Financial needs of Iowa's County Roads

Assessment and prediction

TR-608

FINAL REPORT

December 2012

ICEA Service Bureau
5500 Westown Parkway #190
West Des Moines, IA 50266

Principal Investigator: Stephen W. De Vries, P.E.
Database & Coding: Matthew Mathers

Abstract

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16. Abstract

The TR-608 project developed methods and processes for determining current and future Iowa secondary (county) road needs. These tools will be permanently maintained and operated by the Iowa County Engineers Association Service Bureau to provide ongoing need determination services for the state's ninety-nine county road departments.

The systems established via this project will annually tally and report a) how much funding is needed to sustain the county roads long term, b) the adequacy of the secondary roads for the traffic they carry and c) what upgrade needs exist.

A "Trend Projection Engine" will also be available to project from current circumstance, with continuation of known revenue and cost trends, to estimate potential outcomes occurring in the next fifteen years.

Now that it has been developed, the TR-608 system will continue as an ongoing resource of county road and bridge numbers, condition, trends and issue information for use by counties, either individually or collectively.

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Overview

The TR-608 project arose from issues confronting Iowa's secondary road departments during the late 2000's. County engineers, struggling with stagnating revenues and escalating costs, wanted to develop a more accurate statewide assessment of how much money should be spent on county road and bridge upkeep – and a means for communicating this information to the public and political leaders. At the same time, rapid changes in agriculture, (fewer farmers, bigger operations and larger equipment), created concerns about whether or not the system would be able to hold up under future road-user demands – igniting a desire to be better able to predict the eventual outcome of current trends.

The Iowa Highway Research Board identified these concerns as worthy of further research and published a Request for Proposals in April 2009. The Iowa County Engineers Service Bureau responded with a proposal to build, and then permanently maintain, a system to a) annually reassess current needs, b) enable projection of current trends to see how the future may turn out and c) provide means for translating the results into visual formats for communicating findings to the general public. The proposal was accepted and a contract was executed in July 2009. Work started in the fall of 2009 and consisted of five primary tasks:

Part 1 – Method for determination of current need levels
The research team compiled and processed historical secondary road cost data to build a system for identifying how much needs to be expended in order to maintain the existing secondary road network, unchanged in extent, configuration, and condition, into the future. The end results, labeled "Carrying Costs", provide a clear needs baseline. This work extended from the fall of 2009 through the spring of 2012, as the task proved more challenging to accomplish than anticipated. Nonetheless, results from FY10 and FY11 were able to support public education efforts and provided counties with the means to articulate their needs alongside other jurisdictions during consideration of a fuel tax increase.

Part 2 – Derivation of key relationships for forward projections
Because of a desire to be able to look ahead at how secondary traffic may change, factoring in how changes in condition affect the cost of the system and accounting for feedback effects, background research had to be performed before a Trend Projection Engine, (TPE), could be built. Work in this phase included correlation of traffic with population and land use, adoption of road and bridge deterioration models, and identification of physical/economic feedback mechanisms. This was completed in the spring of 2012.

Part 3 – Creation of Trend Projection Engine to estimate future circumstances and needs
This work consisted of defining, coding and testing a twelve step TPE calculation process to model all aspects of a one-year cycle of road use, funding, upkeep, and change. The annual modules were then bundled and placed under a control routine that directs execution of up to fifteen annual cycles -- to estimate the possible outcomes of current starting conditions and trends. It can be executed for a single county or for all ninety-nine, and allows comparison of up to three alternate tracks in any given scenario. Completed in August 2012.

Part 4 – Future need data extraction, comparison and graphing
To enable counties to use the analysis engine to analyze or illustrate the secondary roads story from almost any perspective, the TPE saves a prodigious volume of information. To make it possible to sort through the multitude of results, it was necessary to create an interface that would allow a user to browse through a catalog of data items, select those of interest and then extract or graph them for analysis. Completed in October 2012

Part 5 – Pre-defined public information formats
A final goal of the project was to create some prototype documents that individual counties could download, when desired, to provide their public and supervisors for up to date information about the configuration and costs of their network. Two prototypes were created. More work will be needed in the future, but will be performed outside of TR-608.

Both the Carrying Cost process and the Trend Projection Engine will henceforth be maintained and operated by the ICEA Service Bureau – as an information service available for and about county roads. The former will be updated annually, after each year's County Engineer Annual Reports of Receipts and Expenditures have been processed. The latter will be maintained available to perform projections on an "upon request" basis – whether the need be for a statewide analysis or a request to look at specific things for a single county.

Neither module will ever be considered 'finished'. Now that the models have been built, they will remain open to being improved upon. The initial logic, methods and formulas are subject to refinement. In some cases, the simple passage of time will prove or disprove certain of the assumptions used therein. In the latter case, processing, modeling and calculations will be changed as needed. In other cases, future research will more precisely determine the relationships between the variables and permit increased accuracy.

Evaluation of agriculture based road needs
At the outset of this project, recognizing that the needs of the road system derive from the transportation needs of the people and businesses that operate in rural Iowa, an effort was made to find out more about the rural economy, its drivers and its future. This was accomplished by scanning farm publications to identify issues and then meeting twice with rural economy representatives to get more details. Since the conduct of business and methods of the rural economy are rapidly changing, there was a need to learn about this and how it might affect traffic.

This work revealed that Iowa's agricultural base and rural population have already changed dramatically and that this continues at a rapid pace. Just twenty-five years ago, Iowa was still predominately a place where family farmers, operating off of 250 to 500 acres, raised a mix of crops and livestock, which were sold at market prices to local terminals, to support their families. Today, farm operations often work thousands of acres and livestock production has become highly industrialized. Contract based sales often control both when and where product must be delivered. Farming equipment has scaled up to permit modern operators to achieve economies of scale, reaching amazing sizes and weights. Methods have changed, with many farmers maintaining on-farm storage of their harvests and using semi-trucks to haul grain to market. Concentrated livestock production has created a twice yearly need to apply immense volumes of liquid manure on fields, during rather short windows of time before planting and after harvest. It has also brought traffic back to roads that once appeared destined for closure. Ethanol and bio-diesel plants have created new demand points for grain, rearranging travel patterns accordingly. Ever increasing corn and bean yields have tended to increase the number of loads generated at harvest time, but this has been partly mitigated by the gradual shift to larger and larger grain wagons and semi-trailer grain trucks. Elimination of localized service by railroads, in favor of unit trains and shuttle-elevators has caused many small town terminals to close. Technology has increased the speed at which farming can performed, made application of chemicals more precise and optimized the use of fertilizers. Today's farm economy is dramatically different than that of the past and uses the rural road system in ways not foreseen when the network was laid out and later paved.

As farming becomes more efficient, it takes fewer people to produce more output. This leads, over time, to a reduction in farm family population, with those remaining concentrated at busier but more sparsely situated farmsteads. Simultaneously, there has been a trend for many former city dwellers to move out into the country to live in rural residences, equestrian ranches, and scenic subdivisions. And a few counties have experienced sufficient urban growth to have had rural land areas annexed into adjoining cities, removing associated road mileage from the secondary system.

In light of all of the above, agri-business representatives and experts were asked to identify future trends and changes that will impact rural travel and road use. Following is a summary of issues identified:

- Population
  - Farm efficiency is expected to continue increasing, gradually reducing farm operator numbers.
  - But farmers will begin hiring seasonal labor, which will call for the ability of temporary workers to commute in to field locations.
  - Rural residence growth around urban areas and recreational locations will continue.
- Grain production
  - Corn and bean yields will grow at substantial rates for some time to come, increasing harvest volumes needing transport from the fields.
  - More use of corn for ethanol will create a need to haul distiller's grain by-product out to livestock operations.
- Animal production
  - Swine, cattle and poultry will all be produced at large, concentrated facilities, often located along roads that had been reverting to earth surfaced.
  - More livestock operations will need to operate on a 24/7/365 basis and thus will be more sensitive to road service interruptions, such as winter storm closures, than in the past.
- Land use patterns
  - Although farming may someday consolidate into big enough units to allow closure of some roads, this will not be the case in the near future.
  - Instead, farm operators will assemble sets of non-contiguous fields and need to travel rapidly between them.
  - This will sustain demand for a highly interconnected rural road system that affords easy movement from place to place with minimal backtracking required.
- Business arrangements
  - The growth of contract based sales and delivery will reduce seasonality of grain haulage, making it more of a year-round operation.
  - Contracted sales and delivery of animals will decrease farming's tolerance for road service impairments – and lead to more hauling taking place at times of the year when roads are most susceptible to damage.
- Vehicles
  - Agricultural production and harvest equipment will continue getting larger, creating a need for adequate road widths to allow passage.
  - The equipment will also become heavier, increasing the wear and tear that it imposes on the roads embankments and surface courses
  - A migration to six and seven axle semis will allow more bushels to be hauled per load with fewer ESALs. But there will also be calls to increase truck weight limits.
- Off farm employment
  - Many farms and most rural residences will have one or two family members employed off-farm, often in regional business hub communities. This will increase the number and length of commutes and increase demand for extended snow removal hours.
- Personal travel trends
  - As rural population contracts, personal errand trips, for groceries, health care, grooming, shopping, obtaining services and repairs, school, and church attendance will get longer – so rural citizens will spend more time traveling than in the past.

With such a dynamic mix of trends and considerations, it's a challenge to identify and enumerate a list of resultant road system needs. But a few key items seem clear:

a) Rural population will continue to contract in most counties but the remaining citizens will drive greater distances and desire a high degree of route reliability.
b) Road use by agriculture will become more year-round and less seasonal.
c) Grain production will increase significantly, but transport vehicle capacity increases will minimize how much this increases rural trips.
d) However, size/weight increases in both production and haulage vehicles will increase the road impacts per trip.
e) Iowa's extensive and strongly interconnected grid of roads will remain of significant value.
f) Growth in animal operations will induce new travel demand on roads previously expected to go to Class B status or be closed.

Part 1 – Method for determination of current need levels

This part of the project developed a process by which the financial needs of the Secondary Roads system can be annually re-determined and published – county by county, with statewide totals.

Objectives

The goal of this section was to create a means for determining a baseline need for secondary roads that can be used for public awareness efforts, legislation advocacy, general information and long term trend analysis. It needed to reflect each county's unique characteristics, be based on real, reported cost figures, be transparent, and as automated as possible.

Sources of information

Cost data used in this module comes from the following sources: a) County Engineer Annual Reports, b) HF-324 reports of projects completed, c) GASB-34 reports of projects capitalized and d) TPMS (Iowa Transportation Program Management system) records of projects completed. Inflation information was obtained as follows: a) CPI: from US Bureau of Labor statistics, b) Labor cost: from secondary roads wage survey submittals, c) Diesel fuel: from Iowa state fuel price records and d) Construction costs: from Iowa DOT. System data – a) Roads: from annual download of Iowa DOT base records maintained by the Office of Transportation Data, and b) Bridges: NBIS structures list from Iowa DOT. *(See Appendix A for more details regarding the sources)*

Analytical basis

The "cost" of providing and operating a road system depends on how need is defined and the strategic goals being pursued, so special attention was given to crafting a specific definition to be used in TR-608.

The basis adopted was *: "The CARRYING COST of a road system is the amount that needs to be spent, per year, to operate, maintain, extend and renew the roads and bridges, keeping them in the exact same extent, configuration and condition as they are today – for a very long time into the future."*

Actual circumstances may differ from those implicit in the definition. While it 'calls' for keeping all bridges that are open today in service forever, it may well be that changing priorities will result in a decision to let some of them be closed. If that is done, ultimate needs will end up less than figured under the definition. On the other hand, if economic development efforts results in expansion of paved miles, long term expenditures will end up higher than the baseline.

In addition to the Carrying Cost needs, counties often also have Upgrade needs.   These expenditures become warranted when the volume of traffic using a road exceeds the safe conveyance capacity of the road's design level.   If the traffic level on a granular road exceeds a safe level, for example, it should be rebuilt and paved – to reduce driver operating costs, service interruptions and crashes.   In TR-608, Upgrade Needs represent the estimated expenditures needed to take care of the most pressing upgrade priorities.

Carrying Costs and Upgrade Needs affect each other: Upgrades consume funding that could have covered Carrying Costs. This can potentially lead to a decline in asset conditions, which in turn increases Carrying Costs and the cost of making future Upgrades. Conversion from a lower surface class to a higher one automatically increases ongoing system needs. For example, it takes more money per mile per year to sustain a paved road than it does to sustain a gravel road.

<u>Data breakdown and reconstitution (Actual expenditures)</u>
The determination of Carrying Costs need was accomplished by rigorously assessing what counties have been spending on their roads and bridges, (Actual expenditures), evaluating whether or not these layouts have been adequate to sustain the system in the long term, and if not, identifying special multipliers to be applied to derive Carrying Costs values from those Actual expenditures.

Collection of raw cost data and conversion thereof to Actual Expenditure figures requires a detailed series of process steps. County Engineer annual reports cover most, but not all expenditures, that counties make from their local budgets.   Farm-to-Market and Federal Aid expenditures are paid out of a special account (Farm-to-Market fund) managed by the Iowa DOT and must be separately obtained from project completion reports.   The Annual Report accounting codes, while relatively detailed and thorough, often mix expenditure purposes, targets, and road classes together.   Each county has a different mix of surface types, which affects how they allocate funds.   Some cost items fluctuate significantly year to year, which necessitates computing averaged expenditures, which then requires paying attention to the effects of cost inflation.

A time base of eight years was selected for use in computing costs because one a) needs a period long enough to capture all relevant expenses - including those that don't occur every year, and b) needs to keep the analysis period short enough that basic circumstances remain about the same throughout the interval.

The Actual Expenditure determination process developed in this project evolved through repeated iterations, as the research team worked to organize and condense the data.   Along the way, the following conventions and breakdowns were adopted:

1. All system expenditures can be, at the most basic level, said to be either for **Roads** or for **Bridges.**

2. The Roads & Bridges categories can then be further subdivided by the Surface Class of the roadway involved. Four such classes were identified and used: **Earth** surfaced, **Granular** surfaced, **Hard surfaced** (which includes seal coats, thin HMA lifts over rock bases, and other water-proof but non-structural surface applications), and **Paved**. *[The Hard Surface category was almost omitted, as some counties have none, costs thereof are not charged to the same accounting codes in every county, and it would have simplified processing to only have three surface classes. But a number of counties do have substantial Hard Surface mileages and it would have seriously distorted their cost / need pictures to assign those miles to either Granular or Paved.]*

3. Four expense classes apply to every asset, whether it be a roadway or structure.   They were defined as follows:

    a. **Operations** – Expenditures that are made to keep the system open for use and which do not significantly affect road or bridge condition.   Examples of this type of expense include electricity for intersection

lights, maintenance of road records in the office, winter-time snow and ice clearing, mowing, etc.

b. **Maintenance** – Expenditures made to prevent or slow deterioration of highway assets. Includes things like crack-sealing, painting of bridges, blading of granular roads, etc.

c. **Extension** – Layouts made to partially restore deteriorated assets. Examples: application of a seal coat on a raveled pavement, spot rock on granular roads, replacement of a bridge deck, insertion of a liner in a culvert, repair of damaged guard-rail, etc.

d. **Renewal** – Work done to restore road/bridge assets back to new or near new condition: reconstruction, cold-in-place-recycling plus overlay, full length re-rocking of a granular road, complete replacement of guard-rail, repaving, bridge replacement and so on.

Table 01 shows how the cost classifications, taken all together, result in a grid of thirty-two (32) total cost items to be derived from the input data:

Table 01:	Roads				Bridges			
	Earth	Granular	Hard Sfc	Paved	Earth	Granular	Hard Sfc	Paved
Operations	$	$	$	$	$	$	$	$
Maintenance	$	$	$	$	$	$	$	$
Extension	$	$	$	$	$	$	$	$
Renewal	$	$	$	$	$	$	$	$

The total of any column will give the gross cost of the associated Road/Bridge + Surface Class item. Summing the values in a particular row gives the overall cost of any of the four expense classes.

The raw Annual Report data and Project gets transformed into the thirty-two cost-class grid, via the process outlined below:

1. Acquire fresh data (after the end of each successive fiscal year)
   a. Road segment base records - from Iowa DOT Office of Transportation Data
   b. Bridge NBIS records – from FHWA/Iowa DOT
   c. Annual Report data from most recent eight years – from AR database at ICEA Service Bureau
   d. Completed projects data from most recent eight years. – from database at ICEA Service Bureau
   e. Cost inflation data for CPI, labor, diesel fuel and construction costs for most recent eight years.
   f. Current cost-to-upgrade figures – determined from recent project costs.

2. Convert inflation data into Price Index Factors (PIF) to be applied to past year expenditures to convert them to their current year equivalent purchasing power. Four different inflation measures were included, to reflect the fact that different cost items inflate at different rates: CPI, County labor costs, diesel fuel and construction costs.
   a. Divide the current year inflation factor by each past factor to compute the PIF's.
   b. Combine the individual PIFs into composite factors that represent the inflation for three cost categories that correlate with individual annual report cost codes types.
      i. AEL : Administration – Engineering – Operations -- Light Maintenance: 2/5 CPI, 2/5 Labor, 1/5 Diesel
      ii. MAINT : Heavy Maintenance: 1/3 Labor, 1/3 Diesel, 1/3 Construction cost index
      iii. CONST: Construction: 100% DOT Construction cost index

Table 02 illustrates the Price Index Factors that result from the input inflation measures. The PIF's are multiplied times the cost figures from the year of occurrence to produce numbers that represent what the same goods and services would cost when purchased with end of period dollars.

Table 02 : Derivation of Price Index Fators from base inflation components

Typical Source inflation measures									
Year	2002	2003	2004	2005	2006	2007	2008	2009	
CPI	177.1	181.7	185.2	190.7	198.3	202.416	211.08	211.143	Dept. of Labor
CWI	$ 14.25	$ 14.74	$ 15.14	$ 15.62	$ 17.36	$ 17.75	$ 17.87	$ 18.02	ICEA Salary Survey
DFPI	139.3	161.8	175.5	209.2	282.4	296.6	369.7	264.4	EIA
DOT CCI	150.1	146.8	159.4	173	194.1	212.5	245.5	247.5	Iowa DOT

Final Price index factors									
Category	2002	2003	2004	2005	2006	2007	2008	2009	Composite annual rate
AEL	1.362395	1.280763	1.233489	1.15725	1.028483	1.001762	0.946593	1	4.517%
MAINT	1.604348	1.516014	1.4179	1.284309	1.085148	1.025313	0.911614	1	6.986%
CONST	1.648901	1.685967	1.552698	1.430636	1.275116	1.164706	1.008147	1	7.406%

For example, if a certain type of maintenance work cost $1000 in 2003, the PIF's indicate that one would have had to pay 1.516014 x $1000 = $1516.01 to obtain the same end results in 2009.

3. Determine weighted-mileage cost distribution factors: to reflect that each county will deploy its resources according to the mix of surface types it has, multiply Earth (E), Granular (G), Hard Surface (H) and Paved (P) miles times weighting factors, total the weighted results, and divide individual weighted factors by the totals. Ten such sets of weighting factors were defined. The final percentages are saved, county by county, to be used in distributing Annual report cost code amounts that apply to more than one Surface class.

Table 03 (next page) illustrates determination of weightings for a typical county:

Table 03 : Determination of weightings for a typical county:

Surface types	Earth	Granular	Hd sfc	Paved	Total
Surface miles	140.78	789.825	8.073	79.999	1018.677

Weighting coefficients

ID	Weighting	UI/E	G	H	P
DP01	Standard	1	1	2.5	3
DP02	Pavement weighted	0.2	1	9	10
DP03	Maintenance weighting	0.5	1.5	9	9
DP04	Guardrail weighting	0	0.1	6	10
DP05	Winter Plow / Spread weighting	0	0	1	2
DP06	Winter Plow / Blade weighting	0	1	2	2
DP07	Earth and unimproved roads	1	0	0	0
DP08	Granular roads only	0	1	0	0
DP09	Hard surfaced roads only	0	0	1	0
DP10	Paved roads only	0	0	0	1

Miles x coefficients

UI/E	G	H	P	Total
140.78	789.825	20.1825	239.997	1190.785
28.156	789.825	72.657	799.99	1690.628
70.39	1184.738	72.657	719.991	2047.776
0	78.9825	48.438	799.99	927.4105
0	0	8.073	159.998	168.071
0	789.825	16.146	159.998	965.969
140.78	0	0	0	140.78
0	789.825	0	0	789.825
0	0	8.073	0	8.073
0	0	0	79.999	79.999

ID	Weighting	UI/E	G	H	P
DP01	Adm wtd	11.82%	66.33%	1.69%	20.15%
DP02	Pvmt wtd	1.67%	46.72%	4.30%	47.32%
DP03	Mnt wtd	3.44%	57.85%	3.55%	35.16%
DP04	Guardrail		8.52%	5.22%	86.26%
DP05	Plow/spread			4.80%	95.20%
DP06	Plow/Blade	0.00%	81.77%	1.67%	16.56%
DP07	UI/E only	100.00%			
DP08	G only		100.00%		
DP09	H only			100.00%	
DP10	P only				100.00%

4. Assign distribution factors to each individual cost code
   a. AEL, MAINT, or CONST inflation factor
   b. Percent road / percent bridge
   c. Weighted-miles based cost allocation factors
   d. Operations, Maintenance, Extension and Renewal factors (OMER)

5. Perform the calculations (for each cost code)
   a. Inflate each of the past eight years' worth of expenditures by multiplying them by their Price Index Factors
   b. Sum and average the eight years to obtain an representative long-term-average amount
   c. Deduct a percentage to reflect that reimbursements from others reduce final county costs
   d. Split the long-term average between Roads and Bridges
   e. Split the Road and Bridge amounts according to the weighted-miles factors.
   f. Assign the costs to each item's OMER factors.

Table 04 illustrates all the factors used to break costs down into the thirty-two target slots:

Acct. Code	Description	Inflation basis	Cost Dist. Basis	Asset allocation		Cost class allocation			
				Road Cost	Bridge Cost	Operate	Maint	Extend	Renew
591	Signs	AEL	DP03	100%	0%	0.0	1.0	0.0	0.0
592	Signals	AEL	DP10	100%	0%	0.0	1.0	0.0	0.0
593	Pavement markings	MAINT	DP10	100%	0%	0.0	1.0	0.0	0.0
594	Guardrail	MAINT	DP04	50%	50%	0.0	1.0	0.0	0.0

6. Consolidate the results from all Annual Report cost codes to obtain an initial set of the thirty-two items (Roads/Bridges x four surface class x four expense categories) sub-totals

7. Process construction costs
   a. Acquire a listing of construction projects completed in the most recent fiscal year and qualify them:
      i. Decide whether Road or Bridge
      ii. Assign a Road surface class
      iii. Assign an expense category: Maintenance, Extension, Renewal OR Upgrade*
         Some projects will represent a change from a lower design level to a higher one- an Upgrade. Those amounts need to be excluded from Carry Cost calculations.
   b. Deduct un-inflated Annual Report 300 Series construction costs from HF-324/GASB-34 reported costs to avoid double counting.
   c. Inflate the cost of the project of the last eight years using the Construction price index factors
   d. Add the construction costs coded M, E, or R into the previously compiled Annual Report totals to obtain a completed picture of secondary road long-term-average costs.

8. The end results provide an accurate picture as to what has been spent, on average, over an eight year period, to provide the public with a rural road network. It reflects the highs and lows of the time period, as adjusted for inflation. The voluminous source data will have been reduced to the thirty-two item grid of costs, per county – representing Roads/Bridges (2 targets) x EGHP (4 surface classes x OMER (4 expense categories).

Determination of sustainable system needs (Carrying costs)
After the Actual Expenditures calculations are finished, two questions must be asked about each of the 32 expense categories: a) has this amount been sufficient to keep the road/bridge conditions unchanged and b) if not, by how much would it need to be increased or decreased to achieve long term sustainability?

Because there are few direct measures of road surface condition/quality available for secondary roads, answers to the "was the amount expended adequate to keep the system unchanged " and "how much should it be increased/decreased

to achieve sustainability" have had to be semi-subjective.   The situation with bridges can be more objectively determined, by comparing sufficiency ratings at the beginning of the time period to those at the end.

Roads

The initial determination of expenditure adequacy was accomplished by sharing actual expenditure results with county engineers and evaluating, based upon their knowledge of needs, revenues and conditions, how things have been going.

Their judgments and the adjustment factors that arose from these discussions follow, referring to Table 05.

