michigan. Included in the economic effects are transportation-related benefits in the form of time savings for households and businesses, as well as the beneficial effect of an increase in construction and engineering activity. Each transportation investment decision MDOT implements has direct implications for Michigan's economy. The purpose of this study is to measure the differences in the effects of alternative highway investment mixes on Michigan's economy. We estimate the differences in economic effects on Michigan of alternative investment mixes by reducing *road-bridge rehabilitation and repair* (R&R) priorities as *increased capacity/new roads* (IC/NR) investments are increased. This report identifies the effect on Michigan's economy of each mix, and then identifies the portfolio that best stimulates the economy. The alternatives reflect different priority choices, shifting emphasis between R&R and IC/NR. The analysis of the economic effects of alternative investment mixes includes estimates of their spin-off benefits, as generated by the REMI (Regional Economic Models, Inc.) model of the Michigan economy. The projects to be included in each alternative investment bundle were identified based on their ranking within the model and their cost to complete. Four alternative investment bundles were compared against the baseline condition, which reflects the current strategy of devoting 10 percent of highway program funding to IC/NR. As more investment shifts toward IC/NR there is less reliance on MDOT staff for P/E activities and, even more significant, zero reliance on MDOT staff for construction. Any of the investment alternatives representing a shifting of funding toward increased capacity is superior to the heavy preservation spending associated with the baseline.

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1. Introduction

The Michigan Department of Transportation (MDOT) spends approximately $1.3 billion annually on the preservation and enhancement of the state's road and bridge system. A well-maintained and efficient transportation system provides the backbone for all economic activity within Michigan. Included in the economic effects are transportation-related benefits in the form of time savings for households and businesses, as well as the beneficial effect of an increase in construction and engineering activity. Investment priorities are established each year by the five-year highway program adopted by MDOT. Each transportation investment decision MDOT implements has direct implications for Michigan's economy.

The purpose of this study is to measure the differences in economic effects on Michigan of alternative investment mixes. The alternatives reflect different priority choices, shifting emphasis between *road-bridge rehabilitation and repair* (R&R) and *increased capacity/new roads* (IC/NR). Determining the appropriate mix of funding between the two is a yearly juggling act for MDOT; currently, preservation projects command 90 percent of highway program funding.

The analysis in this study considers the temporary economic impacts arising from the construction phase of competing investment alternatives, as well as the longer-term economic impacts of the travel benefits conferred on Michigan households and businesses by each investment alternative. The study builds on many of the methods and tools used by our project team in a recent study for MDOT of the fiscal year 2007 five-year highway program (Fulton, Grimes, and Petraglia 2007).[1] The results from this analysis will show the trade-offs between IC/NR and R&R, and identify the point where there is a decreasing marginal return for additional dollars devoted to IC/NR.

Our analysis of the economic effects of alternative investment mixes includes estimates of their spin-off benefits, as generated by the REMI (Regional

[1]The project team also reported on MDOT's highway program for fiscal years 2005 and 2006 (Fulton, Grimes, and Petraglia 2005, 2006).

Economic Models, Inc.) model of the Michigan economy. Spin-off effects come from two sources: indirect effects, or purchases from local suppliers (e.g., steel, concrete, professional services); and expenditure-induced effects, or spending by people who receive income attributable to transportation-policy-related activity (e.g., spending by realtors of income received from selling homes to construction workers). It is the sum of the direct and spin-off activities that determines the total benefits of MDOT's investments to the Michigan economy.

The REMI model is designed to generate such estimates. REMI is probably the most widely applied regional economic forecasting and policy analysis tool in the nation. REMI was established in 1980, and since then has been developing models that answer "what if" questions about the effect of policy initiatives on regional economies. The University of Michigan has been using various versions of the REMI model since 1983 to assess projects for several state government agencies in Michigan, including MDOT. More detail on the model and procedures is provided in section 5.

MDOT provided much of the initial input data. The Economic Development Research Group (an independent consulting firm located in Boston, Massachusetts) took primary responsibility for estimating the time and cost savings that result from the investments and apportioning investment-related spending in Michigan, so as to make the savings and spending computations compatible with the structure of the economic model. The University of Michigan's Institute of Labor and Industrial Relations took primary responsibility for generating the estimates of the economic benefits of the investments that derive from the inputs. The two units did work as a team, though, each contributing to both phases of the project.

The following sections summarize the alternative investment approaches, that is, reducing R&R priorities as IC/NR investments are increased (section 2); the direct construction, travel, and economic benefits from the alternative investment bundles (sections 3 and 4); the REMI model methodology (section 5); and the results of processing the direct benefits through the economic model to derive

the total economic benefits to Michigan of the alternative investment mixes (section 6). A summary of the findings concludes the report (section 7).

2. MDOT's Alternative Investment Approaches

Each investment alternative represents a distinct portfolio of individual transportation projects identified by MDOT. First, MDOT used its MAPSCORE database to prioritize preservation projects within the 2006–10 Five-Year Highway Program (alternative A in table 1). The resulting projects served as the baseline against which the preservation priorities were reduced as IC/NR investments were increased.

Next, MDOT used its benefit/cost prioritization model to develop a list of sample IC/NR projects for a given investment level to compare against the baseline projects. The prioritization model is a component of a larger prioritization process developed and agreed upon by Michigan Planning Organization directors, MDOT region planners, MDOT system engineers, region engineers, and MDOT leadership. The projects to be included in each alternative investment bundle were identified based on their ranking within the model, and their cost to complete. This approach identifies a representative sample of IC/NR projects for each investment alternative considered in this study.[2]

Table 1 shows the investment breakout of the four alternatives that are evaluated in comparison with investment alternative A. Alternatives B through E represent increasing allocations of an annual $1.362 billion investment toward IC/NR projects, with the maximum allocation of 50 percent represented in alternative E.

[2]MDOT assessed only the benefits of corridor IC/NR projects. Interchange projects were not included, as MDOT currently has no method to model the expected travel-time savings associated with interchange improvements in a manner compatible with the savings calculated for corridor projects. Where necessary, the limits of some projects were reduced to be consistent with the available investment dollars.

Table 1. Investment Alternatives, Anticipated Annual Expenditure

	Alternative				
	A*	B	C	D	E
Pavement preservation (millions)	$541	$510	$480	$422	$285
Other system preservation-related investment (millions)	$687	$648	$610	$532	$396
% pavement preservation and related investment	90%	85%	80%	70%	50%
IC/NR (millions)	$134	$204	$272	$408	$681
% IC/NR investments	10%	15%	20%	30%	50%
Estimated total investment (millions)	$1,362	$1,362	$1,362	$1,362	$1,362

*Alternative A is representative of average conditions in the 2006–10 Five-Year Highway Program.