Table 05: Initial Actual Cost to Carrying Cost multipliers

Road factors	Road surface categories			
Cost classes	Earth	Granular	Hd Surface	Paved
Operate	1.00	1.05	1.05	1.05
Maintain	1.00	1.20	1.15	1.15
Extend	1.00	1.25	1.50	1.25
Renew	1.00	1.30	1.80	1.30

- Earth Roads: It was felt that the amount being spent on earth roads is roughly adequate to meet the needs of the citizens using those routes – so all four cost class factors were set to 1.00, representing "no need for adjustment".
- "Operate" cost class: (Granular, Hard Surface and Paved)   Due to rapid increases in costs outpacing stagnant revenues in the 2003 to 2012 time period, counties have deferred repair and replacement of equipment, such as motor-graders, trucks, and excavators.   While this is an acceptable short-term response to a budget squeeze, it's not sustainable long term: either the equipment will have to be updated or the service that the units support will deteriorate.   So the G, H and P multipliers in this category were set to 1.05, so show that more money will need to be spent in this area going forward.
- "Maintain" cost class: (Granular, Hard Surface and Paved)   As with "Operate", counties have dealt with decreased resources by deferring maintenance tasks.
  - A lot of ditching, erosion control, weed spraying, brush cutting and so on has been put off in the last few years, yet must eventually be attended to. And given the weight of modern agricultural machinery, graders must work hard to maintain a good crown on granular roads – so a factor of 1.20 was used.
  - Hard Surface and Paved road preventive maintenance has had to be curtailed in recent years, which while not having an immediately impact, does allow these assets to age faster than Extension and Renewal will be able to keep up with in the long run. So factors of 1.15 were selected to represent the amount by which maintenance work would need to increase to help achieve steady state conditions.
- Granular Extend and Renew: While a generally accepted practice for keeping granular roads "healthy" is to apply 400 tons per mile of new rock every three years, many secondary road departments have had to cut back to 350, 300 or even 250 tons per mile.   The nature of granular roads allows this to be done for a while without major problems, but there eventually comes a winter or spring where freeze-thaw dynamics quickly makes the lack of sufficient surface material dramatically and painfully apparent.   Despite a number counties experiencing severely compromised systems during the 2008-2010 time period, a hard reminder of the need, many are still not been able to fully fund a 400 TPM re-rocking pace. So factors of 1.25 (Extend) and 1.30(Renew) were chosen to represent how much more expenditure is needed to return to sustainable operation.

- Hard Surface Extend and Renew: Factors were set to 1.5 and 1.8, respectively, because Hard Surface roads have been a clear and visible casualty of limited resources in the last decade.   They have not been sustained, and in many counties, a substantial number of Hard Surface miles have been converted back to Granular.
- Paved Road Extend and Renew: There has been mixed news in this area. While many counties have not been able to keep up, some that have taken advantage of TIF and Wind farm tax revenues have improved the overall condition of their paved networks.   It may be that there will need to be individual factors, for each county, to better reflect their differing circumstances, but for this project, factors of 1.25 (Extend) and 1.3(Renew) were used.   This increase would help reduce pavement's average restoration cycle from the current 30-40 years plus level back down to a more steady state 20 to 25 years.

Bridges

Factors to be applied to bridge expenditures were determined from evaluation and comparison of bridge counts, deck areas and sufficiency ratings over time.

Table 06: Sample comparison of bridge data between two different years

Bridges	Earth			Granular		
Year	Count	Sq. Ft.	Avg SR	Count	Sq. Ft.	Avg SR
2006	1,024	1,063,422	52.77522	14,221	23,834,627	74.29719
2011	1,021	1,106,161	56.32364	14,001	24,348,150	76.65459

Bridges	Hard surface			Paved		
Year	Count	Sq. Ft.	Avg SR	Count	Sq. Ft.	Avg SR
2006	348	801,914	73.58313	3,962	13,371,679	78.28457
2011	314	741,901	73.80193	4,066	14,091,723	81.33188

Generally, average, Sq.Ft.-weighted sufficiency ratings (SR) are being maintained or improved.   Counts of Earth and Granular Road structures, however, are decreasing – which suggests that the SR's are being sustained by closing bridges rather than restoring them – so the system's "extent, configuration and condition" are not really being sustained.   In contrast, total square footage of bridge deck area is generally increasing – reflecting the reality that those structure that do get replaced end up longer and wider due to hydraulic and minimum design standard requirements.   Over time upgrades, say from gravel to paved, or downgrades, say from hard surface to granular, causing some non-structure condition related shifts in counts, deck area and sufficiencies.

Table 07: Initial bridge cost multipliers established in TR-608

Bridge factors	Road surface categories			
Cost classes	Earth	Granular	Hd Surface	Paved
Operate	1.00	1.00	1.00	1.00
Maintain	1.00	1.00	1.00	1.00
Extend	4.00	1.00	1.30	1.00
Renew	5.00	1.20	1.40	1.00

- Operate and Maintain: Bridge lifetimes are not much affected by Operate and Maintain expenditures, so factors for these cost classes were set to 1.00 to indicate that they are roughly adequate.
- Extend and Renew factors were selected as follows:
  - Earth – although their SR is improving, a large number are posted and inadequate. So factors of 4.00 (Extend) and 5.00 (Renew) were chosen to show that substantial additional expenditures would be needed to achieve sustainability.
  - Granular – A factor of 1.2 for Renew – to reflect that although the SR is being sustained, structures are being closed, deck area increases are adding future need, and Hard Surface downgrades are reverting some structures back to the Granular category.   (Further work is needed here, as the 1.2 might be too low a multiplier value for this surface class.)
  - Hard Surface – Factors of 1.30 and 1.40 represent a perceived lack of investment.   They may be too strong, since the SR has been maintained; this will be investigated and adjusted as future years' data comes in.
  - Paved – both factors were left at 1.00. While the deck area is increasing, so is the average Sufficiency Rating, so Paved bridges appear to be near or above sustainment levels.

After their determination, the adjustment factors are applied to their matching Actual eight-year averaged Expense items. The resulting figures represent how much ought to be expended to sustain the system over the long term – the Carrying Costs of the system.

The following table illustrate the Carrying Cost calculations:

Table 08: Calculations performed for FY 2011 produced the following results:

ROADS	Total avg expenditure by category				Bridges	Inflation Adjusted 8 year avg.			
Actual	Earth	Granular	Hd Surface	Paved	Earth	Granular	Hd Surface	Paved
Operate	1,536,714	76,729,171	5,101,971	64,238,717	200,867	8,429,686	558,286	7,020,616
Maintain	1,419,314	61,562,429	4,105,842	35,746,716	55,968	4,048,241	283,385	3,620,889
Extend	900,376	46,125,803	4,378,119	62,221,281	136,115	7,893,040	600,050	8,475,313
Renew	286,429	74,622,900	2,599,205	121,932,069	659,516	29,049,398	2,586,932	51,378,288
Totals	4,142,833	259,040,303	16,185,136	284,138,783	1,052,466	49,420,365	4,028,653	70,495,107

Roads: 563,507,055

Bridges 124,996,591

Grd Total: 688,503,646

ROADS					Bridges				
Multipliers	Earth	Granular	Hd Surface	Paved	Earth	Granular	Hd Surface	Paved
Operate	1.00	1.05	1.05	1.05	1.00	1.00	1.00	1.00
Maintain	1.00	1.20	1.15	1.15	1.00	1.00	1.00	1.00
Extend	1.00	1.25	X 1.50	1.25	4.00	1.00	1.30	1.00
Renew	1.00	1.30	1.80	1.30	5.00	1.20	1.40	1.00

ROADS	Calculated amount needed per year				Bridges	Calculated amount needed per year			
CarryCost	Earth	Granular	Hd Surface	Paved	Earth	Granular	Hd Surface	Paved
Operate	1,536,714	80,565,626	5,357,069	67,450,650	200,867	8,429,686	558,286	7,020,616
Maintain	1,419,314	73,874,918	4,721,718	41,108,723	55,968	4,048,241	283,385	3,620,889
Extend	900,376	57,657,253	6,567,178	77,776,601	544,461	7,893,040	780,065	8,475,313
Renew	286,429	97,009,766	4,678,569	158,511,684	3,297,580	34,859,279	3,621,705	51,378,288
Totals	4,142,833	309,107,563	21,324,534	344,847,658	4,098,876	55,230,246	5,243,441	70,495,107

Roads: 679,422,588

Bridges 135,067,669

Grd Total: 814,490,257

Table 09: Carrying Costs (from FY11) converted to a Per-mile basis

	ROADS	Computed "Need" per mile per year			Bridges	Computed "Need" per mile per year			
CarryCost	Earth	Granular	Hd Surface	Paved	Earth	Granular	Hd Surface	Paved
Operate	303	1,215	3,733	3,909	40	127	389	407
Maintain	280	1,114	3,290	2,382	11	61	197	210
Extend	177	869	4,576	4,507	107	119	544	491
Renew	56	1,463	3,260	9,185	650	526	2,524	2,977
Totals	816	4,661	14,860	19,983	807	833	3,654	4,085

Upgrade needs (System enhancement warrants and costs)

In addition to the Carrying Costs, which are the amounts that must be expended annually to keep the system going, traffic growth can create a second type of need: the amounts that ought to be expended to bring the design level of the road up to that which best serves the traffic it is carrying.   In TR-608, this cost category was named : "Upgrade needs"

Upgrade Needs are extensive and of such magnitude that they cannot all be addressed.   One must prioritize and fund them according to urgency and potential benefits.   Upgrades are also discretionary: a road agency typically ought to make them but can do so only if funds are available to finance the work. If the upgrades aren't made, the traveling public suffers from continued elevation of operating costs, delays and accident rates – but these types of improvements can only be made if revenues beyond those needed to cover Carrying Costs are available.

The task of determining Upgrade Needs takes several steps:

1. Identify road segments where traffic counts exceed the level for which the road is designed
2. Filter the list to eliminate segments where the traffic level vs design difference isn't large enough to justify action.
3. Prioritize the remaining candidates according to urgency.
4. Calculate the cost of upgrade for each prioritized segment
5. Tally miles and costs by surface class & priority – to give a picture of both physical and financial need.

Definition of service levels

The starting point for determination of whether or not roadways' design levels are appropriate for the traffic being carried is to define a set of design level classes and establish what VPD ranges they best service.   This was accomplished by reviewing the secondary road design aids provided in the Iowa DOT's Instructional Memorandums for Local Public Agencies, under Section 3.2 – Design Guides and Exceptions. These memos, which were jointly developed by DOT and County engineers, taking into account safety, economy, serviceability and liability concerns, outline design parameters deemed most appropriate for various traffic levels.   A thorough study of those design aids resulted in the selection of fifteen design levels to represent the ranges of surface types, lane counts, and road geometry best for secondary roads in Iowa.

Table 10: County road Design Levels utilized in TR-608

Design Levels	Description	Traffic range best served by DL		
		Min_vpd	Avg_vpd	Max_vpd
1	Earth - unimproved	0	1	1
2	Earth - improved	2	7	11
3	Granular surfaced - narrow	12	18	24
4	Granular surfaced -medium	25	37	49
5	Granular surfaced - wide	50	87	124
6	Hard surfaced	125	162	199
7	Two lane Paved - Narrow	200	300	399
8	Two lane Paved - Medium	400	575	749
9	Two lane Paved - Wide	750	1125	1499
10	Two lane Paved - Max	1500	2750	4000
11	Two lane Paved with right turn lanes or three lane	4000	5500	6999
12	Four lane paved	7000	8750	10499
13	Four lane paved - with median	10500	12750	14999
14	Four lane paved with median or five lane	15000	22500	29999
15	Six lane paved - with median	30000	40000	49999

Design levels 2 through 13 cover nearly all existing secondary roads in Iowa. DL's 14 and 15 were included because a) there are a few such segments around – typically transferred from the DOT to the county when primary bypass has taken place and b) to assure that extrapolated future traffic wouldn't exceed the range of the model for some time to come.

Design Level assignments and comparisons

Once a set of design levels has been defined, the next task is to link them to each road segment being studied. This association needs to be done on two levels: first, one must use the geometric characteristics of the segment to associate a Physical Design Level (PDL) thereto; second, one must determine, via comparison of the segment AADT to the DL traffic VPD) ranges, what the roadway's Traffic Design Level (TDL) is. For instance, a road with an AADT of 650, will have a TDL of 8. If that road's physical characteristics fit the definition of "Two lane Paved – Medium" then the PDL would also be an 8.

If a road segment's PDL and TDL are the same, it is an indication that the physical character of the route is appropriate for the traffic carried   But if the PDL is less than the TDL, such as if a Granular Surfaced – Wide road is carrying 220 vehicles per day, a need for upgrade is manifest. In that case, the PDL would be 5, while the TDL would be 7, a difference of two. If, on the other hand, the PDL of the route exceeds its TDL, the road has reserve capacity for additional traffic and need not be considered for upgrade at this time. So, if the result of subtracting a segment's PDL from its TDL is positive, the road may be considered for improvement.

Since a minor difference between Traffic's needs and a road's physical character isn't sufficient to justify action, TR-608 adopted the convention that segments would be considered eligible for upgrade only if the TDL minus PDL difference was two or greater. And the upgrade strategy is to target improving the route to one level higher than that of the Traffic Design Level – which allows the upgraded segment some reserve capacity to accommodate future growth before possibly becoming eligible a second time.

Design scoring

In order to link a Physical Design Level to each road segment, there needed to be a way to combine key road geometry parameters into a single number, or Score. Data items available for both segments and design levels included the

following: Surface type, number of lanes, surface width, shoulder width and type, median width and type, and traffic numbers (VPD values of AADT). A high and low score range was determined for each Design Level, then scores were computed for every segment. From there, every segment could be assigned a Physical Design Level.

The formula chosen for computing the Design Level score is:

Let "T" = Surface Class [0 – Unimproved, 1 – Earth, 2 – Granular, 3 – Hard Surface, 4 – Paved]
Let "L" = Number of lanes [1-6]
Let "R" = Roadway width in feet
Let "S" = Shoulder width in feet (Shoulders have a surface type of Paved or Not paved)
Let "M" = Median width, if any, in feet
Let "N" = Number of shoulders in cross-section: 2 for roads w/o median; 4 for those with medan.

Shoulder width effectiveness factors
Let "SWF" = 1 if shoulder is paved or 0.5 if not

$SCORE_{PDL} = (T \times 10) + L + ((R + [N \times S \times SWF] + M/2) / 100$

Example: A two lane paved road with 22 ft. roadway and 6 ft. rock shoulders would score as follows:
PDL = (4 x 10) + 2 + ((22 + [2 x 6 x .5] + 0/2)/100
PDL =   40   + 2 + (22 + 6 + 0) / 100 = 42.28 (Falls inside PDL 9)
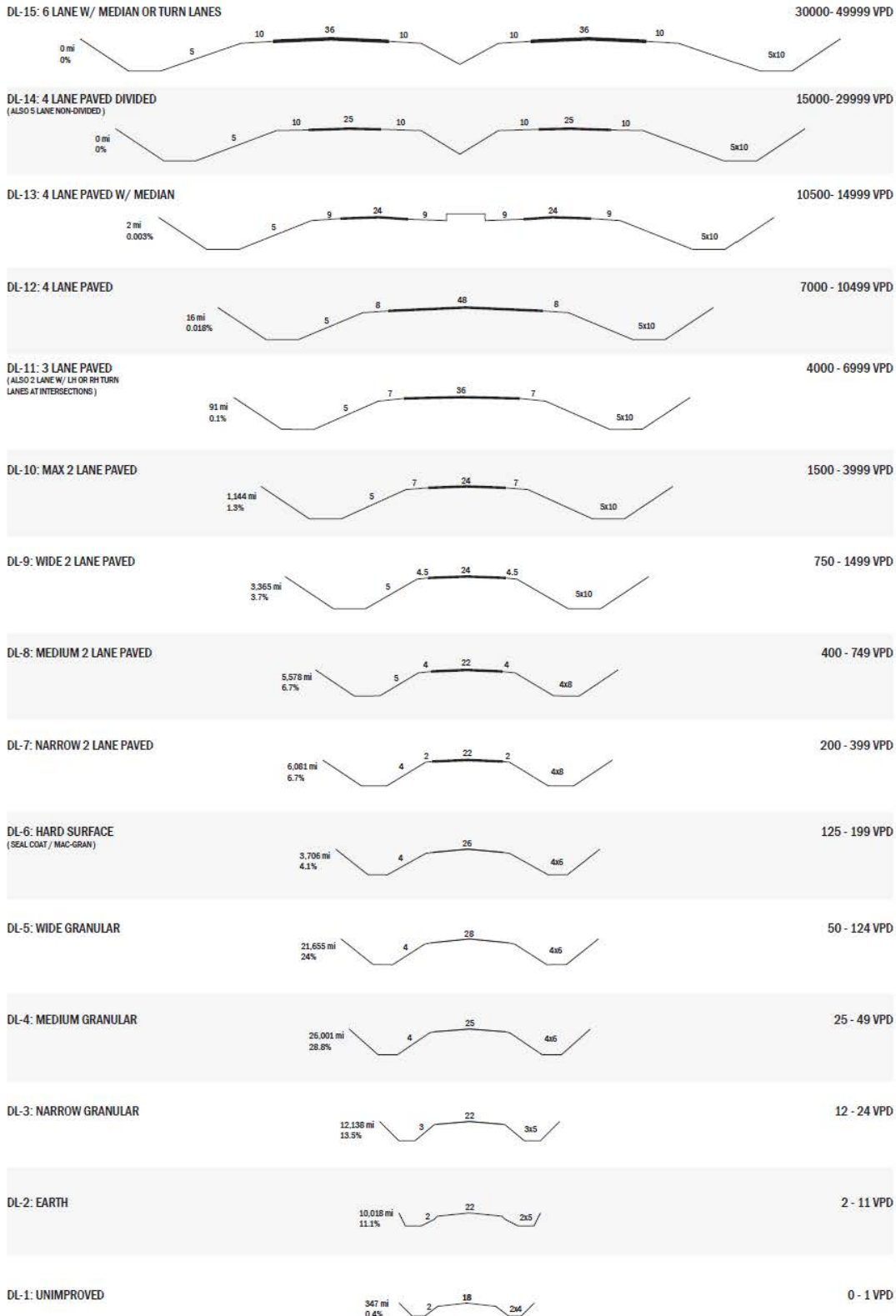
Design level score ranges
The score ranges for the fifteen design levels from each one's high and low end physical characteristics. End results are shown in Table 11

Table 11 – Design level score ranges

Design Levels	Description	Min. Score	Max. Score	Short form ID
1	Earth - unimproved	0	1.36	UNIMPR
2	Earth - improved	1.36	11.41	EARTH
3	Granular surfaced - narrow	11.41	22.24	GRAN1
4	Granular surfaced -medium	22.24	22.26	GRAN2
5	Granular surfaced - wide	22.26	22.36	GRAN3
6	Hard surfaced	22.36	32.33	HDSFC
7	Two lane Paved - Narrow	32.33	42.25	PVD2A
8	Two lane Paved - Medium	42.25	42.265	PVD2B
9	Two lane Paved - Wide	42.265	42.29	PVD2C
10	Two lane Paved - Max	42.29	42.31	PVD2D
11	Two lane Paved with right turn lanes or three lane	42.31	43.48	PVD3
12	Four lane paved	43.48	44.655	PVD4A
13	Four lane paved - with median	44.655	44.78	PVD4Bm
14	Four lane paved with median or five lane	44.78	45.92	PVD5m
15	Six lane paved - with median	45.92	99	PVD6Am
		>	<=	

Figure 01: Geometrics of the fifteen Design Levels

REPRESENTATIVE DESIGN CROSS-SECTIONS
FOR TR-608 "DESIGN LEVELS" USED TO EVALUATE "UPGRADE NEEDS"

DL-15: 6 LANE W/ MEDIAN OR TURN LANES — 30000- 49999 VPD
0 mi / 0% — 5 — 10 — 36 — 10 — 10 — 36 — 10 — 5x10

DL-14: 4 LANE PAVED DIVIDED (ALSO 5 LANE NON-DIVIDED) — 15000- 29999 VPD
0 mi / 0% — 5 — 10 — 25 — 10 — 10 — 25 — 10 — 5x10

DL-13: 4 LANE PAVED W/ MEDIAN — 10500- 14999 VPD
2 mi / 0.003% — 5 — 9 — 24 — 9 — 9 — 24 — 9 — 5x10

DL-12: 4 LANE PAVED — 7000 - 10499 VPD
16 mi / 0.018% — 5 — 8 — 48 — 8 — 5x10

DL-11: 3 LANE PAVED (ALSO 2 LANE W/ LH OR RH TURN LANES AT INTERSECTIONS) — 4000 - 6999 VPD
91 mi / 0.1% — 5 — 7 — 36 — 7 — 5x10

DL-10: MAX 2 LANE PAVED — 1500 - 3999 VPD
1,144 mi / 1.3% — 5 — 7 — 24 — 7 — 5x10

DL-9: WIDE 2 LANE PAVED — 750 - 1499 VPD
3,365 mi / 3.7% — 5 — 4.5 — 24 — 4.5 — 5x10

DL-8: MEDIUM 2 LANE PAVED — 400 - 749 VPD
5,578 mi / 6.7% — 5 — 4 — 22 — 4 — 4x8

DL-7: NARROW 2 LANE PAVED — 200 - 399 VPD
6,081 mi / 6.7% — 4 — 2 — 22 — 2 — 4x8

DL-6: HARD SURFACE (SEAL COAT / MAC-GRAN) — 125 - 199 VPD
3,706 mi / 4.1% — 4 — 26 — 4x6

DL-5: WIDE GRANULAR — 50 - 124 VPD
21,655 mi / 24% — 4 — 28 — 4x6

DL-4: MEDIUM GRANULAR — 25 - 49 VPD
26,001 mi / 28.8% — 4 — 25 — 4x6

DL-3: NARROW GRANULAR — 12 - 24 VPD
12,138 mi / 13.5% — 3 — 22 — 3x5

DL-2: EARTH — 2 - 11 VPD
10,018 mi / 11.1% — 2 — 22 — 2x5

DL-1: UNIMPROVED — 0 - 1 VPD
347 mi / 0.4% — 2 — 18 — 2x4

After assigning a Physical Design Level, PDL, and Traffic Design Level, TDL, to every road segment, a cross-tabulation can be assembled to show how many miles of roadway fall into each combination of PDL versus TDL.   The tabulation can then be analyzed to assess how much upgrade needs exists and at what levels of urgency.   Table 12   shows results for FY 2011.

Table 12 – Crosstab showing miles of road belonging to each Traffic and Physical design level combination

		U	E	G1	G2	G3	HS	P2A	P2B	P2C	P2D	P3	P4A	P4Bm	P5m	P6Am	
TDL's	2011	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TDL totals
U	1		34	288	0			0									323
E	2		13	7615	1748	617	11	39	6	1	1		0				10051
G1	3		3	6933	3749	1629	10	27	1	1							12353
G2	4		3.979	11823	8809	5476	65	92	12	4	0	0					26285
G3	5		2.610	7434.669	6470	5999	402	777	78	10	3	5	0				21182
HS	6		0.916	596.441	554.660	730	343	1254	99	28	4	1					3611
P2A	7		1.221	273.071	189.948	252.789	387	4412	503	81	14	8	1		1		6124
P2B	8		0.265	32.626	14.678	22.809	177.600	4314	863	111	11	8	0				5556
P2C	9		0.011	7.552	2.905	6.550	77.624	2302.039	839	112	25	28	2				3402
P2D	10		0.011	1.364	1.094	1.902	17.940	543.838	267.473	206	27	32	5		0		1103
P3	11			0.431		0.021	1.377	22.866	24.536	12.415	4	9	11	0	1		86
P4A	12			0.614				3.567	1.913	2.754	1.018	1	2		0		13
P4Bm	13							0.874	0.374		0.162	0.403	0				2
P5m	14							0.050			0.130	0.040	0.288				1
	PDL	0	59	35007	21539	14734	1492	13789	2696	569	91	94	21	0	1	0	90092

Table 13's columns show the miles of road having a particular Physical Design Level. In each column, the rows show how many miles of have a traffic level corresponding to one of the Traffic Design Levels.   The colored diagonal banding can be interpreted as follows:

YELLOW   : TDL and PDL match; road design optimally fits the traffic level.

Lt. YELLOW   : TDL is only 1 step higher or lower than PDL; not optimal: not far enough off to warrant action

GREEN   : PDL is greater than TDL: roadway has reserve capacity for serving additional traffic

Lt. ROSE   : TDL is 2 to 3 steps higher than PDL; upgrade is warranted

Md. ROSE   : TDL is 4 to 5 steps higher than PDL; upgrade should be given priority

Dk. ROSE   : TDL is 6 or more steps higher than PDL; upgrade need urgent

A summary tally of the band-groupings is shown in Table 13.

Table 13: Miles by priority level

Design Level difference	Miles	Percent
P>>T	5718	6.35%
P>T	19211	21.32%
P=T	27521	30.55%
P<T	24779	27.50%
P<<T	12468	13.84%
P<<<T	382	0.42%
P<<<<T	12	0.01%
	90092	

This indicates that 6.4% of the system has reserve capacity, 79.4% has a good match between design and traffic, and 14.2% warrants upgrade; but only 0.43% is in upgrade priority or urgent status.

Dollar estimate of upgrade needs

The last step in the determination of upgrade needs is to assign a per mile improvement cost to each case where the TDL exceeds the PDF by 2 steps or more. This is done by multiplying the miles needing upgraded by an incremental upgrade cost. The incremental cost represents the difference between what would be spent, per mile, the next time the road segment came due for Renewal (see the previous section Carrying Costs), and the absolute cost of upgrading from the current Physical Design Level to the Traffic Design Level PLUS ONE.   The "PLUS ONE" is emphasized as a reminder that roads are upgraded to a somewhat higher design level than current traffic demands – so that there will be some reserve capacity to handle future increases over an anticipated service life of 15-20 years.

The incremental costs of improvement are figured as follows: If the absolute cost to upgrade from PDL_x to TDL_{y+1} is $450,000 / mile, while the cost of renewing at PDL_x is $75,000 / mile, then the incremental cost will be $375,000 / mile.

Absolute costs were developed using cost information from two sources, then merging them. The first source was obtained by estimating construction quantities, per mile, to build each design level's cross-section on new location. Then, for each PDL x TDL pair, quantities were multiplied by current unit prices and an 'overhead' factor for 1.20, to obtain a new construction cost.   The incremental costs were figured by subtracting part, but not all, of the PDL's Renewal amount.   The deduction of the PDF Renewal avoids a possible double counting of costs.   But only part of Renewal is deducted because upgrade projects always require partial destruction of the old cross-section before the new can be built.

Dollar estimate of upgrade needs

This report primarily describes how the repeating annual processes created in TR-608 operate. The actual end output will change every year, so there really aren't any 'final' numbers to be published. Nonetheless, to illustrate what the results look like and how they may be used, a sampling is provided below in Table 14.

Table 14 : Tabulation of Upgrade Needs ($Millions)

TDL's	2011	U 1	E 2	G1 3	G2 4	G3 5	HS 6	P2A 7	P2B 8	P2C 9	P2D 10	P3 11	P4A 12	P4Bm 13	P5m 14	P6Am 15	TDL totals
U	1	PDL = TDL															
E	2		PDL = TDL														
G1	3			PDL = TDL													
G2	4		$0.6		PDL = TDL												$0.6
G3	5		$0.6	$1,541.2		PDL = TDL											$1,541.8
HS	6		$0.6	$351.5	$306.9		PDL = TDL										$658.9
P2A	7		$0.8	$166.4	$108.9	$139.1		PDL = TDL									$415.2
P2B	8		$0.2	$25.9	$11.1	$16.7	$120.4		PDL = TDL								$174.4
P2C	9		$0.0	$6.7	$2.5	$5.5	$60.3	$831.0		PDL = TDL							$906.0
P2D	10		$0.0	$1.3	$1.0	$1.7	$15.1	$231.1	$101.6		PDL = TDL						$351.9
P3	11			$0.8		$0.0	$2.3	$28.5	$29.5	$13.4		PDL = TDL					$74.5
P4A	12			$1.2				$4.9	$2.6	$3.3	$0.7		PDL = TDL				$12.7
P4Bm	13							$1.4	$0.6		$0.1	$0.3		PDL = TDL			$2.4
P5m	14							$0.1			$0.2	$0.1	$0.2		PDL = TDL		$0.6

														Totals	Miles	$ / mi
Warranted	$1.2	$1,892.7	$415.8	$155.9	$180.7	$1,062.2	$131.2	$16.7	$0.8	$0.4	$0.2		$3,857.8	12468.1	$309,410
Priority	$1.3	$192.3	$13.6	$7.2	$17.4	$33.5	$3.1	$0.0	$0.2	$0.0	$0.0		$268.5	382.036	$702,874
Urgent	$0.2	$10.0	$1.0	$0.0	$0.0	$1.5	$0.0	$0.0	$0.0	$0.0	$0.0		$12.8	12.287	$1,038,270
Totals	$2.7	$2,094.9	$430.4	$163.1	$198.1	$1,097.1	$134.3	$16.7	$1.0	$0.4	$0.2		$4,139.0	12862.42	

The total amount needed to 'perfect' the road system so that all mileage would fall in to the yellow, "adequate service" bands works out to an estimated $4.139 Billion.   Obviously, this will not be attained.   But the Priority and Urgent categories total only $281.3 Million. If counties had the funds to invest $30 Million per year into upgrades, the affected segments could be all taken care of in 9 to 10 years.   Caveat: Priority and Urgent sections wouldn't get completely eliminated, as traffic growth in Upgrade Warranted segments would no doubt push some new miles back into the highest urgency categories.

<u>Annual renewal and refinement</u>

The goal of this project was to create a system that could provide annually updated financial needs information for Iowa's county roads. The system has been developed and built. It will henceforth be maintained, operated and kept current by the Iowa County Engineers Association Service Bureau. The preceding pages describe the methods used to ascertain two key need figures:

- Carrying Costs – representing the ongoing cost of providing the public with a road system.
- Upgrade Needs – representing addition costs necessitated by increased use of the system

These items will be recomputed annually by the Service Bureau, based on the latest County Engineering Annual Reports, inflation data, construction costs unit prices and other needed inputs. The results will be compiled both on a county by county and statewide basis, for use in analyzing trends, establishing needed, and educating the public about what it costs them to have a secondary road system like Iowa's available. Typically, the renewal work will get performed in November and December of each year, after the Iowa DOT has finished reviewing and approving the Annual Reports.

Over time, the Service Bureau expects to refine and improve the process, automating it to the extent possible. As readers may have noted in the section on using multipliers to convert "what has been expended" amounts into "what should be spent" figures, all the multipliers are stated in increments of 0.05: e.g. 1.05 or 1.15 or 1.8. This was intentional – reflecting the fact that the initial multiplier selections can and must be improved upon. The research team believes that more rigorously determined multipliers might turn out to be numbers like 1.038594 or 1.839402. The multipliers will be refined to reach that level of precision, year by year, as trends and results become clearer and as objective source data becomes available.

In the Upgrade Costs section, the determination of incremental costs will be refined and improved over time.

A side goal of this project was process transparency, often cited as insufficient in past need studies. To that end, all calculations can be traced from original data to end result. This will allow anyone interested to personally evaluate the methods used and to propose better ones.

<u>Observations about results</u>

The results of the Carrying Cost determination indicate that Iowa secondary road funding is falling short of the level needed for long term sustainability. The computed annual need comes to $814 Million per year (2011 results) while actual expenditures have been running around $690 Million(2011). That is a substantial difference and suggests that action should be taken to get things more in balance. One option is to seek more revenues, either from local taxes or from the road user's fees and fuel tax. Another would be to reduce the extent, configuration and quality of the system, down to a point that could be funded with existing revenues. Neither alternative will enjoy ready acceptance, yet society has no choice but to work through these issues and resolve them in some fashion or another.

A sobering add-on is to note that, at least for the last 8 to 10 years, road upkeep costs have been rising at least six percent per year. To keep up with that, any new combination of revenue sources would also need to be capable of similar growth rates or the solution they provide will be only temporary.

Upgrade needs, being primarily composed of construction costs, have been impacted by two trends. Construction costs have escalated at better than 7% per year since 2002. In a bit of a mixed blessing, traffic growth stalled out, and in some cases reversed, reducing the magnitude and urgency of making upgrades – at least temporarily. But that also depressed revenue growth. A return to traditional annual traffic growth in the range of, say, two percent per year would dramatically boost upgrade needs and produce some, but not enough, new revenue to cover the costs thereof.

Areas where additional research or data collection would help improve the model and results

The Carrying Cost and Upgrade Needs determination processes have reached a workable state and can now be maintained for long term use.   But they could still be improved by any or all of the following:

- It would be helpful to have a means by which the condition of the four surface classes could be more objectively assessed.   There would not necessarily need to be a segment by segment evaluation, but a method that could give an aggregate assessment of the overall condition of Granular, Hard Surface and Paved miles in each county would enable tracking long term trends.   Having a data based determination of the trends would enable more accurate determination of Carrying Costs multipliers.
- At some point in the future, it might be helpful to combine HF-324 and GASB-34 reporting into a single system and expand it to also capture project data needed for Carrying Cost determination.
- The scoring formula used in assignment a Physical Design Level to each road segment is workable as is, but could be made more precise if the following additional data items were to be recorded:
    - Expanded type options for shoulders: instead of just knowing if the shoulder is paved or not-paved, it could be tagged as PCC paved, HMA paved, Hard surfaced, Granular or Earth.
    - It would be helpful to have more data on medians: an expanded range of surface types, (as for shoulders), plus whether or not it's raised or depressed.
    - A uniform and consistent indicator of structural capacity of pavements.
    - Representative design speed for each segment, based on cross-section, plus and line and grade.
- The cost account codes used in tracking expenditures and preparation of annual reports do not always capture cost information that can easily be separated into surface classes and expenditure type categories. Refinement of the codes to be more precise would help the accuracy of downstream systems, such as the TR-608 Carrying cost determination process.

Part 2 – Derivation of key relationships for forward projections

The Carrying Cost and Upgrade Needs information developed in Part 1 provides answers to the question of what does it cost, right now, to operate and upgrade a secondary roads system.   The next question, what will things cost in the future, is harder to answer, because the relationships between revenues, costs, system configuration, and system condition are complex and interwoven.

Before attempting to make forward projections about the roads and bridges, it was necessary to derive some fundamental base values, define relationships between causes and effects and synthesize analytical methods. This section summarizes work done in this regard. The end products of Part 2 are employed in Part 3, which presents the full Trend Projection Engine that was developed to provide insights into future costs.

Rates of change

The Trend Projection Engine is based on and uses a broad slate of source data. Most of the items have values that change over time, so it was necessary to determine starting values and expected rates of change. Items so researched were as follows:

a) Population and dwellings
b) Land use
c) Agricultural production
d) Road department revenues – tallied from County Engineer annual reports
e) Rates of inflation for cost items – Bureau of Labor, Annual reports, Fuel cost tallies, DOT Const. cost index
f) Accident rates – obtained from Iowa DOT Office of Traffic Safety

Some of these items can be obtained directly from US Census or USDA sources. Rate of change for agriculture and population require some additional analysis post acquisition.

Correlation of trips and VMT with population and land use

The traditional approach to estimating future traffic has been to apply growth/decline rates, as recorded in DOT base records, to their matching AADT figures.   That approach works, but provides little insight into how the rural economy produces traffic, what the mix of vehicles will be and how agri-business trends will affect road use in future years.

To better explore the linkages between population, land use and traffic, a model of rural travel demand was developed and then tuned to fit AADT of record. Once established, this model permitted estimation of future traffic to be based on rural demographic and business trends.

To start work on this task, each road segment's AADT was multiplied times its length, to compute VMT.   County by county total VMTs, along with Earth, Granular, Hard Surfaced, and Paved subtotals, were tallied and saved. Traffic distribution factors were computed by dividing each subtotal by the grand-total in each county.

Next, an effort was made to ascertain or establish the number of secondary road trips per day arising from various rural personal, business and agricultural-production activities.   Trip sources and rates used are shown in Table 15. The trip factors, while adequate for first-generation modeling, need to be refined over time.

Table 15: TR-608 Trip factors

TripSource	Factor	Units	Basis
Urban Population in County	0.01	TPD per Cap	Per Day
Farmsteads	7	TPD per site	Per Day
Farmstead trips growth factor		TPD annual increase	1.015
Rural Residences	5	TPD per site	Per Day
CornAcres	0.23	TPY per AC	Per Year
BeanAcres	0.15	TPY per AC	Per Year
OtherAcres	0.005	TPY per AC	Per Year
Hogs	0.003	TPD per AC	Per Day
Cattle	0.002	TPD per head	Per Day
Poultry	0.01	TPD per head	Per Day
Corn Harvest Loads	Corn acres x yield ÷ BU per load		Per Year
Bean Harvest Loads	Bean acres x yield ÷ BU per load		Per Year

The number of trips, as computed from the actual population and land use parameters for each county was then divided into the matching total VMT amounts to obtain "*VMT of travel taking place on county roads per rural trip*". Rural trips also include VMTs made upon primary highways, but those miles of travel are 'off' the secondary road system.

The VMTs per trip results initially appeared too diverse to be credible. At the low end, there were counties exhibiting only 4.5 miles of secondary road travel per trip while others had nearly 12.0. Discussions with representative county's engineers and field trips, however, confirmed that such a large range does exist. In low VMT per trip counties like Monroe and Clarke, county routes don't connect to form convenient cross-county corridors, so travelers migrate to the primary road system highways as soon as they can. While many of the low VMT per trip jurisdictions had low population densities, geography also played a role – Dubuque County is well populated, but the rough terrain in the eastern sections pushes travelers to use primary roads. On the other end, counties with high VMT to trip ratios typically have extended corridors that encourage traffic to 'stay on county' and/or offer bypass routes that attract primary or urban traffic onto county roads. Webster, Cerro Gordo, Buena Vista and Clay counties are representative of the higher VMT group. Clay County provides an especially clear-cut example: Both US 71 and 18 traffic prefers to follow county routes that bypass downtown Spencer, the county roads that ring Spencer function as if they were actually urban perimeter collector/arterials, and recreational traffic to/from the Iowa Great Lakes makes heavy use of county pavements in the NW part of that county.

To better account for these effects, positive or negative, non-rural overhead VMT amounts were established for counties where it appeared warranted. This brought the range of VMT per local trip down and resulted in more congruency between counties of like size, population and land use.

After establishing the county VMT per trip and non-rural overheads, one can estimate future total VMT by multiplying the trip factors times time adjusted values of the demographic / land-use / ag-production data, summing the trips per day and multiplying by the VMT factor. The total can then be allocated to the four surface classes in proportion to the that existing at the start, (after any adjustments for changes in system configuration), and divided by the surface mileages to obtain VPD numbers. Factors representing the number of heavy truck / implement of husbandry movements from each source, can next be used to estimate the total count and percent of traffic stream for trucks.

Average ESALs per Truck

Wanting to use fundamentals to the extent possible, the TR-608 team chose to include projected truck and implement of husbandry impacts into models used to predict annual changes in hard surface and paved road conditions. Since DOT base records don't record vehicle type classifications for county roads, data from low-volume rural primary highways was analyzed as a proxy therefor. For this, data was acquired from the DOT Iowa on Hwy 92 across southwest Iowa. The results of 336 counts were averaged to determine a typical breakdown of traffic per 1000 vehicles. This data was then used to compute a representative ESALs per Truck value, as shown in Table 16.

Table 16: Rural highway traffic mix

Highway 92 SW Iowa Vehicle dist.	Average Count per Thousand veh.	ESALS per Truck (FHWA)	ESALS per day
MOTORCYCLE	10.91		
AUTOMOBILE	632.42		
PICKUP	238.64		
BUS	6.20	0.2	1.2394
SU2AXLE	25.99	0.3	7.7979
SU3AXLE	9.73	0.5	4.8640
SU4AXLE	1.43	0.7	0.9987
ST4AXLE	17.07	1.1	18.7805
ST5AXLE	51.95	1.35	70.1258
ST6AXLE	3.91	1.4	5.4747
MT5AXLE	0.55	0.8	0.4388
MT6AXLE	0.06	1.1	0.0659
MT7AXLE	1.00	1.4	1.3985

Motorcycles	10.91	
Cars/Pickups	871.06	
Truck & Bus	**117.88**	111.1842
Heavy Imp. of Husbandry mult.		1.115
Final ESALS / day (both lanes)		**123.9704**

Final ESALS / Lane-day	61.9852
Final ESALS / Lane-year	22640.1
20 Year ESALs per Lane	452801.9

Average ESALs per truck	**1.051658**

The ESAL factors were taken from FHWA literature (see 6-TPE-ESALs in Appendix D) on the average ESALs per truck, including both loaded and unloaded movements, for each truck type. A "Heavy Imp. Of Husbandry" multiplier was applied to the raw truck results to provide some account for the effects of such vehicles. This value was selected by the principal investigator based on some preliminary estimating of the percentage of IOH vehicles in the traffic stream. This needs to be further refined at such time as actual research data becomes available.

Derivation of mathematical representation of deterioration curve

Out of a desire to base Trend Projection calculations on as realistic terms as possible, an effort was made to incorporate the concept of a pavement condition deterioration curve into the calculations. This proved somewhat challenging because the concept of a pavement condition deterioration curve concept, while widely accepted and discussed, isn't all that well defined or documented.

Once can easily find representations of a deterioration curves, along with representations of how a repair or improvement fully or partial restores condition, followed by the next interval of decline, as illustrated below, but very little in the way of specific numbers or formulas.

Figure 02 : Pavement Preservation concepts
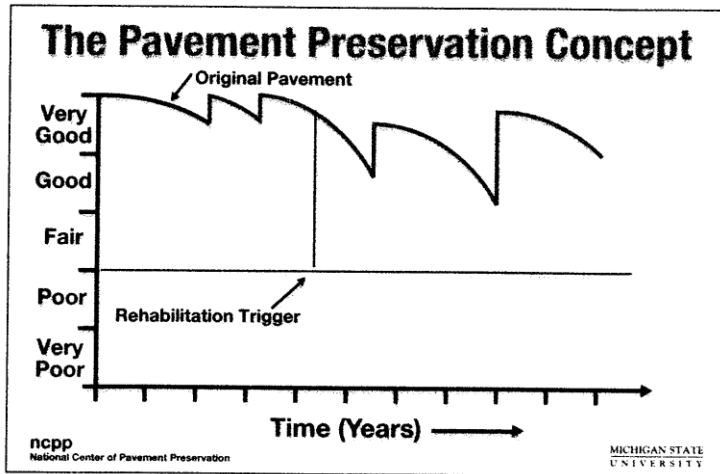
The diagram in Figure 02, which comes from the National Center for Pavement Preservation, University of Michigan, shows deterioration curves that accelerate with time, but its non-dimensional and the condition ranges appear educational rather than formally determined.

Figure 03 : Second Pavement Preservation concept
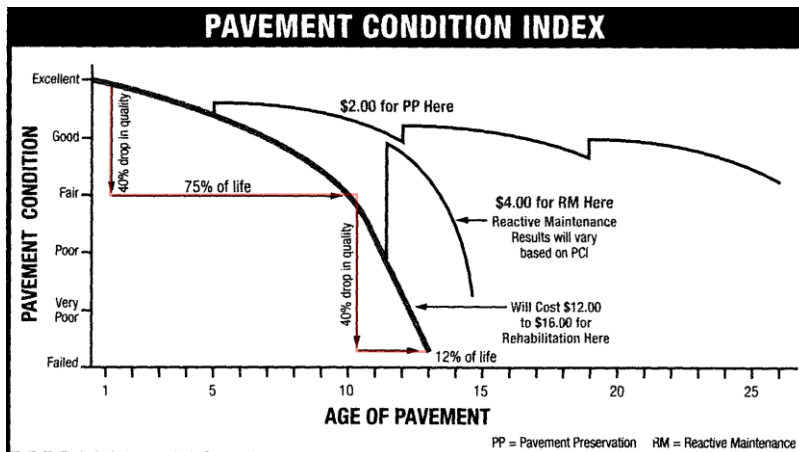
Another version, located in a brochure distributed by the International Slurry Surfacing Organization (ISSO), suggest clues as to the mathematical properties of the curve, going from 100% at the start, down to 60% after 75 percent of the lifetime has elapsed, an on to 20% residual condition after 87 percent of the lifetime.

Another diagram, of unknown origin, associates condition states and possible treatment options available.

Figure 04: Treatment recommendations at various stages of pavement aging.
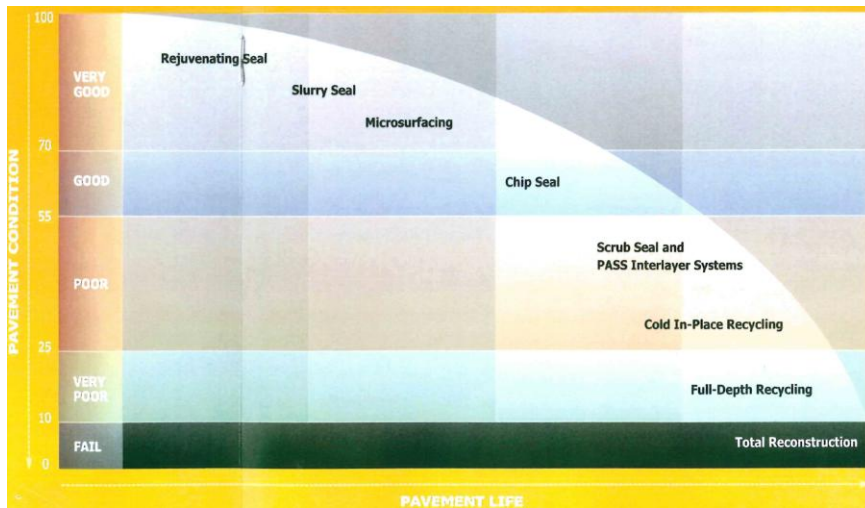
This diagram illustrates possible condition ranges, with implied linkages between lifetime points and degree of deterioration, but also appears somewhat arbitrary.

In exploring pavement conditions around the state, the principal investigator noted some additional issues that needed to be included and considered.   First, pavements don't just go out of service because their deterioration trajectory has reached a certain point; in fact, if a county is not able to repair them right away, they reach a point of maximum deterioration at around their halfway point, with the pace falling there after because there's no long enough good sections left to sustain the rate of condition loss.   This would call for a curve that starts out flat, has a steeper range in the mid-life of the asset and then flattens and gradually trends towards zero.   Also, it became apparent that determination of condition is not just time dependent.   A visit to Wayne County revealed that extra thickness pavements, subjected to less traffic than originally anticipated, can remain in good condition much longer than would be the case in a high traffic location. This reconfirmed that although pavements do experience a more or less fixed amount of weathering per year, the primary driver of how fast condition deteriorates is the number of ESALs experienced annually.

Based on those observations, it was concluded that pavement deterioration curves, as conventionally displayed, appear to represent the upper half of the inverse of a common mathematical curve known as the Sigmoid or Logistics function, which has the formula: $P(t) = 1 / (1 + e^{-t})$

Figure 05: Sigmoid function curve (Wikipedia : http://en.wikipedia.org/wiki/Logistic_curve)

Standard logistic sigmoid function
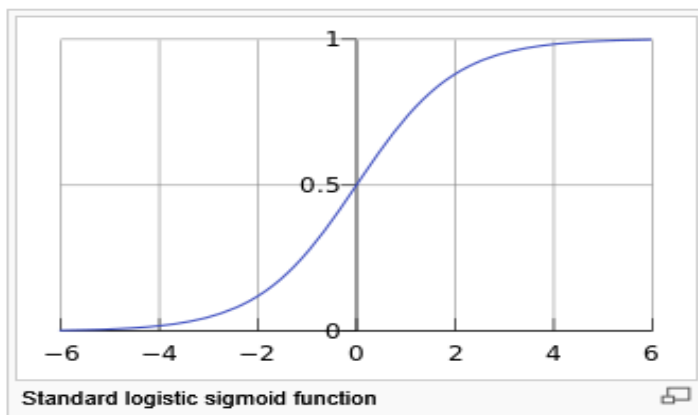
After working to fit a Sigmoid based curve to the data points available from the ISSO diagram (Figure 3 / p29), the following formula evolved for use in TR-608.

```
Public Function PCOND(SL As Double) As Double

    K = 0.197842440980155
    L = 2.14196125399413
    A = SL * K
    B = (A * L ^ A) - 5
    PCOND = 1 - (1 / (1 + Exp(-B)))

End Function
```

SL is a non-dimensional value representing elapsed Service Life, and ranges from 0 to 12 (with 10 the practical max.)

Figure 06 : Mathematically fitted deterioration curve
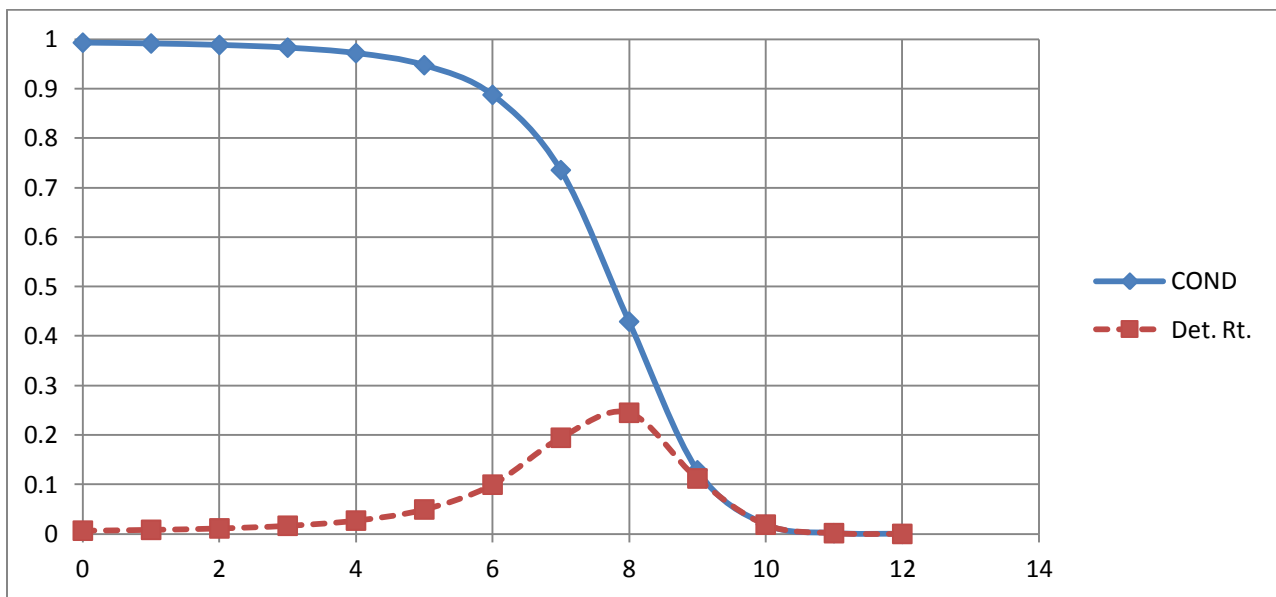
Deterioration is slow in the first third of the Service Life, becomes significant in the second third, and then finishes in the final period. The dashed curve illustrates that the rate of deterioration, the slope of the main curve, grows steadily until the 80 percent of Service Life point, after which it begins decreasing.