Source: MDOT, July 2006

3. Direct Construction Impacts and Travel Benefit Impacts

3.1 Direct Construction Stimulus

Each alternative investment approach to a five-year plan comprises a mix of projects and associated construction phase elements. The discussion that follows shows how construction requirements for each of the investment alternatives (B through E) differ in comparison with alternative A.

The first five project areas in table 2 are specific R&R activities. The annual budget for these activities would shrink progressively from alternatives B through E, while the funding toward IC/NR would increase. Table 2 shows how the de-funding of R&R would be broken down, by project area, in order to increase the level of investment for IC/NR.

Table 2. Differences in Annual Spending Relative to Alternative A, by Project Area ($ millions)

	Alternative			
Project Area	B	C	D	E
Repair and rebuild roads and capital preventative maintenance	–31.0	–61.0	–119.0	–256.0
Repair and rebuild bridges	–11.1	–21.9	–44.1	–82.9
Safety program	–3.7	–7.2	–14.5	–27.3
Other programs	–9.1	–18.0	–36.2	–67.9
Routine maintenance	–15.1	–29.9	–60.2	–113.0
Increased capacity and new roads	+70.0	+138.0	+274.0	+547.0

We relied on similar information provided by MDOT for recent five-year plan evaluations in determining (1) each project area's investment allocation to planning and engineering (P/E) activities versus construction, and (2) the portion assigned to private-sector contractors versus performed in-house at MDOT. These allocations are shown in table 3.

Table 3. Allocation of Project Area Dollars, Planning and Engineering (P/E) versus Construction

		% P/E $ to:		% Construction $ to:	
	P/E Component	Contractors	MDOT Staff	Contractors	MDOT Staff
Repair and rebuild roads	20%	55%	45%	100%	0%
Capital preventative maintenance	20%	20%	80%	50%	50%
Repair and rebuild bridges	20%	60%	40%	100%	0%
Safety program	20%	60%	40%	95%	5%
Other programs	20%	60%	40%	90%	10%
Routine maintenance	0%	n.a.	n.a.	0%	100%
Increased capacity and new roads	20%	70%	30%	100%	0%

The implication of tables 2 and 3 is that as more investment shifts toward IC/NR there is less reliance on MDOT staff for P/E activities and, even more significant, zero reliance on MDOT staff for construction. Assigning additional projects to private-sector contractors may result in some loss of construction-related economic benefit to the state, depending on the proportion of Michigan-based contractors doing MDOT work.[3] The higher the proportion of work going to in-state workers, the smaller the leakage of economic benefit beyond the state borders. MDOT has relied heavily on in-state construction firms (88 percent, as shown in table 4), which mitigates concerns about moving investment more and more into IC/NR.

Table 4. MDOT FY Construction Contracts, % of Work Performed by Michigan Contractors

	2005 FY Total	% of Total Contracts
Michigan contractors	$963,278,616	88%
Out-of-state contractors	$131,988,632	12%
Total	$1,095,267,248	100%

The project spending impact of each alternative relative to alternative A, in terms of the amount and direction of dollars flowing into the Michigan economy, is shown in table 5.

Table 5. Direct Impact of Annual Project Spending on Michigan: Alternatives B through E Compared with Alternative A

	— Planning/Engineering —		——— Construction ———		Change in Annual Budget
	Michigan Contractor	MDOT	Michigan Contractor	MDOT	Fulfilled in Michigan
B	$ 3,762,876	$ –932,718	$ 13,610,900	$ –18,495,135	$ –2,054,078
C	7,667,448	–1,259,868	29,273,205	–40,076,135	–4,395,351
D	14,968,054	–3,128,236	55,539,532	–75,740,715	–8,361,365
E	29,108,984	–8,045,976	103,296,591	–139,977,549	–15,617,951

[3]For planning and engineering activities, we assumed that 95 percent of the contract dollars awarded went to Michigan firms.

Recall that alternatives A through E all represent the same amount of annual MDOT spending. But since the investment orientation is different, the project mixes will be different, the need for P/E and construction will be different, and the potential to award some of these functions to out-of-state businesses determines the extent of leakage from project-related spending. Relative to alternative A, alternative E has the largest potential for annual leakage of economic benefit from Michigan since it reflects the upper bound of IC/NR funding (50 percent), which allows for greater participation of out-of-state construction contractors.

3.2 Direct Travel Benefit

The prior discussion focused on the temporary construction-related differences of each alternative on Michigan's economy compared with alternative A. However, the primary reason MDOT invests in transportation system improvements is not to support construction jobs and wages but to deliver a transportation system that is as efficient and well-maintained as possible, which will confer *continuing* travel benefits (though eventually diminishing with traffic growth) to Michigan households and businesses. The following discussion of investment alternatives focuses on the *vehicle hours of travel* (VHT) attributable to each project mix relative to alternative A. The analysis extends annually from the base year of 2006 through the forecast year of 2015.

The annual changes in VHT beyond 2006 for each bundle were derived by MDOT based on a straight-line projection to 2015, using the 2006 program as a representative sample of types of fixes that would likely be implemented over the coming years. On average, R&R projects have an expected fix life of fifteen years, well within the nine-year range of the projection. MDOT is assuming that the VHT savings associated with the improved pavement condition in the initial year will remain constant within the time period of the projection. An alternative method of projection would be based on a decay function, which would represent some geometric decline in road quality over the forecast period, resulting in an increase in VHT. The decay function is the more robust approach; in this context, MDOT's assumption is that for the initial nine years of the program, road quality remains in good condition, with increasing deterioration occurring beyond

that period.[4] In the event of situations where this is not the case, estimates of the impact of R&R activities on travel-time savings could be understated.