Experimentation with different options revealed that the best way to use the curve is to pick a point in the Service Life base and equate it to the point where enough ESALs capacity, (or TPM in the case of granular), have will have been consumed to warrant reconstruction. SL = 9.7 was found to produce results when treated as the point where all design serviceability has been used up. Some additional serviceability remains after 9.7, but condition will be at a low level.

Condition, in the context of the curve can mean any number of things, from IRI, to subjective condition assessment, to cost to restore. For TR-608, condition was considered to be a representation of how much it would cost to restore the road surface to original (near new) condition. The vertical distance from the Condition = 1 line was deemed as proportional to the cost. So, if the area of maximum deterioration were selected as the point where the road surface would require a full rebuild, the Terminal Service Condition would become 0.2 (0.8 below 1.0). Very Poor condition would then be defined as extending from TSC to the point where restoration costs were only one half the maximum: 0.6 (0.4 below 1.0) Poor would then likewise follow to 0.8 (0.2 below 1.0)

This approach resulted in the following condition ranges:

Table 17: Condition ranges defined for road surface deterioration curve   - with estimate 2011/12 sample cost figures

Condition range	Maximum	Minimum	SL value at Min.	Typical Treatment	Cost of Treatment
Excellent	1.0000	0.9875	2.25	Fog seal	$7,500
Very Good	0.9875	0.975	3.80	Sand seal	$15,000
Good	0.975	0.95	4.90	Seal coat	$30,000
OK	0.95	0.9	5.85	Slurry	$60,000
Fair	0.9	0.8	6.70	Thin Overlay	$115,000
Poor	0.8	0.6	7.50	Thk Overlay	$225,000
Very Poor	0.6	0.2	8.70	CIPR+Ovly	$450,000
Physical Failure	0.2	0.0	10.0	Repave	$900,000
	Condition index	Condition index	(Dimensionless values)		Per mile [Approx.]

This formulation of a deterioration curve, along with the adoption of a "powers of two" definition of condition ranges appears to have potential.   As a result, it was used in the Trend Projection Engine.   Further study and refinement would be beneficial.   The curve formula might be of use in evaluating pavement replace or rehabilitate tradeoffs in asset management type analyses.

Concept adopted to model road condition dynamics

At the outset of the TR-608 work, it was thought that pavement deterioration would be best modeled by establishing a starting condition, such as saying a county's paved miles collectively retained a capacity to sustain, say, 260,000 more ESALs before needing to be rebuilt, and then subtracting a fix amount per year, such as 26,000.   However, that approach tended to predict the complete failure of the pavements in a short time, which was not consistent with what can be observed in the field. So an annual proportional loss model was adopted.   This approach operates from the premise that as an asset deteriorates, there comes to be less and less of it that is still subject to further decay. When a pavement is new, for instance, the passage of 10,000 ESALs might cause, in non-dimensional illustrative terms, a five percent reduction in quality.   Since the road now retains only 95 percent of its original reserve capacity, another 10,000 ESALs will further reduce condition to 95% x (1.00 – 0.05) = 90.25%, instead of 95% - 5% = 90%. This mathematical difference leads the proportional loss model to asymptotically approach zero, while the direct deduction approach drops quickly to zero and stays there. The use of the proportional loss methodology produces results that are consistent with field observations and county engineer experience. But the Trend Projection Engine might benefit from further research in this area.

Formulation of bridge quantity, condition and aging model

In order to properly model the state of bridges over time, one needs a concept that can combine three key attributes, (length, width and sufficiency), afford application of annual aging, and accommodate both rehabilitation and replacement options.

Within TR-608, bridges were modeled as three dimensional entities based on LENGTH x WIDTH x SUFFICIENCY RATING. Thus a new 24 ft. x 80 ft structure was assigned an SFSR (Square feet x Sufficiency Rating points) value of 1920 x 100 = 192,000.   After the structure aged, its Sufficiency might drop to 66, leaving it with only 126,720 SFSR units.

Assuming that bridge deterioration is roughly linear, the annual loss of Sufficiency Rating points was modeled as (100 minus lowest serviceable Sufficiency) divided by estimated service lifetime. If the lifetime is 60 years and the terminal Sufficiency is 20, one would expect a loss of (100 – 20)/60 = 1.33 SR points per year for each structure.

If the bridges of any particular county have a combined total deck area of, say, 300,000 square feet, then one would expect that they collectively lose 1.33 * 300,000 = 400,000 SFSR units per year. To achieve long term sustainability, one would therefore need to replace or rehabilitate enough structures to replenish that loss.

System example.
To illustrate the SFSR concept and explain the theoretical scenario used in TR-608 to examine bridge replacement and rehabilitation options, let us define a simplified, imaginary county bridge situation as follows:

- Let it be assumed that the county has 180 structures, with an average lifetime of 60 years. Thus they would need to replace three per year to maintain a stable system in the long term.
- Let it be assumed that the minimum serviceable Sufficiency Rating tolerable is 20. If bridge deterioration is linear in nature and structure conditions are uniformly distributed, the collective average SR would be (100 + 20) /2 = 60.
- If the total square footage of all structures were 259,200 SF, the collective, system-wide SFSR total would be 259,200 x 60 = 15,552,000.
- And the annual loss of SFSR serviceability would be 259,200 x 1.33 = 345,600. This represents the amount of bridge 'utility' that needs to be annually replenished.

Replacement of a bridge was conceived of and modeled as follows.
Illustrated using a 'typical' structure 60 feet long by 24 feet wide, with a terminal SR of 20.

a) The deck area and remaining SFSR points must be deducted from the county total – to represent the fact that removal of the old structure necessarily destroys all remaining serviceability. This amounts to (60 x 24) x -20 = -28,800 SFSR.
b) The replacement deck area* would come in with a new SR of 100. So it would add (60 x 24) * 100 = 144,000 SFSR back into the system.
c) Taking a) and b) together, the net is (-28,800 + 144,000) = +115,200 SFSR. So replacing three such bridges in one year would restore 115,200 x 3 = 345,600 SFSR – mitigating the loss coming from annual aging.

   * Although the example given about illustrates, for clarity's sake, a one for one replacement of bridge deck area, it should be understood that most replacement work INCREASES bridge size, and therefore also expands the system totals. Hydraulic design considerations typically call for a new structure to be longer than the old one, often by a factor of around 1.25. (e.g. 80 ft → 100 ft.) Safety and traffic service considerations call for widening the structure, often by a factor of 1.44. (e.g. 24 ft → 34.6 ft). Combined, the lengthening and widening frequently increase deck area by a factor of 1.25 x 1.44 = 1.8. Thus replacing three equal sized bridges becomes the financial equivalent of reconstructing 5.4 of the original size structures.

Rehabilitation of a bridge was conceived of and modeled as follows.
Illustrated using a 'typical' structure 60 feet long by 24 feet wide, with a terminal SR of 65..

a) In the case of rehabilitation, the structure's residual Sufficiency Rating points are not lost. Instead, points are restored to return the structure to a better condition.

b) The rehabilitation would not likely restore the structure to 'new' condition, so the improvement can be modeled as returning the SR level back to 95. The net gain would be 95 – 65 = 30 SR points per square foot.

c) Multiplying by deck area, the net restoration of SFSR utility would be (60 x 24) x 30 = 43,200. Thus one would need to rehab eight (345,600 / 43,200), such structures in a year to make up for the annual aging loss.

Additional considerations and factors to be considered

This section addresses some additional issues that affect bridge system condition modeling:

- The decision of whether to restore system condition via rehabilitation or replacement is affected by numbers of eligible candidates. At any one time, there will only be a certain number of structures eligible for improvement. So if it takes eight rehabs to replenish annual lost SFSR points but only six are available, some of the SFSR point restoration must come from replacement. The reverse holds true as well.

- Rehabilitation can be the most financially efficient option, in that it does not require expending scarce dollars to expand deck area. But the number of candidates is often limited, and not every structure is amenable to being rehabilitated.

- A county's target average Sufficiency Rating dictates the typical terminal SR points at which replacement should be performed. For instance, if the goal is to maintain an average of 60, system wide, then the minimum must be (60 x 2) – 100 = 20. But the minimum associated with a target of 70 would need to be (70 x 2) – 100 = 40. And an average of 80 would dictate replacement when a structure's SR drops to 60. This suggests that an economic average SR level will lie between 60 and 75.

- Rehabilitation can cost less per square foot than replacement.

- Selection of rehab / replace candidates cannot be modeled just by choosing structures with the lowest SR points, since factors like functional classification, system membership, traffic counts and detour length all influence the decision. To best model the choices that county engineers and supervisors will therefore typically make, TR-608 chose to select candidates in Priority Point order. Priority points are an aggregate index of the aforementioned decision criteria annual computed by the Iowa DOT to help determine which structures are eligible for state bridge aid, and in what order.

Identification and modeling of feedbacks

An interesting aspect of road system operations is that actions taken (or not taken) change future circumstances. These feedbacks can accelerate or retard changes in costs, conditions and system configuration. The Trend Projection Engine identifies and includes a number of these effects:

a) Changes in system extent and configuration, i.e. a shift of miles between surface classes, affects future revenue allocations can change revenue distribution, alter Carry Costs, and shift traffic.

b) The number of trips made and the average length thereof may increase when road conditions decline: if conditions force vehicles to operate with lighter loads, it will take more movements to deliver the same quantity of material to a destination. Likewise, if a route deteriorates to the point that drivers must bypass it, they will of necessity end up traveling along longer pathways.

c) Bridge closures can force more and longer trips.

d) Upgrades transfer VMT, trucks and ESALs from one surface class to another. They also increase the carrying costs of affected road segments

e) A decline in roadway condition tends to increase the cost of vehicle operation per mile of travel, primarily by negatively impacting the average speed of travel – thereby increasing labor costs. Soft road surfaces can also cause an increase in fuel consumption per mile.

f) As traffic grows, delays in upgrading roadways, typically induced by lack of funds, leaves traffic exposed to higher accident rates than would prevail on improved corridors.

g) Changes in road condition affect Carrying Costs: a deteriorated road requires more maintenance and extend work per year than does a counterpart in better shape. Renewal and upgrade costs are also higher when conditions are down, as fewer remedial options are available to be employed.

h) An additional condition based feedback is that the more deteriorated a road is, the more susceptible to it becomes.

i) When bridges are replaced, safety and hydraulic considerations typically result in the new structure having around 80 percent more bridge deck area that the old one. In the long run, this creates an "as more bridges are replaced, the total amount of bridge need grows" effect.

j) Urban population growth eventually consumes rural acreage, reducing the number of farms and decreasing the potential agricultural productivity of the county affected

The Trend Projection Engine, as described in Part 3, includes computations designed to model all of the influences enumerated above.

Part 3 – Creation of Trend Projection Engine to estimate future needs

Parts 1 and 2 of this report outline how to identify current road system operational needs, along with what upgrades are warranted by contemporary traffic levels. The next step in telling the story of county roads is to identify future needs. In TR-608 this was accomplished by setting up a "Trend Projection Engine", (TPE), that would start from current conditions and estimate how things might turn out five, ten or fifteen years hence. Such an engine cannot assuredly predict the future; but it can produce pictures of potential outcomes that facilitate thinking about policies, basic trends, funding levels and road/bridge condition levels.

Structure
As implemented, the TPE is composed of twelve modules, each of which performs calculations designed to mimic the passage of one year's time with regard to basic travel demand drivers, funding, wear and tear, renewal, condition levels and feedbacks. It repeats the simulation steps fifteen times, saving the results of each annual cycle along the way. Each TPE projection is set up as a scenario, unique unto itself, which extrapolates from current starting conditions. To permit what-if explorations and examination of high-low-medium trends, it can generate and store data on up to three tracks per scenario. Each scenario can be for a) a single county, b) a group of counties or c) the entire state.

Set up
The TPE uses the latest compiled results from Parts 1 and 2 as the starting circumstances of each scenario. From there, a set of scenario definition screens allows the system operator to customize initial parameters as needed.

The main menu of the setup screens gives access to the following options:

- New Scenario – *Options for starting up*
    - Define New Scenario – *Set name, title, counties and tracks, then proceed to 'Edit Scenario' to define the initial circumstances, trends and attributes to be studied.*
    - Clone Scenario – *Copy a previously defined scenario so it can be altered and re-run.*

- Select Scenario – *Choose a previously defined scenario to inspect or run*

- Edit Scenario – *Options for customizing the base circumstances and trends – per track*
    - Enter / Edit Scenario Setup
        - Title / Counties / Tracks – *Define scenario, choose counties, set tracks*

- Road Revenue Estimate – *Define starting costs, upgrade costs, revenue growth factors, allocation of revenue between Carrying Costs and Upgrades, and establish a minimum level of Granular Road need coverage.*

  - Set Rural Economic Parameters – *Define basic travel drivers and characteristics*
    - Inflation and Efficiency – *Set cost inflation trends, accident cost factors and accident rates*
    - Population and Production – *Set population trends, agricultural production growth rates, agricultural -product unit values and their own rates of change.*
    - Vehicle Characteristics – *Set Vehicle physical and cost of operation figures.*

  - Set Traffic / Road Use parameters – *Review / set factors for estimating travel*
    - Trips / VMT / Trucks / ESALs – *Establish trip and truck factors.*
    - Road / Bridge Condition basis – *Assign initial conditions of granular, hard surface and paved routes, along with their life cycle modeling parameters. Set multipliers for feedback effects.*
    - Condition modeling factors – *Set bridge life cycle modeling parameters*

- Run Scenario – *Trigger a calculation or re-calculation of the scenario*

- View Results – *Open the results selection and view screen (See Part 4 of this report)*

Modules

The basic modules of the TPE each consist of a set of calculations that use results from prior modules, (and previous years), to develop 'next-year' outcomes for the items processed within their scope. The calculations were defined in EXCEL worksheets, and then translated into Adobe ColdFusion and SQL code for automated operation. The inputs, assumptions, calculations and results of each module are outlined in the following sections. The spreadsheet templates are available for inspection in the TR-608 CD.

[Coincident to the primary mission of determining road system needs, this project was also a test of whether or not a data and computation intensive simulation tool would work on today's fairly advanced desktop computers. It has turned out that it's best to run TR-608 scenario calculations on a multi-threaded, stand-alone server. Running a full state analysis of two tracks takes 3 to 4 hours to complete.]

Special note: In the following sections, readers will occasionally see references to Year-zero (also Year-0) and Year-x. These two items are related but different:

- Year-zero items are typically used to store 'start of scenario' values that similar values from later years in the modeling sequence can be compared to. For instance, the TPE stores Year-zero VPD figures to help compute future adjustment ratios for traffic segment AADT figures. If the Y-Zero value for Pavement was, say, 575 but has risen to 620 in a future year. The ratio becomes 1.078. So if a paved segment had an AADT of 760 in Year-zero, it would now be treated as having one of 1.078 x 760 = 819.
- Year- x values reference the value a parameter has in any given Year, where x can be 0 through 15.

<u>Module overviews.</u>

The twelve modules, hereinafter detailed, start from population and agri-business basics, derive traffic loads, estimate revenue, estimate costs, account for upgrades, determine how well costs cover needs, use those results to estimate condition outcomes, and then use the condition results to determine feedbacks that will affect following year computations.

1. <u>Population and land use / value of rural production</u> [Tab : 1-PopLandUseAgEV in TPE spreadsheet]
   Determines basic drivers of transportation: population and households, land use and agricultural production, value of the rural economy.

   1. <u>Population and dwellings.</u>
      Estimates current / future population, farmsteads and rural residences – to serve as the basis of trip projections.   Uses county specific data derived from US Census and USDA NASS, (National Agricultural Statistics Service).
      a. Does not produce feedbacks
      b. Is not affected by feedbacks
      c. Raw data used
         Urban pop. , rural pop., people per dwelling, number of farmsteads
      d. Factors used
         Growth/decline rates for populations and farmsteads
      e. Results produced
         i. Estimated population in Year 'x' – urban and rural
         ii. Estimated rural dwellings in Year 'x' – total, farmsteads, and residences
      f. Intended applications
         i. Use to compute trips and traffic in Module 3 - TripsVMTTrksESALs
         ii. Provide basic economic drivers to be compared to road results

      Caveat: Although rural population can also change when cities annex land in high growth areas of the state, this is not directly accounted for in this model.   See also Module 12 – Growth Impacts.

   2. <u>Land use and agricultural production</u>
      Develops basic estimates of future farm activity and production levels.   Uses base data from USDA NASS and applies growth factors suggested by ag-representatives at the TR-608 agri-business input solicitation meetings held in 2009 and 2010.
      a. Does not produce feedbacks
      b. Is not affected by feedbacks
      c. Raw data used
         Acres of agricultural land use, livestock numbers, base corn/bean yields and bushels per truck
      d. Factors used
         Corn/bean yield growth rates, livestock growth rates, truck capacity growth rates
      e. Results produced
         i. Corn and bean harvest bushels and loads in Year 'x'
         ii. Hogs, cattle and poultry numbers in Year 'x'
      f. Intended applications
         i. Use to compute trips and traffic in Section 3
         ii. Provide basic economic drivers to be compared to road results

Caveat: The model assumes that acreage splits between corn and beans will remain relatively fixed within the 15 year (maximum) timespan studied via Trend Projection Engine calculations. Also – urban growth could reduce total acres of ag land and livestock numbers, but is not explicitly accounted for herein.

3. Value produced by the Rural Economy

   Estimates the economic value of goods and services produced by Iowa's rural citizens. Provides a basis against which vehicle operations costs, crashes, service interruptions and road costs can be compared. Uses $Dollar per unit conversion factors developed through analysis/estimation by the TR-608 principal investigator.

   a. Does not produce feedbacks
   b. Is not affected by feedbacks
   c. Raw data used

      Uses population/resident data from Section 1A; uses land use and livestock results from Section 1B.

   d. Factors used

      General inflation; growth of corn, bean and livestock market values

   e. Results produced

      i. $Dollar amounts of off-farm earnings – for Year 'x'
      ii. $Dollar amounts of grain and livestock production – for Year 'x'
      iii. $Total estimated value of rural economy – for Year 'x'

   f. Intended application

      Provides a base figure for evaluation of relative magnitudes of transportation related expenses.

2. Road agency revenues

   This module produces estimates of future road revenues likely to become available and then allocates portions thereof to Roads (Earth, Granular, Hard Sfc, Paved) and Bridges (Earth, Granular, Hard Sfc, Paved), based upon the pattern of past expenditures, adjusted for changes in system configuration.

   1. Gross estimate of future revenues

      Starting with recent actual revenues, the system estimates future amounts in nine categories.   The base revenue numbers will be recompiled annually.
      a. Does not produce feedbacks
      b. Is not affected by feedbacks
      c. Raw data used

         Base values for Local Property + TIF + LOST receipts, Secondary Road fund RUTF receipts, Secondary Road fund Time-21 receipts, Transfer of FM road jurisdiction in towns under 500 population monies, Farm to market fund revenues, Federal Aid for STP and bridges, Other revenues (e.g. RISE, State bridge monies, Transportation safety fund, and others), and a reserve category for 'New' sources, if/when determined.
      d. Factors used
         i. Individual growth factors for each item listed above in c.
         ii. A split between money to be applied to cover carrying costs versus money to be applied for upgrades
      e. Results produced
         i. Total estimated revenue for year 'x'
         ii. Allocations thereof to cover Carrying Cost and Upgrade Cost needs
      f. Intended application

         To generate revenue numbers that can be compared to needs in Modules 5 and 6.

   2. Projected allocation of revenues

      Allocates total estimated Carrying Cost revenues to Roads and Bridges by the four surface class categories, (Earth, Granular, Hard Sfc, Paved).   This prepares a set of eight revenue numbers that can be applied to eight basic categories of Carry Cost need in Module 5.
      a. Does not produce feedbacks
      b. Responds to feedbacks

         This module starts out allocating revenues in accordance with recent past expenditure patterns. That works for as long as the system's basic extent, configuration and mix of surfaces remain the same. When they do change, Module 11 calculates proportionate adjustment factors that get applied to adjust the revenue allocations.
      c. Raw data used
         i. Total Carrying Cost allotment from Gross estimate of future revenues
      d. Factors used
         i. Recent expenditure breakdowns: Roads & Bridges by Surface classes
         ii. System upgrade/downgrade adjustment factors from Module 11 (feedbacks)
      e. Results produced
      f. Road & Bridge allocations for Year 'x', broken down by the four surface classes of Earth, Granular, Hard Surfaced and Paved.
      g. Intended use

         Allocated to cover Operations, Maintenance, Extend and Renew Carry cost in Module 5 - Carrying Costs (of existing system).

3. Derivation of trips, VMT, VPD, trucks and ESALs

Uses estimated population, dwelling, land use and agricultural production as basis for forecasting trips, VMT, VPD, Trucks and ESALs in any given year. Links traffic to land use, using the trip factors and Secondary Road VMT per trip information developed as described in Part 2.

    1. Land use → Traffic generation model

Uses basic economic drivers developed in Module 1-PopLandUseAgEV to predict likely future trip counts and daily VMT. Converts the quantity of personal and business activity into transportation demand numbers.

        a. Does not produce feedbacks
        b. Responds to feedbacks

        This sub-module is impacted by both direct and indirect feedback influences

            i. Road conditions, as determined at start and adjusted by Module 11 factors in future years affect how many trips are made and the county road VMT per trip.
            ii. Upgrades made in Module 6 - Upgrade NeedsCalcs lead to changes in the mix of surface miles, changing VMT allocation and dependent parameters
            iii. Bridge closures can increase the length of trips flowing around the structure taken out of service

        c. Raw data used

        This Module uses population, land use and agricultural production numbers generated in Module 1.

        d. Factors used

            i. Trip factors – trips per day or year per units our counts of basic driver parameters in iii above.
            ii. Feedback factors from Module 11: Trips, VMT adjustment for road conditions, VMT adjustment to reflect bridge closures
            iii. County miles per trip and non-rural overhead for each county

        e. Results produced

            i. Trips per day – Total and for each source
            ii. VMT – Base and final adjusted values

        f. Intended use

            i. Used in following Section b. to determine VPDs on each road surface
            ii. Used to calculated cost of vehicle operation in Module 4- RoadUserCosts
            iii. Used to calculate accident numbers and costs in Module 4- RoadUserCosts

    2. VMT Distribution and determination of average VPDs

Allocates the projected total VMT to the four surface classes, then determines associated VPDs. Uses VMT distribution factors compiled from the latest DOT traffic county data; divides each surface class' VMT, (Earth, Granular, Hard Surface and Paved) by the matching mileage to get Vehicles Per Day, (VPD), numbers.

        a. Produces a 'forward' feedback

        The VPD numbers generated in this Section get divided by Year-zero VPD's to generation factors that can be applied to individual segment AADT values in Module 6 - Upgrade Needs

            i. Need to save Year-zero VPD's for use in this annual adjustment.

        b. Responds to feedbacks

            i. VMT Distribution factors get adjusted in Module 10, Step 9

ii. Surface miles after upgrades – adjusted in Module 10, Step 1

c. Raw data used

Uses total final VMT figure from previous section - Land use → Traffic generation model

d. Factors used

i. Annually adjusted VMT distribution factors for Earth, Granular, Hard Sfc and Paved road classes.

e. Results produced

i. Daily VMT figures for E, G, H & P road classes

a. Store Year-zero as base for use figuring future split adjustments

ii. Daily VPD figures for E, G, H & P road classes

a. Store Year-zero values for use in Upgrade Need analysis

f. Intended use

To supply estimated future traffic loads in VMT and VPD units. The next two sections use these results to estimate trucks and ESAL impacts. The traffic and ESAL data get applied in road surface aging calculations in Module 8 – Road Condition analysis.

3. Truck trips - total and as percent of traffic

Estimates how many trips involve truck movements, to determine basis of ESALs. Establishes projected percent truck included in traffic flows.

a. Does not produce feedbacks

b. Responds to feedbacks – indirect, via changes in VPD

c. Raw data used

i. Uses the VPD numbers generated in previous Section

d. Factors used

i. Truck trip factors for each basic economic driver: the estimated ratio of trucks, and agricultural production vehicles, originating from each source.

e. Calculation method

i. Multiply E, G, H & P VPD figures times Truck Trip factors

f. Results produced

i. Estimated daily truck trips generated by each basic economic driver

ii. Total truck trips

iii. Percentage of trucks (Total trucks   Total daily trips)

g. Intended use

For analysis and to generate ESAL estimates.

4. ESAL impacts of trucks and implements of husbandry

Estimates ESALs generated by each potential source, then converts the total to quantity per lane per year.

a. Does not produce feedbacks

b. Responds to feedbacks – indirect via changes in traffic

c. Raw data used

i. Truck trip values from previous section

d. Factors used

i. ESALs per truck movement.   Obtained from FHWA; represents a mix of full, partial load, and empty runs for trucks originating from each source.   Based on primary expected

type of truck expected to operate from the source – as estimated by Principal Investigator.

  ii. Implement of husbandry vehicle ratios for E, G, H & P surface classes. Estimates how much of 'truck' traffic is actually IOH.

    a. Annual growth rate of IOH ratios.

  iii. Implement of husbandry impact magnifiers for E, G, H & P surface classes. Factors that project how much more impact an IOH will have on a road than a truck.

 e. Calculations

  i. Compute factors to represent combined impacts of trucks and IOH vehicles taken together.

  ii. Calculate ESALs produced by trucks alone for each basic trip source

  iii. Sum to get total ESALS and then divide by truck count to get countywide average ESALs per truck

  iv. Computer final ESALs per lane per year for each surface class.

   ESALS / Ln-Yr =((VPD x %Trks x ESALS/trk) ÷ 2) * 365 * IOH adjustment factor

 f. Results produced

  Returns total ESALs per year per lane of the Earth, Granular, Hard Surface and Paved surface classes.

 g. Intended use

  Earth and Granular ESALs are informational.   Hard Surface and Paved ESALS are used in Module 8 - Road Condition Analysis, in estimating pavement aging.

4. Road user costs

Predicts approximate road users costs from four sources.   The goal is to estimate what it costs to operate vehicles upon the road system and enable cross comparison of such expenses to the matching costs of furnishing the roads and bridges.

 1. Cost of Vehicle Operation

  Estimates what vehicle operators/owners collectively expend to purchase, maintain, operate, store, fuel and insure their units.   Omits cost of fuel tax, registration and licensing – as those are contained within the road revenues estimated in Module 2 - RoadRevenue.   A slight feedback is presumed: if road conditions decline, the cost of vehicle operation will increase on a per mile basis, and vice versa.   This is because road conditions affect the amount of fuel needed to travel a mile and the average speed of travel.

  a. Does not produce feedbacks

  b. Responds to feedbacks

   i. Changes in road condition inversely affect cost of vehicle operation.

   ii. Changes in surface miles and total VMT affect cost totals

  c. Raw data used

   i. Earth, Granular, Hard surface and Paved VMTs – from Module 3B - VMT distribution to EGHP --> VPD

   ii. Percent Trucks – from Module 3C - Trucks - count and percent of traffic

   iii. Raw inflation factors for CPI, Labor and Fuel

   iv. Estimated cost per mile to operate Autos, Trucks and IOH vehicles on E, G, H & P surfaces in Year-zero

  d. Factors used

      i.   Portion of truck traffic count attributable to IOH vehicles for E,G,H & P

      ii.   Surface condition feedback multipliers for G, H, and P surfaces – from Module 10b - RoadSurfaceCondtionResults

  e. Calculations

      i.   Divide VMT for each surface into Auto, Truck and IOH components

      ii.   Multiply by associated Year-zero per mile rates to get base costs per E, G, H & P

      iii.   Multiply each base cost by condition feedback factor and inflation factor

  f. Results produced

      i.   Costs for each class of vehicle

      ii.   Costs for each surface class

      iii.   Total operating cost for all vehicles and surfaces

  g. Intended use

      i.   For comparative analysis – to rural economy and/or to other costs

      ii.   For contrast with cost of providing the roads to operate on

2. <u>Cost of impaired or interrupted road service.</u>

This item pertains primarily to winter road use, but can also associate user costs to how fast a road department can restore service after floods, blow ups or failures.   Two levels of compromised service are modeled: a) Impaired use – where traffic can still move but at a reduced speed, with load restrictions and extra fuel consumption, and b) Interrupted use – where the road becomes temporarily unavailable for use, forcing extra distance detours and land-side losses, such as livestock health problems or inability to get product to market.

What-if analysis regarding these costs can be performed as follows: One could model a reduction in 'keep the road open' service as a reduction in Roadway Operations costs – with a commensurate increase in these costs. Or one could postulate that increased Operations expenditures would decrease these costs.

Because land-side operations disruption, inventory and compensating capital investments, that might be needed by the private sector if road usability were to degrade, cannot be precisely determined at this time, TR-608 models them as extra costs derived from the cost of vehicle operation totals developed in the previous section.

  a. Does not produce feedbacks

  b. Responds to feedbacks

      i.   Affected somewhat by road conditions

  c. Raw data used

      i.   Total cost of vehicle operations on each surface class – brought forward from previous section.

      ii.   Estimated days closed or impaired, per year, for each surface class

  d. Factors used

      i.   Degree of impact factors for each road surface class - for both Impaired use and Interrupted use of roads

      ii.   Feedback multipliers – from Module 10b

  e. Calculations

      i.   Compute portion of year impaired or close: e.g 60 days/ yr = 0.1666 Year

ii. Factor by impact factor: e.g. 0.1666 x 0.1 = 0.01666

iii. Adjust by feedback factor. e.g 0.01666 x 1.003 = 0.01671 → 1.01671

iv. Multiply total cost per year by final factor.

    f. Results produced

        i. Rough estimate of costs incurred by private sector and land-side operations when road availability is degraded.

    g. Intended use

    For use in global costs analysis and for comparison to Operations costs

3. Cost of crashes

Crashes burden society and individual travelers with extra costs: vehicle repair, medical treatment, lost time and sales, loss of cargo, and the disruptions inherent in fatalities. All parties involved in transportation: road agencies, drivers, vehicle manufacturers, insurance companies and law enforcement do what they can to minimize this scourge. But, ultimately, mishaps do happen.

This section estimates the number and cost of crashes per year on each of the four surface classes. These numbers can then be compared to the upgrade need figures development in Module 6 - Upgrade NeedsCalcs.

    a. Does not produce feedbacks

    b. Responds to feedbacks

    Accident numbers will fall when roads are upgraded and will increase with traffic growth

    c. Raw data used

        i. Total VMT per year for each surface class, per year – from Module 3 - TripsVMTTrksESALs

        ii. Base cost per accident type (Property Damage, Personal Injury, Fatality) on each surface class – per incident

    d. Factors used

        i. Accident rates, per 100 Million VMT for each type of accident on each surface class. (Obtained from InTrans and Iowa DOT)

        ii. Accident cost inflation rate

    e. Calculations

    For each combination of accident type and surface class

        i. Multiply VMT x rate per hundred million VMT to get accident count

        ii. Multiply count by cost per incident, then by inflation factor

    f. Results produced

        i. Twelve individual accident totals – for (PD, PI and FT acc.) x (E,G,H & P surfaces)

        ii. Total annual accident costs

    g. Intended use

    For general costs comparison and analysis. For contrast with Upgrade costs, since changing to a higher surface class can reduce the accident rate on the miles affected.

5. Road and bridge carrying costs

Future carrying costs can be projected from the most recently compiled figures developed in Part 1 of this report. The results computed herein get compared to revenues in the next Module No. 6 - Upgrade NeedsCalcs,

to determine funding adequacy. In turn, funding adequacy is use in Modules 7(Road condition analysis) and 9 (Bridge condition analysis)

The calculations needed to estimate future Carrying cost needs involve a fair amount of detail, as multiple influences must all be considered together.

1. <u>Future inflation (relative to Year-zero)</u>
   Because Carrying Costs are broken into Operations. Maintenance, Extend and Renew categories, the model computes matching inflation factors for each category.
   a. Does not produce feedbacks
   b. Responds to feedbacks - none
   c. Raw data used - none
   d. Factors used
      i. Inflation rates: CPI, Labor, Diesel fuel and Construction cost
      ii. Labor inflation rate adjustors: a) for recognizing the beneficial effects of efficiency gains and b) for recognizing the dis-efficiencies arising as new regulatory obligations come into existence.   Labor multiplier = Labor base, reduced by efficiency gains, but increased by regulatory impacts.
      iii. Multipliers for combining basic inflation items to produce values appropriate to Operations, Maintenance, Extend and Renew cost categories.
   e. Calculations
      Compute Year-x values for each basis inflation component, then combined them into O, M, E and R values.
   f. Results produced
      Four inflation factors to be applied to Operations, Maintenance, Extend and Renew costs.
   g. Intended use
      To be applied in determining future carrying costs in next two sections; plus the Renew factor will be applied to Upgrade costs in Module 6

2. <u>Road Carrying Costs</u>
   Future road carrying costs are determined by applying a number of different factors to the Year-zero costs grid determined in Part 1.
   a. Does not produce feedbacks
   b. Responds to feedbacks
      i. Changes in road condition cause inverse adjustments in Maintenance, Extend and Renew costs.
      ii. Changes in surface type mileages can increase costs for one surface class while decreasing it in another.
   c. Raw data used
      Uses the sixteen Road cost categories developed in Part 1.   O, M, E, R cost types x E, G, H & P surfaces – the eight year, inflation adjusted, average expenditures per year. Also current Year-x miles for each surface class.

   d. Factors used
      i. Sixteen Actual Costs → Carrying costs conversion factors determined in Part 1
      ii. Nine Road condition feedback factors – for G, H & P x M, E, R

   iii. Four mileage change factors to be applied to E, G, H & P costs

   iv. Level of service cost adjust factor (relates to impaired / interrupted road use costs figure in Module 4)

  e. Calculations

   i. Multiply each base cost by its associated Part 1 Actual Cost → Carry cost conversion factor.

   ii. Adjust for inflation.

    a. Apply Operating cost inflate factor to Operating costs under E, G, H & P surface classes.

    b. Do likewise for Maintenance, Extend and Renew

   iii. Adjust for changes in surface class mileages

    a. Apply Earth miles adjustment to O, M, E & R costs of Earth Roads

    b. Do likewise for Granular, Hard surface and Paved surface classes

   iv. Apply Service Level cost adjust factor to Operations costs of Granular, Hard Surface and Paved .

   v. Apply road condition adjustment factors for G, H & P x Maintenance, Extend and Renew cost items.

  f. Results produced

   i. Estimated total Year-x Road costs: for E, G, H & P surfaces by O, M, E & P cost categories

   ii. Total annual costs for roads by surface class in overall

   iii. Estimated Year-x per-mile costs for each surface class

  g. Intended use

  Module 7 compares costs to revenues to determine how well the funding fulfills the needs. The other results generated herein are available for comparative analysis.

3. <u>Bridge Carrying Costs</u>

 Future bridge carrying costs are determined by applying a number of different factors to the Year-zero costs grid determined in Part 1

  a. Does not produce feedbacks

  b. Responds to feedbacks - none

  c. Raw data used

  Uses the sixteen Bridge cost categories developed in Part 1.   O, M, E, R cost types x E, G, H & P surfaces – the eight year, inflation adjusted, average expenditures per year. Also current Year-x miles for each surface class.

  d. Factors used

   i. Sixteen Actual Costs → Carrying costs conversion factors determined in Part 1

   ii. Four bridge deck area change factors to be applied to E, G, H & P costs – from Module 11

  e. Calculations

   i. Multiply each base cost by its associated Part 1 Actual Cost → Carry cost conversion factor.

   ii. Adjust for inflation.

    a. Apply Operating cost inflate factor to Operating costs under E, G, H & P surface classes.

    b. Do likewise for Maintenance, Extend and Renew

   iii. Adjust for changes in surface class bridge deck areas

        a. Apply Earth BDA adjustment to O, M, E & R costs of Earth Roads

        b. Do likewise for Granular, Hard surface and Paved surface classes

f. Results produced

        i. Estimated total Year-x Bridge costs: for E, G, H & P surfaces by O, M, E & P cost categories

        ii. Total annual bridge costs for roads by surface class in overall

        iii. Estimated Year-x per-mile bridge costs for each surface class

g. Intended use

Module 7 compares costs to revenues to determine how well the funding fulfills the needs. The other results generated herein are available for comparative analysis.

6. <u>Upgrade needs determination (for roads)</u>

The analysis performed in this module identifies, prioritizes, and costs out road upgrade needs – following the Upgrade needs determination protocols developed in Part 1. The results provide information on future year upgrade needs and allow Module 7 to model the selection and improvement of critical road segments, subject to available funding.

1. <u>Compute Year-x segment design level scores</u>

All road segments' traffic design levels must be re-determined in each annual cycle to account for traffic count changes brought about by changes in basic economic drivers, changes in surface class mix, changes in road condition and the closure of bridges.

    a. The new $Traffic_{DL}$ scores are developed by multiplying each segment's Year-zero AADT by the VPD factors calculated and saved in Module 3, then checking to see what Traffic Design Level now fits. Most segments won't change to a new TDL – but there will always be a few that cross up or down to a new level, changing the mix of need. This calculation processes roughly 150,000 records in each annual cycle.

Physical design level scores are not recomputed, as Module 7 can simply assign a new $Physical_{DL}$ to any segment marked as upgraded – in lieu of needing a recalculation process.

2. <u>Compute upgrade priority and cost for each eligible segment</u>

After all segments have had their Traffic Design levels updated, this section identifies all where the $Traffic_{DL}$ is at least two steps higher than the current $Physical_{DL}$. These segments become upgrade candidates, with priority indexes and inflation adjusted cost-to-accomplish figures. Module 7 will select and mark some as upgraded - depending on how much upgrade funding has been allocated.

3. <u>Tally upgrade needs and save</u>

This section takes the upgrade eligible segments and tallies the results: how many miles need upgrade at what cost. The tally is be level of urgency: a)TDL-PDL = 2 (Non-priority), b) TDL-PDL = 3 (Priority) and c) TDL-PDL >= 4 (Urgent). A future need is to redo this section to capture more detail.

While Upgrade needs exist, and are modeled in Module 6, they are not a major area of expenditure. As a rough generalization, it appears to the research team that counties spend, on average, about four (4) percent of secondary roads annual outlays on Upgrades. Not all of this is for Upgrade Needs as they are defined in this report. Some goes to pave a new mile here or there to give access to a new plant or terminal – fulfilling an economic development purpose instead of a traffic convenience and safety function. The model operates as if

ALL upgrade dollars go to addressing traffic driven upgrade needs, and doesn't model the economic development projects. It would be desirable to add in consideration of the latter but, as least for now, that is beyond the sophistication of the Trend Projection Engine.

(Another potential source of upgrade need is adoption of higher design guidelines for any given level of traffic. For instance, if design aids for roads carrying over 1500 VPD, were changed to typically require paved shoulders, it would create a global upgrade need for all such routes.)

But design guides are expected to remain stable, the county road network is nearly complete, and it is being managed in a preservation mode rather than an expansion mode. So, upgrade needs should remain relatively static in the immediate future.

7. <u>Revenue vs. Need analysis</u>
   This module performs a revenue allocation process to determine, for any given year, whether or not the funding is adequate to fulfill the current Carrying Cost needs. It marks each cost type successfully covered as 100% funded; if funding runs low or out before all costs are covered, the Extend and Renew categories may end up with only partial or zero coverage. The results of this analysis are used in Module 8 (Road Condition Analysis) and Module 9 (Bridge condition analysis). Road upgrade candidate selection and funding is also modeled.

   1. <u>Initial total revenue vs. total need comparison</u>
      Although not a likely outcome in real circumstances, there exists the possibility that a Trend Projection Engine scenario modeling very aggressive funding could show more money available to cover Carrying Costs than actually needed. This section exists to deal with such an outcome. In that situation, the model will split the excess into two sums: the first will go towards providing additional Carry Cost coverage -- above 100% - which will simulate investing extra to improve the system's quality/condition; the second sum will go towards additional upgrades. In short: part of any excess goes to system wide condition improvement and the rest towards traffic safety/convenience upgrades.
      a. Does not produce feedbacks
      b. Responds to feedbacks - none
      c. Raw data used
         i. Total projected revenues – from Module 2 – for each surface class
         ii. Total estimated carrying costs – from Module 6 – for each surface class
      d. Factors used
         i. Percent of Excess to go to Upgrades – a factor to split any excess between global system condition improvements and upgrading specific deficient segments. Set to 0.50 in original study but could be changed.
      e. Calculations
         i. For each surface class, E, G, H & P, check to see if Revenue exceeds Carrying Cost.
         ii. If so, multiply the excess by the Pct for Upgrades factor and deduct that amount from the Surface Class' revenue – leaving the revenue reduced but still more than 100% of need.
         iii. Total the amounts of excess funding determined for Upgrades
      f. Results produced
         i. Produces adjusted Carry Cost revenue amounts

<blockquote>

    ii.   Produces an extra amount of Upgrade funding to be added to the base sum from Module 2 -- Road Revenues.

g. Intended use
    i.   Carry Cost figures get allocated to cover costs in the next section
    ii.   Excess for Upgrade goes to Upgrade Needs coverage section in this Module.

</blockquote>

2. <u>Revenue allocations for Roads – Carrying costs</u>

The allocation of revenue is modeled as a four step process, where Operations gets first chance at full funding, then Maintenance, then Extend and finally Renewal.   If funding runs short, this approach 'starves' Renewal work first, then Extend, and, last, Maintenance.   It isn't a perfect simulation of how counties respond to funding shortfalls, but was felt to be an adequate starting model.   It should be replaced with a more sophisticated algorithm when time and research funds permit.

a. Does not produce feedbacks

b. Responds to feedbacks -- None

c. Raw data used
    i.   Uses adjusted final road revenues from previous Section a. of this Module (7)
    ii.   Brings forward the O, M, E & R costs for each surface class – from Module 5

d. Factors used

Because granular roads 'show' the lack of adequate reinvestment very quickly, it is a fact of life in secondary road operations that public distress will force a department to pull back from taking care of more valuable and longer lived assets to keep granular routes open.   To model this sociological/political phenomenon, TR-608 designates minimum levels of granular cost coverage that the model tries to maintain by taking revenue away from pavements.   If granular needs extra support, the model will take up to 2/3 of Paved Road extend revenue and up to 1/2 of Paved road Renewal dollars to attempt to reach the minimum Granular coverage percentage targets.

Factor values:
    i.   Target minimums for coverage of Extend and Renew. The initial targets were set at 75% of Granular Extend needs and 65% of Granular Renewal needs.
    ii.   Allowable 'take from Paved Road revenues: 2/3 of Paved Extend and 1/2 of Paved Renew.

This is a somewhat complicated item to model, but one that must be acknowledged if the final results are to be adequately realistic.

e. Calculations
    i.   The basic sequence to determine revenue adequacy, for each surface class, is as follows:
        a. Allocate the lesser of Operations need or available revenue to cover O costs.
        b. Allocate the lesser of Maintenance need or remaining funds to cover M costs.
        c. Allocate the lesser of Extend needs or remaining funds to cover E costs.
        d. Allocate any and all remaining funds to Renewal coverage.

ii. *As noted in the Factors used part above, the percent targets for Granular E and R cost coverage can cause the model to take revenue away from pavements to try to assure that a minimum level of granular reinvestment remains covered.*

iii. *Hard Surface Extend and Renew Costs have to be combined, since the small mileage of Hard Surface was found to lead to erratic results if the E and R costs were kept separate.*

iv. *If Granular needs additional revenue to meet the minimums, the extra funds are modeled as being taken from Paved Road Extend and Renew – but only when such funds are greater than zero.*

f. Results produced

The end result of this section is a set of sixteen percentages, for E, G, H & P surfaces x O, M, E & R cost types, each representing the degree to which available revenue managed to cover need.

g. Intended use

The percentages get used in Module 8 – Road condition analysis, to assist with predicting the condition of the system at the end of each annual cycle.

3. Revenue allocations for Bridges – Carrying costs

Bridge revenues are allocated in the same manner as described for roads in Section b. above, except that there is no need to set minimum support levels for Granular.

a. Does not produce feedbacks

b. Responds to feedbacks - none

c. Raw data used

i. Projected revenues for bridges on E, G, H & P routes – from Module 2

ii. Estimated carrying costs for structures – O, M, E & R costs for each of the four surface classes.

d. Factors used – none

e. Calculations

i. The basic sequence to determine revenue adequacy, for each surface class, is as follows:

a. Allocate the lesser of Operations need or available revenue to cover O costs.

b. Allocate the lesser of Maintenance need or remaining funds to cover M costs.

c. Allocate the lesser of Extend needs or remaining funds to cover E costs.

d. Allocate and remaining funds to Renewal coverage.

f. Results produced

The end result of this section is a set of sixteen percentages, for E, G, H & P surfaces x O, M, E & R cost types, each representing the degree to which available revenue managed to cover need.

g. Intended use

The percentages get used in Module 9 – Bridge condition analysis – to help model bridge aging and restoration.

4. Revenue allocations for Road upgrades

Road upgrade selection is modeled on a most-urgent-first basis. This is a practical, although not perfect, way to model the general decisions on upgrades that county engineers and supervisors might make, given full knowledge of all pertinent factors.   The results produced herein are only reported in

aggregate, as the intent is to model system-wide changes, not to try to predict which specific segments should be upgraded in any particular year.

    a. Produces feedbacks

        When the analysis process in this section models that road segments get upgraded from one surface class to another, it results in changes to mileage, condition, VMT distribution and all dependent parameters.

    b. Responds to feedbacks - none

    c. Raw data used

        i. Road upgrade revenue: (Basic amount from Tab 2) + (Any Excess Carry cost converted to Upgrade revenue in Module 7, Section a.) + (any Upgrade revenue carried over from prior years.)

        ii. List of eligible road segments present in order of priority – from Module 6

    d. Factors used – none

    e. Calculations

        i. For as long as the remaining Upgrade revenue exceeds the cost of the next-in-line segment presented for Upgrade:

            a. Mark the segment upgraded to the Traffic Design Level + 1

            b. Deduct its cost from the Upgrade fund balance.

        ii. When done, save any unassigned funds for re-use in next annual cycle

    f. Results produced

        i. Total miles and cost of Upgrade modeled, for the E, G, H & P surface classes in Year-x

        ii. Miles added to and subtracted from each of the four surface classes in Year-x

        iii. Base year (Year-zero) VMT to be added to or subtracted from Base-VMT running totals first established in Module 3.

    g. Intended use

        i. Year-X upgrade activity is saved for analysis and comparison to other parameters

        ii. Mile and VMT adjustments are used to compute system reconfiguration adjustments in Module 10b - RoadSurfaceCondtionResults.

        iii.

8. Road surface condition changes

A major goal of the TR-608 project, was to find a way to model how the combined influences of existing condition at start of year, weathering, traffic wear, Extend work and Renew work lead to a new, adjusted condition twelve months later. It is a challenging but important process to simulate, as many consequences cascade from changes in road surface conditions: a) road users' per-mile vehicle operation costs increase/decrease, costs of taking care of the roads increase/decrease, and even the rate of future deterioration itself is affected.

Within the TR-608 Trend Projection Engine, the system models condition outcomes for Granular, Hard Surface and Paved routes only. Earth surfaced roads were omitted because a) their condition isn't really going to get much better or worse, regardless of future funding and b) there's no actual quantity of surface capacity to be used.

Condition was modeled in the aggregate: Each surface class has a mix of segments all having different condition levels and remaining service lifetimes. A representative average condition is determined, or when precise data is lacking, estimated. This is used as indicating of the overall state of that class of roadway mileage.

Road surface condition is, as discussed in Part 2, Road conditions, follows a non-linear deterioration curve as serviceability is consumed.   Because of this, the best way to compute an representative, system-wide condition state is to a) determine the condition factor for each segment, b) multiply the segment's lengths by the condition factors, add up all the factor-miles results, divide them by the total mileage and then back-figure what remaining service capacity corresponds to the mileage weighted average factor. This is complicated but important, as older segments' lower scores have a disproportionately strong effect on the system average – similar to how a "D" grade brings a grade point average down much more than an "A" can bring it up.

Example

The following graphic portrays the hypothetical distribution of tons-per-miles surface status for a system containing 1026 miles of granular road. The distribution represents a situation where one could say that overall, the roads are "more good than bad".

Figure 07 : Distribution of granular road miles by TPM – illustrative example
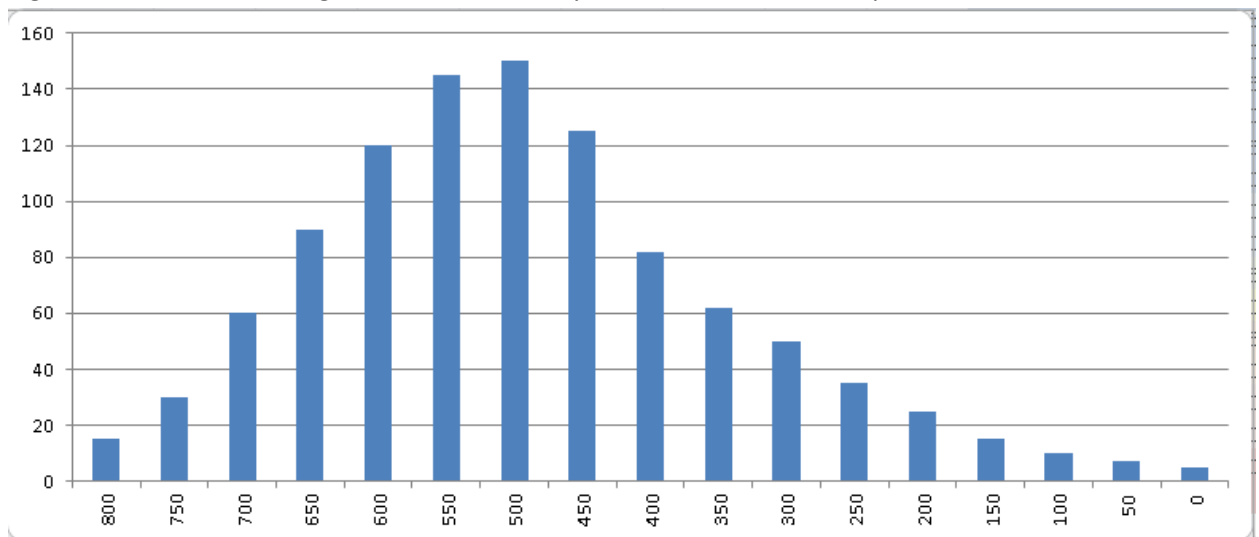
The average nominal TPMS works out to 492 TPM, but the TPM that best represents the state of all the granular roads taken together is 360.   Thus, effective condition TPM ends up at about 73 percent of nominal condition TPM.   Nominal has a deterioration curve condition factor of 0.968309 (GOOD) while effective's is only 0.894833 (FAIR).