Table 6. Predicted Daily VHT Changes by Alternative and Investment Orientation

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
R&R-related VHT savings (hours) forfeited relative to alternative A										
B	–231	–462	–693	–924	–1,155	–1,386	–1,617	–1,848	–2,079	–2,310
C	–621	–1,242	–1,863	–2,484	–3,105	–3,726	–4,347	–4,968	–5,589	–6,210
D	–1,203	–2,406	–3,609	–4,812	–6,015	–7,218	–8,421	–9,624	–10,827	–12,030
E	–2,563	–5,126	–7,689	–10,252	–12,815	–15,378	–17,941	–20,504	–23,067	–25,630
IC/NR-related VHT savings (hours) relative to alternative A										
B	1,760	3,519	5,279	7,039	8,798	10,558	12,318	14,077	15,837	17,597
C	3,512	7,025	10,537	14,049	17,562	21,074	24,586	28,098	31,611	35,123
D	4,366	8,732	13,098	17,464	21,829	26,195	30,561	34,927	39,293	43,659
E	4,564	9,128	13,692	18,256	22,820	27,384	31,949	36,513	41,077	45,641
All Projects: Daily VHT savings (hours) relative to alternative A										
B	1,529	3,057	4,586	6,115	7,643	9,172	10,701	12,229	13,758	15,287
C	2,891	5,783	8,674	11,565	14,457	17,348	20,239	23,130	26,022	28,913
D	3,163	6,326	9,489	12,652	15,814	18,977	22,140	25,303	28,466	31,629
E	2,001	4,002	6,003	8,004	10,005	12,006	14,008	16,009	18,010	20,011

The total (daily) VHT impact for each alternative is shown in the bottom section of table 6. In advancing from alternative B to C to D there are increasing daily VHT *saved* due to the overall project mix. By alternative E, however, the daily VHT *forfeited* by the level of R&R projects foregone is unmatched by the gain of VHT saved through IC/NR. As a result, alternative E yields decreasing marginal returns for additional dollars of IC/NR investment. This is also apparent in the incremental annual VHT savings allocated between commercial vehicles and automobiles, as shown in table 7.

[4]It was beyond the scope of this study to incorporate a decay function into MDOT's travel demand model to project VHT changes. This could be an important addition to the model, however, and essential to studies involving longer time periods.

Table 7. Annual VHT Implications by Type of Vehicle

	Annual VHT Saved	
Alternative	Commercial Vehicles	Automobiles
A	194,551	2,032,791
B	227,809	2,557,456
C	259,632	3,023,050
D	285,294	3,096,616
E	252,453	2,705,175
Extra hours saved relative to alternative A		
B	33,258	524,664
C	65,080	990,259
D	90,743	1,063,825
E	57,902	672,384

For each alternative, new projects initiated each year create additional travel benefits. The cumulative VHT saved for the interval 2006 through 2015 are shown for each alternative in table 8. These cumulative travel benefits then must be considered against an accepted *trip table*[5] for each type of vehicle to determine what portion of the VHT saved belongs to Michigan households or businesses (i.e., some of the trips on Michigan roads are pass-through, with no origin or destination in the state). This aspect of VHT savings is shown in table 9.

[5]We use the MDOT 2005 trip table for autos from the Statewide Travel Demand Model and a July 2006 update of the TRANSEARCH database for the truck (or commercial vehicle) trip composition on the state's road network. We used the same data in both the 2006 and the 2007 five-year highway program analyses (Global Insight, Inc., July 2006 update).

Table 8. Forecast of Cumulative VHT Saved, 2006 through 2015

Default Investment Mix			Alternative Investment Mixes, Hours Saved							
A			B		C		D		E	
Autos	Comm. Vehicles		Autos	Comm. Vehicles	Autos	Comm. Vehicles	Autos	Comm. Vehicles	Autos	Comm. Vehicles
2,032,791	194,551	2006	2,557,456	227,809	3,023,050	259,632	3,096,616	285,294	2,705,175	252,453
4,065,582	389,103	2007	5,114,911	455,618	6,046,100	519,263	6,193,232	570,588	5,410,350	504,906
6,098,373	583,654	2008	7,672,367	683,428	9,069,151	778,895	9,289,848	855,881	8,115,525	757,359
8,131,165	778,205	2009	10,229,822	911,237	12,092,201	1,038,526	12,386,463	1,141,175	10,820,700	1,009,813
10,163,956	972,756	2010	12,787,278	1,139,046	15,115,251	1,298,158	15,483,079	1,426,469	13,525,876	1,262,266
12,196,747	1,167,308	2011	15,344,733	1,366,855	18,138,301	1,557,790	18,579,695	1,711,763	16,231,051	1,514,719
14,229,538	1,361,859	2012	17,902,189	1,594,665	21,161,352	1,817,421	21,676,311	1,997,057	18,936,226	1,767,172
16,262,329	1,556,410	2013	20,459,645	1,822,474	24,184,402	2,077,053	24,772,927	2,282,351	21,641,401	2,019,625
18,295,120	1,750,961	2014	23,017,100	2,050,283	27,207,452	2,336,684	27,869,543	2,567,644	24,346,576	2,272,078
20,327,911	1,945,513	2015	25,574,556	2,278,092	30,230,502	2,596,316	30,966,159	2,852,938	27,051,751	2,524,532

Table 9. Cumulative VHT Saved (%), Trips with At Least One Trip-End in Michigan

	Automobiles	Commercial vehicles
2006	99.99%	94.3%
2007	99.99%	94.3%
2008	99.99%	94.3%
2009	99.99%	94.3%
2010	99.99%	94.3%
2011	99.99%	94.3%
2012	99.99%	94.3%
2013	99.99%	94.3%
2014	99.99%	94.3%
2015	99.99%	94.3%

Combining the information from tables 8 and 9 identifies the *locally relevant* travel benefits by type of vehicle, which are then apportioned for autos into the specific trip-purpose in table 10. The cumulative annual time savings relative to alternative A are shown in table 11 for autos and in table 12 for trucks.