Module 8 contains three sections, all similarly structured, to perform condition analysis for Granular, Hard Surface and Paved Roads.   The explanatory narrative that follows will describe the data and computational sequence in general. For specific details, the reader should refer to the TR-608 Analysis Engine Formulae spreadsheet file contained in the TR-608 CD.

a. Produces feedbacks
    Changes in condition create a variety of feedbacks – which get determined in Module's 10b and 11
b. Responds to feedbacks – yes
    Rate of deterioration is affected by condition itself; also affected by changes in traffic numbers.
c. Raw data used
    i.   Condition curve base and ratios
    ii. New, nominal and effective conditions

        iii. Surface miles & VPD

        iv. Percent of Extend and Renewal covered by Year-x revenues.

  d. Factors used

        i. Extend and Renew recovery factors – determines what share of annual loss is to be restored by E or R.

        ii. Loss rates for weathering and traffic.

        iii. Basic annual retainage and loss factors.   (Note: these items are used to implement the concept that the amount of damage done by a given amount of traffic will decline year by year.   If a road starts with 1000 units of serviceability and traffic impacts result in a loss of 5%, the resulting end of year reserve will be 950 – a net loss of 50.   If the 5% loss repeats the next year-end result is 950 * (1-0.05) = 902.5 – a net loss of only 47.5.   This is because there are only 950 units of serviceability remaining to be consumed in the second year.   [This description leaves out impacts of other effects to clearly describe this one.) See discussion of 'proportional loss' above and in Part 2.)

  e. Calculations

        i. Figure annual loss of service units due to traffic

        ii. Compute total loss = traffic loss plus weathering loss

        iii. Calculation how much of the loss would be restored by Extend and how much by Renewal IF revenues are 100 percent of need

        iv. Multiply by actual percent of coverage to obtain 'actual' amount of restoration

        v. Determine recovery factor = 'actual' divided by 100% potential

        vi. Basic annual recovery = Retainage factor +(Loss factor x recovery factor)

        vii. Get end-of-year Service Units: Start units x Basic annual recovery

        viii. Convert to effective service units

        ix. Compute end of year condition factor

        x. Accumulated loss/gain: $1 - (\text{Ending Eff. Condition} / \text{Year}_0 \text{ starting condition})$

  f. Results produced

        i. A new condition state, to be used as starting state for next annual cycle

        ii. Miles restored and resulting restoration cycle time, in years.

  g. Intended use

    To illustrate the interrelationships between traffic, funding, and condition and to produce end-of-year condition values to be used in computing next year feedbacks.

Caveats regarding this module:

- The methodology used herein is experimental. It's an attempt to model complex real-world phenomena using a mix of fundamentals, condition concepts based on the sigmoid curve and some empirical steps designed to produce a deterioration result that fits with county engineering experience.

- The proportional loss concept was included in the model after initial, direct subtraction of losses method was found to produce too harsh of outcomes.

9. Bridge condition changes

In the Trend Projection Engine computations, the system works to mimic county engineer/supervisor decisions about which bridges should be rehabilitated or rebuilt, given traffic service needs, situational constraints and fund limits. Results are reported "in aggregate" because the model only attempts to forecast a generalized outcome, not actions on specific structures. The analysis is performed first on those structures situated upon Earth roads, then those on Granular, then on Hard Surface and finally on Paved.

The basic concept used in this Module is as follows:

1. Multiply the total deck area involved by the annual loss of Square Feet by Sufficiency Rating points, SFSR units that typically need to be restored. For example, if there are 346010 SF of Granular bridged deck and annual lifetime is around 55 years, then the annual replacement need is 346,010 * (100/55) $\rightarrow$ 629,108 SFSR units per year.

2. Use allocation factors to assign how many SFSR units are to be recovered via Extend and Renewal work at 100 percent coverage – say 0.30 Extend and 0.70 Replacement$\rightarrow$ E is assigned responsibility for 188,733 SFSR units and R gets 440,375.

3. Multiply 100 percent allocations by actual allocation percentages from Module 7. For example, if the Rev vs. Need factors come in at 100% and 64%, the model will presume that all Extend need is to be covered, but only 280,869 SFSR units will be recovered under Renew, not the full 440,375. (The Renew shortfall will result, in the model as it would in actual practice, in a net loss of collective structure conditions for the year in question.)

4. Select bridge rehab candidates to fulfill the Extend SFSR replacement needs, until they have covered the full need. For example, a 24 ft x 80 ft structure with an SR of 70, would cover 24 x 80 x (95-70) $\rightarrow$ 48,000 pts of the 188,733 needed. Stated inversely, one would need to rehab roughly four such bridges per year to cover the full restoration need under Extend.

5. Select bridge replacement candidates to fulfill the Replace SFSR needs, until they have covered the full amount possible under the 64% fiscal constraints. The amount restored is larger in this category: a 24 x 800 foot structure would cover 24 x 80 x (100 – Old SFSR) points.

Deck area expansion due to bridge replacement

This Module models that if a bridge is replaced, the new structure will be longer and wider. Hydraulic design criteria have tightened of the years, with more freeboard above higher flood crests being requested by flood plain project approval agencies. Higher elevated structures tend to be longer, and TR-608 uses a length expansion factor of 1.25 to account for this. For example, an 80 foot structure likely will be replaced with one that is 100 feet long. Increase safety requirements and ever wider farm equipment similarly push counties to make replacement structures wider, and TR-608 models this with a width expansion factor of 1.44. Taken together, the length and width expansions results in a new deck area that is 180 percent of that of the old structure.

Details of computations

The following data and computational details relate how the system models selection and improvement to structures on the Granular road sub-network. Since the exact same process is also used for the other three surface classes, they will not be covered individually. But differences between then and Granular will be noted.

1. Does produce feedbacks
   Bridge replacements tend to increase the total bridge deck area for which a county is responsible, thereby increasing future Carrying Costs. On the other hand, bridge closures can reduce total deck and

create a slight increase in VMT – since detour routes tend to be longer than the pathway afforded by the now closed structure.

6. Responds to feedbacks - None
7. Raw data used
    a. Group characteristics of the bridges included in the surface class: count, total bridge deck area, typical structure lifetime, the Sufficiency Rating level at which structures should be closed.
    b. List of structures and their key details: length, width, Sufficiency ratings
    c. Iowa DOT Bridge Priority Points worksheet - a list, annual published by the Iowa DOT Office of Local System, that blends consideration of traffic, sufficiency, detour length, and other factors to establish the order in which candidates for State Bridge funding will be selected.   (The final Priority Point results get used in TR-608 to provide a proxy method for modeling which bridges counties would themselves likely select to work on, and on what order.)
    d. Percent of Extend and Renew coverage for Year-x, as computed in Module 7 – Revenue vs Needs analysis
8. Factors used
    a. Allocation factors to split annual recovery need between Extend and Renew
    b. Length and width expansion factors for replacement structures
9. Calculations – done for each surface class' set of structures separately
    a. Determine annual SFSR replacement needs
        i. Split it into Extend and Renew Parts
        ii. Factor those parts by Rev. vs. Need coverage percentages
    b. Select as many structures as will fulfill the SFSR allowances and mark them as Improved
        i. Rehab structures keep same deck area
        ii. Replacement structures have 1.8x the old deck area – which will be included in future annual processing – modeling a system increase in Carrying Costs.
    c. Locate any remaining structures that are below the closure threshold and mark them as Closes / Taken out of Service – Their deck areas get removed from further analysis and will not be counted in future annual cycles.   (Not the model presumes that ONLY earth and granular route structures will get closed.)
10. Results produced
    a. Number of structures rehabbed, replaced and closed
    b. New counts and sufficiencies by surface class – (not yet adjusted for road upgrades)
11. Intended use
    Provides generalized results indicative of the health of all structures taken collectively.

10. Update of system configuration

As a consequence of road and bridge upgrades, the model must adjust affected system parameters. Miles in each surface class, and corresponding VMTs, need adjusted.   Condition of road surfaces must be updated and VMT splits must be recomputed. Last, bridge priority points must be recalculated to reflect changes in rank that come from upgrades and general aging.

Sub-section 10b then calculates a series of feedback factor due to changes in road surface condition for Granular, Hard Surface and Paved roads.

Roadway data updates
Updates road miles and conditions to reflect Upgrades

1. Produce feedbacks – changes in road system configuration affect all dependent variables in future annual cycles
2. Responds to feedbacks -- Changes in road condition in Module 8 affect outcome of this section
3. Raw data used
    a. Starting miles – all surfaces
    b. Mileages added and subtracted from each surface class – per Module 7, Section D
    c. Surface condition ratios from Module 8 - Road Condition Analysis
    d. Surface condition 'new' values
4. Factors used – none
5. Calculations
    a. Compute new total miles of each surface – Earth, Granular, Hard Surface and Paved.
    b. Adjust average condition factor for each surface to reflect that Upgrade segments come in as 'brand new', raising the overall condition level.
    c. Compute VMT weighted average surface condition for all surface classes
6. Results produced
    a. New miles and conditions
7. Intended use
    a. To help in calculating feedback factors to be applied in next annual cycle.

VMT adjustments
Applies effects of Road upgrades and bridge closures to model change in total VMT and in the VMT split factors to be used in Module 3
1. Produces feedbacks – results affect future year traffic
2. Responds to feedbacks - none
3. Raw data used
    a. Base year (Y0) running sums of VMT
    b. VMT added to and subtracted from each surface class
    c. Bridges closed in the current cycle
4. Factors used - none
5. Calculations
    a. Compute new running sums of base year VMT
    b. Additionally add VMT into system for each closed structure: Incremental VMT = (VPD$_{bridge}$ x Detour) ÷ 4.
    c. Calculation

6. Results produced
    a. Adjusted VMT splits by surface
    b. Factor to adjust future VMT's to reflect impacts of bridge closures
7. Intended use – in Module 3

Bridge priority points recalculation

First the system runs a check to see if road Upgrades have caused any structures to become associated with a new surface class. For example, if a Granular surfaced road with a structure became Paved, then the structure must be removed from the Granular group and added to Paved.   Then the Priority Points calculation is rerun for all structures.   In most case the net changes will be minimal, but new Rehabbed or Replaced structures will drop from the top of the list back down to lower levels, and a few will have gained just enough traffic or lost just enough SR points to shift relative position.
1. Does not produce feedbacks
2. Responds to feedbacks - none
3. Raw data used
    a. County bridge list, as adjusted for Rehabs and Replacements
4. Factors used
    a. Uses DOT Priority Point formula
8. Calculations – each structure has new Priority Points calculated (approx. 18,000 each cycle)
9. Results produced
    a. Priority points adjusted for cumulative changes in traffic, surface and upgrades.
10. Intended use – for use in next annual cycle's selection of Extend and Renew candidates.

Sub-module 10b

Uses road condition results, as adjusted in Module 10, to compute physical and financial feedback factors. This is done for G, H and P surfaces.

1. Produce feedbacks – road agency and road user cost multipliers
2. Responds to feedbacks - none
3. Raw data used
    a. Basic surface life cycle definition parameters from Module 8
    b. Nominal remaining serviceability units from Module 10
4. Factors used
    a. Multipliers to use in convert Accumulated Loss/Gain factor, resulting from new conditions, into specific feedback multipliers.   For instance, the model assumes that any change to maintenance costs will be only 10% of the magnitude of the physical condition change, while vehicle operating costs will be 25% thereof.
5. Calculations
    a. Compute nominal and effective ending surface condition
    b. Figure condition factor of the effective condition
    c. Compute final Accumulated Loss/Gain factor
    d. Compute depended feedback factors based on each ones relative percent of impact factor
6. Results produced

         a. Feedback factors for Maintenance, Extend and Renew costs.

         b. Feedback factors for Vehicle operations and Level of Service costs

         c. Rate of loss multiplier that models the phenomenon where a road's susceptibility to deterioration increases as its condition decreases.   (and vice versa)

7. Intended use

         a. Affects Carrying Costs and Road Upgrade costs in future annual cycles

         b. Affects road user costs in the future.

11. <u>Update feedback factors (to be applied to next annual cycle)</u>

This module catalogs the results produced from Sub-Module 10b, then computes global, system-wide, traffic weighted VMT and Trip factors to be applied to future annual cycles

1. Produces feedbacks – changes in road condition affect future trip generation and VMT per trip.
2. Responds to feedbacks – responds to changes in road condition
3. Raw data used

         a. Starting effective road condition factors

         b. Original VMT's by surface class

4. Factors used

         a. Adjustment factors to reflect relative impact of road condition changes on rural travel. These numbers represent a maximum estimated increase if condition has gone to zero.

            i. VMT percentage add-on (for condition decline): 5%

           ii. Trips percentage add-on : 3%

5. Calculations

         a. Compute a composite average condition factor using the VMT times condition factor of each surface class: a) for start of scenario and b) for current Year-x

         b. Compute a resulting accumulated Loss/ Gain factor

         c. Use the L/G factor to compute feedback factors for future VMT and Trip calculations

6. Results produced

         a. Trip factor to adjust future calculations thereof in Module 3

         b. Similar factor for VMT per trip.

7. Intended use

Determines an impact on traffic from changes in road condition and projects the effects into the future.

12. Accounting for urban growth

Although Iowa's population is nearly static, a few counties are seeing rapid growth due urbanization.   One can surmise that the city growth is offsetting a good portion of population losses in the more rural counties.

Urban growth affects the counties in which it takes place.   It results in more city residents taking trips on rural roads to access parks, go hunting or patronize rural businesses, etc. As it progresses, cities end up annexing land into their corporate limits, converting a quantity of rural land area, population and road miles from county to city.   Meanwhile, rural residence subdivisions tend to develop in the environs of an urban core, creating the potential for many more trips per day.   The interactions of these various forces is quite complex and creates a problem for TR-608: a general prediction of urban growth can be made, but identification of where and when annexations will take place, and consequently which road segments will be affected, is beyond the scope of the study.

Because the location, extent and timing of growth induced annexations can't be predicted easily, the Trend Projection Engine does not attempt to do so. Instead, it documents possible urban conversions – for reference – without actually adjusting model outcomes.

1. Changes in rural area and mileage
   The first is to estimate and note the quantity of urban growth annexation that could potentially occur. This acknowledges the phenomenon and gives a generic summary of its magnitude, but no attempt is made to estimate how this might change rural travel.

   For example: Dallas County's long range plan suggests that each increment of 2000 population will result in development of approximately an additional square mile of land.   But, most towns have ample vacant land within their borders already, so only a portion of the expansion will require new corporate territory. For TR-608, the new-land-needed ratio was set at 0.40. This value represents the likelihood that cities will typically develop land they already control before trying to gain control of more.

   For Dallas County, an increase of, say, 16,000 population in the next fifteen years isn't outside the bounds of reasonable probability. At 2.75 persons per household, that would result in around 388 new dwellings per year.   Using the rates cited above, annexations might come to (16000/2000) x 0.4 = 3.2 square miles, (2048 acres), over the fifteen years.   At a ratio of about 1.8 miles of county road per rural square mile, the 3.2 miles annexed could contain 5.76 miles of county road.   This would reduce the size of Dallas' secondary road network and remove some traffic from secondary road counts. The mix of surface class miles and number of bridges involved would depend on precisely where the annexation took place.   5.76 / 592 ~ 1% change.

   So TR-608 quantifies and reports the potential urbanization impacts, but doesn't try to include them directly in the TPE model's traffic analyses.

2. Impacts on agricultural activities
   An second area where the urban growth annexation effects can be estimated is that of agricultural production numbers. As the cities take up land, agricultural uses thereon come to an end. So Module 12, Section B, performs adjusting calculations.   No attempt is made to estimate impacts on livestock operations.
   a. Produces feedbacks – changes in ag-land area will affect future rural trip estimates

b. Responds to feedbacks - none
c. Raw data used
    i. Estimated square miles of potential annexation (3.2 – Dallas, example)
    ii. Area of county in square miles (592 – Dallas, example)
    iii. Acres of land being used for Corn, Beans and Other type land usage
d. Factors used – none
e. Calculations
    i. Determine total agricultural land use in Sq. Mi.
    ii. Determine what percentage the annexation will take from the agricultural base – presuming that development will likely take over vacant land.
    iii. Computer new ag-land acres: Acres x (1 – PctLoss) for Corn, Beans and Other land-use
f. Results produced
    i. New land use acres
g. Intended use
    Adjusted acres will be used to estimate rural economy and trips in Modules 1 and 3, during the next annual cycle.

Comments on the TPE methodology

The twelve modules of the Trend Projection Engine collectively estimate future needs in a manner consistent with most of the aspects of the real-world phenomena they model:

1. Unlike past Needs studies, TR-608 doesn't try to estimate how much revenue would be needed to cover all needs. Instead it presumes that resources are finite and adjusts system conditions in response to shortfalls or surpluses.
2. It incorporates consideration of how changes in one aspect of the road circumstances alter the rates at which others change – feedback mechanisms.
3. It is reasonably transparent and auditable – both in formulas and data.
4. It has been implemented on an ongoing basis and will be open to sequential refinement and tuning as time passes.
5. It does not purport to actually predict the future; instead it permits exploration of how current starting conditions and trends may play out.

Future refinements

The Trend Projection Engine has been established as a read-to-use resource available to perform forward looking analysis on demand. It will be available to any single county, region or the entire state association.   Two on-going refinement processes will update and improve it year by year.   First, it needs to be tuned.   Lacking a sufficiently long historical record, the research team had to make a number of best-judgment selections of factors and multipliers used in the calculations. As time passes, the gradual accumulation of more background data will permit annual adjustments in those values, enabling long term convergence on optimal choices.   Second, the research team anticipates that further work by themselves and by others will bring about better understanding of the processes being modeled. This will lead to revisions and improvement to the formulas used in the modeling calculations. In particular, the Road and Bridge condition simulation methodology will benefit from more thorough investigation.

Part 4 – Future need data extraction, comparison and graphing

The Trend Projection Engine simulation runs to fifteen years in the future. In the process, the system computes and saves year by year values of many different parameters, grouped under twelve headings. This is done to permit detailed analysis and comparison of many disparate factors.

Rich data set

The results tally contains over 350 separate data elements. The top level categories are as shown in Figure 08, below left. Figure 08 : TPE results categories

Population/Land Use	Contains values of the base economic drivers that produce travel
Rural Economic Value	Stores the estimates of year by year value produced by rural activity
Road Revenue	Estimates of future road revenues, on a fund by fund basis
Traffic Generation	Summary of project trips, VMT and VPD – broken down by road surface classes
Truck Trips	Resultant truck trips and ESALs per source
Cost of Vehicles	Vehicle cost of operation, service interruption and accident costs
Carrying Costs	Cost figures total and per-mile for O, M, E & R costs on E, G, H & P surfaces
Percent Covered	Results of comparing revenues to needs
Road Condition	Condition base values and rations for Granular, Hard Surface and Paved roads
Bridge Condition	Bridge rehab, rebuild and closure counts, plus ongoing average Suff. Ratings
Upgrade Needs	Estimated road upgrade tallies
Feedback Factors	Year by year tally of feedback factor, to permit assessment of their influence

Most end users won't require more than five to ten data items to either 'tell the story' or serve as the basis for analysis/decision making. So with this extensive data set, few users will find that their area of interest isn't covered. An additional reason for saving so many data items is to enable anyone interested to dig in and determine, step by step, how the modeled results came to be.

<u>Scenario Results Interface</u>

To enable efficient selection and evaluation of the results of any modeled scenario, it was necessary to build a specialized console via which the user could express their choices regarding data, time period, counties, separate-or-consolidated, and row-vs-column preferences.

Figure 09 : Basic Results selector layout

Miniaturized view of the results selection and viewing console – for accessing data from a scenario.
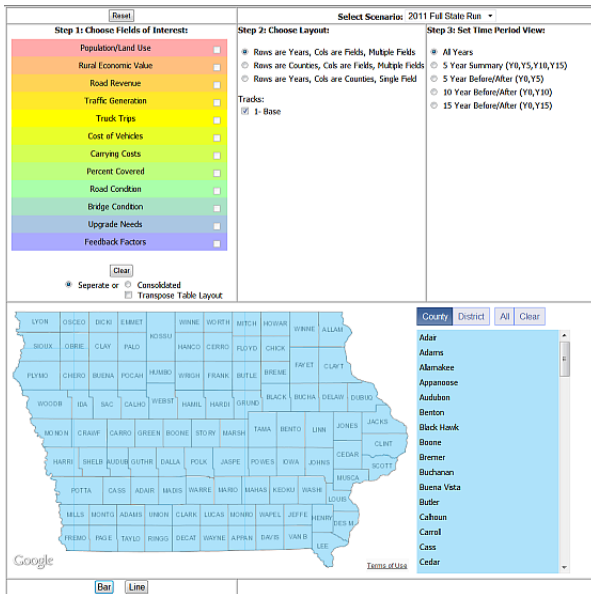
Step 0: Pick the Scenario to inspect

Step 1: (rainbow) allows the user to select result items to be studied, and view counties Separate or Consolidated. (upper left)

Step 2: Top-Center affords a choice of how the output tables are to be structured

Step 3: Allows selection of 15 year, five year intervals, or before-after comparisons. (upper right)

Step 4: (map) allows choosing which counties' data to view

Step 5: (bottom-left) allows choice between viewing results in bar-graph or line plot formats

<u>Data selection options</u>

The following narrative describes the purpose and use of each control panel included in the Basic Results Selector interface.

Step 0: Choose scenario

A drop down list of all scenarios which have been defined and run is provided in the top row, right side, of the console. Use it to pick the one whose results are to be examined.
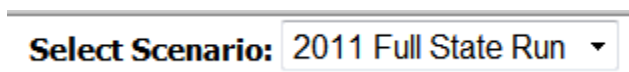
Step 1: Choose results

The result items selection block allows one to choose which items to inspect. The exact choice will depend on what the user needs, either to explain something about the road system or to analyze/compare potential future outcomes. The selection block expands and collapses as needed. Click on a heading to open a view of the data elements group underneath, check mark the ones of interest, click to re-collapse the header, and move on to any others.

← Note that the expanded heading reveals a hierarchy of subordinate items, each represented by a short form description

Step 2: Chose Layout

The basic building blocks for structuring how the selected results are to be display are: Years, Counties and data Fields. The Choose Layout panel provide three options: a) multiple Fields, arrayed in columns, showing each year's results as a row, b) multiple Fields, arrayed in columns, showing county by county results in rows, c) for a single Field, display results from multiple counties arrayed in columns, showing each year's results in the rows. These options provide a great deal of flexibility, but one must experiment to find the optimal output format for any given circumstance.

Step 3: Time periods

This panel allows definition of the timeframe to be used in viewing and evaluating results. There are choices between extracting all fifteen years, examining results only at five year intervals, or just comparing beginning and ending values.

Step 4: Processing options

Located under the Step 1 Results selector, this small panel affords user choices on two useful options. First, when dealing with multiple counties, one can elect to see their individual results – or just view their consolidated totals. Second, the row / column layouts selected in Step 2 can be transposed, if that better suits the user's need.

Clear

⊙ Seperate or ○ Consolidated
☐ Transpose Table Layout
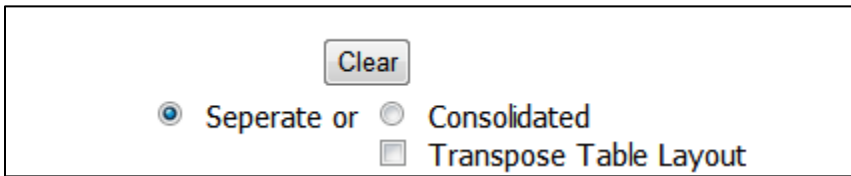
Step 4: County Selection panel

The last step in extracting results is to choose which counties for data is to be viewed.   The map will show all counties processed in the selected scenario. The convention is that they show BLUE if selected and WHITE if not. The All button selects all counties covered by the scenario. Clear deselects all of them. Clicking on the map or the list will toggle any particular county on or off.   The District button allows toggling all counties in a DOT district on or off.
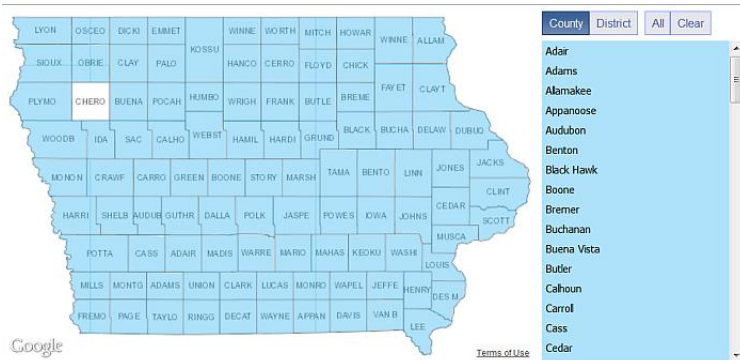
Step 5: Graphic output format

This final option lets a user view properly structured data plotted in either bar chart or line graph form.   Not all Year-County-Fields combinations can be so presented, but the graphs are displayed whenever possible.