Table 10. Cumulative Auto VHT Saved, by Trip Purpose, Trips with At Least One Trip-End in Michigan

Default Investment Mix				Alternative Investment Mixes											
A				B			C			D			E		
Commute	O-T-C	Personal		Commute	O-T-C	Personal	Commute	O-T-C	Personal	Commute	O-T-C	Personal	Commute	O-T-C	Personal
466,317	97,248	1,469,226	2006	586,674	122,348	1,848,434	693,480	144,622	2,184,948	710,356	148,141	2,238,119	620,560	129,415	1,955,200
932,634	194,496	2,938,452	2007	1,173,347	244,696	3,696,868	1,386,960	289,244	4,369,897	1,420,711	296,283	4,476,238	1,241,120	258,830	3,910,400
1,398,951	291,745	4,407,678	2008	1,760,021	367,044	5,545,302	2,080,440	433,866	6,554,845	2,131,067	444,424	6,714,357	1,861,680	388,245	5,865,600
1,865,268	388,993	5,876,904	2009	2,346,695	489,392	7,393,736	2,773,919	578,488	8,739,794	2,841,422	592,565	8,952,476	2,482,240	517,660	7,820,800
2,331,585	486,241	7,346,130	2010	2,933,368	611,740	9,242,170	3,467,399	723,110	10,924,742	3,551,778	740,707	11,190,595	3,102,801	647,074	9,776,001
2,797,902	583,489	8,815,356	2011	3,520,042	734,088	11,090,603	4,160,879	867,732	13,109,691	4,262,134	888,848	13,428,714	3,723,361	776,489	11,731,201
3,264,219	680,737	10,284,582	2012	4,106,715	856,436	12,939,037	4,854,359	1,012,354	15,294,639	4,972,489	1,036,989	15,666,833	4,343,921	905,904	13,686,401
3,730,536	777,986	11,753,808	2013	4,693,389	978,784	14,787,471	5,547,839	1,156,976	17,479,587	5,682,845	1,185,130	17,904,952	4,964,481	1,035,319	15,641,601
4,196,853	875,234	13,223,034	2014	5,280,063	1,101,132	16,635,905	6,241,319	1,301,598	19,664,536	6,393,200	1,333,272	20,143,070	5,585,041	1,164,734	17,596,801
4,663,170	972,482	14,692,260	2015	5,866,736	1,223,480	18,484,339	6,934,798	1,446,219	21,849,484	7,103,556	1,481,413	22,381,189	6,205,601	1,294,149	19,552,001

Table 11. Cumulative Auto VHT Saved, by Trip Purpose, Relative to Alternative A

	Alternative Investment Mixes											
	B			C			D			E		
	Commute	O-T-C	Personal	Commute	O-T-C	Personal	Commute	O-T-C	Personal	Commute	O-T-C	Personal
2006	120,357	25,100	379,208	227,163	47,374	715,722	244,039	50,893	768,893	154,243	32,167	485,974
2007	240,713	50,200	758,416	454,326	94,747	1,431,445	488,077	101,786	1,537,786	308,486	64,333	971,948
2008	361,070	75,299	1,137,624	681,489	142,121	2,147,167	732,116	152,679	2,306,679	462,729	96,500	1,457,922
2009	481,427	100,399	1,516,832	908,651	189,495	2,862,890	976,154	203,572	3,075,572	616,973	128,667	1,943,897
2010	601,783	125,499	1,896,040	1,135,814	236,869	3,578,612	1,220,193	254,466	3,844,465	771,216	160,833	2,429,871
2011	722,140	150,599	2,275,248	1,362,977	284,242	4,294,335	1,464,232	305,359	4,613,358	925,459	193,000	2,915,845
2012	842,497	175,699	2,654,456	1,590,140	331,616	5,010,057	1,708,270	356,252	5,382,251	1,079,702	225,167	3,401,819
2013	962,853	200,798	3,033,664	1,817,303	378,990	5,725,780	1,952,309	407,145	6,151,144	1,233,945	257,333	3,887,793
2014	1,083,210	225,898	3,412,872	2,044,466	426,364	6,441,502	2,196,348	458,038	6,920,037	1,388,188	289,500	4,373,767
2015	1,203,567	250,998	3,792,080	2,271,628	473,737	7,157,225	2,440,386	508,931	7,688,930	1,542,431	321,667	4,859,742

Table 12. Cumulative Annual Truck VHT Saved Relative to Alternative A

	B	C	D	E
2006	31,366	61,378	85,580	54,608
2007	62,732	122,756	171,160	109,216
2008	94,098	184,133	256,740	163,823
2009	125,464	245,511	342,320	218,431
2010	156,829	306,889	427,901	273,039
2011	188,195	368,267	513,481	327,647
2012	219,561	429,645	599,061	382,255
2013	250,927	491,023	684,641	436,862
2014	282,293	552,400	770,221	491,470
2015	313,659	613,778	855,801	546,078

4. Direct Economic Benefit from MDOT's Alternative Investment Bundles

In the prior section, the *direct* travel benefits (expressed as VHT) associated with each investment bundle relative to alternative A were partitioned by type of vehicle—auto and truck (or commercial vehicle)—and assigned to Michigan households and businesses that travel the state's roads, adjusting for pass-through trips and trips with only one trip-end in Michigan.

These Michigan-relevant travel benefits take on a *value* that represents either an economic savings to the road user, which then prompts additional economic transactions in Michigan's economy, or a *social benefit* such as when a household saves time on any of the auto trips it generates. The latter is referred to as an *amenity effect*, credited toward the quality of living in the region where the benefit occurs. The dollar basis for valuing the time saved is taken from assumptions used in our fiscal year 2006 five-year plan economic impact evaluation report (Fulton, Grimes, and Petraglia 2006).[6]

[6]The average hourly wage in Michigan is approximately $18, and one-half (or $9) of this is awarded to Michigan's household segment for every hour of auto time saved on non-work-related trips (U.S. Department of Transportation, Office of the Secretary 1997). The value of time assigned to truck trips affecting Michigan businesses is $50 per hour (Transport Canada 2000; U.S. Department of Energy, Energy Information Administration 2007; Wyoming Department of Employment, Planning and Research 2001).

Table 13. Monetized Direct Benefit to Michigan-Based Drivers Relative to Alternative A (Millions of 2006 dollars)

	Alternative (% IC/NR)			
	B (15%)	C (20%)	D (30%)	E (50%)
Auto				
Households: value of time saved annually	$19.1	$22.6	$23.2	$20.2
Businesses: value of time saved annually, worker commutes and on-the-clock	$12.9	$14.9	$15.9	$14.1
Truck				
Businesses: value of time saved annually	$ 8.1	$ 9.2	$10.1	$ 8.9
Auto and truck				
Businesses: total savings annually	$21	$24	$26	$23

We see from table 13 that Michigan's businesses accrue travel-related savings from both truck and auto trips. Auto trip savings accrue to Michigan employers with on-the-clock trips[7] (100 percent of these savings are tied to the state's service sector economy) and 50 percent of the commute-time savings of their employees (the balance is awarded to the household segment). For the state's business base then, the value of the travel-savings impact (in 2006 dollars)—relative to alternative A, which allocates 10 percent of the budget to IC/NR projects—is $21 million greater when IC/NR is allocated 15 percent of the budget (alternative B), and $26 million greater when the allocation is 30 percent (alternative D). When the IC/NR allocation reaches 50 percent of the budget, the value of travel savings to businesses is still positive (at $23 million), but this result would conceivably have been realized with an IC/NR allocation between 15 and 20 percent, as shown by the results for alternatives B and C.