Bar   Line

Taken all together, the results selection and display options will enable nearly all users to obtain results in a layout that best suits their needs and objectives. The sample output in Figure 10 illustrates the 'end product'. In this case, the model's predictions for number of bridges rehabbed, replaced and closed is tabulated and graphed:

Figure 10: Sample TPE Tabular and Graphical outputs

County	79	79	79
Item	Rehab-B-G	Replace-B-G	Closed-B-G
Track	1	1	1
Year	EACH	EACH	EACH
2011	0	2	0
2012	0	2	0
2013	2	3	0
2014	1	1	0
2015	4	1	0
2016	1	2	3
2017	4	0	0
2018	3	2	1
2019	3	1	0
2020	1	0	3
2021	14	1	6
2022	1	1	0
2023	2	1	0
2024	0	2	1
2025	2	0	0
2026	5	4	2
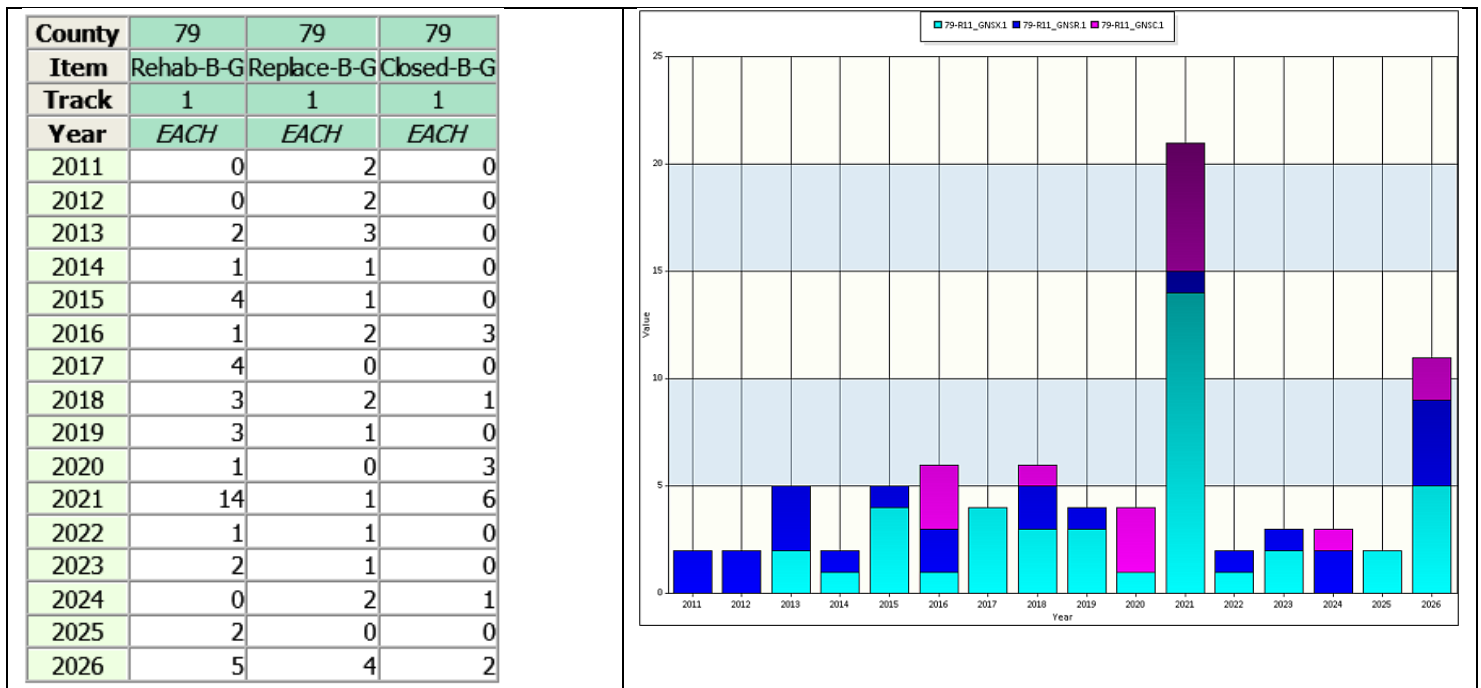
Part 5 – Pre-defined public information formats

An original objective of the TR-608 project was to develop pre-formatted public information sheets that counties could download, print and make available for educating and informing the public about road issues.   This work did not get accomplished and will have to be implemented after the project is complete.

The research team developed some ideas in this regard, as are described below, but came to the realization that more effort had to be invested in perfecting the model before spending much time on this secondary activity.   Development and deployment of PR extracts will be undertaken as part of TR-608's post completion implementation work. Following are short descriptions of the formats so far envisioned:

Carrying cost summary
This would be a sheet listing both statewide and single county information on the size and scope of the secondary road system, along with needs vs. actual spending information.

Upgrade needs summary
In this format, the goal would be to communicate to the public regarding system adequacy, upgrade needs and potential costs

Future needs graphical representations
Here it's envisioned that a standard annual scenario could be run once per year. Then a pre-determined set of data items would be extracted and graphed, to help show the outcomes of a) the basic trend rates, b) a best case scenario and c) a worst case scenario.

Analysis of results (Validity, applicability, utility)

The TR-608 project has arrived at a point where it can produce reliable answers to the following questions:

1. How much have counties been investing in their systems?
2. How much should they be investing in order to sustain the system long-term?
3. How does last year's budget compare to either 1. or 2. ?
4. How well does the extent and configuration of the system serve the traffic it carries?
5. What portion of the system is under-designed for its traffic and deserves consideration for upgrade?
6. What is the urgency and potential cost of warrantable upgrades?
7. How might things turn out if, starting from current circumstances, present trends continued fifteen years into the future? -- Population, land use, revenues, traffic, needs, condition, etc.
8. How might things alternately turn if circumstances or trends were better or worse than anticipated?

The results it can produce will be applicable in a number of ways. First and foremost, it will enable county government to determine and communicate rural road needs more accurately and effectively than in the past. It can help educate the public about both the role and cost of their roads.   It can assist county engineers and supervisors in explaining what road funds are used for and why.   Over time it will accumulate a historical record of information useful in identifying future trends.   It will provide engineers with another method for evaluating how well their systems are doing and for identifying future revenue needs.

Nonetheless, the results of this study are only of indirect benefit to the counties and the public in general. It helps identify where more must be done and how much, but cannot, by itself, actually provide more resources or cut costs. But it is hoped that it will be an aid towards achieving such goals.

Every effort has been made to maximize the validity and accuracy of study results.   In particular, starting with FY2012 data, the multipliers selected to convert "what has been spent" numbers to "what should be spent" results, are being cross tested against asset life cycle times, annual renewal needs, and current per mile (roads) and per square foot (bridges) unit prices.   Over time, as the annual renewal of the carrying cost and upgrade needs is performed, it's expected that it will become possible to gradually refine and improve the accuracy of the factors.

The validity of the Trend Projection Engine results has not yet reached a level equal with that of the Carrying Costs and Upgrade needs outcomes.   But, again over time, it's anticipated that the model's factors and formulas can be tuned and refine to find a best fit with recorded historical data.   As that is done, the validity of the future projections will be enhanced.

Conclusions

Most of the effort expended on this project went towards conceiving of and building tools with which secondary road needs can be assessed.   The goal was to create the means by which county needs can be continually re-determined in the future. Nonetheless, the end results so far obtained from those processes are informative about the roads and have been used, in 2010, 11 and 12, to help explain to the public why (and how much) more road funding should be raised.

This section discusses results for FY2012 and what they tell about the road system and its future.

Present situation

Carrying costs – actual vs current vs need

The results so far produced indicate that the resources Iowa has been allocating to operate, maintain, extend and renew the secondary road system fall short of sustainability.   The eight year, inflation adjusted average of county road expenditures, ending with fiscal year 2012 results, is $733 million per year.   That is a large number but falls short of

being enough to assure keeping the system at today's condition level over the long term, as the Carrying Cost is estimated to be around $830 to $860 million per year.   And, in striking contrast, actual cash expenditures made in 2012 were only $628 million. The differences between these numbers suggests that the current situation cannot long continue.

Carrying costs – where additional resources are needed – by Cost type, Surface class and Roads or Bridges
With the TR-608 methodology established but still needing a few more years of data to enable 'tuning' the Carrying Cost multipliers, one cannot yet state that the factors are definitive. But they can provide insights into the road finance situation.

Table 18: Carrying Cost factors originally developed in 2010 and 2011

Original CC factors	ROADS				Bridges			
	Earth	Granular	Hd Surface	Paved	Earth	Granular	Hd Surface	Paved
Operate	1.00	1.05	1.05	1.05	1.00	1.00	1.00	1.00
Maintain	1.00	1.20	1.15	1.15	1.00	1.00	1.00	1.00
Extend	1.00	1.25	1.50	1.25	4.00	1.00	1.30	1.00
Renew	1.00	1.30	1.80	1.30	5.00	1.20	1.40	1.00

These factors were developed through consultation with county engineers and tested against such condition data was available. The details of this are fully described in Part 2 of this report.

Additional efforts have been made to tune the factors to achieve a coherent, internally consistent balance between them, asset life cycles, quantities needing renewal per year, and typical costs per mile or square foot.   This work, as further outlined in Appendix C, has produced an updated set of factors

Table 19: Latest Carrying Cost factors being considered (Dec 2012)

Multipliers	ROADS	2012 'tuned' TR-608 factors			Bridges			
	Earth	Granular	Hd Surface	Paved	Earth	Granular	Hd Surface	Paved
Operate	1.00	1.05	1.05	1.05	1.00	1.00	1.00	1.00
Maintain	1.00	1.10	1.15	1.15	1.00	1.00	1.00	1.00
Extend	1.00	1.10	1.65	1.05	3.00	1.80	0.90	0.90
Renew	1.00	1.10	1.90	1.15	3.85	2.42	0.80	0.85

As can be seen, the tuning process has resulted in some factors being increased and others being reduced.   Under roads, the Extend and Renew multipliers for Granular and Pavement were adjusted downwards, while those for Hard Surface were increased.   Under bridges, Granular extend and renew factors were dramatically increased to reflect that structures of that surface class appear to be significantly underfunded for long term sustainability.   Earth, Hard Surface and Paved bridge factors were reduced.   Of special interest is the fact that the tuning suggests that perhaps the rate of reinvestment in Hard surface and Paved route structures can be slightly reduced without losing ground in the long term. It would be premature to declare the new factors as 'fully validated', but they are consistent with the Sufficiency Ratio trends presented in Table 6, (page 15). No doubt it will be necessary to scrutinize them more carefully and to even devise a back-up tuning method for them.

Looking at eight year, inflation adjusted average expenditures, one finds that the counties have been spending about $603 million per year, (82%), on road work and another $130 million, (18%), on bridges. The corresponding long term Carrying Cost amounts, using the tuned factors, suggest that $665 million per year, (79%), should be expended on roads and $173 million, (21%), on bridges, for a total of $838 million / year.   As one reads these numbers and compares them to the revenue that has actually been available for expenditure, it is important to note that the Carrying Cost figures

represent what's needed to keep the rural road system intact, in its current extent, configuration and condition over a long period of time.   It is not asserted that this MUST be society's goal. It may be possible that not all roads and bridges will be needed in the future.   It's also possible that certain roads will end up needing to be upgraded in response to economic development needs.   These considerations need to be kept in mind when thinking about the Carry Cost results.

Using the tuned, 2012 Carrying Costs and dividing them by the mileage within each surface class, per mile per year figures for different road types come out as follows: Earth - $950, Granular - $4,570, Hard Surface - $16,665 and Paved - $19,365.   This illustrates something often forgotten when the public requests road improvements – that each mile of betterment increases long term costs; for instance, if a county upgrades 10 miles of Granular to paved, their annual budget thereafter should be increased by ($19,365 - $4,570) x 10 = $147,950 per year – to cover the newly incremented paved road needs..

Bridge costs run from around $4.01 per square foot of deck area on Earth surface structures to $4.75 PSF for Hard surface routes, with an average of $4.29 overall. So one can generically say that a 25 ft x 80 ft structure costs about $8,580 per year to keep in the system.   And any replacement will likely need to be 36 ft x 100 ft. due to the width and length expansion typically encountered.

Looking at things from the cost type side reveals that counties typically spend 22% of their resources on Operations, 16% on Maintenance and 62% on Extend/Renew work.

Upgrade needs – System adequacy
TR-608 provides a new basis, via Upgrade Needs analysis, to answer the sometimes contentious question, "Are the county roads over or under-built?" The determination and comparison of Physical and Traffic design levels, as described in Part 2 of the report, indicates that the balance of miles between the four surface classes is largely a good fit with the traffic needs that exist.   Eighty five percent of the system is adequate and 15 percent merits some degree of upgrade, but only 388 miles (0.40%) could be classified as urgently needing attention.   Nonetheless, that small quantity of upgrade would potentially cost a grand total of $326 million, given today's construction costs.   If spread out over ten years, that would call for about $33 million per year.   Assuming that Upgrade expenditures run around four percent of total outlays, one can approximate that counties have been investing around $733 x (4/96) = $30.6 million per year in upgrades.

Upgrade needs – by surface class, by urgency - miles
The Upgrade analysis shows a priority need to improve 8.3 miles of Earth road, 333 miles of Granular, 19 miles of Hard surface and 27 miles of Paved road, statewide. If traffic growth resumes an upward trend, these numbers will increase; conversely a downward trend would reduce the need.   In addition to the priority needs, there are about 1,552 miles medium level need, and 11,305 miles of mild need.

Bridges – SR status and recent changes
Comparisons of past bridge records with more current data typically reveal that sufficiency ratings of county road bridges are holding steady. This good news is somewhat tempered by the fact that the number of structures on Earth and Granular routes is decreasing with time. That would suggest that the sufficiency level is not being sustained by repairing and preserving, but rather by closing structures as they come to the end of their service life.   This dovetails with the large actual-to-need multipliers that came out of the factor tuning process.

Table 20 : Bridge counts and Sufficiency Ratings by road surface class

2011 data	Earth	Granular	HardSfc	Paved	Grand Total
Structures	1188	13967	314	3818	19287
Avg Suff Rtg	61	75	72	80	76

Forward looking results

The Trend Projection Engine takes the results of the Carrying Cost / Upgrade Cost analysis and develops a picture of where current trends, in basic drivers, revenue, need growth and condition may take us. It cannot provide iron-clad previews of the future, but will provide useful insights about possible outcomes.   The following topical summaries illustrate the types of results available from a TPE scenario.

The challenge of starting out with a gap and differential growth rates
One issue, confronting road agencies of all kinds, that the TPE model makes all too clear, is that society faces two problems in finding a way to preserve and perpetuate their road networks.   First, as noted above, current expenditure levels already fall significantly short of fulfilling need.   Second, costs are inflating much faster than revenue growth rates – causing the shortfall to worsen year by year.

As Figure 11 shows, if some way of dealing with the challenge is not found, the funding gap already extant will become ever more difficult to deal with.   It suggests that any viable revenue solution will need a) to provide an initial 'catch-up' increment and b) be capable of robust annual growth.

Figure 11 : Carrying Costs vs. Revenue (A potential outcome for District 1 counties)
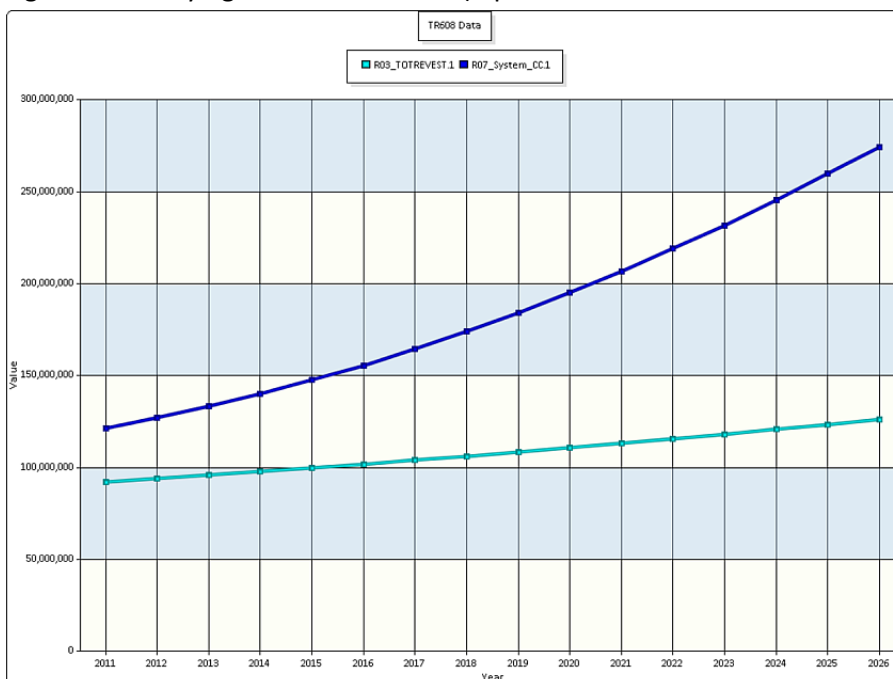
Economic drivers
Some counties will see population growth, while the majority continue to experience out-migration as agriculture consolidates and becomes more efficient.   But in many cases travel volumes will grow despite any population losses, as the remaining rural citizens take longer and longer trips to conduct personal or business activities.

Table 21 : Projection of Population and VMT trends for Dallas (25) and Page (73) counties

County	25	25	73	73
Item	POP-TOTAL	VMT-FINAL	POP-TOTAL	VMT-FINAL
Track	1	1	1	1
Year	CT	VMT/DY	CT	VMT/DY
2011	65,996	219,133	15,352	79,211
2012	69,257	228,618	15,198	79,094
2013	72,680	238,596	15,046	79,007
2014	76,273	249,142	14,896	78,964
2015	80,045	260,283	14,747	79,003
2016	84,005	272,166	14,599	79,082
2017	88,162	284,865	14,453	79,415
2018	92,526	298,379	14,309	79,628
2019	97,107	312,638	14,166	79,887
2020	101,916	327,536	14,024	80,117
2021	106,965	343,025	13,884	80,551
2022	112,266	359,119	13,745	80,734
2023	117,831	375,844	13,607	80,970
2024	123,673	393,214	13,471	81,099
2025	129,806	411,234	13,336	81,244
2026	136,246	429,906	13,203	81,277

Revenue

Revenue growth, if recent past trend lines continue, will grow at around 2.1 percent per year.   (Needs have been climbing at 4.5 to 5.5 percent per year.)

Traffic

The model suggests that total daily trips will grow and that trucks will make a slowly increasing percentage of those movements.

Table 22 : Daily rural trips and estimated truck percentages

Item	TRIPS-TOTAL	Trucks-Percent
Track	1	1
Year	#/DY (Sum)	Pct (Avg)
2011	1,758,738	13.24%
2012	1,770,634	13.30%
2013	1,783,214	13.36%
2014	1,796,555	13.42%
2015	1,810,722	13.48%
2016	1,825,687	13.54%
2017	1,841,386	13.60%
2018	1,857,796	13.66%
2019	1,874,774	13.72%
2020	1,892,250	13.78%
2021	1,910,100	13.84%
2022	1,928,286	13.90%
2023	1,946,752	13.95%
2024	1,965,361	14.01%
2025	1,984,091	14.07%
2026	2,002,849	14.13%

Needs

The system estimates needs, allowing for feedback influences that can either retard or accelerate the rate at which these items grow.

Carrying costs

As shown in Figure 12 below, paved and hard surface road costs are likely to grow faster than those of granular and earth, because the former require a lot more construction contract work – which is the area of strongest cost inflation.

Figure 12 : Earth, Granular, Hard Sfc and Paved Carrying Costs need projection
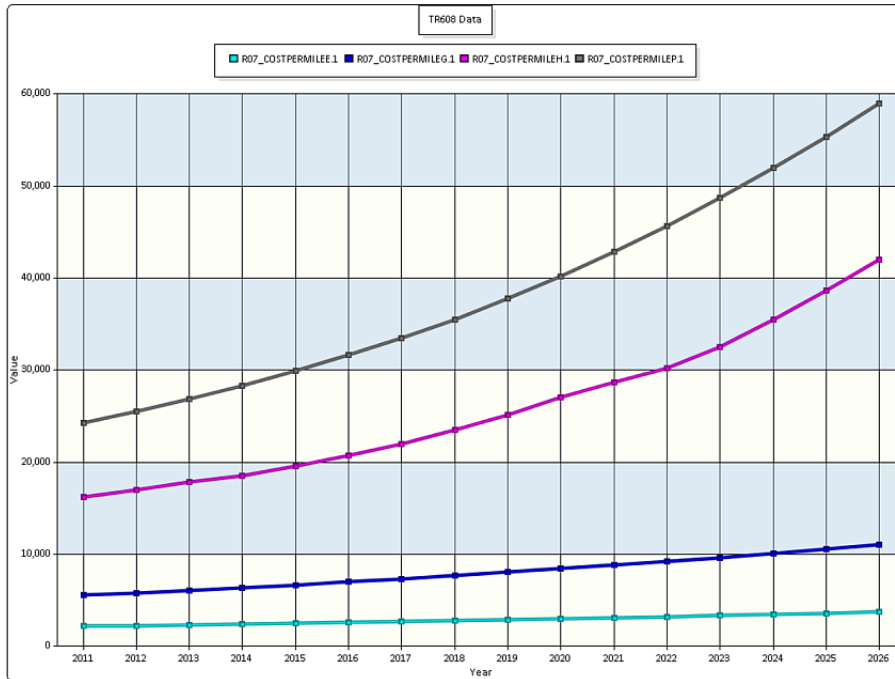
Upgrade needs

Upgrade needs will escalate on two levels: first, any traffic increases will tend to increase both miles needing upgrade and their collective priority; second, upgrade costs are also highly reflective of construction cost increases.

Condition outcomes

The TPE actively models condition outcomes for G, H and P road surfaces because the relative state of road surface assets affects traffic, cost of driving, cost of caring for the roads and even future rates of deterioration.

Roads

Given that the model starts with an apparent serious funding gap that worsens over time, projected condition outcomes tend to point to decline.

Figure 13 : Granular, Hard surface and Paved condition trend lines
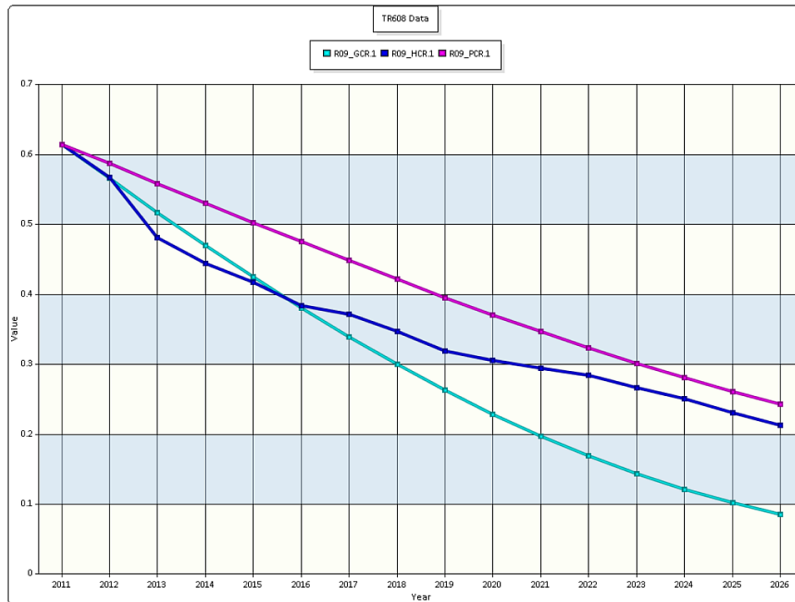
Bridges

Structures would likely see some deterioration as well, but the rates would be more moderate than for the roadways themselves.   The TPE process does model that some earth and granular structures would end up getting closed, so the average SR values shown below would be for the structures still in service at the end of each annual cycle.   In the scenario for which the SR results are displayed, the system modeled that 638 and 1881 Earth and Granular structures could be closed over a fifteen year time period.