The amenity effect on Michigan's household segment, from the value of time saved with each alternative investment bundle, is almost as large as the bundle's direct economic benefit on Michigan's business segment. This follows from the predominance of auto-personal trips in total annual trips on the state's road network (see tables 8 and 10). Progressing from alternative B through E, the household segment in Michigan gains (in 2006 dollars) $19.1, $22.6, $23.2, and

[7]On-the-clock travel refers to trips made by workers during their work day as part of the job.

$20.2 million, respectively, in value of time saved over alternative A. We see that alternative E still creates positive travel-related benefits, but at a rate slower than alternative C or D.

5. REMI Economic-Demographic Model and General Procedures

As indicated in section 1, the tool used to estimate the total effect of the alternative investment mixes on the Michigan economy is an economic-demographic model constructed by Regional Economic Models, Inc. (REMI) of Amherst, Massachusetts, and adapted by the research team at the University of Michigan for the purposes of this study. The REMI model is based on past and current research and development, and has been fully documented and peer-reviewed in the professional literature (Treyz 1993, Treyz et al. 1992). The REMI model has been designed particularly for carrying out simulations of the type generated for this study, and has been used nationwide for such studies for nearly three decades. Some version of the model is currently used by hundreds of governmental agencies, universities, utilities, and private consulting firms for forecasting and policy analysis.

The industry interactions associated with the presence or absence of an activity are captured by an input-output process, which identifies the buying and selling relationships among a detailed breakout of industries. The REMI model is much more complex than its input-output component, though, having a very detailed calibration of the workings of the macroeconomy. Such detail enables the model to capture the complexities of interactions among economic sectors in response to a policy change.

The general procedure in estimating the economic effect of each alternative investment strategy is to run the model both with and without the investment. The difference between the two results represents the economywide impact of the investment, including both direct and spin-off effects associated with the investment.

The details underlying the general modeling procedure are complex. To the extent possible, the model inputs were tailored to the specific investment

components rather than being left as more general representations of the components. Adjustments were made to avoid double-counting activities, and to distinguish the portion of activity retained in the state from that flowing out to benefit other localities. In general, the reliability of the answers generated is much affected by the care taken to translate the economic questions so as to be properly interpreted by the model's complex structure.

6. Economic Effect on Michigan of Alternative Investment Approaches

To this point, the differences among the various investment bundles have been established in terms of construction-related spending and the dollar value of travel-time-savings benefits, both specific to Michigan—in other words, these estimates establish the direct impact on Michigan of each investment alternative. It remains to determine the total impact of these investments, that is, including spin-off effects. This involves first sorting the monetized direct benefits for Michigan and then mapping them into the REMI model structure.

The direct benefits are introduced into the REMI model in three general areas. First, the value of travel-time savings for businesses is mapped into the appropriate policy variables in the REMI model after adjusting for the local (Michigan) benefit. This involves several sets of data, mapped into the policy variables by relevant industry, and REMI treats the business savings as reductions in production costs for those industries.[8] Second, 50 percent of the travel-time savings calculated for households are mapped into the REMI model's quality-of-life policy variable (non-monetary amenity), as explained in section 4. Third, construction- and engineering-related investment expenditures are calibrated by type of activities performed and what sectors perform them. The calibration includes an adjustment for how much of the activity is performed by local companies. The resulting calculations then serve as inputs to the appropriate sectors of the REMI model.

[8]As a technical note for economists, the overall production costs are changed without changing the relative costs among the factors of production (labor, capital, and fuel).

The model results are organized into the tables and figures that follow.

The employment effects on Michigan of the investment alternatives are shown in table 14, both for employment in total and for certain key sectors: manufacturing; construction; and professional, scientific, and technical services (including planning and engineering services). The employment effects for the remaining industries are combined into one additional entry in the table. The results are presented annually for ten years (2006 to 2015) for investment alternatives B, C, D, and E, all in comparison with the base case, alternative A.

Two cautions are called for before interpreting the results. First, it is important to keep in mind the comparative nature of the results while reviewing the entries in the table. To reiterate: shown are the differences in the effects of each investment bundle compared with the effects of alternative A—not the larger total effect of each investment strategy alone on the Michigan economy. Second, the results for the first year reported (2006) include the differential effects of both construction-related spending and the first-year effects of travel-time savings. The nine years that follow (2007 to 2015) show only the benefits of travel-time savings for Michigan's businesses and residents. The experiment reported here can be viewed in two parts: part 1 covers the year 1 results, and part 2 covers the findings for years 2 through 10.

In the first year (2006), shifting a fixed budget away from preservation (R&R) and toward a greater emphasis on increased capacity (IC/NR) results in a negative employment effect. That is, fewer jobs are created in that year with an increasing shift from R&R to IC/NR spending. This is a consequence of the construction of new roads and bridges being less labor-intensive than the repair of existing roads and bridges, thus requiring fewer construction workers. This is apparent in the results for the construction industry shown in the table. In contrast, IC/NR is more engineering-intensive than R&R, and thus engineering employment sees additional jobs when there is a shift toward IC/NR. The effects on the manufacturing sector are negligible in the first year. The negative effects on

construction employment dominate, leading to the negative, albeit small, total employment effects across investment comparisons in year 1.

The employment effects are positive for years 2 through 10, which exclude construction-related expenditures and include only the effects of travel-time-savings benefits. Since the economic profile is qualitatively consistent across years, the findings can most easily be observed by focusing on year 10, the terminal year (2015). The employment effects of each investment bundle in comparison with alternative A for year 10 are also portrayed in figure 1 to highlight the two main findings. First, any of the other investment alternatives create more jobs than alternative A. Thus, the heavy preservation spending associated with alternative A (90 percent of highway program funding) does not create as many jobs as would result from shifting some of the funding toward increased capacity.

Second, the optimal investment bundle, among those tested, from a job creation perspective is alternative D (that is, with 30 percent of highway program funding devoted to IC/NR). As even more funding is shifted to IC/NR with alternative E (50 percent of the highway program allocation), the job gains relative to alternative A drop off significantly, from 1,182 to 746 workers. Underlying the retreat is the fact that by alternative E, travel-time savings forfeited by R&R projects foregone are unmatched by the gain in travel-time savings from IC/NR (see section 3.2).[9] The employment effect is still decidedly positive for alternative E, but a similar job increase would conceivably have been realized with an IC/NR allocation between 15 and 20 percent, as shown by the results for alternatives B and C (increases of 525 and 1,005 jobs, respectively, averaging 765). In sum: with the discrete number of alternatives evaluated in this analysis, alternative D (with 30 percent assigned to IC/NR) is the optimal bundle for job creation, and by alternative E (50 percent allocation) there is a decreasing marginal return for

[9]With a pattern of more rapid pavement deterioration over time, forfeiture of R&R activities would prove to be more costly, resulting in less favorable results than depicted here. With the treatment of pavement deterioration in this study, the adverse drag of preservation forfeited alone is small. See section 3.2 for a more detailed discussion on modeling pavement conditions.

additional dollars devoted to IC/NR. As might be expected, a similar pattern was found when assessing the direct economic benefits in isolation (see section 4).

The largest employment gains occur in manufacturing (122 jobs), construction (96 jobs), and professional, scientific, and technical services (58 jobs). For manufacturing, this reflects the concentration of travel-time savings in the goods-producing industries. The gains in construction and professional services include the direct employment of highway construction workers and planning/engineering workers, respectively.

Other key measures of economic performance are reported in table 15, where the economywide effects on Michigan of the investment alternatives are represented by Gross State Product (GSP), personal income (both nominal and inflation-adjusted), population, and state government tax revenue.[10] The table has the same setup as the previous table on employment. Again, to underline the findings, figure 2 represents the results for year 10 (2015).

It is clear from figure 2 that the effects on these economic indicators follow the same pattern as for employment. All other investment bundles are superior to alternative A. The optimal investment portfolio among those tested remains alternative D, with positive but decreasing marginal returns for additional dollars devoted to IC/NR by alternative E. Alternative D (30 percent funding to IC/NR) generates an additional $111.3 million (2006 dollars) in GSP compared with alternative A (10 percent funding to IC/NR) in year 10. A portion of the GSP gains, that is, output gains measured in value-added terms, translates into increases in personal income of $92.8 million (2006 dollars), which in turn is associated with additions to state government tax revenue of $6.5 million (2006 dollars). With a somewhat stronger economy and Michigan being viewed as a more attractive place to live (in technical terms, benefiting from a positive

[10]Gross State Product is a state measure comparable to Gross Domestic Product for the nation. Personal income is the income of Michigan residents from all sources, after deduction of contributions to social insurance programs but before deductions of income tax and other personal taxes. Population includes all residents, civilian and military. State government tax revenue is consistent with the concept developed by the U.S. Bureau of the Census (www.census.gov/).

amenity effect), the state's population is 2,977 residents greater in year 10 with a strategy of pursuing alternative D rather than maintaining the base case investment portfolio.

The relative benefits to Michigan of these alternative road-bridge investment mixes have been established in terms of construction-related spending and the dollar value of travel-time-savings benefits—including the social benefits that accrue when a household saves time on an auto trip. There are, of course, other considerations that could be in play, such as safety, air quality, transportation equity both to regions and to people, and tourism enhancement, among others. Although difficult to quantify, especially by individual investment project, these quality-of-life benefits remain an important part of the discussion on transportation-related investment strategies.

**Table 14. Differences in Employment Effects among Investment Alternatives*
(Positive values indicate that the first-mentioned alternative creates more jobs)**

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Total employment differences										
Alternative B compared with A	–11	60	104	152	207	263	323	389	456	525
Alternative C compared with A	–27	115	198	291	394	502	619	745	872	1,005
Alternative D compared with A	–91	137	233	344	466	593	729	877	1,027	1,182
Alternative E compared with A	–279	86	147	217	293	375	459	552	647	746
Manufacturing employment										
Alternative B compared with A	1	5	9	14	19	24	30	36	42	49
Alternative C compared with A	1	10	18	27	37	47	57	69	82	95
Alternative D compared with A	0	13	24	35	48	60	74	90	106	122
Alternative E compared with A	–6	9	15	23	31	38	47	57	67	78
Construction employment										
Alternative B compared with A	–48	5	8	12	17	21	26	31	37	42
Alternative C compared with A	–105	10	16	23	31	40	50	60	71	82
Alternative D compared with A	–199	12	19	27	37	47	58	71	83	96
Alternative E compared with A	–368	10	13	17	23	30	36	44	52	60
Professional, scientific, and technical employment										
Alternative B compared with A	7	3	5	7	10	13	15	19	22	26
Alternative C compared with A	25	5	9	14	19	24	30	36	42	49
Alternative D compared with A	39	6	11	16	22	29	35	42	50	58
Alternative E compared with A	27	4	7	10	14	18	22	27	31	36
Employment in all other industries**										
Alternative B compared with A	29	46	81	119	162	205	252	303	355	408
Alternative C compared with A	52	89	155	226	306	391	482	579	677	780
Alternative D compared with A	69	104	180	265	359	456	562	675	789	905
Alternative E compared with A	67	63	112	167	226	289	354	425	496	572

*For ease of reference, the IC/NR share of each investment alternative is: A (10%), B (15%), C (20%), D (30%), E (50%).

**The designation “all other industries” includes the following categories: (1) natural resources and mining; (2) trade, transportation, and utilities; (3) information; (4) financial activities; (5) business services except professional, scientific, and technical; (6) private education and health services; (7) leisure and hospitality; (8) other services; and (9) government.

Figure 1. Differences in Employment Effects among Investment Alternatives Compared with Alternative A, 2015