Table 23 : Projected Sufficiency Rating Outcomes for E, G, H & P surface classes

Item	Avg. Suff Rating E	Avg. Suff Rating G	Avg. Suff Rating H	Avg. Suff Rating P
Track	1	1	1	1
Year	SF-Pts (AVG)	SF-Pts (AVG)	SF-Pts (AVG)	SF-Pts (AVG)
2011	62.99	74.57	72.39	79.41
2012	60.66	73.40	70.70	78.87
2013	59.15	72.45	68.81	78.37
2014	58.59	71.97	66.95	77.65
2015	58.40	71.34	64.70	77.09
2016	58.45	71.22	62.23	76.16
2017	57.61	71.31	60.44	74.81
2018	56.49	70.54	58.69	73.84
2019	55.22	70.12	56.88	72.84
2020	56.25	69.38	54.95	72.35
2021	56.55	68.81	53.23	71.39
2022	55.50	68.55	51.48	70.65
2023	55.21	68.63	50.63	70.02
2024	53.97	68.01	48.87	69.54
2025	53.40	67.47	47.28	68.70
2026	52.09	67.40	45.90	67.68

Special note: The examples presented in this section have mostly been based on consolidated, state-wide totals.   Due to the inclusion of 99 data points for each item, the results produce relatively smooth plots.   If one examines results for just a single county, the output will typically have a more jagged appearance, as year to year changes are relatively more significant for one than for all.

Implementation

This section addresses how the processes, applications and results of the TR-608 project will be used to serve county road information and data needs in the future.

TR-608 will become a permanent service provided by the ICEA Service Bureau

A key original goal of the project was to create the ability to provide annually update results in perpetuity – rather than just a one-time document.   The Service Bureau has already integrated the work involved in maintaining the TR-608 processes into its annual schedule and is prepared to continue to keep them going for as long as Iowa county engineers deem it worthwhile to do so.

The annual task list (major items) will include:

- June – Update population, and land use information
- July – obtain new DOT road and bridge records
    - Review and update trips and VMT trip information
    - Review and update splits of VMT between surface classes
- August – Update Upgrade Needs tally
    - Refigure design level scores
    - Redo the physically tally of miles x urgency
    - Update the Upgrade construction costs table
    - Refigure and tally funding needed to address upgrade backlog
- September
    - Update inflation data and prepare factor for processing latest fiscal year into the Carrying Cost analysis
- October
    - Clean up database, archive current year information
- November – Update Carrying Cost information
    - Redo the eight year, inflation adjusted averages
    - Compute, save and store new Average Sufficiency ratings and Number of bridges in service info.
    - Obtain current per-mile / per-SF unit costs and re-tune the model
- December – prepare for new year
    - Distribute county by county data to county engineers
    - Review and adjust factors in Trend Projection Engine, as may be needed.
- January through June
    - Provide data on request
    - Run full state scenario based on current trends, plus best case / worst case and keep results available

Ongoing availability of data and analysis

TR-608 results and background data will be available to any single county, region or all counties together, on an as requested basis.   The Trend Projection Engine will be open for use whenever needed.   The protocol for seeking an analysis therewith will be: a) the party seeking the analysis will contact ICEASB staff to request a 'run'; ICEASB and the requestor will meet to discuss what is to be modeled, what assumptions will be needed, and what the key questions are; then ICEASB staff will set up and run the simulation, proof the output, gather and save the results; then make the results available to the requestor for use.

Gradual accumulation of historical record

There often come times when a county individually or all counties collectively need to compare the present to the past, cite trends lines, and/or obtain statistics for public dissemination. A side benefit of the on-going nature of this project is that a historical record of base data, factors, statistics, system extent-configuration-condition tallies will gradually accumulate in the database.   This will help counties analyze trends, explain how present circumstances came to be, and discern relationships.

Progressive refinement of the model

The methods, procedures and code modules delivered with this report are not static items to be operated into perpetuity with no further changes.   Due to the modular design of both the Carrying/Upgrade process and the Trend Projection Engine, they will be amenable to being improved whenever needed/desired.

Additional research recommendations

TR-608's end products would benefit from additional research on topics related to the analytical model's internal assumptions.   Some of these items qualify as pure research while others would be more administrative.

- It would be of benefit to develop a better understanding of rural trip generation – sources, daily movements, vehicles used, etc.
- The road surface deterioration model could benefit from review leading to validation, refinement or replacement.
- Feedback influences have been identified and estimated in this study. It would be helpful to objectively quantify them
- The existing Secondary Roads account codes and cost reporting system should someday be modernized and better integrated to help capture and tell the county roads story.   Currently, for instance, the Annual Report, HF-324 and GASB-34 reports overlap and duplicate.   Accuracy and ease of use could be improved by integrating them with a shared cost code basis.
- There would be utility in setting up and annually updating a system or process whereby counties could evaluate and record the 'end-of-year' condition of their Granular, Hard surface and Paved routes.   While an automated PMS is a possible solution, a simple annual evaluation as to remaining years of service life on strategic segments would fulfill at least 85% of the need.   Having such data available would enable better tuning of TR-608's Carrying Cost determination process, and provide a base – over time – that could be used to tune the Trend Projection Engine against actual outcomes.

Utilization to date

Data produced by TR-608 research has been used a number of times.   Carrying Cost and Upgrade needs results were communicated to media outlets and the Legislature in both 2011 and 2012.   The Carrying Cost tallies have been shared with all counties for their use.   A detailed presentation on county road needs was assembled in 2011, using TR-608 outputs, and delivered to the Governors Blue Ribbon Transportation Task Force committee.   Additionally, ICEASB staff have extracted and tabulated data on roads or bridges, on request, for a number of counties.

Special concept modeling potential

As conceived, developed and deployed, TR-608 can provide good insight into the needs of the secondary roads system in its current state. But it is not immediately ready to analyze hypotheticals involving major changes. For instance, if one asks any of the following questions, the current TR-608 process and coding will be unable to provide answers:

1) Would road user costs go down enough as a result of paving all paved county road shoulders where traffic exceeds say 1500 VPD to justify the initial expenditure and subsequent Carry Cost increase required to do so?

2) Would conversion of every county bridge to 60 ton capacity create sufficient efficiencies of operation for the private sector to justify the upgrade cost and carrying cost increase for the structures – plus the increase in road carrying costs from the passage of heavier vehicles?

3) How much could be saved (or reallocated) per year if the least used 10% of the secondary road network were closed?

Evaluation of such issues could be pursued, using TR-608 results as a starting point, but additional manual calculations would be required. In Question 1, it wouldn't be too hard to estimate the increase road cost, but accurate prediction of how that might change traffic counts, vehicle operations costs and accident rates would require careful pre-analysis. Answering Question 2 or 3 would be harder, in that one would need to predict the potential changes in vehicle fleet mix, ESALs produced by newly heavier trucks and IOH units, along with an estimated reduction in the number of truck trips (due to extra capacity per load).

So, such questions can be studied as extrapolations of TR-608 numbers and results, but not directly modeled by the system as-is. Question 2 also might have secondary effects that would be interesting to evaluate but hard to model – such as if trucks could carry more per load, some grain transport would shift from railroads to highway movement.

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Sedat Gulen, et. al.   2000   "*Determination of Practical ESALs Per Truck Values on Indiana Roads*" Joint Transportation Research Program. Paper 52. http://docs.lib.purdue.edu/jtrp/52

Smart Growth America 2011 "*Repair Priorities – Transportation spending strategies to save taxpayer dollars and improve roads*"

Statewide Urban Design and Specifications   2008 "*5D-1 HMA Pavement Mixture Selection*"   Iowa Department of Transportation & Institute for Transportation - Iowa State University

Appendix A – Source of data used in the project

- Population and Land use
    - US Census – 2009 and 2010 results
    - USDA – NASS Farm Census 2007
    - ISU Extension – Livestock

- Inflation
    - CPI See: ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt (January column)
    - CWI   Average wage of Grader Operators at start of FY -- From Annual Salary Survey summary
    - DFPI   Average Diesel fuel price of the fiscal year: http://www.eia.gov/petroleum/gasdiesel/
    - DOT_CCI From Iowa DOT: Price Trend Index for Iowa Highway Construction

- Trips, Traffic and Trucks
    - Iowa DOT 30-yr VMT chart
    - Crash Rates and Crash Densities on Secondary Roads in Iowa by Surface Type 2001 – 2009
      Iowa DOT - Office of Traffic and Safety
    - Vehicle Classification on rural highway – IA 92 traffic counts from SW Iowa – Iowa DOT
    - Vehicle Registrations by County – Iowa DOT - 2011

- Road Revenues & Costs
    - Iowa County Engineer Annual Reports – 2002 to 2012
    - Annual "Secondary Road Fund Distribution Committee" revenue estimate spreadsheets
    - Surface Transportation and Highway Bridge program allocation reports – Iowa DOT Office of Local Systems
    - Iowa Secondary Road GASB-34 Reports

- Road/Bridge Extent, Configuration and Condition
    - Iowa DOT base records – 2002 – 2012

Agri-business trend meetings – participating groups

- Iowa Corn Growers Association
- Iowa Farm Bureau
- Iowa Pork Producers
- Iowa Cattlemen's Association
- Iowa Ethanol Producers Assn
- Iowa Institute for Cooperatives
- Iowa/Nebraska Equipment Dealers Assn.
- Iowa Soy Bean Association
- Iowa Renewable Fuels Association

Appendix B – Results of 2012 Carry Cost Factor tuning

This specialized worksheet allows a user to interactively match asset quantities, lifetimes, quantity of renewal needed annually and restoration costs with Extend and Renew Carrying Costs multipliers. When things have been properly 'tuned' all items become internally consistent with each other. If that is achieved, (which is not a given), confidence in the Carry Cost factors is increased.

TR-608 2012 Actual vs Need analysis
Tuned to fit Per mile / per SF annual costs below

	Earth	Granular	Hd Surface	Paved					Total - Roads
Miles	4,591	66,283	1,387	17,284					89,543

| | | | | BR Sq. Ft. | 1,102,651 | 24,359,598 | 742,378 | 14,083,314 | **Total - BR** 40,287,941 |

A

		ROADS	Total avg expenditure by category			Bridges	Inflation Adjusted 8 year avg.		
	Actual	Earth	Granular	Hd Surface	Paved	Earth	Granular	Hd Surface	Paved
	Operate	1,481,174	81,366,881	5,205,688	68,683,111	195,089	8,960,833	583,502	7,537,489	174,013,767
	Maintain	1,478,899	66,815,289	4,309,806	39,144,184	54,818	4,320,858	293,335	3,825,555	120,242,744
	Extend	930,923	49,664,288	4,612,409	68,691,511	344,517	8,570,139	645,992	8,866,417	142,326,196
	Renew	476,362	81,195,091	2,674,548	126,475,824	815,632	29,724,483	2,584,868	53,044,766	296,991,574
	Totals	4,367,357	279,041,549	16,802,451	302,994,631	1,410,055	51,576,314	4,107,696	73,274,227	

Roads: 603,205,989   Bridges 130,368,292
                           Grd Total: 733,574,281

B

		ROADS	2012 'tuned' TR-608 factors			Bridges			
	Multipliers	Earth	Granular	Hd Surface	Paved	Earth	Granular	Hd Surface	Paved
	Operate	1.00	1.05	1.05	1.05	1.00	1.00	1.00	1.00
	Maintain	1.00	1.10	1.15	1.15	1.00	1.00	1.00	1.00
	Extend	1.00	1.10	1.65	1.05	3.00	1.80	0.90	0.90
	Renew	1.00	1.10	1.90	1.15	3.85	2.42	0.80	0.85

C

		ROADS				Bridges			
	Tuned CarryCost	Earth	Granular	Hd Surface	Paved	Earth	Granular	Hd Surface	Paved
	Operate	1,481,174	85,435,221	5,465,972	72,117,263	195,089	8,960,833	583,502	7,537,489	181,776,543	21.69%
	Maintain	1,478,899	73,496,818	4,956,277	45,015,811	54,818	4,320,858	293,335	3,825,555	133,442,371	15.92%
	Extend	930,923	54,630,717	7,610,475	72,126,087	1,033,551	15,426,250	581,393	7,979,775	160,319,171	19.13%
	Renew	476,362	89,314,600	5,081,641	145,447,198	3,140,183	71,933,249	2,067,894	45,088,051	362,549,178	43.26%
	Totals	4,367,358	302,877,356	23,114,365	334,706,358	4,423,641	100,641,190	3,526,124	64,430,870	

Roads: 665,065,437   Bridges 173,021,826
                           Grd Total: 838,087,263

D

Costs per mile per year				Cost per square foot per year			
$951	$4,569	$16,665	$19,365	$4.01	$4.13	$4.75	$4.57

E

	Earth	Granular	Hd Surface	Paved	Earth	Granular	Hd Surface	Paved	
Approx. asset life in Years	20	3	8	22	60	60	60	60	Years
Resulting quantity needing restoration - per year	229.55	22094.33	173.38	785.64	18378	405993	12373	234722	Mi or SF
					1.8	1.8	1.8	2	Deck area expansion
$dollars per unit	$5,300	$4,500	$65,000	$260,000	$120	$115	$110	$110	$ per Mi or SF
($dollars / ton @ 400 TPM)		$11.25							
		$99,424,500	Rock replacement						
Grade, Ditch, Clvrts Cycle time		30							
Miles reworked per year		2,209	**F1**				**F2**		
Approx. cost per mile		$15,000							
Total		$33,141,500	Roadway & culverts						

Cycle time needs	$1,216,615	$132,566,000	$11,269,375	$204,265,455	$3,969,544	$84,040,613	$2,449,847	$51,638,818

TR-608 results	$1,221,100	$133,019,174	$11,170,021	$203,148,067	$3,967,024	$84,274,249	$2,533,009	$51,471,871

80% of Extend + 100% Renew

	Earth	Granular	Hd Surface	Paved	Earth	Granular	Hd Surface	Paved	
What has been expended	$4,367,357	$279,041,549	$16,802,451	$302,994,631	$1,410,055	$51,576,314	$4,107,696	$73,274,227	$733,574,280	8 year avg
What's recommended	$4,367,358	$302,877,356	$23,114,365	$334,706,358	$4,423,641	$100,641,190	$3,526,124	$64,430,870	$838,087,263	TR-608
Difference	$1	$23,835,807	$6,311,914	$31,711,727	$3,013,586	$49,064,876	-$581,572	-$8,843,357	$104,512,983	
Percent Difference	0.00%	8.54%	37.57%	10.47%	213.72%	95.13%	-14.16%	-12.07%	14.25%	

G

The following page details what's in the 'data-tuning' page and how the 'tuning' has been performed.

TR-608 Data tuning worksheet (Appendix B)		
Item	**I.D.**	**Description**
A	Asset quantities	The 'top of form' gray boxes list the total miles of road and square feet of bridge deck for the four road surface classifications.
B	8-Yr, inflation adjusted average expenditures	Displays the results of an eight year period's worth of road expenditures, adjusted for inflation and then averaged – to obtain a picture of "what have counties spent" on the roads they are responsible for. Figures are in $Dollars per year.
C	Actual spending → Carrying Cost multipliers	In this worksheet, the multipliers of primary interest are those for Extend and Renew activities (shown in red / bottom two rows) as these are the ones that pertain to sustaining road and bridge conditions. The Extend and Renew factors can be interactively adjusted, along with asset lifetimes and restoration unit costs to seek an optimal balance between all three.
D	Calculated Carrying Cost amounts	These numbers are computed values: each one is the value of the corresponding value in B times the multiplier in C. These amounts represent the true Carrying Costs of the system – the annual expenditure level needed if the roads and bridges are to remain serviceable for a long time to come.
E	Carrying Costs in $Dollars per mile(or SqFt)-year	The totals of each Road/Bridge x E, G, H & P surface combination in D divided by the total quantity of road/bridge asset tallied in A. Produces typical need per mile (or SF) for each asset class and surface type.
F	Data tuning work area	The user inserts estimated replenishment life cycle time periods for each Road/Bridge x Earth, Gran, HdSfc, Paved surface combination in the top row of Section F. Next, the total asset quantities from A are divided by the Life Cycle number to obtain the quantity that must be renewed every year in order to maintain the system in steady state condition. These annual numbers are then multiplied by $Dollars per mile or $Dollars per SqFt. typically required when the subject assets are restored. If the results of these calculations match the results from Extend and Renew in Section D, then one has 'tuned' the spreadsheet so all numbers are internally consistent and coherent. For costs, quantities and multipliers to be in 'tune' the numbers in the Cycle time needs and TR-608 results rows should end up nearly equal.
	1 Road costs tuning	For Earth, HdSfc and Paved roads the Annual replenishment quantities are multiplied by straight $/mi cost factors. For Granular, costs for rock replacement are separated from the cost to restore cross-section.
	2 Bridge costs tuning	Bridge cost tuning requires consideration of an extra factor: the expansion of bridge deck area as structures get replaced. In the example worksheet, the tuning suggests annual spending rates on Hard Sfc and Paved road bridges could be reduced – which is somewhat corroborated by the Sufficiency rating trends findings noted elsewhere in this report.
G	Comparison of Actual with Recommended expenditures	The final section of the worksheet compares the tuned Carrying Costs needs from D to the actual expenditures tallied in B – so identify where needs and actual outlays differ and to establish what (if any) changes should be made.

Appendix C -- Outline summary of Trend Projection Engine: Modules and sub-sections

1-PopLandUseAgEV
> 1A - Population and Residences
> 1B - Landuse and Ag Production
> 1C - Economic Value of Rural Economy

2 - RoadRevenue
> 2A - Secondary Road Revenue estimate
> 2B - Projected allocation to BR xEGHP

3 - TripsVMTTrksESALs
> 3A - Landuse --> Traffic generation
> 3B - VMT distribution to EGHP --> VPD
> 3C - Trucks - count and percent of traffic
> 3D- ESALS - total, per truck, per lane/year

4- RoadUserCosts
> 4A - Cost of Vehicle Operation
> 4B - Costs of Impaired/Interrupted Road Svc
> 4C - Cost of Crashes

5 - Carrying Costs (of existing system)
> 5A - Inflation calculations
> 5B - Road Carrying Costs
> 5C - Bridge Carrying Costs

6 - Upgrade NeedsCalcs
> 6A - Compute Road Segment DL scores
> 6B - Compute Upgrade priority and cost
> 6C - Tally upgrade needs

7 - Revenue vs. Need analysis
> 7A - Check for / allocate excess revenue
> 7B - Allocate Revenue to OMER for Roads
> 7C - Allocate Revenue to OMER for Bridges
> 7D - Allocate funds to Upgrades

8 - Road Condition Analysis
> 8A - Granular Road Condtion calcs
> 8B -Hard Sfc Road Condtion calcs
> 8C - Paved Road Condtion calcs

9 - Bridge Condition Analysis
> 9A - Earth road bridges
> 9B - Granular road bridges
> 9C - Hard Sfc road bridges
> 9D - Paved road bridges

10 - EndOfCycleAdjustments
> 10A - Adjust miles and condition for Upgrades
> 10B - Adjust VMT for Upgrades & Bridges
> 10C - Update bridge records & Priority Pts

10b - RoadSurfaceCondtionResults
> 10bA - Granular road factors & feedbacks
> 10bB - Hard Sfc road factors & feedbacks
> 10bC - Paved road factors & feedbacks

11 - Set Feedbacks
> 11A(1) - Tally and organize feedbacks
> 11A(2) - Computer VMT wtd TRIP and VMT factors

12 - GrowthImpacts
> 12A - Loss of Rural area and road miles
> 12B - Decreases in Ag-land and production

Topical Grouping	CD File title	Description
1-Inflation	2002-2012 Cost Inflation.xlsx	Spreadsheet illustrating how inflation indices were processed and combined to create cost adjustment multipliers.
2-BasicDrivers	IowaCountyPopEstimates.xlsx	Spreadsheet illustrating derivation of population numbers, dwelling counts and rates of change.
2-BasicDrivers	USDA_NASS_FarmCensus2007.xls	Information on farms, farming, acres, livestock, etc.
3-Traffic	IowaVMT_30yrHistory.xls	VMT levels and trends for Iowa
3-Traffic	LandUse_vs_VMT-CorrelationWksht.xlsx	Spreadsheet illustrating how Population – Land use – Grain production – Livestock base numbers were converted into Trips per day and VMT per trip.
4-CarryingCost	CostDistMasterWksht-general.xlsx	Master specification on how to process each Secondary Roads accounting code into the Carrying Costs' Rd/Bridge x Earth/Gran/HdSfc/Paved x Operate/Maintain/Extend/Renew format.
4-CarryingCost	TR-608_TableDocumentation	Lists tables used along with description of how Carrying Cost figures are developed.
4-CarryingCost	TR-608 Cycle Time analysis.xlsx	Spreadsheet showing a 'tuned' analysis of FY 2102 results
5-UpgradeNeed	2012 Upgrade need analysis.xlsx	Spreadsheet showing the basic structure and concepts of Upgrade need analysis
5-UpgradeNeed	DesignLevelEncoding.xlsx	Shows the details behind the derivation of Physical and Traffic Design Level determinations.
5-UpgradeNeed	roads-cross-section2.pdf	Graphic illustration of cross section geometry for each of 15 design levels used in TR-608 analysis
6-TPE - Accidents	crash_rate-density_comparables_segments_2001-2009_20100706_secondary_surfacetype.pdf	Report from Iowa DOT Office of Safety – provided crash rate information for secondary roads in Iowa per Earth, Granular, Hard Surface and Paved surface classification.
6-TPE - Bridges	BridgePriorityPointSpreadsheet.xlsx	Spreadsheet produced annually by Iowa DOT Office of Local Systems to establish a priority for structures eligible for state bridge funds.
6-TPE-ESALs	FHWA_VehicleClassesTabulation.docx	Tally of estimated average ESALs per truck for various combinations of tractors, bodies and trailers. Source: http://training.ce.washington.edu/wsdot/Modules/04_design_parameters/trucks_buses.htm
6-TPE-ESALs	FHWA_VehicleClassifications.PNG	Picture diagram showing how to classify vehicles - FHWA
6-TPE-ESALs	Hwy92_ESALcalcsheet.xlsx	Tally of IaDOT base record vehicle classification counts from Iowa Hwy 92 in Southwest Iowa. Used to derived an estimated mix of vehicles using county roads.
6-TPE-Outline	TPE Outline.txt	Electronic version of Appendix C – ASCII Text format
9-TR-608 Final Rpt	TR-608 Final Report.docx	Electronic version of this report – in Microsoft WORD 2007 format

Appendix E – List of tables in TR-608 database

Carrying Cost derivation tables

Basic constants, factors, multipliers and base data

- AdjustedOMER
- Constants
- DesignLevelCosts
- FieldMapping
- Multipliers
- PopLandUseBase
- TripFactorsBase
- VMTDistFactors

Tables that hold data to be used in producing Carrying Cost results:

- tmp_BridgeArea_New
- tmp_CurrentAR
- tmp_CurrentProjects
- tmp_CurrentRBPerMilePerYear
- tmp_InflateAR
- tmp_InflateProjects
- tmp_LclConstructExtract
- tmp_LUTrafficCalcs_2010
- tmp_NonInflateAR
- tmp_Population
- tmp_PriorityPoints
- tmp_PriorityPoints_2011
- tmp_ProjectsForReview
- tmp_ProjectsRaw
- tmp_RBPerMilePerYear
- tmp_SurfaceMiles
- tmp_SurfaceTypeToSurfaceClass

Tables that hold Carrying Cost Results:

- T01_Weightings
- T02_SurfaceMiles
- T03_MilesXWeightings
- T04_FinalDistFactors
- T05_PriceIndex
- T06_PriceIndexFactors
- T06a_PIConversionFactors
- T07_CostFactors
- T08_OMERFactors
- T09_CurrentRB_OMERDistribution
- T09_RB_OMERDistribution
- T10_Consolidated_Expenses
- T10_CurrentConsolidated_Expenses
- T11_ConsolidatedCostPerMileYear
- T11_CurrentConsolidatedCostPerMileYear
- T12_DesignLevels
- T13_SegmentScores
- T13_SegmentScores_2010
- T13_SegmentScores_2011
- T14_TrafficPhysicalDLs
- T15_BaseRevenue
- T16_BaseRevenueDist
- T17_BridgeData_2011
- T17_BridgeData_New
- T18_DetRcvryFactors

Appendix E – List of tables in TR-608 database, cont.

Trend Projection Engine – scenario setup:

- A00_ScenarioDefaults
- A01_Scenarios
- A02_EconomicInputs
- A04_Agricultural
- A05_Vehicles
- A06_RoadsAndBridges
- A07_RevenueAndCosts
- A08_TripsVMTsESALs
- A09_ConditionModeling
- AdjustedOMER
- Constants
- DesignLevelCosts
- FieldMapping
- Multipliers
- PopLandUseBase

- Tracks
- TripFactorsBase
- VMTDistFactors

Trend Projection Engine results:

- R01_PopLandUseAgEV
- R02_EconValRurEcon
- R03_RoadRevenue
- R04_LandUse
- R05_TruckTrips
- R06_CostOfVehicles
- R07_CarryingCosts
- R07a_PercentCovered
- R08_UpgradeNeeds
- R09_RoadCondition
- R10_Bridges
- R11_BridgeCondition
- R12_Stats
- R13_Feedbacks