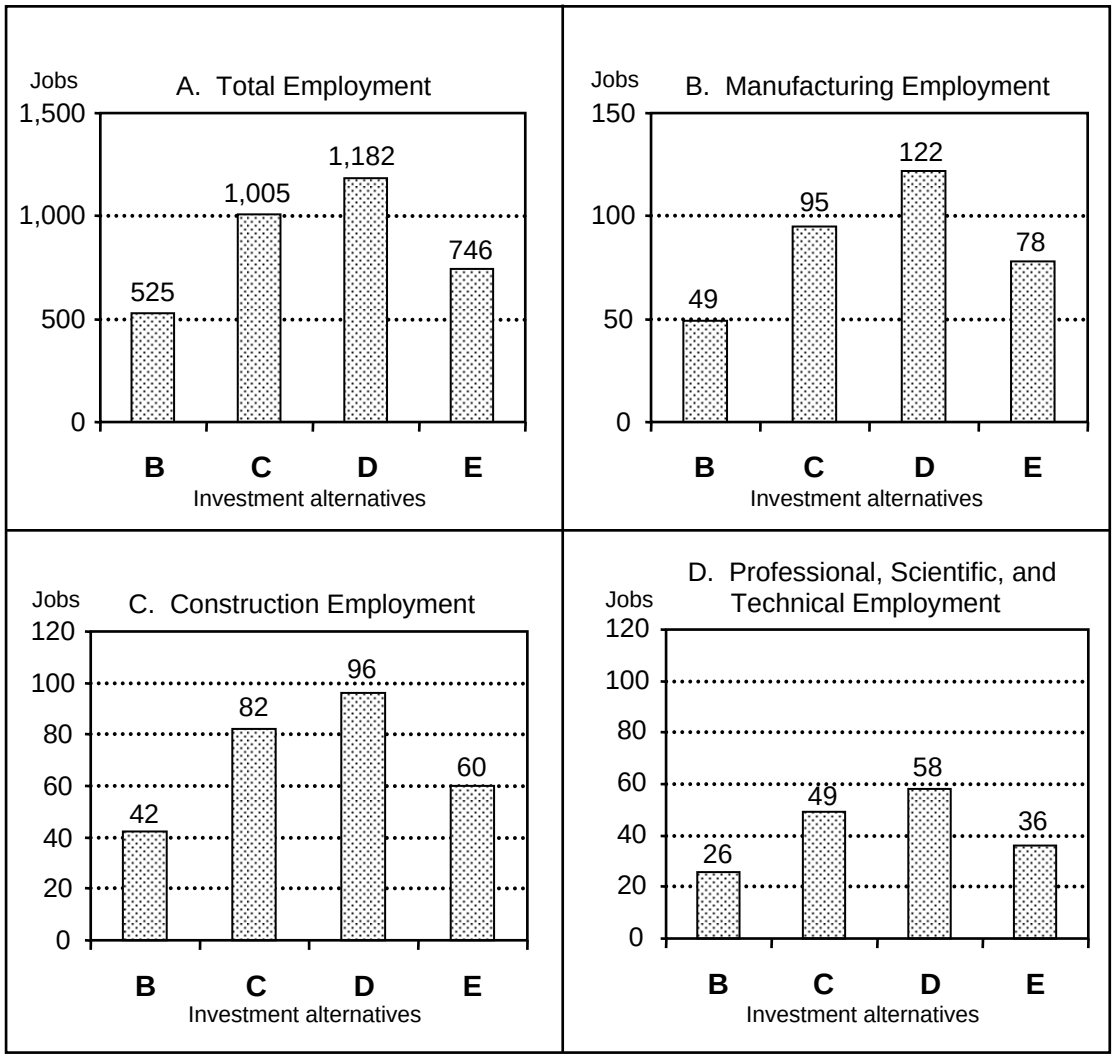
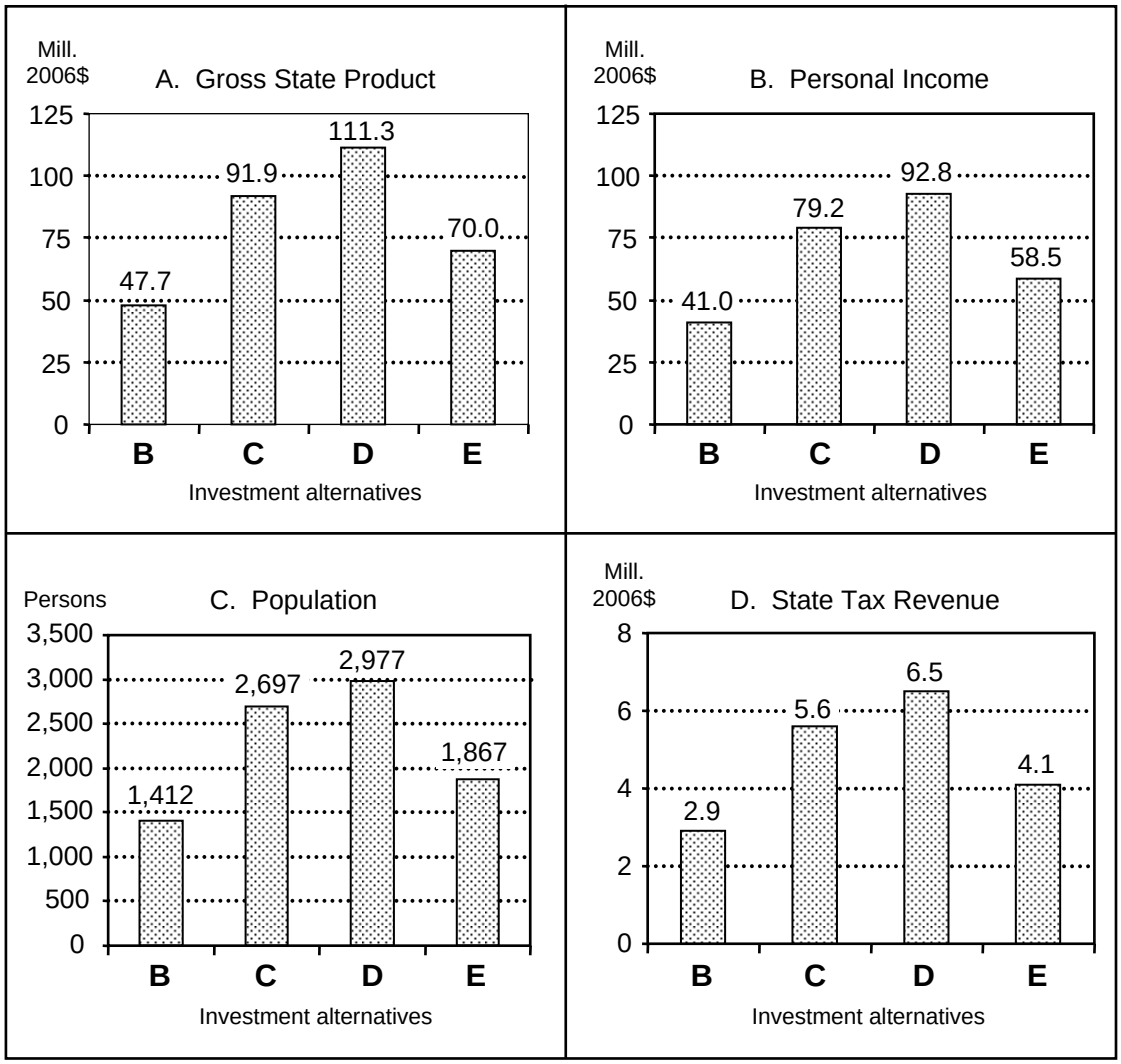


Table 15. Differences in GSP, Income, Population, and State Government Tax Revenue among Investment Alternatives* (Positive values indicate that the first-mentioned alternative creates more of the metric)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
GSP differences (millions 2006$)										
Alternative B compared with A	–$0.7	$3.7	$7.4	$11.8	$16.5	$22.0	$27.9	$34.2	$40.8	$47.7
Alternative C compared with A	–$0.6	$7.4	$14.5	$22.8	$31.9	$42.3	$53.6	$65.8	$78.5	$91.9
Alternative D compared with A	–$3.3	$9.2	$17.8	$27.9	$39.1	$51.7	$65.4	$80.0	$95.3	$111.3
Alternative E compared with A	–$11.6	$5.3	$11.0	$17.2	$24.3	$32.2	$40.7	$50.0	$59.8	$70.0
Personal income differences (millions $)										
Alternative B compared with A	$3.8	$3.0	$5.6	$8.7	$12.6	$16.9	$21.8	$27.4	$33.5	$40.1
Alternative C compared with A	$8.2	$5.7	$10.7	$16.8	$24.2	$32.5	$41.9	$52.6	$64.3	$77.2
Alternative D compared with A	$13.7	$6.7	$12.6	$19.7	$28.4	$38.2	$49.4	$61.9	$75.7	$90.6
Alternative E compared with A	$21.4	$3.8	$7.8	$12.4	$17.7	$24.0	$30.9	$39.0	$47.6	$57.1
Personal income differences (millions 2006$)										
Alternative B compared with A	$4.7	$4.5	$8.0	$11.8	$15.7	$20.0	$24.9	$30.1	$35.5	$41.0
Alternative C compared with A	$9.9	$8.6	$14.9	$22.0	$29.9	$38.3	$47.7	$57.6	$68.0	$79.2
Alternative D compared with A	$15.7	$10.1	$17.4	$25.8	$35.1	$44.9	$55.9	$67.5	$79.8	$92.8
Alternative E compared with A	$22.9	$5.8	$11.1	$16.2	$21.8	$28.3	$35.1	$42.7	$50.3	$58.5
Population differences										
Alternative B compared with A	32	102	200	322	465	625	801	994	1,197	1,412
Alternative C compared with A	60	192	379	612	885	1,192	1,529	1,897	2,285	2,697
Alternative D compared with A	56	204	411	668	971	1,311	1,685	2,089	2,520	2,977
Alternative E compared with A	10	104	239	403	596	813	1,048	1,306	1,580	1,867
State government tax revenue (millions 2006$)										
Alternative B compared with A	$0.3	$0.3	$0.6	$0.8	$1.1	$1.4	$1.8	$2.1	$2.5	$2.9
Alternative C compared with A	$0.7	$0.6	$1.1	$1.5	$2.1	$2.7	$3.4	$4.1	$4.8	$5.6
Alternative D compared with A	$1.1	$0.7	$1.2	$1.8	$2.5	$3.2	$3.9	$4.8	$5.6	$6.5
Alternative E compared with A	$1.6	$0.4	$0.8	$1.1	$1.5	$2.0	$2.5	$3.0	$3.5	$4.1

*For ease of reference, the IC/NR share of each investment alternative is: A (10%), B (15%), C (20%), D (30%), E (50%).

Figure 2. Differences in Economic Performance among Investment Alternatives Compared with Alternative A, 2015



7. Conclusion

MDOT makes substantial investments to preserve and enhance Michigan's complex infrastructure network, spending about $1.3 billion annually on the state's road and bridge system. Time after time, MDOT is confronted with the task of choosing the appropriate investment mix between road-bridge rehabilitation and repair (R&R), and increased capacity/new roads (IC/NR). Among the consequences of implementing any given investment portfolio is the implications for Michigan's economic well-being.

In this study, we estimate the differences in economic effects on Michigan of alternative investment mixes by reducing R&R priorities as IC/NR investments are increased, determining the effect on Michigan's economy of each mix, and then identifying the portfolio that best stimulates the economy. The economic effects we capture for each investment bundle are derived from travel-time-savings benefits conferred on Michigan households and businesses, the (temporary) beneficial effects of increased construction and engineering activity, and the spin-off effects from these direct benefits. Throughout, we use the most complete information available, together with state-of-the-art research tools.

We evaluate four alternative investment bundles in comparison with alternative A, which reflects the current strategy of devoting 10 percent of highway program funding to IC/NR. Alternatives B through E specify an annual budget of $1.362 billion, with the alternatives increasing progressively in commitment to IC/NR (15 percent, 20 percent, 30 percent, and 50 percent, respectively). We find that for both the direct travel benefits and the total effects on the state economy, any of the investment alternatives representing a shifting of funding toward increased capacity is superior to the heavy preservation spending associated with alternative A. Moreover, for both direct travel benefits and the total effects on the economy, the optimal investment bundle is alternative D, with 30 percent of highway program funding devoted to IC/NR. With the further extension to 50 percent funding allocated to IC/NR in alternative E, there is a positive but decreasing marginal return for additional dollars devoted to IC/NR, as the

savings forfeited by R&R projects foregone are unmatched by the gains from IC/NR. Underlying these results is a relatively conservative treatment of pavement deterioration; assumptions of increasingly more rapid deterioration could, at some point, modify the findings.

For the optimal investment bundle (30 percent of funding allocated to IC/NR), we find that Michigan households realize travel-time savings annually worth $23.2 million, and Michigan businesses save $26 million per year (2006 dollars), compared with the base case investment portfolio (10 percent of funding allocated to IC/NR). Including spin-off effects, by 2015 there is an additional $111.3 million generated in Gross State Product, $92.8 million more in personal income, and an increase of $6.5 million in state government tax revenue, all in inflation-adjusted 2006 dollars, and again in comparison with the base case. The gains in job creation would mean employment for 1,182 workers.

A final note: As important as economic progress is to a state currently undergoing economic trauma, we should not lose sight of the myriad quality-of-life considerations in assessing our strategies. Benefits related to safety, health, and equitable treatment of the state's citizens are all part of the value of living, working, and playing in Michigan.

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